Puget Sound Technical Recovery Team (TRT) Review Comments on May 2005 Salmon Recovery Plans

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Puget Sound Technical Recovery Team
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Introduction

The Puget Sound Technical Recovery Team (TRT) reviewed 15 individual watershed salmon recovery plans and the regional nearshore plan in the spring of 2005. The general question we asked in our review was "What is the certainty that the actions described in the plans will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plans were to be implemented (i.e., our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented). The TRT used a probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical reviews conducted on earlier drafts of the plans in the summer of 2004. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site (http://www.sharedsalmonstrategy.org/resources.htm#docs_watershed_tech). The TRT reviews at that time were designed to provide technical feedback to plan authors so that their revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon.

The purpose of the 2005 technical review was to summarize what elements in the plans were well described and where significant technical uncertainties in the plans' strategies or actions still remained. Together, the TRT and Shared Strategy used the information from the technical reviews below to explicitly identify the strengths and remaining gaps in the plans, and the means through which such gaps can be filled. The elements in the plans, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy (available at **http://www.sharedsalmonstrategy.org/**.)

The pages that follow contain the technical reviews for each of the 15 watershed chapters and the regional nearshore chapter. A description of the methods we used to estimate certainty in plan outcomes is appended to the end of each watershed section.

WRIA 1 (Nooksack) Plan: North Fork and South Fork Nooksack Chinook Salmon Populations
May 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the 2005 WRIA 1 (Nooksack) Recovery Plan. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the

plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the WRIA 1 Plan is an excellent start for recovery of the North and South Fork Nooksack Chinook populations. The Plan does a comprehensive job of organizing and summarizing the status of the population and what is known about the historical and current limiting factors and impacts on the populations based on qualitative and quantitative assessments. One of the strengths of the Plan is its detailed list of habitat recovery objectives and 10-year and long-term action strategies to improve landscape forming processes and habitat conditions as well as quantitative and narrative descriptions of habitat attribute targets for recovery. Although the Plan has identified recovery strategies for managing hatchery production and harvest, we concluded there is significant uncertainty of achieving the recovery objectives with these strategies in part because of issues that the WRIA 1 recovery planners and managers have little control. A major weakness of this plan is the adaptive management plan, which needs to be fully developed and implemented to help counter these uncertainties.

Habitat Strategy

Key Technical Gaps

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

1. Develop an adaptive management plan and decision framework in the Plan that highlights the following elements: strategic goals and objectives, metrics to measure progress toward objectives, nature of the data required to evaluate metrics, criteria for using the metrics to make decisions, alternative pathways for decisions in the attainment of recovery.
2. Refine strategies and timelines and develop a set of actions for addressing estuarine capacity issues and evaluate them using an analytical tool such as EDT.
3. Conduct sensitivity analyses for the EDT model to explain the relative importance of assumptions and model inputs for the estimated (modeled) effects of recovery actions on habitat conditions and population parameters.
4. Document that logic of sequencing habitat actions is consistent with overall freshwater and estuarine habitat strategies.

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

The Plan relied on a single quantitative model, the Ecosystem Diagnosis and Treatment model (EDT) to evaluate the response of the Chinook population to changes in habitat conditions. A variety of qualitative models (e.g. hydrological, limiting factors, etc.) developed from assessments in the basin were also used to link expected changes landscape forming processes and habitat conditions to viable salmonid population (VSP) characteristics and to ground truth the EDT analyses. Certainty of these analytical models is no more than moderate given the lack of clear quantitative links among land use, dominant processes, and habitat conditions that produce the fish response.

The EDT model was used to estimate the effects of habitat conditions on all 4 VSP parameters for both the North Fork and South Fork populations. The EDT model, however, did not incorporate quantitative estimates linking habitat-forming processes (e.g., sediment dynamics, riparian dynamics, hydrologic and floodplain dynamics) and land use characteristics to habitat conditions and population characteristics (VSP parameters). It includes a good discussion of forestry and land use that could be carried forward via a qualitative or semi-quantitative model to link with habitat-forming processes. Documentation for the model inputs is contained in appendices but project inputs for the model remain as digital spreadsheets—the assumptions are not provided or summarized in the body of the plan. No sensitivity analysis of the EDT model is apparent so it is unclear how the modeled effects of habitat projects on environmental conditions would change under differing assumptions. Similarly, no analysis has been undertaken to explore the sensitivity of the model's population results (VSP) to differing assumptions about habitat conditions in the future.

No empirical test was performed on the model although one could have been done for abundance and productivity using observed R/S data. Similarly, there is no discussion in the plan about calibration of the model rules and relationships to current habitat conditions in the Nooksack watershed or for chinook abundance and productivity. Likewise, no calibration occurred to fit the model's assumptions to empirical effects of habitat actions or for the VSP parameters of diversity and spatial structure.

Key Issues to Improve Certainty:

- Document assumptions for how the effects of project actions (protection and restoration) affected in-stream habitat conditions.
- Conduct sensitivity analyses for the EDT model to explain the relative importance of assumptions and model inputs for the estimated (modeled) effects of recovery actions on habitat conditions and population parameters.

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

The hypotheses of the plan appears to be that habitat conditions---especially channel structure, riparian condition, and estuary capacity---are limitations to viability (recovery) and that these conditions are mediated through altered habitat-forming processes such as hydrologic and sediment transport dynamics. Data in support of these hypotheses is moderate. The comprehensive discussion of habitat limiting factors based on assessments in the Basin indicates that these data were available and were probably used with the EDT model, although documentation is not clearly provided in the plan. The Plan also has limited data concerning juvenile use of the estuary on which to base conclusions about capacity. Life-stage specific productivity data is lacking.

Key Issues to Improve Certainty:

- Document a summary of the empirical habitat and population data that supports the hypotheses found in the plan. Especially discuss the mechanistic links between land use and the altered processes that drive habitat condition;
- Collect data on juvenile use and survival in various habitat types in order to evaluate life stage specific productivity; this is particularly important for the estuary. This data should be geared toward evaluating life stage productivity and the capacity of the estuary;
- Refine spatially-explicit analyses to evaluate the mechanistic links between land use and the habitat forming processes in the Nooksack watershed.

Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?

Yes. The recovery strategy is consistent with the recovery hypotheses for population status and the key habitat factors limiting recovery. The inclusion of flow and floodplain management strategies is an important improvement in the Plan. Several key issues remain. First, to be most effective the strategy needs to address sequencing and prioritizing of habitat actions by considering the role of landscape forming processes as well as the opportunities that are immediately available. Likewise, several areas need more development. For example, although there is an assumption that estuary capacity is well above current population requirements—and will be for some time—the habitat status descriptions in the Plan note that changes in freshwater processes have had a direct impact on the quality and quantity of estuarine habitat. Although the Plan provides a list of general strategies for the estuary, a complete restoration strategy should eventually address capacity issues that might limit recovery.

Key Issues to Improve Certainty:

- Refine strategies and timelines for addressing estuarine capacity issues;
- Document logic of sequencing habitat actions as part of different strategies.
- Develop a truly all-H integrated strategy in the Nooksack plan.

Does the habitat recovery strategy preserve options for recovery of all four VSP parameters across all Hs?

No. The WRIA 1 Recovery Plan does not have an adequately developed adaptive management plan that preserves options for recovery. The 2005 Plan contains general definitions of types of monitoring and habitat, biotic interactions, and population characteristics for monitoring that were not identified in the 2004 draft, but it still lacks a plan that if implemented would reduce both the scientific and policy uncertainties of the strategy.

Key Issues to Improve Certainty:

- Develop an adaptive management plan and decision framework in the Plan that highlights the following elements: strategic goals and objectives, metrics to measure progress toward objectives, nature of the data required to evaluate metrics, criteria for using the metrics to make decisions, alternative pathways for decisions in the attainment of recovery.

Are the habitat recovery actions consistent with the recovery strategy?

No. Many of the actions appear to be mostly consistent with the recovery strategy. More detail is needed for us to adequately evaluate other strategies, such as those for floodplain and flow management. Likewise the consistency of habitat recovery actions with the recovery strategy greatly depends on spatial implementation and sequencing of the actions and this logic is not well described in the Plan. An aggressive habitat strategy cannot be effective if it is mostly opportunistic unless those opportunities make sense geomorphically and biologically. In addition, lack of adequate consideration of sequencing of habitat actions can jeopardize the successful integration of recovery actions in hatchery and harvest.

Key Issues to Improve Certainty:

- Describe the sequencing and spatial distribution of the set of habitat actions proposed by the plan. Discuss the predicted outcomes of these actions on habitat conditions and VSP parameters;
- Develop a set of actions derived from the estuarine strategy and evaluate them using a predictive model such as EDT.
- Develop actions that are consistent with an all-H integrated strategy in the Nooksack plan.

How well have the habitat actions been shown to work?

Support for habitat actions is moderate. There is good empirical evidence for the effect of many of the individual actions proposed by the habitat portion of the plan in other watersheds as well as the Nooksack River. For example, reopening stream habitat that has been blocked can expand spawning distributions and increase abundance, although the results can be highly variable from watershed to watershed and year to year. In contrast, the magnitude of the cumulative effects of some habitat actions, such as the aggressive use of engineered log jams, has been little studied. There is an (assumed) expectation that effects from the actions will be mainly positive, which may prove to be true, but we should expect some significant changes in habitat structure and rates and magnitudes of various in-channel and riparian processes as the river responds to the renewed LWD loadings.

Ways to improve certainty in plan outcomes:

- Systematically analyze the potential cumulative effects of protection measures. Specifically,
    - Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
- Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.

North Fork Nooksack Hatchery Strategy

Key Technical Gaps

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

- Develop and implement an appropriate adaptive management plan.

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 (BRAP) cited in co-managers' resource management plan) to understand the potential affects of hatchery actions on populations. The model addressed all VSP criteria. Documentation is 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 model for Nooksack River populations. The recovery plan indicates that the co-managers have good genetic and demographic data, which we assumed were used to assess the effects of hatchery actions on abundance, diversity, and to some extent spatial structure. Information to assess the effects of ecological interactions (e.g. competition, predation, and disease) and domestication on productivity and spatial structure appeared to be less available.

Since the original assessments using the BRAP, addition tools and assessments have been developed that could refine this understanding, including the Hatchery Scientific Review Group (HSRG) review; the All 'H' Hatchery Analyzer (AHA) model also developed by the HSRG; and quantitative models developed to evaluate domestication, effects of small population size, and competition and predation by WDFW and the NWIFC as part of the hatchery risk assessment modeling project (RAMP).

Key Issues to Improve Certainty:

- Refine existing assessments or use additional models that will allow managers to assess through sensitivity analyses how the certainty of the results and their decisions is affected by changes in different factors (such as the factors that can be controlled through hatchery management actions).

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

Support for the recovery hypothesis using watershed specific data for was low. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. In the Nooksack River watershed, the co-managers had good genetic information supporting affects of straying on diversity and spatial structure. Most of the information appeared to be inferential or based on local knowledge. More empirical information is needed on ecological effects, such competition or predation from hatchery programs for other species.

Key Issues to Improve Certainty:

- Over the long-term, collect information on ecological interactions of hatchery and wild fish

- In the short-term, use available data from other watersheds to increase the analytical support and to document the assumptions that would be part of that.

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

Yes. The overall hatchery strategy of North Fork Chinook salmon (e.g. reductions in the coho salmon releases, ending fall Chinook production at Kendall Creek, introductions into the Middle Fork) indicate a strategy that should be consistent with recovery.

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

No. The Plan strongly emphasizes preserving genetic diversity, which does preserve future options within the population. The ability to monitor and make intelligent management decisions to accomplish this goal also requires a carefully developed and implemented adaptive management plan to respond to changes and uncertainty as they occur. This is especially important because overall, it is not clear that all the hatchery programs in the basin---including Kendall Creek early-returning North Fork Chinook, Lummi Bay fall Chinook, Samish fall Chinook, and the proposed South Fork to protect the genetic diversity of early-returning South Fork Chinook---have commensurate goals and integrated strategies.

Key Issues to Improve Certainty:

- Develop and implement an appropriate adaptive management plan
- Develop a truly all-H integrated strategy in the Nooksack plan that can be monitored and adapted over time.

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 a possible strategy for maintaining the genetic diversity of this population.

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

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. Supplementation programs have been shown to prevent extinction and their effectiveness in recovering populations to viable status is still unknown. Areas that are especially uncertain in the Nooksack are 1) the actions to reduce competition or predation, if it occurs, 2) the actions to reduce straying of the North Fork hatchery fish, 3) and the size of the North Fork program given the capacity of the habitat and ability to support natural spawners.

Key Issues to Improve Certainty:

- Develop and implement an appropriate adaptive management plan

South Fork Nooksack Hatchery Strategy

Key Technical Gaps

The most important ways to improve the certainty of an effective hatchery strategy in this plan are to

1. Develop the details of the hatchery program for South Fork Chinook salmon
2. Develop an adaptive management plan.

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. See the discussion for the North Fork for an explanation.

Key Issues to Improve Certainty:

- Refining existing assessments or use additional models that will allow managers to assess through sensitivity analyses how the certainty of the results and their decisions is affected by changes in different factors (such as the factors that can be controlled through hatchery management actions).

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

Support for the recovery hypothesis using watershed specific data for was low. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. The co-managers had good genetic information supporting hypotheses about the effects of straying of North Fork early-returning Chinook salmon and fall Chinook on diversity and spatial structure. These were linked to the changes in habitat in the stream as well as hatchery practices. It is not clear that the available data and analyses are adequate to develop brood stock collection protocols and strategies for a hatchery population. Other information appeared to be largely inferential or based on local knowledge of the watershed. More empirical information is needed on ecological differences, distribution, and reproductive success of non-native North Fork early-returning Chinook salmon and fall Chinook in the South Fork.

Key Issues to Improve Certainty:

- Over the long-term, collect information on ecological interactions of the three stocks of hatchery and wild fish using portions of the South Fork.
- In the short-term, refine genetic data that will allow development of brood stock collection protocols and strategies for a hatchery program to prevent extinction of native South Fork early-returning Chinook.

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

Yes. Many of the actions being proposed for the watershed such as the recovery hatchery program for early-returning South Fork Chinook salmon suggest the beginning of a strategy that should be consistent with recovery. Critical details of the plan (e.g., brood stock collection protocols, adequacy of the facility to maintain and rear early-returning Chinook, and the interactions with other programs also underway at the hatchery) were undeveloped and without careful planning, actions could jeopardize the consistency of the strategy with recovery.

TRT concluded that a well-designed and operated program that maintains the genetic integrity of the population could contribute to recovery in two ways. First, it could be a short-term solution to the level of straying into the South Fork that is an immediate and serious threat to viability of this population. Second, the hatchery could provide a demographic buffer to the population if the aggressive use of engineered logjams to rehabilitate habitat is not as successful as the planners hope and the intervention leads to short-term loss of spawning habitat until the system equilibrates.

Key Issues to Improve Certainty:

- Develop the details of the proposed supplementation for the South Fork and have the plan reviewed
- Implement the program as soon as possible after an acceptable plan has been developed.

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

No. The Plan strongly emphasizes preserving genetic diversity, which does preserve future options within the population. The ability to monitor and make intelligent management decisions to accomplish this goal requires a carefully developed and implemented adaptive management plan to respond to changes and uncertainty as they occur. This is especially important because overall, it is not clear that all the hatchery programs in the basin---including Kendall Creek early-returning North Fork Chinook, Lummi Bay fall Chinook, Samish fall Chinook, and the proposed South Fork to protect the genetic diversity of early-returning South Fork Chinook---have commensurate goals and integrated strategies. This directly threatens an effective strategy in the South Fork and unless these other programs change, a strong adaptive management plan is the best (only) way to provide for a robust strategy.

Key Issues to Improve Certainty:

- Develop and implement an appropriate adaptive management plan
- Develop a truly all-H integrated strategy in the Nooksack plan that can be monitored and adapted over time.

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

Yes. Many of the current and proposed actions appear to be consistent with a possible strategy for maintaining the genetic diversity of this population. However, as noted above, the plan lacks details. These details need to be developed and the actions reevaluated for consistency with the recovery strategy.

Key Issues to Improve Certainty:

- Develop the details of the proposed supplementation for the South Fork and have the plan reviewed for consistency with the recovery strategy
- Explicitly link actions in harvest, hatchery and habitat to an integrated, all-H strategy for the Nooksack watershed.

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

Support for the proposed actions is low. The proposed hatchery actions were too vague to evaluate critically for effectiveness. There is some empirical evidence from other watersheds that well-designed and implemented recovery hatchery programs can be successful in maintaining populations, but we had too few details to evaluate that (See discussion above). Other areas that are especially uncertain are 1) actions to ensure homing of South Fork Chinook salmon under the proposed supplementation program, 2) actions to reduce competition or predation, if it occurs, and 3) the actions to reduce straying of North Fork early-returning hatchery fish and fall Chinook salmon.

Key Issues to Improve Certainty:

- Develop the details of the proposed supplementation for the South Fork
- Develop and implement an appropriate adaptive management plan

North & South Fork Nooksack Harvest Management Strategy

Key Technical Gaps

This evaluation is based on the Nooksack Management Unit profile, pages 85-94 of the *Comanagers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the plan submitted by the WRIA 1 group.

The harvest management portion of the recovery plan is based on the hypothesis that the intrinsic natural productivity of the NF Nooksack population, under current habitat conditions and recently observed poor marine survival conditions, is sufficiently high to allow for the population to recover if the adult equivalent exploitation rate is less than or equal to the rebuilding exploitation rate (RER). It is also acknowledged that due mainly to fishery interceptions of the Nooksack North and South Fork populations north of the United States border, the spawning escapement is not likely to exceed the lower threshold of 1000 set for each population. Therefore, the harvest management plan is to maintain the exploitation rate south of the US/Canada border to a level supporting a very minimal set of directed fisheries and incidental impacts in fisheries directed at other stocks and species. RERs have been calculated for the Nooksack populations, but they have not been formally reviewed or adopted because lower escapement threshold will continue to drive management in the near term.

The most important ways to improve the certainty of an effective harvest strategy in this plan are to:

1. Develop a strategy for managing both southern U.S. and northern fisheries to allow recovery of these populations
2. Develop an adaptive management plan
3. Compete development of RERs for the two Nooksack populations
4. Expand the strategy to include the effects of harvest on diversity and spatial distribution.
5. Incorporate results from analytical tools (for example AHA, EDT, and SHIRAz) to assess the effectiveness of the harvest management strategy given the habitat and hatchery strategies.

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

The harvest management analysis used one model (VRAP) that looks at three different functions for the spawner-recruit relationships. The VRAP simulation model is used to determine the rebuilding harvest rate (RER) and used as input for spawner-recruit relationships that were determined from two models, the Dynamic Model and EDT. The Plan does not describe how the lower abundance escapement threshold of 1000 was determined.

Key Issues to Improve Certainty:

- Refine analyses of RERs by incorporating simulation results from additional models

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

Support is low. Only two of the four VSP characteristics are considered. The model included qualitative and quantitative descriptions of the link between harvest management and two VSP characteristics: abundance and productivity. The recovery hypothesis is supported by local escapement data in that escapements have increased as exploitation rates have declined. There are empirical data available from the South Fork demonstrating density dependence and therefore the appropriateness of the Beverton-Holt model for that population. The effects of harvest on diversity and spatial distribution, however, were not addressed by the harvest models. In particular, harvest management based on the aggregation of independent populations into a single management unit may not accurately account for the different spatial distribution and diversity of the two populations.

Key Issues to Improve Certainty:

- Incorporate spatial structure and diversity in to the modeling of harvest effects on VSP

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

Support for the recovery hypothesis was moderate. There were some empirical data available to support the modeling, but these have not yet been used to develop relationships for management. There were good local data on the contribution of hatchery strays to the natural escapement so that escapement trends for natural origin fish can be assessed. There are also local data available to support hypotheses regarding the effects of harvest on diversity and spatial distribution, although these aren't assessed in the plan. An in-system coded-wire tag group could be used as an exploitation rate indicator for this population. Data to calculate effects of northern fisheries may also be available.

Key Issues to Improve Certainty:

- Collect and use data from each of the two populations to incorporate spatial structure and diversity into the modeling of harvest effects on VSP

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

No. The harvest management strategy takes a logical approach consistent with the hypothesis for abundance and productivity and the ability of co-managers to manage harvest in the southern United States. Although the management of fisheries north of the border cannot be controlled by co-managers in the Nooksack watershed, overall the lack of description of a strategy for how to manage both Canadian and U.S. fisheries to allow recovery of the populations is not consistent with the recovery hypothesis and could ultimately greatly inhibit recovery of these populations. In addition, the strategy does not address diversity and spatial distribution. Finally, although it appeared to us that the strategy is probably consistent with habitat and hatchery strategies, this is not well analyzed or supported in the plan.

Key Issues to Improve Certainty:

- Expand the strategy to include the effects of harvest on diversity and spatial distribution.
- Develop a strategy for managing the entire gauntlet of fisheries impacting Nooksack Chinook to allow recovery of these populations
- Incorporate results from analytical tools, to document integration of habitat, harvest, and hatchery strategies

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

No. The harvest strategy appears to protect parts of the existing VSP structure. However, as the plan acknowledges, the existing threats to the populations are critical. This is demonstrated for abundance and productivity from recent spawner-recruit data and assumed for diversity and spatial structure because of declining exploitation rates and straying of hatchery fish produced for harvest. The Plan lacks an adequate adaptive management strategy. Although in general the regional and international harvest management frameworks provide good adaptive management of fisheries, in this case co-managers have reduced abilities to respond because of lack of control over interceptions north of the border.

Key Issues to Improve Certainty:

- Develop and implement an adaptive management plan appropriate to the particular circumstances of Nooksack Chinook.

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

Yes. Actions appear to be consistent with the harvest strategy and with the overall integrated strategy that includes hatchery and harvest actions. The latter needs better documentation.

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

Support for recovery actions is moderate. It is clear from the information presented that spawning escapements can increase to some degree if exploitation rates are reduced. However, it isn't clear that the proposed action (tight control of exploitation rates on Nooksack Chinook south of the border; only broadly-based limits on Chinook interceptions north of the border) will provide sufficient, or any, overall control of exploitation rates on Nooksack Chinook to levels appropriate to allow rebuilding.

Key Issues to Improve Certainty:

- Develop a strategy for managing the entire gauntlet of fisheries impacting Nooksack Chinook to allow recovery of these populations

II. 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.

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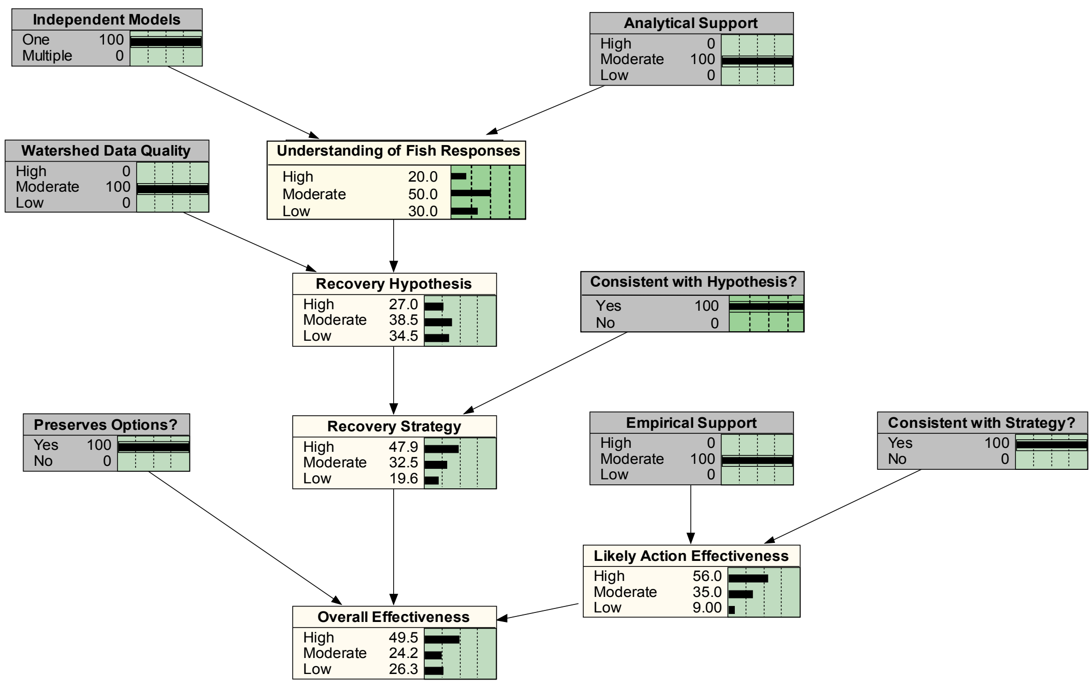

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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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, landuse, 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)
Harvest 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

San Juan Plan:
November 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the San Juan Islands (WRIA 2) recovery plan submitted to the Shared Strategy in April 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. Summary of Certainty Analysis

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the San Juan Islands plan provides the basis for a good guidance framework for restoration and protection actions in nearshore and marine habitats that will promote the recovery of Puget Sound Chinook salmon. The fact that Chinook salmon from throughout the Puget Sound ESU use the islands at a number of key life stages is well documented. Because of the large amount of shoreline and the high ratio of shoreline length to land area, the plan is organized around shoreline-related management. The plan is based on a rough conceptual model of how Chinook salmon use habitats in the San Juan Islands. Further work needs to be done to bring this model into better focus so that the effects of specific actions on life stages in particular places and times can be better predicted.

Habitat Strategy

Key technical gaps

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

- Better document the data used to relate ecological processes and habitat conditions.
- Develop explicit, conceptual life stage-specific linkages relating habitat conditions to responses in population status.

- Use available data from other areas on juvenile utilization and on specific life stage linkages to habitat conditions to increase the analytical support; document the associated assumptions.
- Develop a habitat recovery strategy tiered down from more explicit hypotheses on conceptual linkages relating habitat conditions to salmon viability via life stage specific potential responses and integrate the habitat strategy with hatchery and harvest management strategies in the planning area.
- Develop an adaptive management plan.

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

A *qualitative* model was used to relate ecological processes and habitat conditions using general information on nearshore processes. The San Juan chapter utilizes a generalized conceptual model to assess the affects of habitat factors on potential fish status and responses. Table XVIII linking actions, processes and VSP is a good start for hypotheses. The maps linking freshwater upland areas to nearshore processes supports the emphasis on shoreline-related management, instead of drift-cell-related management. The certainty in the analytical model used to link changes in habitat conditions and processes to fish population response is moderate.

Ways to improve certainty in plan outcomes:

- Better documentation of the data used to relate ecological processes and habitat conditions
- Development of explicit, conceptual life stage-specific linkages relating habitat conditions to responses in population viability characteristics.
- Collaboration with other planning entities and nearshore investigators to continue development of model(s) and analytical support.
- Collection of new data on use of marine and nearshore habitats by specific life stages and populations of Chinook salmon to calibrate these models

2. *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?*

The hypothesis underlying this plan is that open water and nearshore marine habitats in the San Juan Islands support several salmon life stages from populations spanning a broad geographical area. At least some of these habitats are used year-round by salmon. Because of the unique geographical location of the islands in the salmon migration pathway, as well as the relatively undisturbed nature of many of the islands' habitats, the plan assumes that this area is critical for maintaining VSP attributes of many populations. Local data on the use of islands' habitats by juvenile Chinook salmon is currently lacking.

There is good general information regarding habitat-forming processes that affect salmon in the marine environment (Table VIII). There is also a detailed inventory of some important habitats and habitat modifications (Tables X – XVI and associated text), and some general discussion of freshwater limiting factors and the connections between freshwater processes and marine nearshore function. However, there is little support in watershed-specific data for the nearshore and freshwater habitat factors estimated to be limiting recovery of the Chinook populations using the San Juan Islands.

Ways to improve certainty in plan outcomes:

- Include support for an hypothesis for how disruption of the food web structure and function—e.g., competitors, predators, forage fish, and non-indigenous species—is likely to affect VSP. For example, it is a strength of the plan that forage fish spawning beaches are given high importance. The rationale for this should be discussed through the hypothesized food web effects.
- Provide existing data on juvenile use of habitats in the San Juan Islands and include a prioritized program to collect new data to fill gaps in the conceptual model of juvenile use of and survival in different habitat types.
- Include the hypothesized mechanistic links among habitat-forming processes and land-use attributes; discuss how land use conditions affect freshwater and nearshore habitat quality and quantity in the hypotheses. Monitor and study these linkages so that mechanistic links among those can be better understood, and therefore protected and restored.
- Use available data from other areas on juvenile utilization and on relating specific life stage linkages to increase the analytical support.
- Collaborate with other planning entities and nearshore investigators to populate model(s) with watershed specific data or otherwise strengthen analytical support.

3. *Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?*

The habitat recovery strategy in the draft San Juan Islands recovery plan is not completely consistent with the hypotheses for what population status and habitat, harvest and hatchery problems are limiting recovery. The strategy is largely a protection and filling-in the knowledge gaps strategy. The TRT supports the strategy of monitoring and research to test the effectiveness of existing regulatory mechanisms, and the desire to be strategic and specific about designing protection measures such as Critical Areas Ordinances and Shoreline Management Plans. The strategy should help decision makers decide where these protection measures should be prioritized for implementation. Protection measures aren't related clearly back to specific hypotheses; and it isn't stated how the applied research measures will be related to improving the strategy.

We encourage the addition of sub-area hypotheses, strategies, and actions so that the potential effects of the plan can be better evaluated. Currently, both the hypothesis relating habitat conditions to potential fish status and responses and the strategies for habitat recovery are too general to evaluate for consistency.

Ways to improve certainty in plan outcomes:

- Further develop the habitat recovery strategy tiered down from more explicit hypotheses on conceptual linkages relating habitat conditions to salmon viability via life stage specific potential responses. Focusing the restoration strategy on a well-defined habitat recovery strategy could serve as a useful starting point for reducing uncertainties.
- Integrate the habitat strategy within the planning area with hatchery and harvest management strategies for the populations using the planning area. For example, there is information about local hatchery releases included in the plan. How are these hatchery fish expected to affect the survival and recovery of wild fish using San Juan habitats?
- Develop more explicit detailed conceptual and qualitative linkages between each of the specific protection and restoration action plans for nearshore or shoreline areas and the hypothesized VSP responses.
- In collaboration with others, move toward quantitative, explicit linkages among actions, habitat conditions, and population attributes.

4. Does the habitat recovery strategy preserve options for recovery in all 4 VSP attributes through all of the H's?

The existing habitat recovery strategy does not state how it interacts with other Hs to preserve options for recovery. Preserving options requires an adaptive management plan to respond to changes in salmon population attributes and habitat attributes, and to test the effectiveness of management strategies in all Hs.

Ways to improve certainty in plan outcomes:

- Include an adaptive management decision framework in the plan that highlights where information from monitoring and evaluation of habitat projects and fish population responses will affect decisions about the overall recovery strategy.
- Design and implement a comprehensive monitoring and evaluation program that can track the integrated, cumulative effects of habitat protection and recovery actions over time.

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

Empirical support for recovery actions in this plan is moderate. General experience suggests that nearshore protection and restoration actions have been successful, although there are some conflicting results and uncertainties associated with evaluating their effects. Areas that are especially uncertain are 1) the effectiveness of shoreline regulatory protection programs, 2) validation that habitat actions to rehabilitate or enhance nearshore habitats increase the capacity of the nearshore to support chinook and chum salmon life stages. However, given the large amount of relatively unimpacted habitat in this area, the precautionary principle suggests that giving a priority to protection actions until we learn more, as this plan does, is a prudent approach.

Ways to improve certainty in plan outcomes:

- Use available data and document assumptions for the habitat actions (by type) to increase the strength of the empirical support for their effectiveness.
- Strengthen the empirical support for each type of protection and restoration action by testing (through monitoring and adaptive management) their effectiveness and by validating that the actions result in the predicted responses.

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

The actions described in the plan are very general, so it is difficult to evaluate whether a clear and logical relationship exists between the "all-H" recovery strategy and the proposed habitat recovery actions. The detailed information on tools, strategies, and actions (Chapter VII), provides specifics regarding how protection of key habitats could be accomplished through the appropriate regulatory authorities. This information helps increase the certainty that protection actions consistent with the overall strategy can be implemented.

Ways to improve certainty in plan outcomes:

- Focus first on connecting the overall recovery hypothesis and strategy with protection and restoration actions in specific locations.
- Develop better empirical and analytical support for the relationships between protection and restoration actions and hypotheses specific to VSP characteristics or ESU persistence.
- Systematically analyze the potential cumulative effects of protection measures. Summarize existing modeled or empirical support for the effectiveness of habitat protection and restoration actions identified in the plan. Areas that are especially uncertain are 1) the effectiveness of shoreline regulatory protection programs, 2) validation that habitat actions to rehabilitate or enhance nearshore habitats actually increase the capacity of the nearshore to support chinook and chum salmon life stages. Specifically,
    - Having already identified what groups have the authorities to address each threat through regulation (Chapter Vii), assess whether there are any gaps in which threats are identified and whether there is a mechanism to address them. If gaps are found, identify approaches to filling the gaps.
    - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.

Hatchery Strategy

No independent Chinook populations spawn in this area, although Chinook salmon from other areas use nearshore and open water marine habitats in this region. No comprehensive hatchery strategy was included in the plan, although data on local hatchery releases were provided. Preliminary assessments have raised questions about the potential incidence and impacts of competition and predation in nearshore areas that remain unresolved. See technical comments on certainty in hatchery strategies for each of the watershed plans for further discussions.

The most important ways to improve the certainty of effective hatchery strategies in this region are to:

- Develop coordination between the different watersheds and managers producing wild and hatchery fish that use this area to establish an integrated monitoring and adaptive management plan, and
- Evaluate the effects of current hatchery management activities on capacity of the nearshore environment for wild Chinook (hatchery-wild interactions)

Harvest Management Strategy

This plan, appropriately, does not include a harvest management strategy because harvest of populations throughout their life cycle is addressed in the watershed plans for the areas where the populations spawn. However, in developing an integrated adaptive management program for waters around San Juan County, recognition of harvest actions will be necessary in order to assess the effectiveness of habitat preservation and restoration actions.

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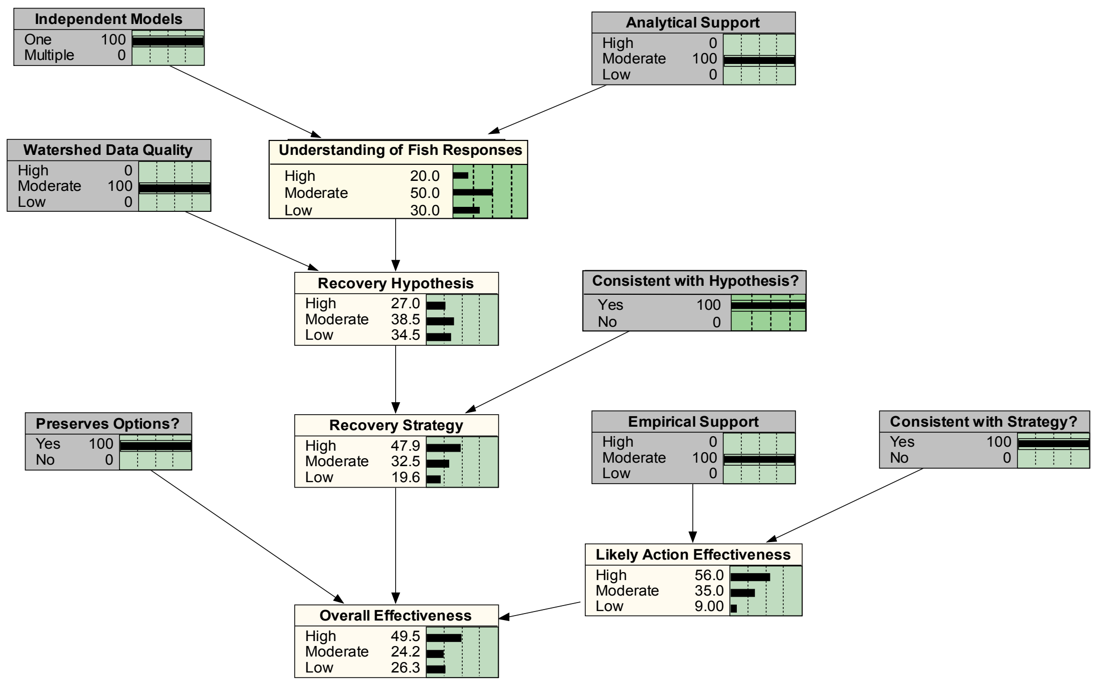

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Table 1. Attributes for different states of analytical support for models.

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, landuse, 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)
Harvest 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

Island County Watershed Plan:
May 2005 Technical Gap Analysis
Puget Sound Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the Island watershed recovery plan submitted to the Shared Strategy in May, 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The combined elements in the plan, plus clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. Summary of Certainty Analysis

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see Section II of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. The analysis was done separately for habitat, hatchery, and harvest elements. The Island County chapter dealt only with habitat management, so that is the only factor affecting recovery that the TRT evaluated and comments on here. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the plan makes a good start on developing a recovery program that links users and regulators. The plan addresses only habitat/nearshore issues as Island County is not involved with hatchery and harvest decisions. However, the response of salmon to habitat recovery actions within the Whidbey Basin will depend in part on the number of hatchery fish utilizing the basin and changes in harvest patterns in the area. The certainty in the Island County Plan will be greatly increased if they consider the effects of their habitat management actions in the context of hatchery and harvest management affecting salmon in the Whidbey Basin. Until such truly integrated strategies for salmon recovery are considered, the certainty of the Island County Plan to achieve its objectives for salmon will remain relatively low. A well designed monitoring and adaptive management program for Island County habitat recovery actions will go a long way towards increasing the certainty in the plan's success for salmon. An adaptive management program should identify strategic goals and objectives, identify metrics to measure progress toward objectives, determine the nature of the data required to evaluate these metrics, develop criteria for using the metrics to make decisions, develop a program to determine alternative pathways for decisions when needed in the attainment of recovery, and identify the authorities needed to make these changes.

Habitat Management Strategy

Key Technical Gaps

- Better document the source of data used and the details of the conceptual model as information becomes available; apply Skagit System Cooperative data and other data sources on juvenile salmon utilization of nearshore habitat to help provide empirical support for the model used.
- Develop a quantitative model that can help determine relationships between proposed actions and fish response. Estimating the potential magnitude of responses from proposed actions is important in prioritizing actions.
- Further develop a detailed and specific habitat recovery strategy tiered down from more explicit hypotheses on conceptual linkages relating habitat conditions to salmon viability via life stage specific potential responses.
- Utilize information/hypotheses from the nearby watershed plans that deal with the populations that utilize Whidbey Basin and with the nearshore chapter.
- Develop an adaptive management plan for monitoring and evaluating actions, and that can suggest potential changes to habitat management actions to improve results for the salmon.

1. *Did the analysis use one or multiple independent models to understand potential fish responses to actions? What is the nature of the analytical support for the model linking salmon population status to changes in habitat-forming processes and habitat conditions?*

- The plan utilized one conceptual model to assess the affects of habitat factors on potential fish responses for all 4 VSP. Documentation was good and based in large part on the nearshore chapter information.
- The use of the conceptual models outlining the hypotheses in Appendix F is a good, explicit way to express the hypotheses.
- No quantitative model was used. The use of one or more quantitative models would help define the relationships used in the modeling effort and provide an analytical tool for adaptive management. The use of two or more models allows one to compare differences between models and assumptions used for those models.

2. *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?*

    - A *qualitative* model was used to relate ecological processes, habitat conditions, and all four VSP. General information on nearshore processes and some specific information on habitat conditions were provided to support the hypotheses.
    - Support for the recovery hypotheses using watershed specific data moderate, and could be improved with documentation of basin-specific available data. Use of the limiting factor studies and the habitat condition mapping is good.

    Ways to increase certainty in plan outcomes:
    - Explicitly state assumptions used and any information/documentation that would help support the assumptions.
    - Develop hypotheses related to responses of habitat actions as affected by hatchery and harvest actions and identify strategies to address these effects if needed (integration).
    - Discuss empirical testing and validation of the model (even if qualitative) used to link habitat actions to VSP.
    - Improve quality of data by using more data from neighboring watersheds that contain populations utilizing the Whidbey Basin (e.g., data from the Skagit, Snohomish, and Stillaguamish on juvenile salmon estuary and nearshore utilization. Also, data/estimates from terminal fisheries and CWT recoveries could be cited to document use of basin by the various populations.)

3. *Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?*

    - No. The overall strategy is to improve the condition of degraded nearshore habitat areas and to protect natural shorelines. The individual habitat strategies presented appear to be well thought out and developed and are consistent with the individual hypotheses. However, the hypotheses for the relationships between stressors and VSP characteristics could be further developed.

Ways to improve certainty in plan outcomes:
- Develop hypotheses specific to VSP characteristics or ESU persistence to better define habitat recovery strategies for protection and restoration that will, in turn, result in improvements in the VSP characteristics.
- Provide more specific definitions of protection and restoration strategies to better evaluate consistency with the hypotheses.
- Focus the recovery actions through a more defined habitat recovery strategy. The strategy builds on the success of a number of protections and restoration projects which obviously involve a lot of effort and have a lot of public

support. However, specific projects are not well linked to the hypotheses presented in the plan, nor are they linked to the status of the target populations.
- Estimate the potential magnitude of the VSP response likely from specific measures.

4. *Does the habitat recovery strategy preserve options for recovery in all 4 VSP attributes through all of the H's?*

   - No. The strategy for protection is not well spelled out. It is not stated what will be done to evaluate or implement further protection approaches during the first 10 years, although it is stated what will be done for building public support and gathering data to better understand the habitat and salmon connection. Education is a good first step. How are options preserved for the future in the existing strategy?

   Ways to improve certainty in plan outcomes:
   - Document the rationale for the habitat protection and public education approach and discuss the predicted effects on VSP.
   - Collect data on effects of the strategy to build public support for protection and restoration in the short term.
   - Preserve options through developing an adaptive management plan to respond to changes as they occur. Describe how the strategy can be adapted in the future as more information is obtained from the effects of all of the H-strategies.

5. *Are the recovery actions consistent with the recovery strategy?*
   - Yes. Actions to provide public education are given.
   - Good links between objectives/strategy and actions on p. 58ff. Good specificity of actions and timeframes. pp. 65ff for commitments that will need to be achieved for actions to be implemented.

6. *How well have the recovery actions been shown to work (empirical support)?*

   - Support for the proposed actions is moderate.
   - General experience suggests that nearshore protection and restoration actions can work, although there are some conflicting results and uncertainty with some actions. Areas that are especially uncertain are 1) the effectiveness of shoreline regulatory protection programs, and 2) validation that habitat actions to rehabilitate or enhance the nearshore will increase the capacity of the nearshore to support chinook and chum salmon.
   - Systematically analyze the potential cumulative effects of protection measures. Specifically,

  - Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
  - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
  - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
- Increase consistency between pre-existing agreements (e.g. Federal consultations —HCPs, Sect. 7, others) and content of recovery plans.

Hatchery Management Strategy

No independent Chinook populations spawn in this area, although Chinook salmon from other areas use the nearshore of this region. No comprehensive hatchery strategy was included in the plan. Preliminary assessments have raised questions about the potential incidence and impacts of competition and predation in nearshore areas that remain unresolved. See technical comments on certainty in hatchery and harvest strategies for each of the watershed plans for further discussions.

The most important ways to improve the certainty of effective hatchery strategies in this region are to:

- Develop coordination between the different watersheds and managers producing wild and hatchery fish that use this area to establish an integrated monitoring and adaptive management plan,
- Evaluate the effects of current hatchery management activities on capacity of the nearshore environment for wild Chinook (hatchery-wild interactions).

Harvest Management Strategy

This plan, appropriately, does not include a harvest management strategy because harvest is addressed in the watershed plans for the areas where the populations spawn. However, in developing an integrated adaptive management program for waters around Island County, recognition/knowledge of harvest actions will be necessary in order to assess the effectiveness of habitat preservation and restoration actions.

II. 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*.

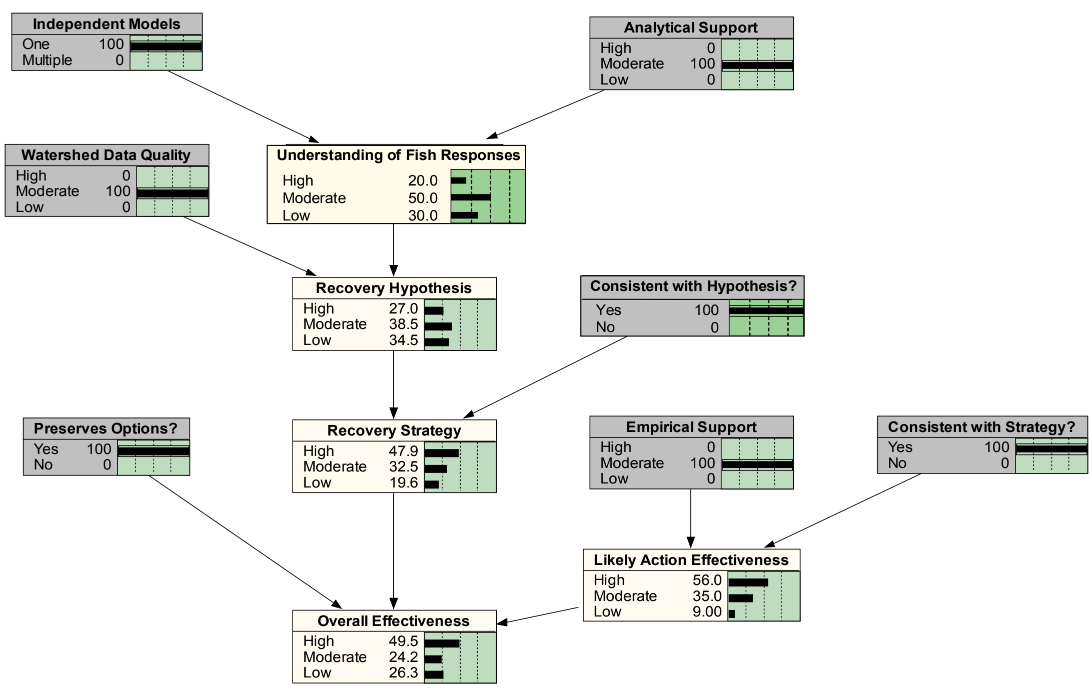

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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.

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

Analysis	Total Score	Attributes (Maximum Possible Score)
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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)
Harvest 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

Skagit Chinook Salmon Populations
May 2005 Technical Gap Analysis
Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the 2005 Skagit Recovery Plan. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the Skagit Plan is an excellent start for recovery of the six Skagit Chinook populations. The Plan does a comprehensive job of organizing and summarizing the status of the population and what is known about the historical and current limiting factors and impacts on the populations based on qualitative and quantitative assessments. The plan should give the basis for the recovery goals stated.

Habitat Management Strategy

Key Technical Gaps

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

- Integrate the strategy for protecting and restoring nearshore marine habitats with the all-H strategies
- Develop an adaptive management plan and decision framework in the Plan that highlights the following elements: strategic goals and objectives, metrics to measure progress toward objectives, nature of the data required to evaluate

metrics, criteria for using the metrics to make decisions, alternative pathways for decisions in the attainment of recovery.

- Document assumptions used in EDT model.
- Conduct sensitivity analyses for the EDT model to explain the relative importance of assumptions and model inputs for the estimated (modeled) effects of recovery actions on habitat conditions and population parameters.
- Coordinate nearshore recovery plans with Island recovery watershed.
- Determine how to sequence implementation of recovery actions.

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

The plan used both a qualitative and quantitative model approach. The qualitative model was used for habitat process and linking habitat conditions to effects on all four VSP parameters. A quantitative model was used to determine the biological responses to restoration actions. There was good analysis for productivity and abundance and how marine survival affects the stocks. There is little to explain affects on diversity and spatial structure. Analyses are done on management units rather than individual populations.

Key Issues to Improve Certainty:

- Documentation of basis for recovery goals

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

Quality of data is high. The information is generally good, but is lacking in population specific information.

Key Issues to Improve Certainty:

- Develop population specific estimates.

Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?

Yes for all populations. The recovery strategy is consistent with the recovery hypotheses for population status and the key habitat factors limiting recovery. There is good H-integration included.

Does the habitat recovery strategy preserve options for recovery of all four VSP parameters across all Hs?

No for all populations. The plan does not have an adequately developed adaptive management plan that preserves options for recovery.

Key Issues to Improve Certainty:

- Fully develop the adaptive management plan and decision framework. An adaptive management plan should highlight the following elements: strategic goals and objectives, metrics to measure progress toward objectives, nature of the data required to evaluate metrics, criteria for using the metrics to make decisions, alternative pathways for decisions in the attainment of recovery.

Are the habitat recovery actions consistent with the recovery strategy?

Yes for all populations.

Key Issues to Improve Certainty:

- Make sure that the opportunistic nature of choosing actions doesn't miss important sequencing of projects or classes of actions needed to meet the strategy.

How well have the habitat actions been shown to work?

Support for habitat actions is moderate. There is good empirical evidence for the effect of many of the individual actions proposed by the habitat portion of the plan in other watersheds as well as the Skagit River. The tidal delta restoration project monitoring gives a good example of actions working.

Ways to improve certainty in plan outcomes:

- Systematically analyze the potential cumulative effects of protection and restoration measures.

Skagit Hatchery Management Strategy

Key Technical Gaps

The most important ways to improve the certainty of an effective hatchery strategy in this plan are to

- Develop contingency conservation plan for early-run Chinook as requested by HSRG.
- Develop and implement an appropriate adaptive management plan.

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 (BRAP) cited in co-managers' resource management plan) to understand the potential affects of hatchery actions on populations. The model addressed all VSP criteria. Documentation is 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 model for Skagit River populations. The recovery plan indicates that the co-managers have good genetic and demographic data, which we assumed were used to assess the effects of hatchery actions on abundance, diversity, and to some extent spatial structure. Information to assess the effects of ecological interactions (e.g. competition, predation, and disease) and domestication on productivity and spatial structure appeared to be less available.

Since the original assessments using the BRAP, addition tools and assessments have been developed that could refine this understanding, including the Hatchery Scientific Review Group (HSRG) review; the All 'H' Hatchery Analyzer (AHA) model also developed by the HSRG; and quantitative models developed to evaluate domestication, effects of small population size, and competition and predation by WDFW and the NWIFC as part of the hatchery risk assessment modeling project (RAMP).

Key Issues to Improve Certainty:

- Refine existing assessments or use additional models that will allow managers to assess through sensitivity analyses how the certainty of the results and their decisions is affected by changes in different factors (such as the factors that can be controlled through hatchery management actions).

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

Support for the recovery hypothesis using watershed specific data was low. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. In the Skagit River watershed, the co-managers had some genetic information supporting affects of straying on diversity and spatial structure. More empirical information is needed on ecological effects, such competition or predation from hatchery programs for other species. Recovery rates of adults is low for strays, is not good for mark rates. There is some genetic information for hatchery versus natural populations, but there is no information for phenotypic differences. There is some information on likelihood of ecological interactions in the estuary for hatchery and wild Chinook salmon, but not for other hatchery species.

Key Issues to Improve Certainty:

- Use available data from other watersheds to increase the analytical support and to document assumptions.
- Collect information on ecological interactions of hatchery and wild fish.

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

Yes, given that the hypothesis is that indicator stock objective of program is not impeding recovery.

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

No. The Plan strongly emphasizes many actions that should help preserve options for recovery. Until an adaptive management plan is designed and implemented, however, the ability to make intelligent management decisions that will accomplish this goal is not great.

Key Issues to Improve Certainty:

- Develop and implement an appropriate adaptive management plan.
- Develop a truly all-H integrated strategy in the Skagit plan that can be monitored and adapted over time.

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 a strategy for maintaining the genetic diversity of these populations.

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

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. Supplementation programs have been shown to prevent extinction and their effectiveness in recovering populations to viable status is still unknown. Areas that are especially uncertain in the Skagit are actions to reduce competition or predation, if it occurs, and actions to reduce straying of hatchery fish.

Key Issues to Improve Certainty:

- Develop and implement an adaptive management plan and an appropriate monitoring program.

Skagit Harvest Management Strategy

Key Technical Gaps

This evaluation is based on the Skagit Summer/Fall and Spring Management Unit profiles, pages 95-130 of the *Comanagers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the Skagit watershed plan.

The harvest management portion of the recovery plan is based on the hypothesis that the intrinsic natural productivity of the Skagit populations, under current habitat conditions and recently observed poor marine survival conditions, is sufficiently high to allow for the population to recover if the adult equivalent exploitation rate is less than or equal to the rebuilding exploitation rate (RER). The intent is to allow harvest of Skagit Chinook incidental to fisheries targeting harvestable returns of other species or hatchery origin Chinook, while keeping the total exploitation rate on Skagit Chinook below RER. The

Skagit chinook are managed by two management units (early and late runs) rather than for the individual populations.

Ways to improve plan certainty:

- Demonstrate how managing for RERs computed for management units (MU) will protect the individual populations within each MU or Develop RERs for each of the six Skagit populations.
- Integrate harvest recovery with the other hatchery and habitat recovery actions. Incorporate results from analytical tools, such as AHA, EDT, or SHIRAz, to document integration of habitat, harvest, and hatchery strategies
- Develop an adaptive management plan
- Expand the strategy to include the effects of harvest on diversity and spatial distribution. How does harvest management affect achieving recovery goals for the four existing life history types seen in the Skagit?

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

The harvest management analysis used one model (VRAP) that looks at three different functions for the spawner-recruit relationships at the management unit level. The VRAP simulation model is used to determine the rebuilding harvest rate (RER) and used as input for spawner-recruit relationships that were determined from the Dynamic Model.

Ways to Improve Plan Certainty:

- Refine analyses of RERs by developing population specific estimates and by incorporating simulation results from additional models.

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

Low. Only two of the four VSP characteristics are considered. The model included qualitative and quantitative descriptions of the link between harvest management and two VSP characteristics, abundance and productivity. The recovery hypothesis is supported by local escapement data. The effects of harvest on diversity and spatial distribution, however, were not addressed by the harvest models. In particular, harvest management based on the aggregation of independent populations into two management units may not accurately account for the different spatial distribution and diversity of the six populations.

Ways to improve plan certainty:

- Incorporate spatial structure and diversity in to the modeling of harvest effects on VSP
- Develop population specific indicator stocks.

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

Moderate. There were some empirical data available to support the modeling, but these have not yet been used to develop relationships for management. There were good local data on the contribution of hatchery strays to the natural escapement for some, but not all populations.

Key Issues to Improve Certainty:

- Collect and use data from each of the six populations to incorporate spatial structure and diversity into the modeling of harvest effects on VSP

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

No. The harvest management strategy is that a single RER derived from data combined for groups of three populations will be appropriate for all three simultaneously.

Key Issues to Improve Certainty:

- Explore the potential differences in relevant RERs for the individual populations.
- Expand the strategy to include the effects of harvest on diversity and spatial distribution.
- Incorporate results from analytical tools, such as AHA, EDT, or SHIRAz, to document integration of habitat, harvest, and hatchery strategies

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

No. The harvest strategy appears to protect parts of the existing VSP structure. However, it does not respond to the needs of individual populations. If only one population within a MU were drastically reduced, and if this could be detected through preseason forecasting, then that population would drop below the critical escapement level triggering a minimum fishing regime. However, that portion of the strategy does not sufficiently guard against the possibility that a management unit RER is inappropriate for a single population within the management unit.

Key Issues to Improve Certainty:

- Develop population-specific RERs.
- Develop and implement an appropriate adaptive management plan.

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

Yes. Actions appear to be consistent with the harvest strategy and with the overall integrated strategy that includes hatchery and harvest actions. The latter needs better documentation.

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

Support for recovery actions is high. Reduced exploitation rates have resulted in increased escapements.

II. 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*.

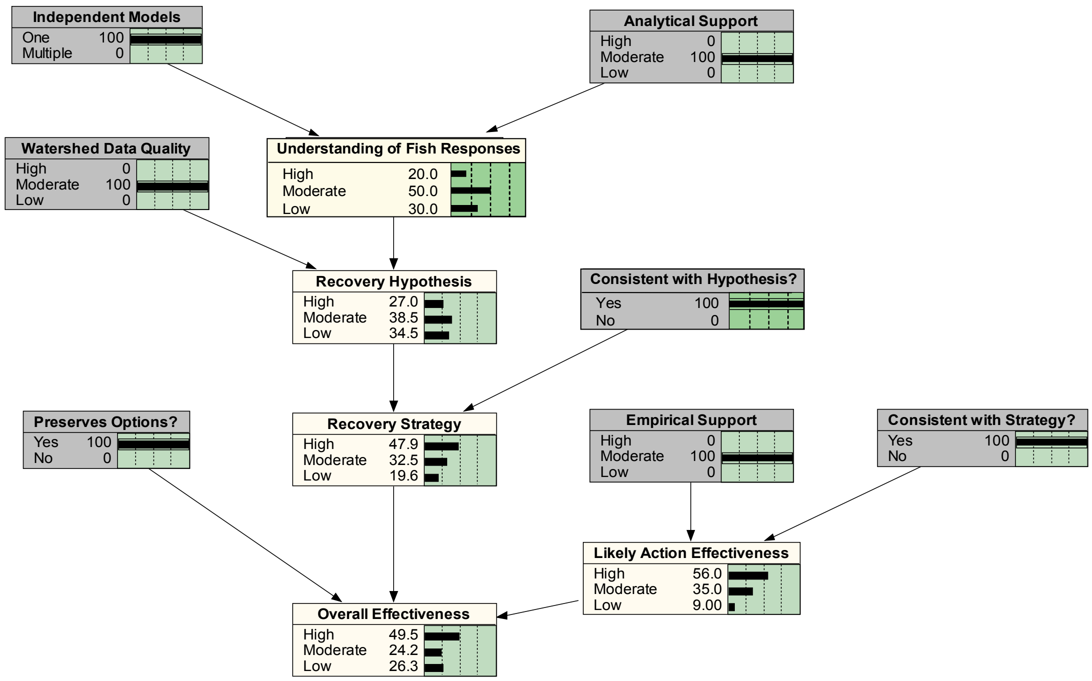

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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

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

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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, landuse, 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)
Harvest 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

Stillaguamish Plan: North Fork and South Fork Stillaguamish Chinook Salmon Populations – November 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the Stillaguamish watershed recovery plan submitted to the Shared Strategy in April 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies

or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. Summary of Certainty Analysis

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall the Stillaguamish plan provides a comprehensive, multi-faceted, approach to a very difficult situation for chinook salmon recovery. The strategies for habitat, harvest management, and hatchery actions are by and large based on a consistent set of hypotheses for understanding the reasons that chinook productivity and abundance have declined in the system. Although prospects for recovery are not good under current habitat conditions, the combined actions called for in the plan, if carried out, have some likelihood of changing habitat for the better ad increasing the probability of recovery. Persistence of the North Fork Stillaguamish population is currently dependent upon a hatchery supplementation program, which should provide recruitment to rapidly take advantage of habitats that improved as this plan is implemented. The actions in the three h-s are pretty well coordinated, and the comments below suggest some plan improvements that could increase the effectiveness of this coordination and thus the probability of the plan's success.

Habitat Strategy

Key Technical Gaps

The most important technical gaps remaining in this plan are discussed below. We highlight key issues that, if addressed, will improve the certainty of an effective habitat strategy in the near-term plan. Approaches to address the gaps below have been identified for this watershed in the Shared Strategy regional recovery plan:

- Base the projections of future effects of plan actions on a 'current path" rather than a "current conditions" baseline. Because likely ongoing habitat degradation was not part of the baseline used in this plan, projections of future benefits of habitat actions may be overly optimistic.
- Include habitat protection or restoration strategies that take into account the potential effects of floodplain structure and connectivity on in-stream habitat conditions such as flows and fine sediment.
- Integrate the strategy for protecting and restoring nearshore marine habitats with the freshwater habitat strategies, then revise the all-H strategy, if necessary.
- Develop and describe the overall approach to managing urban growth (via CAO, SMP, etc.) and actions aimed at addressing growth.
- Complete the description of how the habitat recovery strategy is consistent with the strategies for hatchery and harvest management for the NF and SF Stillaguamish populations. For example, including a consideration of how the proposed habitat restoration measures may affect interactions between hatchery and wild fish is one way in which consistency between the habitat and the hatchery strategies can be checked.
- Complete the adaptive management and monitoring plan along the lines of the framework presented in the chapter. Identify in the adaptive management plan which agencies or authorities specifically have the authority to make management decisions for choosing or modifying particular actions.

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

One model was used for each of the NF and SF Stillaguamish populations to evaluate the potential responses of Chinook populations to changes in habitat conditions. The certainty in the analytical model used to link changes in habitat conditions to fish population response in the Stillaguamish plan is moderate.

EDT was used to estimate quantitatively the effects of changes in habitat conditions on all 4 VSP attributes of the NF and SF Stillaguamish populations. The EDT model did not incorporate quantitative estimates of the effects of changes in habitat-forming processes (e.g., sediment dynamics, riparian function, floodplain dynamics) or land use/land cover conditions on in-stream habitat conditions or on Chinook VSP. The Stillaguamish plan did have a good qualitative model of the potential degrees of impairment of habitat-forming processes in the Basin, and how those might have affected in-stream habitat conditions relevant to Chinook. How the effects of modeled projects were translated into habitat conditions in EDT is documented in spreadsheets in the computer, but these methods are not yet summarized in the plan. No sensitivity analyses for EDT have been conducted, so it is not clear how modeled results of the effects of habitat restoration and protection projects on habitat conditions might change under different assumptions. Similarly, no analyses have been conducted exploring the sensitivity of the EDT model results to assumptions about how habitat conditions affect Chinook population status. A calibration of the EDT model in the Stillaguamish watershed was conducted for current habitat conditions and current Chinook abundance and productivity data. While the observed data and the EDT model for the NF Stillaguamish agree, the fit is poor in the SF Stillaguamish. No calibrations of the model occurred for the effects of habitat restoration projects or for how Chinook diversity might respond to modeled actions.

Ways to improve certainty in plan outcomes:

- Conduct sensitivity analyses for EDT so that the relative importance of assumptions and model inputs for estimated effects of recovery actions can be understood.
- Document assumptions made and inputs to EDT for how habitat-related protection and restoration projects affected in-stream habitat conditions.

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?

There is moderate support in watershed-specific data for the habitat factors estimated to be limiting recovery of the NF and SF Stillaguamish populations. There is a good discussion of the potential effects of flow on juvenile survival using in-system data.

The stated hypothesis in the draft Stillaguamish recovery plan is that 6 primary habitat factors are limiting recovery and if they are corrected, the Chinook in the NF and SF populations will recover. The current condition of the 6 habitat factors in the Basin is relatively well understood. Life-stage specific Chinook productivity data are not available for either the NF or the SF population. Information on the VSP status of the SF Stillaguamish population is not provided. In addition, there is very little information in the Basin on the interactions among habitat-forming processes and land use attributes and how they affect the in-stream habitat conditions used in their modeling.

Ways to improve certainty in plan outcomes:

- Summarize what is known in the Stillaguamish Basin about the mechanistic links between land use, habitat-forming processes, and in-stream habitat conditions.
- Collect data on juvenile use of and survival in different habitat types.
- Monitor and study linkages between habitat-forming processes, land use, and in-stream habitat conditions so that mechanistic links among those can be better understood, protected and restored.

Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?

The habitat recovery strategy in the draft Stillaguamish recovery plan is not completely consistent with the hypotheses for what population status and habitat, harvest and hatchery problems are limiting recovery.

The habitat hypothesis stated in the plan is that flow and sediment problems in the lower Stillaguamish River are limiting recovery. The proposed habitat recovery strategy addresses potential sources of fine sediment and impaired hydrology by examining land uses throughout the basin. However, the context used to estimate the effectiveness of habitat actions is based on "current conditions" rather than a "current path" (under which conditions will change over time) scenario. Furthermore, it is not clear how the habitat strategy stated in the Stillaguamish plan relates to the hatchery and harvest management strategies for recovery of the 2 populations.

Ways to improve certainty of plan actions:

- Include a "current path" or "build-out" analysis as part of the baseline against which proposed habitat actions are measured.
- Explicitly consider the interacting effects of hatchery and harvest management on the habitat management strategy.

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

The habitat recovery strategy in the draft Stillaguamish recovery plan includes a framework for an adaptive management plan that could be effective in adjusting actions as new knowledge is gained and preserving options for recovery. In this framework the triggers for adjusting actions are workable and clear, and the structure for decision making is promising. However, the certainty analysis rated this question a "NO", since the plan still needs to identify decision makers who can implement and change actions. The final adaptive management plan will need to bring in monitoring of process and landscape-scale aspects of the watershed so the basin's (and population's) degree of functioning over time can be tracked.

The habitat recovery strategy protects existing VSP structure and opportunities for future improvements in the "all-H" condition for both the NF and SF Stillaguamish populations.

Ways to improve plan certainty:

- Complete adaptive management and monitoring plan, building on the excellent framework that is in the chapter.

How well have the habitat recovery actions been shown to work?

There is moderate empirical support for the habitat recovery actions identified in the draft Stillaguamish recovery plan.

There is some empirical evidence of the effectiveness of the proposed habitat restoration actions in similar settings, but there are few tested applications of projects such as engineered log jams in the broader context of other restoration and protection actions. Although model predictions about the effects of individual actions are available, some conflicting empirical results occur. Very little is understood about how the cumulative and interactive effects of the various actions affect habitat-forming processes or in-stream habitat conditions. Furthermore, the analysis of the effects of habitat recovery actions does not incorporate uncertainty in the assessments nor is the consistency among various agreements such as HCPs, consultaions, etc. evaluated. In particular, evidence for the effects of habitat protection measures (e.g., critical areas ordinances, shoreline management plans) is not discussed.

Ways to improve certainty in plan outcomes:

- Summarize existing modeled or empirical support for the effectiveness of habitat protection and restoration actions identified in the plan.
- Design and implement a comprehensive monitoring and evaluation program that can track the integrated, cumulative effects of habitat protection and recovery actions over time.
- Systematically analyze the potential cumulative effects of protection measures. Specifically,
    - Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
- Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.

Are the habitat recovery actions consistent with the recovery strategy?

A clear and logical relationship exists between the “all-H” recovery strategy and the proposed habitat recovery actions in the draft Stillaguamish recovery plan.

- The major habitat protection and restoration actions identified clearly reflect the major elements of the recovery strategy.
- The habitat recovery actions logically derive from the spatial and temporal elements of the recovery strategy, and the actions have clear and logical outcomes that are predicted to be consistent with achieving the recovery strategy.

Hatchery Strategy - *North Fork Stillaguamish*

The objectives of the Chinook hatchery program in the North Fork Stillaguamish are 1) to supplement natural production such that the extinction risk will be reduced and the likelihood of recovery will be increased and 2) provide a group of coded-wire tagged fish that can act as an indicator stock in fisheries for Stillaguamish natural Chinook and other North Sound Chinook stocks.

The N.F. Stillaguamish population faces uncertainty because of the habitat conditions in the watershed, their expected duration, and the opportunities to correct them. Based on our analysis, the hatchery strategy for the population does one of the better jobs of reducing uncertainty.

Key Technical Gaps

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

- Improve consistency of strategy with recovery hypothesis by identifying how the strategy is consistent with long-term goals for all VSP attributes
- Develop and implement an adaptive management plan.

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 (the Benefit-Risk Assessment Procedure (BRAP) cited in co-managers' resource management plan) to understand the potential affects of hatchery actions on populations. The model addressed all VSP criteria. Documentation is 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 model for Stillaguamish River populations.

The co-managers have relatively good genetic and demographic data from this watershed. Consequently, it may is possible to use quantitative models to assess the affects of hatchery actions on some VSP characteristics. Since the original assessments using the BRAP, additional tools and assessments have been developed that could refine understanding, including the Hatchery Scientific Review Group's All 'H' Hatchery Analyzer (AHA) model and quantitative models developed to evaluate domestication, effects of small population size, and competition and predation by WDFW and the NWIFC as part of the hatchery risk assessment modeling project (RAMP). The co-managers also used AHA modeling results from HSRG to show that broodstock management in North Fork is consistent with maintaining positive genetic integration between the hatchery stock and the natural North Fork population. The co-managers also applied quantitative modeling using the newly developed dynamic EDT to explore effects of hatchery program in NF on population abundance and productivity. These modeling results did not include potential effects of ecological interactions between hatchery and wild fish (see region-wide issue for H-integration). No sensitivity analyses were done on the models to examine how much the results or decisions for proposed actions might depended on knowing specific variables.

Key Ways to Improve Certainty:

- Provide better documentation of assumptions used in each of the analyses described above
- Conduct sensitivity analyses to assess how uncertainty in the different factors used in the models might affect the certainty of the results and proposed hatchery management decisions.

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

Support for the recovery hypothesis using watershed specific data for was moderate. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. The co-managers had relatively good demographic information and some genetic information to support their hypothesis. Information to assess the effects of ecological interactions (e.g. competition, predation, and disease) and domestication on productivity and spatial structure is lacking.

Key Ways to Improve Certainty:

- Over the long-term, collect information on ecological interactions of hatchery and wild fish
- In the short-term, use available data from other watersheds to increase the analytical support and to document the assumptions that would be part of that.

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

Yes. Overall, the actions this program has taken to date and the proposed actions in the plan indicate a strategy that should be consistent with recovery. We had two questions about consistency with the recovery hypothesis, however. First, although the plan emphasizes using the hatchery strategy to protect current VSP characteristics, the primary emphasis of the program appears to be on maintaining abundance in the face of lack of productivity because of habitat degradation. This may be consistent with recovery in the short-term, but the long-term exit strategy for the program, for example, also appears to be based only on achieving a level of abundance and on some consideration of diversity rather than all four VSP characteristics. We believe it should be possible to identify goals for other VSP characteristics as well and that future changes in the production goals of the hatchery may depend on these attributes as well as the current focus on abundance. Given the thoughtfulness of the overall plan, these may actually exist, but they were not as well identified in the plan.

Key Ways to Improve Certainty:

- Identify all VSP goals for the program and how they relate to possible exit strategy or major changes in the nature of the hatchery program.

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

Not yet. The plan emphasizes protecting current VSP characteristics (see comment above), which is important for preserving future options for recovery. Preserving options also requires an adaptive management plan to respond to changes and uncertainty as they occur. The hatchery and genetic management plan (HGMP) lists some of the monitoring and evaluation criteria. An additional important piece is how decisions will be made given the results of monitoring and evaluation.

Key Ways to Improve Certainty:

- Develop and implement an appropriate adaptive management plan the builds off of proposed monitoring outline and includes framework for decision making.

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

No. The details of the strategy outlined in the recovery plan and associated documents, such as the co-managers' resource management plan and the hatchery and genetic management plan (HGMP) are consistent with the recovery strategy. The major factor that was missing was that actions for implementing the strategy do not appear to include those that could assess and reduce potential negative impacts of ecological interactions between hatchery and wild fish.

Key Ways to Improve Certainty:

- Document or identify actions that address any potential negative impacts from ecological interactions between hatchery fish from proposed programs and wild Chinook salmon.

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

Support for the proposed actions is moderate.
Experience in other watersheds and the N.F. Stillaguamish River suggests the actions may be working to maintain abundance of the population, although there is considerable uncertainty about other VSP characteristics. Areas that are especially uncertain are 1) the long-term effect of domestications on productivity, and 2) the actions to reduce competition, predation, and other ecological interactions to the extent they may be a problem.

Hatchery Strategy - *South Fork Stillaguamish*

The South Fork Stillaguamish population faces uncertainty in recovery planning because of the genetic status of the population is unknown, habitat conditions in the watershed are degraded, and there has been a lack of focus on recovery planning for the population. The Stillaguamish watershed planning group has prioritized the recovery of the North Fork population, which represents important life history diversity in this region.

Key Ways to Improve Certainty

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

- Collect better information on the status of the South Fork.
- Develop an adaptive management plan
- Develop a better-defined hatchery strategy, including actions consistent with the strategy.

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 (BRAP) cited in co-managers' resource management plan) to understand the potential affects of hatchery actions on populations. The model addressed all VSP criteria. Documentation is 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 model for Stillaguamish River populations. Compared to the available information for the North Fork population, information for the affects of hatchery strategies on the South Fork population appears to be based on expert opinion or local knowledge. These assumptions about the population status need to be better identified and described as they could form the basis for future monitoring, research, and adaptive management.

Key Ways to Improve Certainty:

- Provide better documentation of assumptions used in each of the analyses described above
- Collect better information on the status of the South Fork population.

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

Support for the recovery hypothesis using watershed specific data for was moderate. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. As indicated above, the lack of information on the status of the South Fork population is a key factor in the uncertainty associated with this hatchery strategy. See recommendation above.

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

Yes. Overall, the proposed actions in the plan indicate a strategy that should be consistent with recovery.

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

Not yet. Preserving options also requires an adaptive management plan to respond to changes and uncertainty as they occur.

Key Ways to Improve Certainty:

- Develop and implement an appropriate adaptive management plan and includes framework for decision making.

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

No. The many of the details of the strategy are consistent with the overall recovery strategy. The major factor that was missing was that actions for implementing the strategy do not appear to include those that could assess and reduce potential negative impacts of ecological interactions between hatchery and wild fish.

Key Ways to Improve Certainty:

- Document or identify actions that address any potential negative impacts from ecological interactions between hatchery fish from proposed programs and wild Chinook salmon.

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

Support for the proposed actions is moderate.

Experience in other watersheds suggests the actions may be working to maintain abundance of the population, although there is considerable uncertainty about other VSP characteristics. Areas that are especially uncertain are 1) the long-term effect of domestications on productivity, and 2) the actions to reduce competition, predation, and other ecological interactions to the extent they may be a problem.

Harvest Management Strategy – *North Fork Stillaguamish*

NOTE: This evaluation is based on the Stillaguamish Management Unit profile, pages 131-135 of the *Comanagers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the plan submitted by the WRIA 5 group.

The harvest management portion of the recovery plan is based on the hypothesis that the intrinsic natural productivity of the North Fork Stillaguamish population, under current habitat conditions and recently observed poor marine survival conditions, is sufficiently high to allow for the population to recover if adult the equivalent exploitation rate is less than or equal to the rebuilding exploitation rate (RER) that will guide annual management of this population. The RER for the North Fork Stillaguamish population is .30, which has been adjusted downwards to .25 to reflect the observed discrepancy between exploitation rates estimated directly from coded-wire tag analysis (which the RER calculations used) and exploitation rates estimated by FRAM. The comanagers fitted the observed spawner and recruit data (available in the TRT's Abundance and productivity tables) to a single, hockey-stick type, model and simulated population performance for 25 years with 1000 replications at each exploitation rate tested. The RER was the highest exploitation rate that showed both a smaller than 5% probability of going below the lower escapement threshold of 500 natural spawners in all years and a greater than 80% probability of the population showing positive growth in natural-origin escapement over the 25 year simulation.

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

- Expand the hypothesis and the recovery strategy to include the effects of harvest on diversity and spatial distribution.
- Include existing local data pertaining to spatial distribution and diversity to support the expanded hypothesis and the expanded strategy and actions based on it.

Specific ratings:

Was the analysis based on one or many models?
One simulation model (VRAP).
The simulation model analyzed three spawner-recruit relationships and used the harvest single hockey-stick type function as best representing the behavior of the North Fork population in recent years.

Ways to improve plan certainty:

- The analysis could be improved by including another simulation model that could incorporate spatial structure and diversity.

Analytical support for model:
Moderate.

The model includes qualitative and quantitative descriptions of the link between harvest management and abundance and productivity. The effects of harvest on diversity and spatial distribution are not addressed. The documentation for the quantitative analysis is not presented in sufficient detail, and there was no sensitivity analysis performed. Empirical data from the North Fork Stillaguamish support the model conclusions for abundance and productivity.

Ways to increase plan certainty:

- Documentation for previously-completed work should be fleshed out so that the conclusions can be evaluated.
- There should be some discussion, and analysis if possible, of the potential effects of harvest management on spatial structure and diversity.

Quality of data used to support recovery hypothesis:
High. These are the best data for harvest as an indicator stock in North Puget Sound—these harvest rate estimates are relatively certain. The harvest mgt plan could include estimates of the effects of harvest mgt on all 4 VSP—this is a gap we think can be filled, given existing information.

The recovery hypothesis is supported by local escapement data for the whole population. Recent exploitation rates are well documented for this population by a local exploitation rate indicator stock. There are also local data available to support hypotheses regarding the effects of harvest on diversity and spatial distribution.

Ways to increase plan certainty:

- This rating could be increased if the hypothesis were expanded to include diversity and spatial distribution using existing data pertaining to these factors.

Recovery strategy preserves future options:
Yes
The harvest strategy appears to protect the existing VSP structure. This is demonstrated for abundance and productivity from recent spawner-recruit data and assumed for diversity and spatial structure because of declining exploitation rates. The harvest management plan has adaptive management built in to it and there is a local North Fork Stillaguamish indicator stock, which can be used to assess exploitation rates and productivity annually.

Ways to increase plan certainty:

- The plan needs to include a definite schedule for implementing the adaptive management plan, including the conditions under which the RER would be modified.

Recovery strategy is consistent with recovery hypothesis:
No
The harvest management strategy is consistent with the hypothesis regarding abundance and productivity. However, the hypothesis does not consider diversity and spatial distribution and therefore these are not included in the strategy.

- Expand the hypothesis and the recovery strategy to include the effects of harvest on diversity and spatial distribution.

How certain is the empirical support for the effectiveness of the recovery actions:
High
The recovery plan calls for reduction of the annual exploitation rate to the RER or below. Recent data, from the North Fork Stillaguamish and using a local indicator stock documents that the exploitation rates have been reduced and that these reduced exploitation have resulted in increased abundance on the spawning grounds. The plan discusses the FRAM model that will be used for annual implementation of the RER and the RER has been adjusted based on a comparison of the FRAM and CWT assessments of the exploitation rate.

Ways to increase plan certainty:
- Use existing spawner survey and other data to document whether reduced exploitation rates have improved spatial distribution and diversity.

Are the harvest management recovery actions consistent with the plan's all-H recovery strategy?
Yes
The harvest management strategy is based on an analysis that incorporates the abundance and productivity that results from existing habitat conditions. The strategy includes a discussion of how guidelines will be modified if improved or degraded habitat changes abundance or productivity. The plan also includes an implied hypothesis that harvest rates on hatchery fish will be low enough to allow hatchery supplementation fish to migrate to natural spawning areas in the numbers contemplated by the hatchery plan. However, with the advent of selective fisheries and the possibility of hatchery and wild fish being subject to different exploitation rates, this assumption may not be valid.

Ways to increase plan certainty:
- Inclusion of a strategy for the marking or non-marking of hatchery fish and for management of the harvest of marked fish consistent with the goal of using hatchery fish for supplementation of spawning escapement would improve the plan's likelihood of success.

Harvest Management Strategy – *South Fork Stillaguamish*

NOTE: This evaluation is based on the Stillaguamish Management Unit profile, pages 131-135 of the *Comanagers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the plan submitted by the WRIA 5 group.

The harvest management portion of the recovery plan is based on the hypothesis that the intrinsic natural productivity of the South Fork Stillaguamish population, under current habitat conditions and recently observed poor marine survival conditions, is sufficiently high to allow for the population to recover if the adult equivalent exploitation rates is less than or equal to the rebuilding exploitation rate (RER) that will guide annual management of this population. The RER for the South Fork Stillaguamish population is based on the North Fork Stillaguamish analysis because there is no separate indicator stock for the SF Stillaguamish and observed data for the SF Stillaguamish did not fit any model well.

Ways to increase plan certainty:

- Expand the hypothesis and the recovery strategy to include the effects of harvest on diversity and spatial distribution.
- Include existing local data pertaining to spatial distribution and diversity to support the expanded hypothesis and the expanded strategy and actions based on it.

Specific ratings:

Was the analysis based on one or many models?
One simulation model (VRAP).
The simulation model analyzed three spawner-recruit relationships and used the harvest single hockey-stick type function as best representing the behavior of the North Fork population in recent years. The harvest management strategy implicitly assumes that the RER appropriate for the North Fork Stillaguamish will also work for the South Fork Stillaguamish.

Ways to increase plan certainty:

- The analysis could be improved by including another simulation model that could incorporate spatial structure and diversity.

Analytical support for model:
Moderate
The model includes qualitative and quantitative descriptions of the link between harvest management and abundance and productivity. The effects of harvest on diversity and spatial distribution are not addressed. The documentation for the quantitative analysis is presented in some detail, but there was no sensitivity analysis performed. There are no empirical data from the South Fork Stillaguamish to support the model conclusions for any VSP measure.

- Documentation for previously-completed work should be fleshed out so that the conclusions can be evaluated.
- There should be some discussion of the potential effects of harvest management on spatial structure and diversity.
- Incorporation of a habitat-based model specific to the South Fork population could provide a test of whether the North Fork RER analysis is in fact appropriate for the South Fork population.

Quality of data used to support recovery hypothesis:
Moderate
The recovery hypothesis is supported by local escapement data for the whole population. Recent exploitation rates are well documented for the North Fork Stillaguamish population by a local exploitation rate indicator stock. Escapement data from the South Fork could be used to support hypotheses regarding the effects of harvest on diversity and spatial distribution.

Recovery strategy preserves future options:
No
The harvest strategy appears to protect the existing VSP structure. However, recent population levels are very low compared with the potential indicated by EDT. The harvest management plan has adaptive management built in to it. However the lack of a local South Fork Stillaguamish indicator stock, and the lack of fit of available data to spawner-recruit models, suggests that the adaptive management plan may be difficult to implement for this population.

Ways to improve plan certainty:
- The plan needs to include a definite schedule for implementing the adaptive management plan, including the conditions under which the RER would be modified.
- The plan also needs to include a means by which exploitation rates specific to the South Fork Stillaguamish population will be assessed for monitoring and adaptive management.

Recovery strategy is consistent with recovery hypothesis:
No
The harvest management strategy is consistent with the hypothesis regarding abundance and productivity. However, the hypothesis does not consider diversity and spatial distribution and therefore these are not included in the strategy.

Ways to improve plan certainty:
- The hypothesis needs to be expanded to include the effects of harvest on diversity and spatial distribution and the strategy needs to be expanded to address these factors.

How certain is the empirical support for the effectiveness of the recovery actions?:
High
The recovery plan calls for reduction of the annual exploitation rate to the North Fork RER or below. Recent data from the South Fork Stillaguamish document that South Fork escapements have increased as North Fork exploitation rates have declined. The plan addresses the FRAM model that will be used for annual implementation of the RER and the RER has been adjusted based on a comparison of the FRAM and CWT assessments of the exploitation rate.

Ways to improve plan certainty:
- Existing data should also be used to document whether reduced exploitation rates can improve spatial distribution and diversity.

Are the harvest management recovery actions consistent with the plan's all-H recovery strategy?
Yes
The harvest management strategy is based on an analysis that incorporates the abundance and productivity that results from existing habitat conditions. The strategy includes a discussion of how guidelines will be modified if improved or degraded habitat changes abundance or productivity.

Ways to improve plan certainty:

- Inclusion of an assessment of the stock composition of the South Fork escapement would help determine whether the increased escapement that is correlated with reduced exploitation rates comes primarily from local stock or from strays from nearby hatchery and wild stocks.

II. 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*.

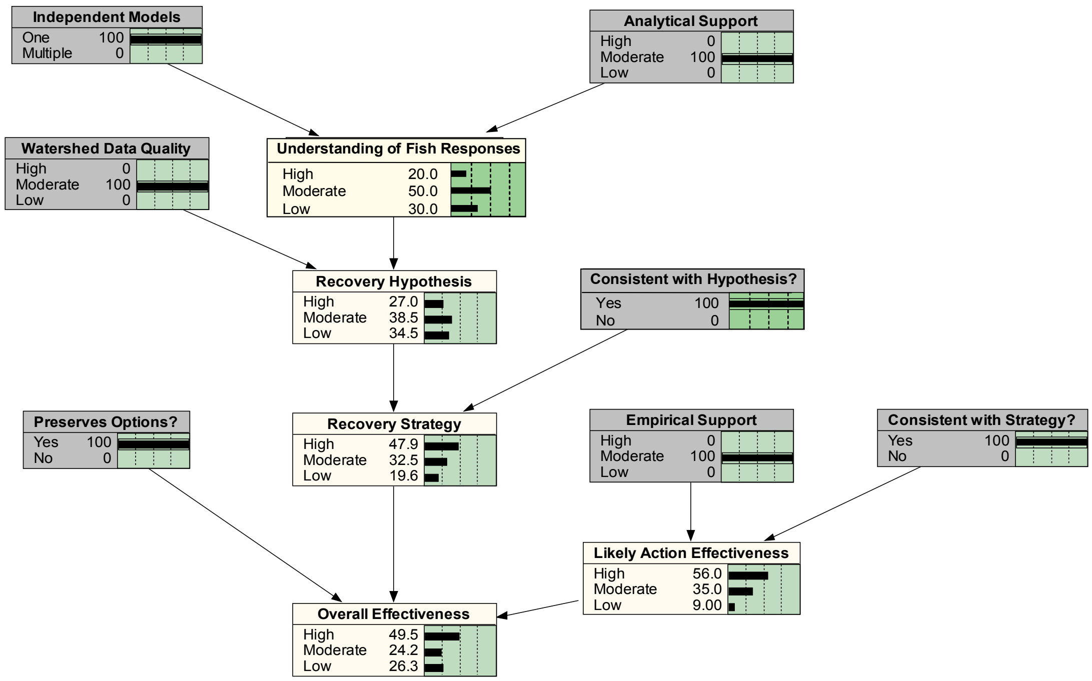

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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

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

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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, landuse, 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)
Harvest 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

Snohomish Plan: Skykomish and Snoqualmie Chinook Salmon Populations – May 2005 Technical gap analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the Snohomish watershed recovery plan submitted to the Shared Strategy in April 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information

from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Habitat strategy

Key technical gaps

The most important technical gaps remaining in this plan are discussed below. We highlight key issues that, if addressed, will improve the certainty of an effective habitat strategy in the near-term plan. Approaches to address the gaps below have been identified for this watershed in the Shared Strategy regional recovery plan:

- Include habitat protection or restoration strategies that take into account the potential effects of water quantity management on flows, temperature, and fine sediment.
- Develop and describe the overall approach to managing urban growth (via CAO, SMP, etc.) and actions aimed at addressing growth.
- Include in the adaptive management and monitoring plan an approach for measuring what biological results are expected from each protection measure

- Continue working to make the habitat recovery strategy consistent with the strategies for hatchery and harvest management for the Skykomish and Snoqualmie populations.
- Integrate the strategy for protecting and restoring the nearshore with the all-H strategies

Based on our analysis, developing and implementing the key items above would greatly increase the likelihood of a "high" level of certainty for this plan.

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

Two quantitative models were used for each of the Skykomish and Snoqualmie populations to evaluate the potential responses of Chinook populations to changes in habitat conditions. The certainty in the analytical models used to link changes in habitat conditions to fish population response in the Snohomish plan is high.

- This is one of the better plans for describing and quantifying a model for how habitat conditions affect VSP. EDT and SHIRAZ models used to estimate quantitatively the effects of changes in habitat conditions on all 4 VSP attributes of the 2 populations.
- Neither model incorporated quantitative estimates of the effects of changes in habitat-forming processes (e.g., sediment dynamics, riparian function, floodplain dynamics) or land use/land cover conditions on in-stream habitat conditions or on Chinook. The Snohomish does have a good qualitative model and quantitative analyses of the potential degrees of impairment of habitat-forming processes in the Basin, and how those might have affected in-stream habitat conditions relevant to Chinook.
- Documentation for process analyses and SHIRAZ is good. Assumptions for current path and test case alternatives modeled in SHIRAZ and EDT are well documented. How the effects of modeled projects were translated into habitat conditions in EDT is documented in spreadsheets in the computer, and these methods are summarized generally in the plan.
- No sensitivity analyses for EDT have been conducted, so it is not clear how modeled results of the effects of habitat restoration and protection projects on habitat conditions might change under different assumptions. Similarly, no analyses have been conducted exploring the sensitivity of the EDT model results to assumptions about how habitat conditions affect Chinook population status. Sensitivity analyses for how improvements in different life stages affect overall population dynamics have been conducted for SHIRAZ.
- A calibration of the EDT and SHIRAZ models in the Snohomish watershed was conducted for current habitat conditions and current Chinook abundance and productivity data. No calibrations of the EDT model occurred for the effects of habitat restoration projects or for how Chinook diversity might respond to modeled actions.

  Ways to improve certainty in plan outcomes:

  - Document assumptions made and inputs to EDT for how habitat-related protection and restoration projects affected in-stream habitat conditions.

- Conduct sensitivity analyses for EDT so that the relative importance of assumptions and model inputs for estimated effects of recovery actions can be understood.

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?

There is moderate support in watershed-specific data for the habitat factors estimated to be limiting recovery of the Skykomish and Snoqualmie populations.

- The stated hypothesis in the draft Snohomish recovery plan is that specific habitat factors are limiting recovery and if they are corrected, the Chinook in the 2 populations will recover.
- The current condition of the habitat and the functioning of habitat-forming processes in the Basin are relatively well understood.
- Life-stage specific Chinook productivity data are not available for either population.
- In addition, there is very little information in the Basin on the interactions among habitat-forming processes and land use attributes and how they affect the in-stream habitat conditions used in their modeling.

Ways to improve certainty in plan outcomes:

- Summarize what is known in the Snohomish Basin about the mechanistic links between habitat-forming processes, land use, and in-stream habitat conditions.
- Collect data on juvenile use of and survival in different habitat types.
- Monitor hypothesized linkages between habitat-forming processes, land use, and in-stream habitat conditions so that mechanistic links among those can be better understood, protected and restored.
- Collect data on juvenile use of and survival in different habitat types.

Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?

The habitat recovery strategy in the draft Snohomish recovery plan is mostly consistent with the hypotheses for what population status and habitat, harvest and hatchery problems are limiting recovery. A strength of this plan is that they took the time to model (coarsely) 'what would it take' to get to longer-term recovery? They were able to use the results from that analysis to strengthen their strategies so that they better identify and anticipate these long term needs.

- As stated above, the habitat hypothesis outlined in the plan is that key habitat problems in the Snohomish River are limiting recovery. The proposed habitat recovery strategy addresses habitat problems such as potential sources of fine sediment and impaired riparian functioning. In contrast, the habitat recovery strategy does not clearly address how changes in water management will affect flows.

- Furthermore, it is not clear how the habitat strategy stated in the Snohomish plan relates to the hatchery and harvest management strategies for what is hypothesized to be needed for recovery of the 2 populations. There is a good start at describing how these 3 H's interact.

Ways to improve certainty in plan outcomes:

- Include habitat protection or restoration strategies that take into account the potential effects of water management actions on flows: are water managers protecting the current status of instream flows while they wait to negotiate new levels?
- Provide a description for how the habitat recovery strategy is consistent with the strategies for hatchery and harvest management for the Skykomish and Snoqualmie populations.

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

The habitat recovery strategy in the draft Snohomish recovery plan does not have a well-developed adaptive management plan that preserves options for implementation of the overall recovery strategy.

- The habitat recovery strategy protects existing VSP structure and opportunities for future improvements in the integration among the H's for both populations.
- In contrast, there is not a well-developed adaptive management and monitoring program that preserves options for implementation of the all-H strategy.

Ways to improve certainty in plan outcomes:

- Include an adaptive management decision framework in the plan that highlights where information from monitoring and evaluation of habitat projects and fish population responses will affect decisions about the overall recovery strategy.
- Design and implement a comprehensive monitoring and evaluation program.
- Use information from monitoring over time to adjust the recovery strategy as needed.

How well have the habitat recovery actions been shown to work?

There is moderate empirical support for the habitat recovery actions identified in the draft Snohomish recovery plan.

- There is some empirical evidence of the effectiveness of the proposed habitat restoration actions in similar settings; there are few tested applications of the effectiveness of projects such as engineered log jams when compared to, or integrated with, other restoration and protection actions.
- Although model predictions about the effects of individual actions are available, some conflicting empirical results occur.
- Very little is understood about how the cumulative effects of the actions interact to affect habitat-forming processes or in-stream habitat conditions.

- The analysis of the effects of habitat recovery actions does not incorporate uncertainty in the assessments. In particular, evidence for the effects of habitat protection measures (e.g., critical areas ordinances, shoreline management plans) is not discussed.

  Ways to improve certainty in plan outcomes:
  - Summarize existing modeled or empirical support for the effectiveness of habitat protection and restoration actions identified in the plan.
  - Design and implement a comprehensive monitoring and evaluation program that can track the integrated, cumulative effects of habitat protection and recovery actions over time.
  - Systematically analyze the potential cumulative effects of protection measures. Specifically,
    - Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
  - Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.

Are the habitat recovery actions consistent with the recovery strategy?

A clear and logical relationship exists between the “all-H” recovery strategy and the proposed habitat recovery actions in the draft Snohomish recovery plan.

- The major habitat protection and restoration actions identified clearly reflect the major elements of the recovery strategy.
- The habitat recovery actions logically derive from the spatial and temporal elements of the recovery strategy, and the actions have clear and logical outcomes that are predicted to be consistent with achieving the recovery strategy.

Snohomish Hatchery Management Strategy

The objective of the hatchery management in the Snohomish Basin is to provide opportunities for harvest, and to minimize the negative effects of hatchery programs on the ability of wild Chinook in the basin to recover.

The recovery plan for Snohomish watershed Chinook salmon populations follows a consistent scientific logic. Based on our analysis, the hatchery strategy for the population does one of the better jobs of identifying and reducing uncertainty. The major element missing is an adaptive management plan. Implementing the adaptive management plan with monitoring and evaluation of ecological interactions would address some of the uncertainties in the plan.

Key Ways to Improve Certainty

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

- Develop and implement an adaptive management plan.

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

Analytical support was high for the Skykomish population and moderate for the Snoqualmie population. The co-managers used a qualitative model (e.g. the Benefit-Risk Assessment Procedure (BRAP) cited in co-managers' resource management plan) to understand the potential affects of hatchery actions on populations. The model addressed all VSP criteria. Documentation is 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 model for the Snohomish River populations.

Since the original assessments using the BRAP, addition tools and assessments have been developed that could refine understanding, including the Hatchery Scientific Review Group's All 'H' Hatchery Analyzer (AHA) model and quantitative models developed to evaluate domestication, effects of small population size, and competition and predation by WDFW and the NWIFC as part of the hatchery risk assessment modeling project (RAMP). In addition, because Snohomish salmon recovery planners are using a population dynamic model, SHIRAZ, to examine a variety of recovery scenarios, they could potentially adapt the model to include a quantitative analysis of hatchery effects, which would allow for sensitivity analyses. This would allow planners to evaluate how their decisions might be affected by uncertainty in different management sector factors that drive recovery. We are aware such analyses exist, and including them in the plan will increase its certainty. In addition, good demographic and genetic data (e.g. straying and interactions with harvest) are available for these populations, which would allow the models to be partially calibrated with local data and to do sensitivity analyses. Most of these models do not included ecological interactions, but studies are underway to examine potential ecological interactions in the estuary. Until such results are available, assessment of ecological affects is based on weak inference.

Key Ways to Improve Certainty:

- Provide better documentation of assumptions used in each of the analyses described above
- Conduct sensitivity analyses to assess how uncertainty in the different factors used in the models might affect the certainty of the results and proposed hatchery management decisions.

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

Support for the recovery hypothesis using watershed specific data was moderate. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. The working hypothesis in this watershed is that the hatchery programs, which are intended to provide harvest, will not interfere with recovery. Demographic and some genetic data supported the watershed recovery hypothesis, but information was lacking for the effects of ecological interactions on VSP characteristics.

Key Ways to Improve Certainty:

- Over the long-term, collect information on ecological interactions of hatchery and wild fish. Potential assessments of ecological interactions among hatchery and wild fish should including interactions with all other hatchery salmonid species—e.g., coho, steelhead—in the basin.
- In the short-term, use available data from other watersheds to increase the analytical support and to document the assumptions that would be part of that.

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

Yes, but some weaknesses. The strategy is to use local stocks and release of hatchery fish at isolated locations to minimize ecological interactions, and to adjust production levels according to escapement and NOR goals in the fishery management plan. This is consistent with the recovery hypothesis for most VSP characteristics. However, the effects of the strategy on spatial structure (e.g. above Wallace River Hatchery) and the effects of the steelhead (e.g. in Tokul Creek) and coho salmon hatchery programs need to be addressed.

Key Ways to Improve Certainty:

- Develop and implement a plan to monitor ecological interactions between hatchery and wild fish and their effects on VSP characteristics.

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

No. Many aspects of this plan focus on preserving options for recovery. Preserving options also requires an adaptive management plan, which does not currently exist except through fishery management processes, to respond to changes and uncertainty as they occur. Overall, some of the best data for Puget Sound Chinook salmon comes from the Snohomish watershed. The co-managers are working on an improved monitoring program.

Key Ways to Improve Certainty:

- Develop and implement an appropriate adaptive management plan the builds off of proposed monitoring outline and includes framework for decision making.

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

Yes. The details of the strategy outlined in the recovery plan and associated documents, such as the co-managers' resource management plan and the hatchery and genetic management plan (HGMP) are consistent with the recovery strategy.

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

Support for the proposed actions is moderate. Some evidence exists that these recovery actions may work, although the evidence is not overwhelming. Especially uncertain is the effectiveness of actions to 1) minimize domestication in production hatchery programs such that it minimizes effects on productivity of natural origin fish and 2) to limit potentially negative ecological interactions of hatchery fish (all species) and natural fish.

Snohomish Harvest Management Strategy—Skykomish population

NOTE: This evaluation is based on the Snohomish Management Unit profile, pages 136-151 of the *Comanagers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the plan submitted by the WRIA 7 group.

The harvest management portion of the recovery plan is based on the hypothesis that the intrinsic natural productivity of the Skykomish population, under current habitat conditions and recently observed poor marine survival conditions, is sufficiently high to allow for the population to recover if the adult equivalent exploitation rate is less than or equal to the rebuilding exploitation rate (RER) that will guide annual management of this population. The RER for the Skykomish population is .24, which has been adjusted downwards to .21 to reflect the observed discrepancy between exploitation rates estimated directly from coded-wire tag analysis (which the RER calculations used) and exploitation rates estimated by FRAM. The comanagers fitted the observed spawner and recruit data (available in the TRT's Abundance and productivity tables) to three spawner-recruit models and simulated population performance for 25 years with 1000 replications at each exploitation rate tested. The RER was the highest exploitation rate that showed both a smaller than 5% probability of going below the lower escapement threshold of 942 natural spawners in all years and a greater than 80% probability of the population escapement being above the current MSY level at the end of 25 years.

Key technical gaps:

The most important ways for this plan to improve the certainty of an effective harvest strategy in the near-term are to:

- Incorporate results from analytical tools, to document integration of habitat, harvest, and hatchery strategies.
- Expand the hypothesis and the recovery strategy to include the effects of harvest on diversity and spatial distribution.
- Include existing local data pertaining to spatial distribution and diversity to support the expanded hypothesis, the expanded strategy, and actions based on the integrated strategy.

Specific ratings:

Did the analysis use one or multiple independent models to understand potential fish responses to harvest actions?

One (VRAP).
The harvest management analysis used one model (VRAP) that looks at three different functions for the spawner-recruit relationship.

Ways to improve certainty in plan outcomes:
The analysis could be improved by incorporating another simulation model that could incorporate spatial structure and diversity. The FRAM model incorporates spatial

structure, at least of the fisheries, which could then be related to the segments of the population being fished. FRAM also addresses differential harvest impacts on different life history types, which could be a start towards assessing the affects of harvest management on diversity.

What is the nature of the analytical support for the model linking population status to harvest management?
Moderate.
The model includes qualitative and quantitative descriptions of the link between harvest management and abundance and productivity. In addition, there is a qualitative discussion of the effects of harvest management on diversity. The effects of harvest on spatial distribution are not addressed. The documentation for the quantitative analysis is presented in detail in the Comanagers' Harvest Management Plan appendix. There was some sensitivity analysis performed for model selection but not for parameter estimates. Empirical data from the Skykomish support the model conclusions for abundance and productivity, however the North Fork Stillaguamish is used as an exploitation rate indicator stock because there is no local indicator stock.

Ways to improve certainty in plan outcomes:
- Use information from the local indicator stock from the Wallace River hatchery, when sufficient years are available, to reassess the RER.
- Include some discussion and analysis of the potential effects of harvest management on spatial structure and diversity.
- Integrated H-modeling could incorporate both diversity and spatial structure in a quantitative assessment of the effects of harvest management. We are aware that the beginning of such an analysis exists in recent results from SHIRAz and EDT, but we did not receive those for this review.

How well supported are the hypotheses for harvest effects? What is the nature of the watershed-specific data used to support these hypotheses?
Moderate
The recovery hypothesis is supported by local escapement data for the whole population. Recent exploitation rates are well documented for this population, but the exploitation rate assessment uses the North Fork Stillaguamish as an indicator stock. There are good local data on the contribution of hatchery strays to the natural escapement so that escapement trends for natural origin fish can be assessed. There are also local data available to support hypotheses regarding the effects of harvest on diversity and spatial distribution.

Ways to improve certainty in plan outcomes:
- This certainty rating could be increased if the hypothesis were expanded to include diversity and spatial distribution using existing data pertaining to these factors.

Does the harvest strategy preserve options for recovery of all four VSP parameters across all Hs?
Yes

The harvest strategy appears to protect the existing VSP structure. This is demonstrated for abundance and productivity from recent spawner-recruit data and assumed for diversity and spatial structure because of declining exploitation rates. The harvest management plan has adaptive management built into, it and there is a local Wallace River indicator stock, which can be used to assess exploitation rates and productivity annually once sufficient CWT recoveries are available.

Ways to improve certainty in plan outcomes:

- The plan could be strengthened with a definite schedule for implementing the adaptive management plan, including the conditions under which the RER would be modified.
- If information from the Wallace River indicator stock is used for assessment of this population's exploitation rates (once sufficient CWT recoveries are available), the plan's certainty would increase.

Is the recovery strategy consistent with the recovery hypotheses?
No
The harvest management strategy is consistent with the hypothesis regarding abundance and productivity. However, the hypothesis does not consider diversity and spatial distribution and therefore these are not included in the strategy. Furthermore, the recovery strategy outlined in the Snohomish draft plan is not yet integrated across habitat, hatchery and harvest management approaches.

- If hypothesis and strategy are expanded to include the effects of harvest on diversity and spatial distribution, the plan's certainty will increase.
- A truly all-H integrated strategy does not yet exist in the Snohomish plan. We are aware that the beginning of such an analysis exists in recent results from SHIRAZ modeling, and additional analyses are underway using EDT. If such results are included in the plan to help design an integrated, all-H strategy, the plan certainty will increase.

How certain is the empirical support for the effectiveness of the recovery actions?:
High/Moderate
The recovery plan calls for reduction of the annual exploitation rate to the RER or below. Unfortunately, there is no direct indicator stock for the Snohomish populations. Results from using aggregate indicator stocks from other populations, FRAM model analysis, and CTC model analysis all indicate that the exploitation rates have been reduced. Natural escapement has shown an increase as exploitation rates have been reduced. There are good data on the contribution of hatchery fish to this natural escapement for the Skykomish population, and these show that the natural-origin component of the escapement has not increased to the degree that the total escapement has. The plan addresses the FRAM model that will be used for annual implementation of the RER, and the RER has been adjusted based on a comparison of the FRAM and CWT assessments of the exploitation rate. Management uncertainty is included in estimates of exploitation rates.

- Integrated analysis of the H's is needed to determine cause of natural-origin escapements not improving significantly in response to decreased exploitation rates.
- Existing data could also be used to document whether reduced exploitation rates can improve spatial distribution and diversity.

Are the harvest actions consistent with the recovery strategy?
Yes
The harvest management strategy is based on an analysis that incorporates the abundance and productivity that results from existing habitat conditions. The strategy includes a discussion of how guidelines will be modified if improved or degraded habitat changes abundance or productivity.

Snohomish Harvest Management Strategy—Snoqualmie population

NOTE: This evaluation is based on the Snohomish Management Unit profile, pages 136-151 of the *Comanagers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the plan submitted by the WRIA 7 group.

The harvest management portion of the recovery plan is based on the hypothesis that the intrinsic natural productivity of the Snoqualmie population, under current habitat conditions and recently observed poor marine survival conditions, is sufficiently high to allow for the population to recover if the adult equivalent exploitation rate is less than or equal to the rebuilding exploitation rate (RER) that will guide annual management of this population. Because it was not possible to fit the observed Snoqualmie data to a model, the same RER was used for the Snoqualmie as for the Skykomish population.

Key technical gaps:

The most important ways for this plan to improve the certainty of an effective harvest strategy in the near-term plan are to:

- Relate those aspects of the comanagers' harvest management plan that are essential parts of the all-H integrated recovery plan.
- Expand the hypothesis and strategy to include the effects of harvest on diversity and spatial distribution.
- Include existing local data pertaining to spatial distribution and diversity to support the expanded hypothesis, the expanded strategy, and actions based on the strategy.

Specific ratings:

Did the analysis use one or multiple independent models to understand potential fish responses to harvest actions?
One (VRAP).

The harvest management analysis used one model (VRAP) that looks at three different functions for the spawner-recruit relationship.

- The analysis could be improved by incorporating another simulation model that could incorporate spatial structure and diversity. The FRAM model incorporates spatial structure, at least of the fisheries, which could then be related to the segments of the population being fished.

What is the nature of the analytical support for the model linking population status to harvest management?
Moderate.
The model includes qualitative and quantitative descriptions of the link between harvest management and abundance and productivity. In addition, there is a qualitative discussion of the effects of harvest management on diversity. The effects of harvest on spatial distribution are not addressed. The documentation for the quantitative analysis is presented in detail in the *Comanagers' Harvest Management Plan* appendix. There was some sensitivity analysis performed for model selection but not for parameter estimates. Because of difficulty is estimating escapement in the Snoqualmie in some years, local escapement data could not be fitted to a spawner-recruit model and therefore the analysis for the Skykomish population had to be carried over to the Snoqualmie.

Ways to improve certainty in plan outcomes:
- Use information from the local indicator stock from the Wallace River hatchery, when sufficient years are available, to reassess the RER.
- Include some discussion and analysis of the potential effects of harvest management on spatial structure and diversity.
- Integrated H-modeling could incorporate both diversity and spatial structure in a quantitative assessment of the effects of harvest management. We are aware that the beginning of such an analysis exists in recent results from SHIRAz and EDT, but we did not receive those for this review.
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How well supported are the hypotheses for harvest effects? What is the nature of the watershed-specific data used to support these hypotheses?
Moderate
The recovery hypothesis is supported by local escapement data for the whole population. Escapements have increased as exploitation rates have declined (the decline in the exploitation rate is assumed from the analysis of the Skykomish data). There are good local data on the contribution of hatchery strays to the natural escapement so that escapement trends for natural origin fish can be assessed. There are also local data available to support hypotheses regarding the effects of harvest on diversity and spatial distribution.

Ways to improve certainty in plan outcomes:

- This rating could be increased if the hypothesis were expanded to include spatial distribution and diversity using existing data pertaining to these factors.

Does the harvest strategy preserve options for recovery of all four VSP parameters across all Hs?
No
The harvest strategy appears to protect the existing VSP structure. This is demonstrated for abundance and productivity from recent spawner-recruit data and assumed for diversity and spatial structure because of declining exploitation rates. The harvest management plan has adaptive management built in to it and there is a local Wallace River indicator stock, which should be used to assess exploitation rates and productivity annually once sufficient CWT recoveries are available. However, the plan lacks a separate assessment of the status of the Snoqualmie population by itself, and there is no adaptive management plan provided for harvest management. Therefore, the adaptive management cannot with existing information be responsive to changes in the status of this population.

Ways to improve certainty in plan outcomes:
- If the plan includes a definite schedule for implementing the adaptive management plan, including the conditions under which the RER would be modified, its certainty would increase.
- Use information from the Wallace River indicator stock to assess this population's exploitation rates once sufficient CWT recoveries are available.

Is the recovery strategy consistent with the recovery hypotheses?
No
The harvest management strategy is consistent with the hypothesis regarding abundance and productivity. However, the hypothesis does not address diversity and spatial distribution and therefore these are not included in the strategy. Furthermore, the recovery strategy outlined in the Snohomish draft plan is not yet integrated across habitat, hatchery and harvest management approaches.

Ways to improve certainty in plan outcomes:
- This rating could be increased if the hypothesis were expanded to include the effects of harvest on diversity and spatial distribution.
- A truly all-H integrated strategy does not yet exist in the Snohomish plan. We are aware that the beginning of such an analysis exists in recent results from SHIRAZ modeling, and additional analyses are underway using EDT. If such results are included in the plan to help design an integrated, all-H strategy, the plan certainty will increase.

How certain is the empirical support for the effectiveness of the recovery actions?:
High/Moderate

The recovery plan calls for reduction of the annual exploitation rate to the RER or below. Unfortunately, there is no indicator stock for the Snohomish populations. Results from using aggregate indicator stocks from other populations, FRAM model analysis, and CTC model analysis all indicate that the exploitation rates have been reduced. Escapement has increased slightly on the Snoqualmie spawning grounds, although it cannot be said whether this is a result of reduced harvest rates. Snoqualmie is augmented by good data on the contribution of hatchery fish to this natural escapement. The plan addresses the FRAM model that will be used for annual implementation of the RER and the RER has been adjusted based on a comparison of the FRAM and CWT assessments of the exploitation rate. Management uncertainty is included in modeled establishment of exploitation rates.

Ways to improve certainty in plan outcomes:

- Integrated analysis of the H's is needed to determine cause of escapements not improving significantly.
- Existing data could also be used to document whether reduced exploitation rates can improve spatial distribution and diversity.

II. 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*.

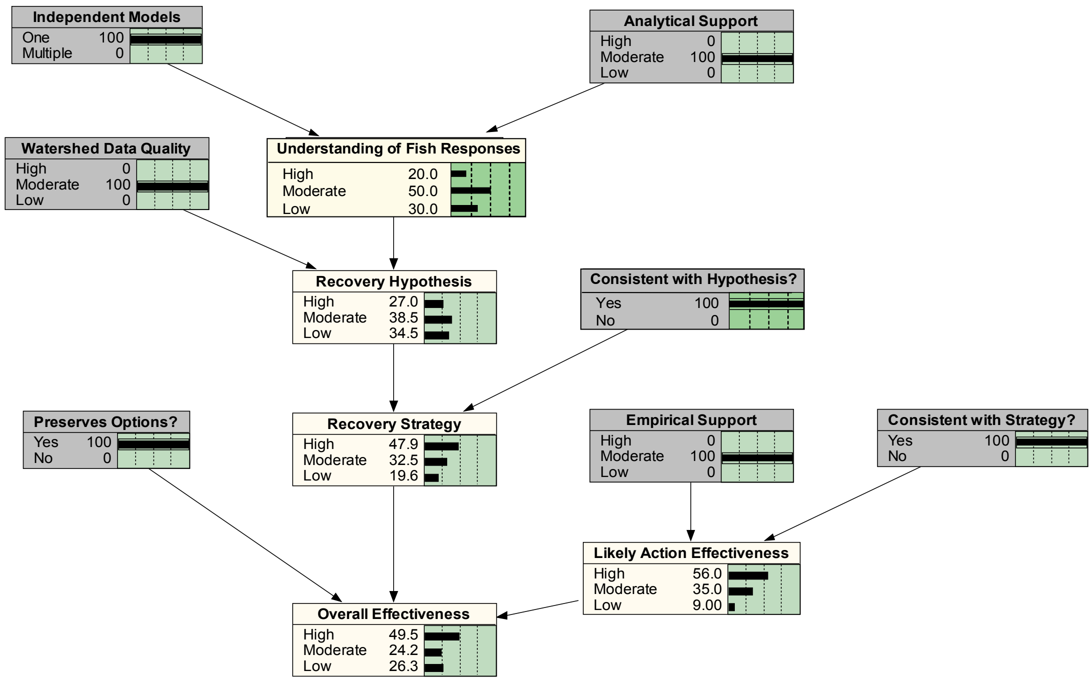

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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.

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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, landuse, 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)
Harvest 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

Lake Washington/Cedar/Sammamish Plan

May 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the Lake Washington/Cedar/Sammamish recovery plan submitted to the Shared Strategy in April 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site (http://www.sharedsalmonstrategy.org/). The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies

or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning uncertainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Habitat strategy

Key technical gaps

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

- When the EDT treatment analysis is undertaken for action-related outcomes, examine the geo-morphological segmentation within streams and shorelines with the objective of aligning the model reaches with the boundaries of basic habitat-forming processes. This more closely reflects the plan's basic conceptual model of habitat formation and recovery. Use this analysis to prioritize and sequence actions to address the alteration in these basic processes;
- Using a build-out scenario, examine and consider the effects of continued habitat degradation in designing the overall habitat recovery strategy;

- Identify life stage-specific limiting factors. Identify the key habitat bottlenecks, their location and magnitude, and the actions necessary to address these factors and achieve recovery;
- Carry out the proposed region-wide analysis of water quality effects (due in late 2005) on VSP attributes;
- Also in the region-wide analysis, evaluate the relationships among land use, habitat conditions, and VSP attributes;
- Develop the indicators, metrics, and thresholds necessary to complete the adaptive management plan.

Did the analysis use one or multiple independent models to understand potential fish responses to habitat actions? What is the nature of the analytical support for the model linking population status to changes in habitat-forming processes and in-stream habitat conditions?

Analytical support for the model is considered moderate. A single model (EDT) was used to describe and evaluate the relationship of habitat conditions to population response (VSP parameters) for both populations. However, spatial structure did not appear to be included as an output for this analysis. A second, qualitative model, was used to describe a set of watershed conditions. This model was not linked through habitat-forming processes to the EDT model; instead, it was used to create "tiers" by which actions could later be prioritized and sorted. There is discussion of "process-based" restoration, but this concept was not carried through the analysis and linked to VSP parameters.

There are no quantitative predictions for the effects of protection or restoration actions on habitat conditions or VSP parameters; the diagnostic phase of EDT analysis was the only one carried out, in order to establish recovery (habitat) hypotheses. There is reasonably good documentation of the habitat conditions that form the inputs to the EDT model for both populations but it could be improved for flow conditions in the Cedar River by discussing the assumptions made in the Cedar River HCP.

The moderate certainty rating is based on the lack of some documentation elements and on the lack of a sensitivity analysis and empirical support. There is little discussion of the assumptions for the effects of project actions or classes of actions in habitat conditions or on VSP parameters; little discussion of the assumptions for protection of current habitat conditions; and virtually no discussion of the effects of the current path of land use on process and habitat conditions. No sensitivity analysis of the model has been done so the effects of varying input assumptions on the model results cannot be determined. No independent empirical comparison of the model output with watershed data has been done, and no calibration of the rules and relationships to local conditions has been done.

Ways to improve certainty in plan outcomes:

- Highlight, if applicable, where multiple lines of evidence are used to support the general analytical model linking land use, habitat forming processes and habitat condition to population response for both populations;

- Create a logic-driven qualitative model between the land use conditions in both watersheds and the habitat-forming processes that could be used to bridge the conceptual gap between watershed condition and EDT inputs;
- Discuss the assumptions for current path land use on the protection of existing habitat conditions and VSP parameters;
- Include a discussion of the flow:habitat assumptions from the Cedar River HCP.
- Use EDT to evaluate the restoration actions proposed in the plan. Document the assumptions used to set the input parameters for this work and compare with the projects derived from the diagnostic phase;
- Conduct a sensitivity analysis of the EDT model so that the relative importance of the assumptions and inputs on model outputs can be understood.

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

The WRIA 8 plan rated a moderate degree of certainty in support of hypotheses. The hypothesis that increasingly intense land uses have led to habitat decline and thus to a decline in VSP attributes is poorly stated, and appears to be based mainly on expert opinion. Little direct empirical evidence linking land use to changes in VSP parameters is provided in the plan although much circumstantial evidence is presented. The watershed condition model is helpful here but requires evidence linking the attributes to habitat condition and then to VSP. Juvenile life stages are assumed to be the most directly affected, particularly productivity and diversity for the fry stage; there is some juvenile survival data for movement through the Hiram Chittenden Locks. There are, however, few other data about juvenile productivity for either population. The habitat data supporting the hypothesis is relatively more robust. If there is more habitat information available to support the hypothesis more strongly and it is documented, the certainty in this hypothesis would be increased. There seems to be information in the plan (and in the EDT work) that could provide life stage- and habitat-specific hypotheses that would be quite useful as links to habitat projects and recovery actions.

<u>Linkages to VSP attributes:</u>
There is little information or analysis to determine the magnitude or location of life-stage specific limiting factors for these populations. Thus, it is not clear whether the recovery strategy is sufficient to achieve the recovery goals or even attainment of the modest goals for improvement in the VSP attributes. For example, what are the relative effects of river channelization compared to lock operations and habitat modification between Lake Washington and Salmon Bay? Or the effects of water quality? This gap may be addressed partially by the EDT analysis scheduled for later in 2005 and should assist recovery planners in comparing such bottlenecks throughout the entire system. The TRT is unsure, from the information provided thus far, why the plan states that its primary focus is on recovering the Cedar River population. Moreover, this work should lead to a more robust priority and sequence of actions across the watershed, thus increasing the certainty that recovery goals can be achieved.

Altered hydrology:
There continues to be a gap in the understanding of the effects of flow prescriptions from the Cedar River HCP on the prospects for Chinook recovery, especially the relationship between flow and habitat-forming processes. The modeling undertaken so far does not include process-based considerations nor does it include evaluations for all VSP attributes. Two (potentially complementary) avenues can be pursued to remedy this gap: 1) further modeling and analyses can be pursued to evaluate how Cedar HCP flow prescriptions are likely to affect the recovery trajectory of chinook in the Cedar River; 2) the relationship between HCP flows and VSP attributes of the population can be monitored carefully, especially during early years of HCP implementation.

Linking land use to processes to habitat conditions to VSP:
This remains a gap in the recovery plan that could inform the potential success of recovery actions throughout the watershed. The proposed regional analysis will go a long way toward filling this gap if it is carried out. Without such an analysis, there is considerable uncertainty in crafting, prioritizing, and sequencing successful habitat recovery actions throughout the watershed.

Ways to improve certainty in plan outcomes:

- If there is direct evidence linking land use intensity and changes in habitat condition to any or all VSP parameters, it should be brought into the plan and documented. The cross watershed analysis of limiting factors and sources of mortality should be carried out;
- Present any habitat or population data that supports the hypotheses independent of the EDT results;
- Without investing in the EDT treatment phase, use the diagnostic information to derive some lifestage-specific hypotheses for VSP parameters and habitat conditions;
- Develop an explicit hypothesis about the effects of the sockeye program on chinook VSP in the Cedar River.
- Calibrate and run the "treatment" phase of the EDT model for the populations;
- Begin collecting juvenile survival data for different habitat types used by the populations;
- Using the watershed evaluation model as a start, develop an evaluation model that links land use to habitat forming processes (hydrology, erosion, etc) and then to habitat condition;
- Use the model to monitor and evaluate suspected mechanisms between land use, processes and habitat conditions;
- Begin monitoring of VSP attributes for the Cedar River HCP.

Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?

The habitat recovery strategy is not consistent with the recovery hypotheses. First, because there are no long term recovery goals adopted for this draft plan, there is no explicit long-term strategy for achieving recovery. Short-term goals are discussed but these are not embedded in an overall strategy for achieving population viability. Second, land use effects are held as a primary cause for habitat degradation. The plan does include measures to address land use (e.g., CAO), but it does not address a widespread, coordinated strategy for addressing land use effects. Third, there is no integration of the habitat work and evaluation with either hatchery or harvest strategies. There is no discussion of how hatchery and harvest strategies are integrated with the habitat strategy to achieve recovery. This is a serious omission and reduces the certainty of the habitat strategy to achieve its objectives. There is no clear discussion of the harvest and hatchery management assumptions and their implication for a habitat strategy. This is particularly important for understanding the effects of the sockeye program in the Cedar River and the Chinook program in Issaquah Creek on Chinook viability and habitat recovery actions.

Ways to improve certainty in plan outcomes:

- Develop recovery goals—even interim ones—for both populations;
- Given the recovery hypotheses in the plan, develop an explicit strategy following the guidance in the PSTRT Watershed Guidance document;
- Examine the assumptions of both hatchery and harvest management programs and discuss the implications for the habitat strategies in the respective watersheds;
- Examine and discuss the implications of the sockeye hatchery program for the habitat strategy in the Cedar River and the Chinook hatchery program in Issaquah Creek for habitat strategies throughout the WRIA.

Does the habitat recovery strategy preserve options for recovery of all four VSP parameters across all Hs?

The habitat recovery strategy does not consider all four VSP parameters (spatial structure is largely absent) and is not integrated with either hatchery or harvest strategies for the populations. Because the habitat strategy is not informed by assumptions or actions in the other Hs, it does not, by definition, preserve options for recovery. It is unclear how VSP attributes will be recovered.

Although there is an excellent discussion and framework for adaptive management, the decision support system and the monitoring and evaluation program that supports it is not developed explicitly enough to evaluate the program's ability to respond to information and make corrections in management direction or in program objectives. This is not unique to the Cedar and Sammamish recovery plans, however. Many plans lack even the framework for adaptive management that this plan describes so well. It is our understanding that the metrics and thresholds, along with the decision model, are undergoing development, however, and will be completed by the end of 2005.

Ways to improve certainty in plan outcomes:

- Evaluate the interaction of the habitat strategy with the other H strategies and their effects on VSP;

- Develop the monitoring and evaluation elements for the adaptive management program. These elements should be included:

Decision model, criteria for decision points, metrics, monitoring protocols, data required, management alternatives at decision points.

Are the habitat recovery actions consistent with the recovery strategy?

The version of the plan reviewed by the PSTRT contained no explicit recovery actions. This element was judged to be "No". This could become a "yes" with the inclusion of strategic recovery actions as the plan progresses.

How well have the habitat actions been shown to work?

Without explicit recovery actions, this cannot be determined. However, proposed protection measures that rely on current regulatory pathways have poor empirical support; the relationship between regulations, their implementation and their outcomes to support recovery is unpredictable. This element was judged to be low due to the lack of empirical evidence and poor predictability. This could improve as further analysis on regulatory protections is done and other recovery actions are included in subsequent drafts of the plan.

Ways to improve certainty in plan outcomes:

- A thorough analysis of the regulatory framework that reveals gaps in protection and evaluates effectiveness should be carried out for these watersheds; this should take the form of a cross-watershed analysis that illuminates the gaps in protections and the implications for habitat and VSP recovery.
- Develop a list of strategic recovery actions to be included in the plan;
- Provide empirical evidence of the actions' effectiveness for improving habitat conditions and VSP attributes.
- Include the evaluation of the regulatory and non-regulatory actions in the adaptive management plan. Summarize existing modeled or empirical support for the effectiveness of habitat protection and restoration actions identified in the plan.
- Design and implement a comprehensive monitoring and evaluation program that can track the integrated, cumulative effects of habitat protection and recovery actions over time.
- Systematically analyze the potential cumulative effects of protection measures. Specifically,
    - Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.

        - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
    - Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.

Hatchery Strategy

Hatchery programs occur in the Lake Washington, Sammamish, and Cedar watersheds, but the recovery planning did not incorporate these as part of the recovery plan. This omission reduces the certainty of the habitat strategy leading to recovery, because the actions are not necessarily integrated. In the absence of integrated planning, the TRT examined the actions and strategies outlined in the co-managers resource management plans for hatcheries.

Key Ways to Improve Certainty

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

- Identify the role of the Issaquah hatchery in the watershed and how this strategy and actions are consistent with Chinook recovery.
- Assess the effects of the existing hatchery programs in Issaquah and Lake Washington on the goals of a locally adapted population in the Cedar River
- Evaluate the potential effects, assumptions, and uncertainties of interactions of the Chinook and sockeye salmon hatchery strategies in the Cedar River for consistency with the goal of a locally adapted stock.
- Develop an explicit monitoring and adaptive management plan to address these uncertainties.

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

This rates a moderate for both the Cedar and Sammamish populations. A single qualitative model (Benefit-Risk Assessment Procedure, BRAP) has been used to support hypotheses for the effects of hatchery management but this model does not include potential ecological effects of the hatchery programs on either the Sammamish or Cedar populations. No quantitative model has been employed. Documentation for the BRAP model is good for abundance but lacking for other VSP attributes.

Since the original assessments using the BRAP, addition tools and assessments have been developed that could refine understanding, including the Hatchery Scientific Review Group's All 'H' Hatchery Analyzer (AHA) model and quantitative models developed to evaluate domestication, effects of small population size, and competition and predation by WDFW and the NWIFC as part of the hatchery risk assessment modeling project (RAMP). In addition, the SHIRAZ population dynamic model could be adapted the model to include a quantitative analysis of hatchery effects. The EDT model, which has been parameterized for habitat conditions, could potentially also be used. Use of these or similar tools would allow planners to evaluate how their decisions might be affected by uncertainty in different management sector factors that drive recovery. Most of these models do not specifically target effects of ecological interactions. Consequently, until these models are refined and research is available to parameterize them, assessment of ecological affects is based on weak inference.

Key Ways to Improve Certainty:

- Use or refine existing models (above) to assess the genetic and ecological interactions of hatchery fish and wild fish and consistency of those results with recovery goals for the Cedar River and for the Lake Washington/Sammamish populations.
- Evaluate the hatchery strategy for Issaquah hatchery program for its consistency with the plan goals and objectives
- Given the goal of a locally-adapted population for the Cedar River, low abundance of natural Chinook salmon in Cedar and straying of non-native hatchery fish into the river, evaluate the interactions of the Chinook and sockeye salmon strategies in the Cedar River for consistency with the goal.

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

This rates a low from the TRT. So far, watershed-specific data are lacking. There are some hypotheses concerning the effects of hatchery strays on the North Lake Washington population and the Cedar population but there is little empirical evidence to support them. Genetic studies are revealing the current genetic relationships among the populations and this could lead to some greater understanding of population separation and introgression and the need for better strategies.

Key Ways to Improve Certainty:

- Complete the genetic analysis of the three major pawning aggregations groups in this watershed (Cedar, North Lake Washington, and Issaquah) to better understand their relationships and how management of those groups is consistent with the TRT's conclusion that only two *historical* populations were present in the watershed.
- Continue to collect and analyze hatchery straying data in the Cedar River and its bearing on maintaining a locally adapted population in the Cedar River
- Collect data on hatchery-wild salmon interactions during the juvenile stage.

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

No. There is no recovery-based hatchery strategy to evaluate despite the presence of the hypotheses for hatchery effects. This is true for both the Issaquah Chinook hatchery program and the Cedar River Sockeye hatchery program. This is a major gap in this plan.

Key Ways to Improve Certainty:

- Following analyses of the potential hatchery effects of hatcheries (see above) and in the plan, revise hatchery strategies to be consistent with the goals for the Cedar River and the Lake Washington/Sammamish Chinook populations.

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

This rates a "No" from the TRT. There is no explicit strategy and a monitoring and adaptive management plan is not yet in place for either hatchery program.

Key Ways to Improve Certainty:

- Develop a hatchery monitoring and adaptive management plan to address the uncertainties associated with the hatchery strategies and actions.

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

Assuming that the co-managers' resource management plans are the current strategy that will be implemented, the actions are consistent with strategy. Independent scientific review of the programs by the Hatchery Scientific Review Group did identify weakness in the strategies and recommended changes to the programs to meet the goals. However, as indicated above, the hatchery goals need to be evaluated against the overall integrated goals of recovery of the Chinook populations in the watersheds.

Key Ways to Improve Certainty:

- Following reevaluation of the conservation strategies of the existing hatchery management plans against the recovery goals of the plan, revise the actions to be consistent the strategies.

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

This plan rates as moderate from the TRT. Hatchery goals have been consistently met for the Issaquah program so the management actions have certainly affected abundance of Chinook in the Issaquah system. The key unresolved issue is the role and strategy of this program in recovery of Chinook populations.

No recovery-based hatchery strategy is included in this plan. This omission reduces the certainty of the actions of the habitat strategy since an integrated analysis cannot be done. The following are key ways to increase the certainty of the plan:

- Discuss the assumptions and uncertainties associated with the sockeye hatchery program in the Cedar relative to its effects on Chinook VSP attributes;
- Develop an explicit monitoring and adaptive management plan to address these uncertainties;
- Discuss the effects of the existing hatchery programs in Issaquah on the goals of a locally adapted population in the Cedar;

- Identify the role of the Issaquah hatchery in Chinook recovery in the watershed.

Harvest Strategy
Lake Washington Harvest Management Strategy

Because harvest management is not addressed in the recovery plan, this review is based on the Lake Washington Management Unit Status Profile, pages 152-157, in the *Comanagers' Puget Sound Chinook Harvest Management Plan* only. The omission of this discussion from the recovery plan reduces the certainty of the plan's outcomes because the implications of this harvest strategy were not integrated with either the habitat or hatchery plans.

The harvest management goal for these populations has two components:
1) Constrain pre-terminal southern US fisheries to below 15% exploitation rate based on recent "highly constrained" fisheries regimes; and 2) maintain terminal fisheries at the "minimum fisheries regime" levels.

Overall exploitation rates have greatly declined in response to this regime since 1990, although there has been somewhat of an increase in recent years. Abundance has increased concurrently with the decline in exploitation rates. Although the regime is intended to increase abundance and maintain diversity, it is not related to viability in any conceptual way.

The most important ways to improve the certainty of the harvest management plan are to:
1. Coordinate the harvest management plan with the recovery plan chapter so that the ability of the harvest plan to work with the hatchery and habitat plans to achieve common goals can be evaluated.
2. Incorporate a monitoring and adaptive management plan into the harvest management plan.
3. Expand the strategy (including the adaptive management plan) to include the effects of harvest on diversity and spatial distribution.

Did the analysis use one or multiple independent models to understand potential fish responses to harvest actions?
One. The harvest management objective is based on a rough qualitative model of population response to harvest based on recent population performance in response to constrained fisheries. The hypothesis is that, if fisheries remain at the recent constrained levels, the populations will be able to maintain themselves at recent abundance level and, if habitat or survival conditions improve, the populations will be able to grow.

What is the nature of the analytical support for the model linking population status to harvest management?
Low. There is a qualitative model for abundance and productivity but the documentation is weak in the management plan, no sensitivity analysis has been done, and there are little watershed-specific empirical data to support the model.

Key issues to improve certainty:
- Use models such as EDT, SHIRAz, and AHA to independently evaluate the effects of harvest management on population VSP parameters.
- Gather population-specific data to test and support the assumptions in the current model and newly developed models;

How well supported are the hypotheses for harvest effects? What is the nature of the watershed-specific data used to support these hypotheses?

Moderate. The data used to support the current harvest management plan includes in-system escapement data but the main conclusions rely on post-season FRAM, which uses proxy data from other watersheds.

Key issues to improve certainty:
- Develop post-season estimates of exploitation rates on the Lake Washington populations independent of the FRAM, for example, using coded-wire tag indicator gorups.

Is the recovery strategy consistent with the recovery hypotheses?

No. The recovery hypothesis is that low exploitation rate plan currently in place will preserve the populations until habitat protection and restoration improves productivity. However, there is no H-integration as yet because there are no accepted long-term goals for the populations in this watershed and because the harvest management plan and the habitat plan are not even part of the same document. This issue could be resolved if objectives for natural stock productivity and abundance were established. Then a harvest management strategy could be developed to help achieve these objectives.

Ways to improve certainty in plan outcomes:
- Develop long-term goals for VSP attributes in these populations;
- Adjust the harvest strategy to reflect the accepted goals.

Does the harvest strategy preserve options for recovery of all four VSP parameters across all Hs?

No. There has been no H-integration in this plan and there is no monitoring and adaptive management plan for the harvest management program.

Ways to improve certainty of plan outcomes:

- Develop a monitoring an adaptive management plan for the harvest management strategy tied to current (and future) plan goals.

Are the harvest actions consistent with the recovery strategy?

No. There is no quantitative analysis to relate the harvest guidelines to the overall recovery strategy. This could be remedied by the use of a model such as AHA, EDT or SHIRAZ that can incorporate harvest rates.

How certain is the empirical support for the effectiveness of the recovery actions?:
Moderate. The current harvest actions seem to be reducing the overall exploitation rates but there is significant uncertainty regarding the extent to which fisheries north of the border could increase.

Ways to improve plan certainty:

- Develop an indicator stock to assess overall exploitation rates on these populations;

II. 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

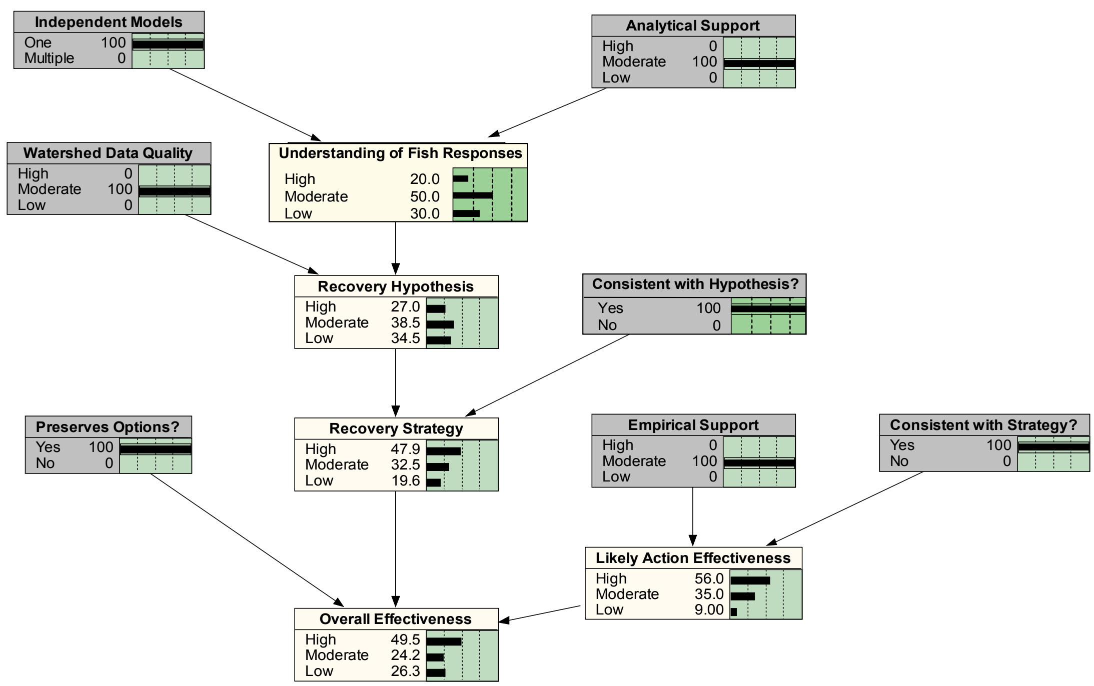

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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*.

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.

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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, landuse, 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)
Harvest 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

Green-Duwamish Plan

May 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the Green-Duwamish recovery plan submitted to the Shared Strategy in April 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information

from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the Green-Duwamish plan provides a useful framework for recovery that attempts to link habitat recovery actions to population recovery objectives through the Ecological Synthesis Model approach, and the Necessary Future Conditions hypotheses, and a set of explicit conservation hypotheses. The habitat strategy that results is well-developed and employs a refugium-based approach to large scale protection and restoration using a geographic segmentation of the river and nearshore. Additionally, there is a more robust linkage of the scientific foundation, hypotheses, and habitat strategy to VSP attributes, and the strategy, through the conservation hypotheses, has better documentation. Discussion of the spatial structure attributes, somewhat lacking in the first draft, has received a more cogent treatment in this draft. Explicit, long-term targets for abundance and productivity have been adopted in this draft as well, and a monitoring and adaptive management program with a good description of indicators and triggers is provided.

Key gaps to be filled that will increase the certainty of the plan to reach its objectives:

- Integrate harvest, hatchery and habitat management for recovery;
- Provide a quantitative estimate of how much habitat is necessary to achieve recovery objectives;
- Establish agreements on recovery goal via an integrated or segregated population in the watershed.

Habitat Strategy

Key technical gaps

- Develop quantitative estimates of habitat volume necessary to achieve recovery using the Necessary Future Conditions (NFC) and the abundance and productivity goals;
- Evaluate the habitat projects for their efficacy in achieving the NFC objectives;
- Carry out a landscape condition analysis at the watershed and sub-area scales to inform the habitat recovery strategy. This should include a "current path" analysis to evaluate current and proposed protections;
- Refine the adaptive management plan.

Did the analysis use one or multiple independent models to understand potential fish responses to habitat actions? What is the nature of the analytical support for the model linking population status to changes in habitat-forming processes and in-stream habitat conditions?

Overall, the analytical support associated with the landscape → habitat → fish response model is moderate.

A single *qualitative* model is the basis for describing the links between land use, habitat-forming processes, habitat structure and population response. This model is adapted from Spence et al. and is mainly a multi-scale, process-based model of salmon recovery. There has been a narrative attempt to link this model with the VSP attributes described in McElhany et al., but a clear and precise logic framework has not been developed that would allow even a qualitative prediction to be made for population attributes. The Muckleshoot Indian Tribe has developed a quantitative model (SHIRAZ) for this watershed but it has not been made available to this planning group and is not discussed in this plan.

The general conceptual model is well documented in Spence et al. However, the assumptions that support the model in its local application are not well documented. Certainty of this element could be much higher if the assumptions used to apply the model to the local riverscape were described and possible alternative assumptions discussed. This would necessarily combine the historical analysis with the current inventories to arrive at a set of assumptions and hypotheses that link changes in land use and management over time to habitat and population characteristics that exist today.

There has been no sensitivity analysis of the general model although such an analysis could be accomplished using a probability network or Bayesian logic model to evaluate the effect of model relationships and changes in assumptions on model predictions, even on this qualitative model. Such a sensitivity analysis would clarify the effects of varying the input assumptions of the model on the expected outcomes. In a watershed so severely impaired, such an analysis could provide a useful look at potential limits to recovery.

Empirical support for the general model has not been discussed in the plan although much of the data probably exists to do so. Spence et al. has marshaled considerable information to support the process-based model and local information that could be brought to bear to assist in validating the major relationships and calibrating the model to watershed conditions. This could be accomplished, for instance, by bounding the abundance extremes derived from an application of the model with historical and current capacity estimates. To some degree this has been done for spatial structure by using the geomorphic model of Benda and Martin (the Core Areas work) to examine and predict the distribution of spawning Chinook in the Green River.

Ways to improve certainty:

- Highlight where multiple lines of evidence were used to support the analytical model for linking land use to habitat-forming processes to habitat conditions to fish response;
- Develop a stronger logical framework between the qualitative process model and the VSP parameters;
- Improve the documentation of the Spence et al model by clarifying how the model applies to the Duwamish-Green population;
- Provide more empirical evidence that the model is applicable to the current conditions of the system and to the VSP responses of the population.
- Develop and apply a sensitivity analysis to the qualitative model to determine the relative importance of the assumptions and inputs of the model to habitat and fish response;
- Employ a quantitative model (consistent with the assumptions of the qualitative one) to begin the task of providing numerical estimates and predictions of population response to recovery actions.

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

The hypotheses for (1) and (2) above are moderately well-supported. The VSP hypothesis is that productivity is the attribute most limiting recovery in this population. The data to support this hypothesis derives mainly from work on abundance and productivity done by the TRT and contained in the Abundance and Productivity tables. This work is model-based, however and direct empirical evidence is difficult to obtain since the population is a combination of hatchery and wild fish. There is some evidence from juvenile trapping that productivity is limiting in the lower river but this is a very short-term data set. Data from smolt traps may be corroborative but documentation is poor.

The habitat hypothesis is that the changes in structure of the river system and the estuary, mainly due to physical modification of the river channel, floodplain and estuary, and the construction of, and subsequent flow management at Howard Hanson Dam, are responsible for the observed reduction in productivity of the extant life history trajectories. This may have affected diversity and spatial structure as well. A sub-hypothesis suggests that competition with hatchery fry may be depressing growth rates for natural lower river-reared fry in the transition zone of the river. The empirical link among the obvious habitat changes and the VSP parameters is not well-defined, however, since historical (pre-dam) observations of the population attributes are largely unknown. The Collins et al. historical work and the historical analysis carried out by the WRIA 8 technical team provides excellent evidence for the habitat alterations that are hypothesized to lead to changes in VSP attributes. Estimates of historical abundance have been done using multiple methods in an attempt to triangulate the estimate but these have not been compared with capacity-based estimates.

Ways to improve certainty:

- More precisely describe the link between land use and habitat-forming processes. Land cover and use maps could be produced that would become the basis for assessing hydrologic change, erosion and sediment processes, and woody debris inputs, for example;
- The limiting factor work could be brought to bear more directly through the qualitative model to support the hypotheses;
- Develop capacity estimates for historic and current habitat conditions using the method of Sanderson et al.
- Develop a monitoring strategy to collect juvenile survival data by habitat type for the river, the estuary and the nearshore;
- Employ existing models to investigate the mechanistic links between land use and the processes that affect habitat conditions.

I*s the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?*

The recovery strategy is not consistent with the hypotheses for these reasons:
The strategy rests on local improvements in habitat conditions in the mainstem river, estuary and nearshore, and on the creation of large scale refugia in each of those

environments. However, this strategy is not linked to population recovery goals—the improvements in VSP parameters needed for recovery. There are no specific population goals in the plan at this time. Nor is the major factor of flow reflected in the strategy.

Furthermore, there is no examination of the assumptions or goals for either hatchery or harvest management and the implications for the habitat strategy and actions. The strategy therefore, cannot be an integrated one and is not consistent with an integrated hypothesis.

Ways to improve certainty:

- Specify recovery goals—even interim or provisional ones—for the VSP parameters, but especially for abundance and productivity;
- Specify habitat goals to meet the VSP targets;
- Obtain the harvest and hatchery management programs for this population and evaluate their assumptions and implications for the habitat strategy. Adjust the habitat strategy if necessary and provide the rationale;

Does the habitat recovery strategy preserve options for recovery of all four VSP parameters across all Hs?

The strategy does not preserve options for recovery of the population. One major element is absent from the plan and a second is insufficiently developed. The missing element is a strategy that integrates the management of the individual Hs into a comprehensive strategy for this population; the second element is an adaptive management plan to respond to environmental conditions and fish response that informs the development and choice of management objectives and alternatives. The adaptive management plan presented in the recovery plan has an excellent framework and proposes indicators and “triggers”. There is insufficient development of the adaptive management plan to evaluate its effectiveness. Moreover, these elements are not yet tied into a decision model that would inform changes in management.

Ways to improve certainty:

- As in 3 above, evaluate the hatchery and harvest strategies for this population to understand the implications for the habitat strategy.
- Develop a more explicit adaptive management program for this plan. This should include decision models, a monitoring element with metrics and data requirements, criteria for assessing change, and decision criteria and critical points along the recovery timeline.

Are the habitat recovery actions consistent with the recovery strategy?

The actions are considered to be consistent with the strategy. In the plan the PSTRT reviewed, the actions were organized by the conservation hypotheses and prioritized into tiers based on their predicted (qualitative) effect on the VSP attributes of most concern in the geographic area. The major actions are now linked logically to the strategy through the conservation hypotheses which have both geographic specificity and VSP specificity. Despite this re-evaluation, there remain the questions of the sufficiency of the actions to achieve the Necessary Future Conditions and abundance and productivity goals of the plan, and the "fit" of the projects in the near term action agenda (NTAA) to the revised strategy of the plan.

Ways to improve certainty:

- Estimate the sufficiency of the actions to achieve the NFCs and the abundance and productivity goals. This will likely require the use of a quantitative model of some sort to relate actions to habitat outcomes and thus to numeric plan goals.

How well have the habitat actions been shown to work?

Empirical support for the habitat recovery actions is moderate. There is an important concern about the types of actions proposed (and implied) in the recovery strategy and the necessary future conditions. The Green River is strongly flow managed and bears little resemblance to the historic river where Chinook are thought to have been abundant. The recovery actions lean strongly toward anchored LWD placement and gravel supplementation. In a regulated river, how well are these projects assumed to work? How long will the beneficial effects persist? The model for such actions is mainly in forested, non-regulated rivers and their effectiveness at producing the necessary conditions in the Green River may be questionable.

Ways to improve certainty:

- Provide empirical evidence that such projects are effective in regulated rivers. Effectiveness should be measured in both short and long time frames and by the persistence of the conditions described in the necessary future conditions work.

Hatchery Strategy

Hatchery programs occur in the Green-Duwamish watershed. The recovery plan discusses potential hatchery effects on wild fish survival, but no integrated strategy for habitat, hatcheries, and harvest was presented in this plan. This omission reduces the certainty of the habitat strategy leading to recovery, because the actions are not necessarily integrated or jointly effective. In the absence of integrated planning, the TRT examined the actions and strategies outlined in the co-managers resource management plans for hatcheries.

Key Ways to Improve Certainty

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

- Develop a recovery hypothesis for the use of hatcheries, and use or refine existing models (above) to assess the genetic and ecological interactions of hatchery fish and wild fish on VSP attributes and consistency of those results with recovery goals for the Green-Duwamish Chinook population.
- Evaluate and modify the hatchery strategies (such as reaching agreement on whether the hatchery strategies might be genetic integration or segregation) for consistency with the plan goals and objectives and evaluate the effectiveness of the habitat management program for its sensitivity to these assumptions
- Develop a monitoring and adaptive management plan.

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

Overall, this element rates moderate in certainty. A single qualitative model (Benefit-Risk Assessment Procedure, BRAP) has been used to support hypotheses for the effects of hatchery management but this model does not include potential ecological effects of the hatchery programs. The hatchery management strategy is not based on an integrated recovery goal or on population viability attributes. No quantitative model has been employed.

Since the original assessments using the BRAP, addition tools and assessments have been developed that could refine understanding, including the Hatchery Scientific Review Group's All 'H' Hatchery Analyzer (AHA) model and quantitative models developed to evaluate domestication, effects of small population size, and competition and predation by WDFW and the NWIFC as part of the hatchery risk assessment modeling project (RAMP). In addition, the SHIRAZ population dynamic model could be adapted the model to include a quantitative analysis of hatchery effects. The EDT model could potentially also be used. Use of these or similar tools would allow planners to evaluate how their decisions might be affected by uncertainty in different management sector factors that drive recovery. Most of these models, however, do not specifically target effects of ecological interactions. Consequently, until these models are refined and research is available to parameterize them, assessment of ecological affects is based on weak inference.

Key Ways to Improve Certainty:

- Use or refine existing models (above) to assess the genetic and ecological interactions of hatchery fish and wild fish on VSP attributes and consistency of those results with recovery goals for the Green-Duwamish Chinook population.
- Evaluate and modify the hatchery strategies for its consistency with the plan goals and objectives

- Document information used in the hatchery management plans.

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

There is moderate support from local data for the effects hatchery programs have on abundance and straying. There is some empirical support for the qualitative model from local straying and abundance data that are used to estimate the effective population size (*Ne*) for hatchery management. The plan lacks a hatchery-specific recovery hypothesis, however.

Key Ways to Improve Certainty:

- Develop an explicit recovery hypothesis for the effects of hatcheries on recovery of the Green/Duwamish River Chinook population that considers the status and functioning of the habitat and uses the most recent available local data on abundance, contribution of hatchery fish to natural spawning, productivity, and spatial distribution.
- Use available data from other watersheds to increase the analytical support and to document the assumptions that would be part of that and begin collecting information from the Green/Duwamish River on hatchery-wild interactions at different life stages.

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

No. There is no recovery-based hatchery strategy to evaluate despite the presence of the hypotheses for hatchery effects.

Key Ways to Improve Certainty:

- Following analyses of the potential hatchery effects of hatcheries (see above) and in the plan and development of explicit hypotheses, revise hatchery strategies to be consistent with the goals Green-Duwamish Chinook population.

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

No. There is no explicit strategy and a monitoring and adaptive management plan is not yet in place for either hatchery program.

Key Ways to Improve Certainty:

- Develop a hatchery monitoring and adaptive management plan to address the uncertainties associated with the hatchery strategies and actions.

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

This rates a YES from the TRT. The hatchery actions are clearly meeting the existing hatchery management objectives for this population. However, the current hatchery management plan has not been integrated with the overall recovery strategy yet and will likely require adjustment when that is accomplished.

Key Ways to Improve Certainty:

- Following reevaluation of the conservation strategies of the existing hatchery management plans against the recovery goals of the plan, revise the actions to be consistent the strategies.

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

Empirical support for the proposed actions is moderate. Some evidence exists that these hatchery management actions may work, although the evidence is not overwhelming. Especially uncertain is the effectiveness of actions to 1) achieve either an integrated or segregated hatchery population (whichever is the chosen goal for this watershed) and 2) to limit potentially negative ecological interactions of hatchery fish (all species) and natural fish.

Key Ways to Improve Certainty:

- Develop and implement a monitoring program

Harvest Strategy

Because harvest management is not addressed in the recovery plan, this review is based on the Green River Management Unit Status Profile, pages 158-161, in the *Comanagers' Puget Sound Chinook Harvest Management Plan* only. The omission of this discussion from the recovery plan reduces the certainty of the plan's outcomes because the implications of this harvest strategy were not integrated with either the habitat or hatchery plans.

Ways to increase certainty in plan outcomes:

1. Coordinate the harvest management plan with the recovery plan chapter so that the ability of the harvest plan to work with the hatchery and habitat plans to achieve common goals can be evaluated
2. Expand adaptive management and harvest planning analyses to include the effects of harvest on diversity and spatial distribution.
3. Gather and analyze population data to support EDT or other modeling predictions of the effects of harvest actions on VSP characteristics.

Did the analysis use one or multiple independent models to understand potential fish responses to harvest actions?

One. Harvest management is based on the assumption that the average escapement observed over a 12-year period in the late-1960s- early 1970s was representative of system capacity, and the fixed escapement goal was set based on that average. There was no separation of natural- and hatchery-origin fish in that escapement assessment, nor was there any analysis of natural productivity.

Ways to improve certainty:

- Use existing data to assess the spawner-recruit relationship for natural origin Green River Chinook and use this relationship as the basis of a rebuilding exploitation rate or some other approach to harvest man agement that will provide some certainty that the population will respond to hatchery and habitat management actions.
- Also use habitat-based models, such as EDT or SHIRAz to provide an alternative assessment of the VSP of Green River Chinook from whoch an appropriate harvest management strategy for rebuilding could be developed.

What is the nature of the model(s) and analytical support for the harvest models linking actions to population status?

Low. The harvest management guideline for this population is not based on a recovery goal or on population viability goals. The model for harvest management does make assumptions of how abundance will be affected but the other VSP attributes are not addressed. In general, there are good data as to total escapement. There are also potentially good estimates of the contribution of hatchery strays to the escapement but disagreement regarding the appropriate method for estuimating these.

Ways to improve certainty:

- Coordinate the population goals in the harvest management plan and the recovery chapter;
- Expand the harvest management hypothesis to include productivity, diversity, and spatial distribution.
- Use a quantitative model such as AHA, SHIRAz, or EDT to assist in evaluating the effects of harvest actions on VSP parameters when considered in conjunction with the strategies for hatcheries and habitat;
- Provide the documentation for the data used in the harvest management plan.

How well supported is the recovery hypothesis with watershed specific data?

Moderate. Although there are good data available on the Green for assessing harvest management, this rates a moderate for the TRT largely because of the lack of documentation for the data and the lack of a harvest-specific recovery hypothesis.

Is the recovery strategy consistent with the recovery hypothesis?

No. There is no stated recovery hypothesis for harvest management so it cannot be consistent with the overall recovery strategy. Certainty could be improved by developing explicit hypotheses for how harvest management will affect recovery (VSP) goals and objectives.

Does the recovery strategy preserve options for the population?

No. There is no monitoring or adaptive management plan. Developing a robust monitoring and adaptive management plan to assess harvest effects will increase certainty in the plan's outcomes.

Are the recovery actions consistent with the recovery strategy?

Yes. The harvest actions are clearly meeting the existing escapement goals for this population.

How well have the actions been shown to work?

High. Given the data and the existing harvest objectives, the actions appear to be working quite well. There is active in-season management of terminal area fisheries and apparently normally sufficient abundance that the terminal fishery can be managed to achieve the escapement goal.

II. 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

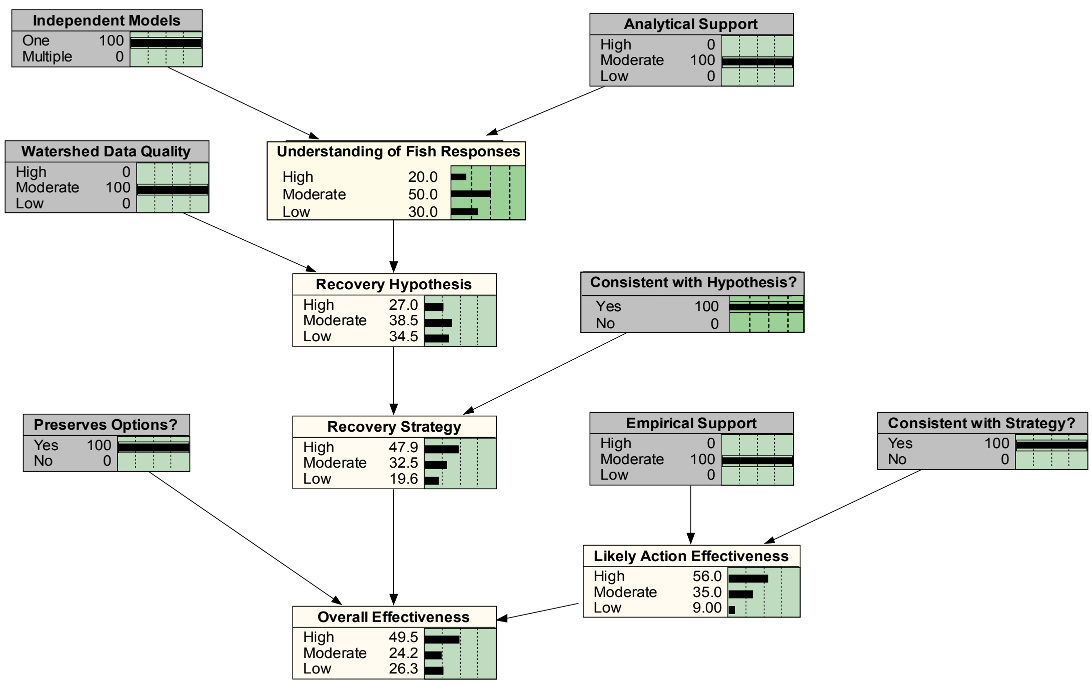

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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*.

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.

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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, landuse, 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)
Harvest 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

East Kitsap Recovery plan

May 2005 Technical gap analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the East Kitsap recovery plan submitted to the Shared Strategy in April 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the

plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, this plan, which is a combination of East Kitsap County and the City of Bainbridge Island (COBI), has improved, largely due to further work by the City. The City has developed a useful salmon restoration framework based on the work of Williams and Thom. This framework is the basis for the excellent ecosystem-based management model—qualitative though it is—that has been developed by the City and is being used to create priorities for restoration. Coupled with the shoreline characterizations done by the City of Bainbridge Island, this work provides a template to carry through to the East Kitsap nearshore evaluation that is in the planning stages. The plan also includes a good example of the integration of watershed planning efforts within Kitsap and COBI sub-areas that are used to establish geographical priorities.

Ways to improve the certainty in reaching the plan's objectives:

- Establish a link between the nearshore processes and the VSP parameters;
- Describe and document the link between habitat protection (relying on (existing) regulatory measures that are deemed sufficient) and VSP outcomes;
- Build on work by COBI to develop an adaptive management and monitoring plan for the whole region covered by this document.

Habitat strategy

Key technical gaps

The most important ways to improve the certainty of an effective habitat strategy in the plan are:

- Develop an adaptive management framework for East Kitsap;
- Complete the shoreline inventory and assessment for East Kitsap shorelines;
- Provide more detail in the county-wide habitat management strategy. This should include detail about which shoreline areas are required for recovery, whether each is a protection or restoration target, and in what sequence each will be addressed;
- Link the effects of actions in freshwater to effects and outcomes in the adjacent nearshore;

Based on our analysis, developing and implementing the key items listed above would increase the level of certainty for this plan.

1. *Did the analysis use one or multiple independent models to understand potential fish responses to habitat actions? What is the nature of the analytical support for the model linking population status to changes in habitat-forming processes and in-stream habitat conditions?*

Analytical support for the model is low. A single, qualitative *stressor* model is used as the conceptual recovery framework. This model, from Williams and Thom, is logically robust and provides a good, and potentially useful, framework for linking a variety of stressors (including land use, processes, or habitat structure) to population responses. This has not been done, however, but the model has been used by the City of Bainbridge Island (COBI) to prioritize areas for restoration.. The model is documented only in the work of Williams and Thom; there may be more documentation of assumptions, model structure and the parameters but it does not appear in the recovery plan. There is no sensitivity analysis although that may be possible given the model structure, and there has been no empirical test or calibration to local conditions. The City of Bainbridge Island has data on nearshore conditions that could serve as a starting point for an empirical test or calibration of some aspects of the model, however.

Ways to improve certainty in plan outcomes:

- Include further documentation of the model assumptions, structure and parameters in the recovery plan;

- Assemble the existing data from Kitsap County and the City of Bainbridge Island for as many of the attributes of the model as possible.
- Use the empirical data assembled above to test the logic and relationships of the qualitative model;
- Collect habitat and salmon data from the nearshore in order to fill in the model and move it toward more quantification.

2. *How well supported are the hypotheses for (1) the VSP parameters most limiting recovery and (2) the habitat-forming processes or conditions that are limiting the population response? What is the nature of the watershed-specific data used to support (either of) these hypotheses?*

The hypothesis that serves as a basis for the East Kitsap Recovery plan appears to be: the East Kitsap nearshore is important to a variety of populations of Puget Sound Chinook; land use and direct modification of salmon habitats has altered habitat-forming processes (e.g., hydrology in freshwater systems) and structure (especially through filling and armoring in the nearshore) that has reduced the ability of these habitats to support salmonids, especially juveniles.

Overall, support for the hypotheses is low. The hypotheses do not include the VSP parameters directly and there is little quantitative data provided to show distribution of Chinook along the East Kitsap nearshore. There is considerably more data to support the habitat hypothesis and the discussion of habitat structure, function, and process is quite useful. The nearshore discussion derives from the conceptual model and has led to some shoreline mapping and evaluation by the City of Bainbridge Island (COBI), with a further analysis based on geophysical properties of the shoreline to follow in both COBI and Kitsap County. There is as yet no direct empirical support for changes in VSP attributes and little data that links structural change in the nearshore to process degradation. There is inventory data in the COBI to show the extent of fills and shoreline modifications that is now being overlain with habitat classifications. It is not yet at the mechanistic, cause-response stage, however, that can be related to VSP attributes.

Ways to improve certainty in plan outcomes:

- If there are more data on the nearshore of East Kitsap, whether in the form of inventory data, historical information, shoreline characterizations, etc, bring them forward in the plan to support the hypotheses;
- Even if it is based on expert opinion, use the conceptual model to link the changes in habitat volume and structure to VSP attributes by probable life stages utilizing the nearshore and tributaries. These will become additional hypotheses subject to testing.
- Apply the COBI inventory and analysis techniques to the entire East Kitsap shoreline as a basis for a “change” evaluation;

- Begin a systematic program to collect salmonid data in the nearshore based on the hypothetical links in the conceptual model and the hypothesis of multiple population use.

3. *Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?*

The strategy for recovery in the East Kitsap is not consistent with the (implied) recovery hypotheses discussed in the plan. The plan has no explicit goals for either habitat or VSP attributes, so a long-term strategy is problematic. However, a general strategy is discussed but there is insufficient specificity in the strategy concerning spatial priorities and sequencing of actions, and there is no link to VSP attributes. The general East Kitsap strategy of education, protection and restoration, and incentives includes the critical elements for recovery but seems quite opportunistic. It is difficult to see how the elements in the plan combine to confidently recover habitat conditions and VSP attributes in the future. If inventory and evaluation of habitats and VSP attributes can be accomplished in a timely manner, the programs within the strategy could be made much more specific to the geography of salmon recovery. For example, what shoreline habitats are most in need of protection; which of restoration? How will they combine to influence spatial structure of the population(s) rearing along or migrating through the nearshore? How much of the nearshore will be preserved (by any means) in a functional condition?

Implicit in the strategy is an understanding of the current path of land use and the future effects on habitat and VSP but there is no analysis by which to judge the effects of this or some alternative path. Thus, the assumption of the sufficiency of the current regulatory path is unsubstantiated by empirical evidence or evaluation of these effects.

Ways to improve certainty for this plan:

- Develop explicit goals for habitat conditions in both freshwater and nearshore habitats of East Kitsap. Using the conceptual model, extend these goals to VSP attributes associated with the habitat goals;
- Conduct a current path analysis to predict the spatial and temporal effects of land use affecting the East Kitsap nearshore;
- Clarify the assumptions that support the current regulatory path;
- Use the basic recovery model to (qualitatively) evaluate the elements and test the assumptions of the general strategy. This should allow gaps in the strategy to be evaluated and some predictions to be made about population response.
- Develop an evaluation strategy to assess the effects of the educational and incentive elements of the recovery strategy.

4. *Does the habitat recovery strategy preserve options for recovery of all four VSP parameters across all Hs?*

The strategy does not preserve options for the recovery of all VSP parameters. The strategy does not reference the desired outcomes for the VSP parameters and has not integrated either the harvest or hatchery assumptions with the habitat work. Neither is there a well-developed adaptive management program to test the elements of the strategy. This is particularly important since there are a number of critical assumptions upon which success of the strategy is based.

Ways to improve certainty for this plan:

- Obtain the harvest and hatchery assumptions (available from the Suquamish Tribe, we assume) and clarify them in the plan. Use these assumptions to evaluate the interaction of harvest and hatchery actions with the habitat strategy;
- Clarify the desired outcomes for the VSP parameters relative to the East Kitsap nearshore (this will require conversations with other watersheds whose populations use the East Kitsap nearshore).
- Further develop the COBI adaptive management strategy to support recovery. Include these elements: decision model(s), decision criteria, monitoring targets and protocols, data requirements, evaluation methods, timelines for data collection and analysis, and decision points. Bring the COBI adaptive management framework to bear in Kitsap County.

5. *Are the habitat recovery actions consistent with the recovery strategy?*

Given the elements of the general strategy, the actions are generally consistent. The action list is incomplete, however, in so far as the incentive programs and the suite of restoration actions necessary are either undeveloped or have not been included in the plan.

Ways to improve certainty for this plan:

- Develop restoration actions and incentive programs linked to the strategy;
- Develop a prioritized sequence of these restoration actions

6. *How well have the habitat actions been shown to work?*

There is moderate empirical support for the habitat actions put forward in the plan. The protective actions based on acquisition—the reserve program—has good empirical support from similar actions Sound-wide. The effectiveness of the current regulatory path to provide protection is much less certain; little empirical support is available (Whatcom County has used the EDT model to evaluate regulatory effectiveness as a first step) and the program will require monitoring and evaluation as part of the adaptive management program. Nearshore restoration actions have a mixed history probably due to our general lack of knowledge of nearshore processes. The educational components of the strategy, while assumed to be of critical importance, should also be made part of the adaptive management program.

Ways to improve certainty for this plan:

- Carry out an analysis of the regulatory framework that reveals gaps in protection and evaluates effectiveness of current regulatory protections;
- Develop a list of strategic recovery actions to be included in the plan;
- Provide empirical evidence of the actions' effectiveness for improving habitat conditions and VSP attributes.
- Systematically analyze the potential cumulative effects of protection measures. Specifically,
    i. Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    ii. Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    iii. Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
- Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.
- Include the evaluation of the regulatory, incentive, and educational actions in the adaptive management plan.

Hatchery Management Strategy

No independent Chinook populations occur in this area, although Chinook salmon are produced here by hatcheries and Chinook salmon from other areas use the nearshore of this region. No comprehensive hatchery strategy was included in the East Kitsap recovery plan although the plan proposed implementing the Hatchery Scientific Review Group's (HSRG) recommendations for the programs the programs in this area. The HSRG recommendations were based on the current objectives for the hatchery stocks and did not consider their effects on ESU recovery. The omission of a hatchery strategy from the plan omission adds uncertainty in the overall ESU recovery strategy that could be addressed with the following actions:

- Evaluate the effects of current hatchery management activities on capacity of the nearshore environment for wild Chinook (hatchery-wild interactions)

- Evaluate the potential straying of hatchery fish from this region into independent populations
- Incorporate these evaluations into a comprehensive hatchery management strategy for this region that helps achieve the recovery of the other independent populations that share the East Kitsap nearshore.
- Develop a monitoring and adaptive management plan.

Harvest Management Strategy

This plan, appropriately, does not include a harvest management strategy because harvest of populations throughout their life cycle is addressed in the watershed plans for the areas where the populations spawn. However, in developing an integrated adaptive management program for waters around East Kitsap County, recognition of harvest actions will be necessary in order to assess the effectiveness of habitat preservation and restoration actions.

II. 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

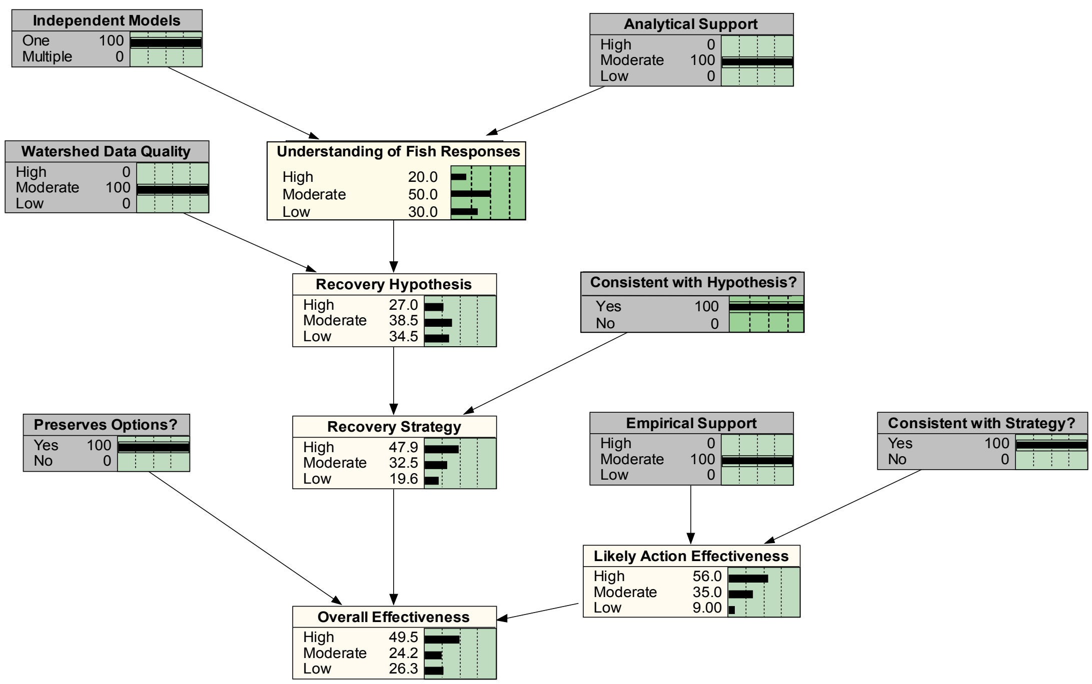

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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*.

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.

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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, landuse, 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)
Harvest 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

Puyallup-White Plan: Puyallup and White Chinook Salmon Populations-
May 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the Puyallup Watershed (WRIA 10) recovery plan submitted to the Shared Strategy in May 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information

from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. Summary of Certainty Analysis

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall Strategy

Key Technical Gaps
Two major technical gaps with this plan are discussed below. We highlight these key issues in overall approach because, if addressed, they will dramatically improve the certainty of an effective overall recovery strategy in the near-term plan:

- The submittal proposes neither specific recovery goals nor a specific set of actions to begin to move the populations away from high risk status and toward recovery. Goals are reported for TRT, co-manager escapement, and Shared Strategy targets, but none of these have been proposed for adoption. While the involved parties' technical workgroups have been operating with some informal objectives, conflicts among objectives, strategies and stock status information make it unclear what recovery goals, strategies, and actions are actually intended for implementation.

- H-integration is a priority need for this plan to direct the H's toward a common goal in a coordinated and efficient manner. For example, the harvest management section of the plan asserts that the harvest level objective for Puyallup Chinook will allow natural adaptation to occur but does not elaborate on how that is expected to occur. The discussion also does not address how the objective will improve the VSP characteristics of the naturally produced Chinook within the Puyallup population. The available data demonstrate that hatchery stray rates are higher than the objective for S. Prairie Creek, yet the escapement objective of 500 fish is not being met. Furthermore, the submitted habitat analyses and strategies demonstrate both that the above harvest management escapement objective appears significantly lower than the habitat can currently support and that S. Prairie Creek is a priority area for increased habitat capacity to improve population viability.

Ways to improve certainty in plan outcomes:

- Local planning entities (including the co-managers, Pierce County, and the federal Services) identify and adopt interim recovery goals, develop recovery hypotheses and integrated habitat, hatchery and harvest strategies directed at progressing toward measurable recovery goals.
- Target the plan's management actions for each of the Hs at a specific recovery outcome. One way to efficiently formulate an integrated plan is to assemble specific sets of all-H actions (alternatives) emanating from clearly stated working hypotheses and recovery goals. The predicted effectiveness of alternatives can then be compared to select a preferred alternative for implementation. The certainty that a strategy will result in the desired outcome is expected to increase as the plan's linkages between working hypotheses, strategies, resulting sets of actions, and predicted population responses are strengthened (see TRT Watershed Guidance document).

Habitat strategy

Key technical gaps

The most important additional technical gaps remaining in this plan are discussed below. We highlight key issues that, if addressed, will improve the certainty of an effective habitat strategy in the near-term plan:

- It is unclear whether new habitat issues were uncovered in the co-managers' analysis that were not covered in the Pierce County EDT based analysis. The separate habitat analyses provided by the co-managers and Pierce County need to be reconciled and the following specific major gaps resolved:

  - White River flows below Buckley. The plan does not provide any good links between demonstrated needs for improving flows to benefit habitat functions and protection and restoration actions for recovery, including protecting present opportunities to restore normal flows. The EDT based analysis conducted by Pierce County shows that restoring normal flows and water quality in the White River below Mud Mountain Dam would have enormous benefits to fish. In spite of this demonstrated priority for recovery action, the plan does not propose any actions to resolve uncertainties for recovery associated with current ongoing proposals for consumptive use and removal of water from the White River. The Cascade Water Alliance use agreement that is proposed by PSE to divert flow from the White River at the Buckley Diversion Dam will have impacts on flows in the lower White and Puyallup Rivers that are expected to adversely impact both the White and Puyallup Chinook populations. The effects of this proposed use and withdrawal have not been evaluated yet. The co-managers' technical staff have preliminarily suggested some potential adverse effects of the diversion and withdrawals that may need to be evaluated. These include reduced function of and access to restoration projects, disruptions of sediment transport and other channel forming processes, temperature degradation, and water quality degradation along the lower White and Puyallup Rivers, as well as direct impacts to fish. Resolution of a flow management regime needed to achieve recovery will dramatically improve the certainty of an effective habitat strategy in the near-term plan.

- Electron Dam Hydroelectric Project. The effects of the Electron project on recovery have not been fully evaluated. Improvement in downstream migrant passage at the project is ranked as the highest single project benefit to the recovery trajectory for the Puyallup Chinook population in the EDT-based habitat restoration assessment. Though improvement in passage survival is a high priority for the watershed restoration plan, there is substantial remaining uncertainty on the action needed. The effects of flows through the bypass reach have not been evaluated as part of recent habitat assessments. Resolving operation of the Electron project in a manner consistent with recovery will dramatically improve the certainty of an effective habitat strategy in the near-term plan.
- A floodplain management program in the White/Puyallup is active and is beginning to be funded. Extensive restoration of floodplain habitat is identified as a key action for recovering these populations. The lower river floodplain areas are currently experiencing rapid build-out, so opportunities for large scale restoration are dwindling: this is a key gap in the ability to achieve recovery of the populations.
- Better information on genetic relationships among Chinook in the basin would also substantially help guide management. In particular, a management strategy is needed for the White River to guide operations at the trap to manage population(s) structure and adapt management as better information is acquired.
- Estuary restoration. No clear set of actions are proposed in response to the high priority restoration needs for recovery identified in the Pierce County plan. Opportunities to implement large scale restoration actions are limited and are disappearing rapidly. This is recognized as a key gap in the ability to achieve recovery of the populations.

In addition, the following more general gaps also need to be addressed to improve the certainty of an effective habitat strategy in the near-term plan:

- Better document the data, assumptions, and models used to describe population VSP characteristics.
- Provide a synthesis of the available empirical support that can be used to relate ecological processes, land use, flow management regime, and habitat conditions to the four VSP responses.
- Provide documentation of the watershed data regarding the relationships among ecological processes, land use, flow management, habitat conditions, and the resulting responses in the viability characteristics of the Chinook populations.
- Develop an adaptive management plan for the habitat recovery strategy that relates the recovery targets to interactions among flow management regime, land use, habitat forming processes, habitat conditions and hypothesized population VSP responses. Include in the adaptive management and monitoring plan an approach for measuring the biological results from each protection measure
- Develop better empirical and analytical support for relationships among specific protection and restoration actions directed at specified recovery objectives (targets). Certainty will increase as linkages between actions, recovery hypothesis, a recovery strategy, and specific population VSP characteristics or ESU persistence are strengthened (see overall strategy comments above). In particular, provide any available empirical data on the effectiveness of the protection actions described or assumed. Further develop and describe the overall approach to managing urban growth (via CAO, SMP, etc.) and actions aimed at addressing growth.
- Integrate the strategy for protecting and restoring the nearshore with the all-H strategies (see overall strategy comments above).

Based on our analysis, developing and implemented the key items above would greatly increase the likelihood of a "high" level of certainty for this plan.

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

The analysis used one model. The submittal reports results from a two phased, detailed EDT based assessment of actions to restore the watershed. The analytical support was moderate.

- Support could be substantially increased by more clearly documenting what has been accomplished and by highlighting how the multiple, independent lines of evidence can be used to support recovery hypotheses and strategies. In particular, hypotheses for the interactions among land use, habitat forming processes, habitat conditions, and specific population VSP responses should be clarified. For example, the qualitative Limiting Factors Analysis (LFA) for the watershed considered the effects of habitat conditions on some of the population VSP characteristics; this could be used as a qualitative model to address the above interactions.

- The EDT method was used to quantitatively model restoration actions and resulting population VSP characteristics responses. However, the reported results did not explicitly discuss the population spatial structure characteristic responses available from the EDT results. Reviewers found it very hard to track down assumptions in the material provided. There is little information on the justification for assumptions of project effects on habitat conditions.
- The level of documentation and support for the assumptions on land use changes due to projects or management actions is also poor. It is noted that documentation for the restoration is complicated because the analysis bundles projects into classes and locations, and those effects are estimated on the group of projects. An example of the need to document and provide support for the assumptions is the nature of the historical baseline assumed for the lower White River. The alternative assumptions on the historical channel route and configuration and on productivity of that channel could lead to significantly different model results. That suggests that further analytical work is needed to reduce the uncertainty in the analytical support. Documentation summarizing 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 assessment would strengthen the analytical support for a recovery plan.
- No sensitivity analysis of the EDT model is apparent, so it is unclear how the modeled effects of habitat projects on environmental conditions would change under differing assumptions. Similarly, no analysis has been undertaken to explore the sensitivity of the model's population results (VSP) to differing assumptions about habitat conditions in the future.
- No empirical test was performed on the model although one could have been conducted for abundance and productivity using observed R/S data. Similarly, there is no apparent documentation of any calibration of the model rules and relationships to current habitat conditions in the Puyallup and White River watersheds or for Chinook abundance and productivity. Likewise, is not known whether calibration occurred to fit the model's assumptions to empirical effects of habitat actions or for the VSP parameters of diversity and spatial structure.
- No validation of the model was provided or proposed.
- The EDT model did not incorporate quantitative estimates linking habitat-forming processes (e.g., sediment dynamics, riparian dynamics, nutrient and contaminant loadings, hydrologic and floodplain dynamics) and land use to habitat conditions and population characteristics. The EDT reports reference sources of evidence regarding processes such as sediment dynamics, riparian dynamics, nutrient and contaminant loadings, hydrologic and floodplain dynamics. Specific linkages of the above processes to life history stages and VSP characteristic responses would significantly strengthen the overall analytical support for a recovery plan. These linkages can be qualitative or even conceptual. However, application of SHIRAZ results that are complete for the White River would add greatly to the certainty of the analytical model support.

Ways to improve certainty in plan outcomes:

- Better document the data, assumptions, and models used as they relate to population VSP characteristics;
- Provide a synthesis of the available empirical support that can be used to relate ecological processes, land use, flow management regime, habitat conditions, and all four VSP responses in a recovery planning context to strengthen the analytical support for a recovery plan.
- Further develop explicit life stage specific relationships among ecological processes, land use, flow management, habitat conditions, and resulting responses in population viability characteristics;
- Conduct sensitivity analyses;
- 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?

Support for the recovery hypothesis using watershed specific data was low.

- Support can be readily improved in the near-term by documenting the local habitat information used to support a recovery hypothesis.
- The main hypothesis is "if these projects are implemented, the resulting VSP will be x." The hypothesis necessarily assumes a status quo baseline is maintained by protection actions, despite human population growth and development. This was rated as low since expert opinion is the primary support for this hypothesis. The extent of local habitat information available to support the hypothesis could be included and should be documented. There is information in the documents submitted and referenced that could be turned into hypotheses regarding the primary habitat problems and the major life stages limiting population recovery. EDT documentation includes a discussion of how EDT is used to construct working hypotheses and what those are for the assessment. A synopsis of the hypotheses relating the inputs and results to VSP could help formulate a recovery logic that would be readily transparent, and, therefore, much more useful to reviewers, users, and other external parties.

Ways to improve certainty in plan outcomes:

- Provide documentation of the watershed specific data regarding the relationships among ecological processes, land use, flow management, habitat conditions, and the resulting responses in the viability characteristics (VSP) of the Chinook populations.
- Develop a more explicit and quantitative life stage model(s) with watershed specific data that relates the interactions among ecological processes, land use, flow management, habitat forming processes, habitat conditions to potential population VSP responses.

Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?

No. No goals have been adopted and no habitat strategy for recovery is explicitly stated. Good integration of all-H strategies to hypotheses is not provided. The co-managers'

White River recovery plan would serve as a readily adaptable source for guidance on interim recovery goals, development of a recovery hypothesis and recovery strategy, and on an integrated approach.

Ways to improve certainty in plan outcomes:
- Local planning entities, including the co-managers and Pierce County, along with the Services, must identify and adopt interim recovery goals, develop a recovery hypothesis and a recovery strategy; and integrate the habitat, hatchery, and harvest management strategies in the planning area into a consistent overall strategy directed at progressing toward measurable recovery goals.

Does the habitat recovery strategy preserve options for recovery in all 4 VSP attributes through all of the H's?
No. Preserving options requires an adaptive management plan to respond to changes and uncertainties as they occur. No goals have been adopted and no habitat strategy for recovery is explicitly stated. It is not clear how VSP can be recovered in the future, given that the list of actions is not related to any specific recovery objectives. The co-managers' technical workgroup has been adaptively managing actions under the White River Rebuilding Program since the early 1980s. The 1996 version of the program plan needs to be updated and integrated into a formal adaptive management plan element of an adopted Puyallup watershed recovery the plan.

Ways to improve certainty in plan outcomes:
- Develop and implement an adaptive management plan for a habitat recovery strategy explicitly relating the recovery targets to interactions among flow management regime, land use, habitat forming processes, habitat conditions and the population VSP responses.

How well have the habitat recovery actions been shown to work?
There is moderate empirical support for the habitat recovery actions identified in the Puyallup/White submittal.
- There is some empirical evidence of the effectiveness of the proposed habitat restoration actions in similar settings, but there are few tested applications of projects such as engineered log jams in the broader context of other restoration and protection actions.
- Although model predictions about the effects of individual actions are available, some conflicting empirical results occur.
- Very little is understood about the cumulative, interactive effects of the actions on habitat-forming processes or in-stream habitat conditions.
- The analysis of the effects of habitat recovery actions does not incorporate uncertainty in the assessments. In particular, evidence for the effects of habitat protection measures (e.g., critical areas ordinances, shoreline management plans) is not discussed.

Ways to improve certainty in plan outcomes:

- Summarize existing modeled or empirical support for the effectiveness of habitat protection and restoration actions identified in the plan.
- Design and implement a comprehensive monitoring and evaluation program that can track the integrated, cumulative effects of habitat protection and recovery actions over time.
- 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 validation that the actions result in the predicted responses.
- Systematically analyze the potential cumulative effects of protection measures. Specifically,
    - Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.

- Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.
- Provide available empirical data on the effectiveness of the protection actions described or assumed. In particular, provide any available empirical data on the effectiveness of the protection actions described or assumed. Further develop and describe the overall approach to managing urban growth (via CAO, SMP, etc.) and actions aimed at addressing growth.

Are the habitat recovery actions consistent with the recovery strategy?

The proposed habitat actions are not consistent with the recovery strategy.
(See #4 above)
Ways to improve certainty in plan outcomes:

- The development of an explicit habitat recovery strategy, based on the hypotheses derived from the LFA and the EDT results is required;
- This strategy should then be used to evaluate proposed actions and develop others that will implement the strategy.

Hatchery strategy

While the co-managers are making significant progress at generally adapting hatchery management programs, local hatchery management objectives do not yet match with recovery needs for either population. For example, as intended, hatchery marking programs are providing new straying data. The data recently reported for South Prairie Creek shows higher than expected proportions of the spawners are hatchery origin fish, which is exceeding the straying rate objective. As a consequence, the actual natural origin escapement to South Prairie Creek in recent years appears to have been well below the harvest management escapement objective. This information along with the EDT based habitat assessment needs to now be used to review the affects of all Hs in an integrated manner to match up the actions with recovery needs. In a similar manner, recent reforms in the evolving White River supplementation program to incorporate more natural broodstock into the program and to better separate and manage early and late returning hatchery and natural origin Chinook are in progress, but better information on genetic relations and hatchery returns is needed. In some cases, recent recommendations for actions from the Hatchery Scientific Review Group (HSRG) review process have not yet been incorporated into the recovery plan. Placement of a weir to reduce strays from the Puyallup tribal hatchery is a potential action that needs to be addressed in the plan.

Key Ways to Improve Certainty

The most important ways to improve the certainty of an effective hatchery strategy in an integrated Puyallup watershed recovery plan include:

- Develop explicit recovery hypotheses for the effects of hatcheries on recovery of the White River population and the Puyallup populations that consider the status and functioning of the habitat and uses the most recent available local data on abundance, contribution of hatchery fish to natural spawning, productivity, and spatial distribution.
- Develop a strategy for achieving watershed goals based on the recovery hypothesis and by integrating sub-strategies across all management sectors (habitat, harvest, and hatcheries).
- Develop an adaptive management plan.

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 (BRAP) cited in co-managers' resource management plan) to understand the potential affects of hatchery actions on populations. The model addressed all VSP criteria. Documentation is 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 Puyallup River populations. Demographic and genetic data exist for the White River hatchery programs in the White River and at Hupps Springs and these data were used to calibrate some parts of the assessment. Most of the analyses were based on weak inference because the assessment did not use local watershed data.

Since the original assessments using the BRAP, addition tools and assessments have been developed that could refine understanding, including the Hatchery Scientific Review Group's All 'H' Hatchery Analyzer (AHA) model and quantitative models developed to evaluate domestication, effects of small population size, and competition and predation by WDFW and the NWIFC as part of the hatchery risk assessment modeling project (RAMP). In addition, the SHIRAZ population dynamic model could be adapted the model to include a quantitative analysis of hatchery effects within the context of a recovery hypothesis for the watershed. The EDT model could potentially also be used. One possible way of doing for the White River, would be to start with the existing White River Plan developed by the co-managers and improve it by addressing all four VSP criteria in the context of results from the above analyses.

Key Ways to Improve Certainty:

- Develop an explicit recovery hypothesis for the effects of hatcheries on recovery of the White River population and Puyallup population that considers the status and functioning of the habitat and uses the most recent available local data on abundance, contribution of hatchery fish to natural spawning, productivity, and spatial distribution.

How well supported is the recovery hypothesis with watershed specific data? (Watershed Data Quality)

Support for the hypotheses using watershed specific data for was low. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. Local watershed data do support the hypothesis that the risk of extinction of the population could be lowered by intensive hatchery intervention. This is not the same as recovery to a viable status, however, and the TRT concluded the support was low because the plan did not identify an explicit recovery hypothesis and it did not use the available information on existing hatchery programs and stocks to look at all four VSP characteristics.

Key Ways to Improve Certainty:

- Use the available, better local information to assess the effects of hatchery actions and to develop and apply models that will allow managers to understand how different factors affect the certainty of the results from hatchery management decisions (e.g. through a sensitivity analysis).
- Use available data from other watersheds to increase the analytical support and to document the assumptions that would be part of that and begin collecting information from the Green/Duwamish River on hatchery-wild interactions at different life stages.

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

No. The TRT did not find a clearly stated recovery hypothesis or a recovery strategy for hatcheries that was based on integration across all management sectors (habitat, harvest, and hatcheries).

Key Ways to Improve Certainty:

- Develop a recovery strategy. This will require a recovery hypothesis (see recommendation above) and recovery goals to integrate hatchery actions across management sectors (habitat, harvest, and hatcheries).

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

No. The lack of a recovery strategy and an adaptive management plan strongly suggested that current actions for recovering White River Chinook salmon are unlikely to preserve options for recovery.

Key Ways to Improve Certainty:

- Develop a recovery strategy
- Develop a hatchery monitoring and adaptive management plan to address the uncertainties associated with the hatchery strategies and actions.

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

No. Many of the actions taken by the Tribes and the Washington Department of Fish and Wildlife to maintain the White River population are consistent with initial efforts at recovery. Although some of these actions may continue to be appropriate, they are not based on recovery goals or a recovery strategy integrated across management sectors (habitat, harvest and hatcheries). Nor is there evidence that they are based on potential changing status of the habitat or population. Consequently, the TRT concluded that these actions were not consistent with a recovery strategy.

Key Ways to Improve Certainty:

- Following reevaluation of the conservation strategies of the existing hatchery management plans against the recovery goals of the plan, revise the actions to be consistent the strategies.

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

Empirical support for the proposed actions is low. However, this could readily be rated as moderate if the available information were applied in a recovery plan per the TRT's Technical Guidance document. Empirical support exists for many of the suites of actions that might be possible under an integrated recovery strategy, although the results will continue to vary based on individual watershed conditions and chance.

Key Ways to Improve Certainty:

- Document effectiveness of existing actions
- Develop and implement a monitoring program

Harvest Management Strategy— Puyallup population

This review is based on the Puyallup Fall Chinook Management Unit Status Profile, pages 165-167, in the *Comanagers' Puget Sound Chinook Harvest Management Plan* as well as information contained in the watershed recovery plan.

Key improvements to development of the harvest management portion of an integrated Puyallup watershed recovery plan include:

- Develop exploitation rate guidelines based on local data and an updated assessment of the expected responses in VSP characteristics of the population (i.e. relationships to abundance, productivity, and considerations for potential effects on diversity and spatial structure).
    - For example, Puyallup River straying data from Voight's Creek hatchery needs to be used to update natural origin exploitation and escapement estimates.
- Develop some discussion of the potential effects of harvest management on diversity and spatial structure;
- Analyze how recent population assessment data support, or suggest modifications to, the EDT modeling as it relates to predictions of the effects of harvest on VSP characteristics;
- Develop an integrated recovery adaptive management plan which includes and addresses harvest strategies to reduce weaknesses in the current escapement and productivity data to test whether the exploitation rate guidelines are effective (i.e. can be sustained under current conditions and allow for population growth with improved habitat conditions);
- Develop a harvest management strategy for achieving watershed goals that explicitly follows from a recovery hypothesis relating harvest management, integrated with the harvest and hatcheries sectors, to responses in all four population VSP characteristics.

Based on our analysis, Develop and implementing the key items above would greatly increase the certainty of success for this plan.

Was the analysis based on one or many models?
One**.**
Harvest management is based on the hypothesis that constraining the exploitation rate below 50% for Puyallup Chinook will not inhibit recovery. This represents a new

focus on setting an objective for natural origin Chinook and it also is a decrease in exploitation rates from past levels.

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

Low.

- The harvest management plan appears to be based on the hypothesis that if exploitation rates are reduced from levels previously observed, VSP parameters will improve for the naturally spawning population. Harvest management will be constrained by an upper limit overall exploitation rate of 50%, but it is not clear how this number was derived and whether it has been related to any expected VSP responses.
- There is no discussion of the effects of harvest on diversity and spatial structure.

Ways to improve certainty in plan outcomes:

- Develop exploitation rate guidelines based on an updated assessment of the population's abundance, productivity, and other VSP characteristics. This could probably be accomplished for interim purposes for abundance and productivity using the Puyallup watershed EDT habitat-based model adjusted for the recent hatchery stray rate information.
- Develop and provide discussion of the potential effects of harvest management on diversity and spatial structure.

How well supported is the recovery hypothesis with watershed specific data? (Watershed Data Quality)

Low.

- The support for the recovery hypothesis is highly uncertain because there is no attempt to relate the conceptual harvest hypothesis to an overall recovery hypothesis or to use local information and discuss how it supports a hypothesis on population VSP characteristics. Green River hatchery stock was reported as the currently used indicator stock for calculating an RER of 50% for Puyallup Chinook because a local indicator stock has not been available. (However, there appears to be some conflicting information on this in the materials provided to the TRT and this information needs to be verified.) System-wide escapement data has been of poor quality and a local CWT database has not existed until very recently. Harvest objectives are based on interim escapement goals for what the system could support in the early 1970s that are not agreed to (see Puyallup write up p. 38). It is also unknown whether South Prairie Creek is a useful indicator of the population's abundance or viability. There is no rationale or analyses provided to support the assertion that a 500 fish escapement objective in South Prairie Creek represents a viable population level. An unknown fraction of those fish are hatchery-origin, so not at all clear that these are naturally self-sustaining (or what their relationship is to VSP, viability).

- The stated rationale for the objective is that reducing the ER from historically higher levels will improve abundance and productivity by allowing sufficient escapement to seed current habitat and encourage local adaptation. An additional stated benefit is that it will allow the co-managers to resolve issue of the contribution rates of hatchery and natural origin fish to the natural escapement. No qualitative discussion of effects of harvest on diversity or spatial structure has been provided; harvest objective does not yet relate to population VSP characteristics. There was discussion that acknowledged a high level of uncertainty exists as to whether the current harvest objective is consistent with recovery. The discussion underscored the need for further review of harvest levels given current high hatchery stray rates and the estimated low productivity of the Puyallup population.
- It appears that the detailed EDT assessment for the watershed could be used, perhaps in conjunction with other data, for deriving harvest management objectives. (See above)
- Development of a means for quantifying the population's abundance and exploitation rates, such as establishing a local CWT indicator group, could markedly increase the certainty of effectiveness in implementation of harvest actions.

Ways to improve certainty in plan outcomes:

- Develop exploitation rate guidelines based on local data and an updated assessment of the expected responses in VSP characteristics of the population (i.e. relationships to abundance, productivity, and considerations for potential effects on diversity and spatial structure). For example, Puyallup River (South Prairie Creek) straying data from Voight's Creek hatchery needs to be used to update natural origin exploitation and escapement estimates.
- Analyze how recent population assessment data supports or suggests modifications to the EDT modeling as it relates to predictions of the effects of harvest on VSP characteristics.
- Determine a means for quantifying the population's abundance and exploitation rates and implement the appropriate actions.

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

No.

- It is not clear whether the population has sufficient productivity to sustain the exploitation rate. The need for documentation of the basis for a strategy that is integrated with an overall recovery strategy is addressed above. Once an explicit integrated strategy is developed, an adaptive management plan, including harvest strategies, can further reduce uncertainties.

Ways to improve certainty in plan outcomes:

- Develop an integrated recovery adaptive management plan, including harvest strategies, to reduce weaknesses in the current escapement and productivity data and to test whether the exploitation rate guidelines are effective (i.e. can be sustained under current conditions and allow for population growth with improved habitat conditions).

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

No

- The harvest management strategy is not clearly related to a hypothesis relating harvest management to VSP characteristics.
- It is not clear whether the intrinsic productivity of naturally-spawning Puyallup Chinook will be sufficient to support the likely exploitation rates. Naturally-spawning Puyallup Chinook will be much more likely to support exploitation rates derived from a harvest management strategy that is better linked to a hypothesis and analytical support for the abundance and intrinsic productivity of the population.
- Development of an expanded hypothesis explicitly including the relationships between harvest actions and expected diversity and spatial structure responses of the population will further improve the likelihood that the strategy will be consistent.

Ways to improve certainty in plan outcomes:

- Develop a harvest management strategy for achieving watershed goals that explicitly follows from a recovery hypothesis relating harvest management, integrated with the habitat and hatcheries sectors, to responses in all four population VSP characteristics.

How certain is the empirical support for the effectiveness of the recovery actions?
Moderate.

- The effects of the harvest plan on diversity and spatial structure have not been evaluated. The general evidence suggests that that reducing harvest rates could improve VSP characteristics. There is weak local evidence that exploitation rates on natural origin recruits (NORs) have been reduced or that escapements are responsive to the harvest actions. Apparent exploitation rates in last seven years, although on average lower than in earlier years, seem quite variable with no trend, while escapement has been decreasing (although variable) during that time. The exploitation rate evidence is confounded by hatchery straying, which has recently been demonstrated to be potentially high (only one year of data), and by lack of NOR outmigrant production data corresponding with escapements. Escapement was relatively high in 1989 and decreasing since then, with no reliable quantitative estimates of NORs. Apparent exploitation rates were reduced in 1995 but escapement has not shown an increasing trend.

Ways to improve certainty in plan outcomes:

- Key actions provided for the other questions will improve the empirical support for the harvest recovery actions.

Are the harvest management recovery actions consistent with the plan's all-H recovery strategy?

Yes.

- Actions are determined to be potentially consistent with a hypothetical integrated recovery strategy based on EDT modeling. As in the habitat section, the strength of the empirical and modeling evidence demonstrated for the effectiveness of the proposed actions will have a significant influence on the implementation certainty of a recovery plan. In this case the weakness of escapement data currently precludes the ability to implement the intended action correctly.

Ways to improve certainty in plan outcomes:

- Key actions provided for the other questions will improve the empirical support for the harvest recovery actions, thereby enabling implementation of harvest recovery actions that are consistent with all-H recovery strategy.

Harvest Management Strategy—White River population

This review is based on the White River Spring Chinook Management Unit Status Profile, pages 162-164, in the *Comanagers' Puget Sound Chinook Harvest Management Plan* as well as information contained in the watershed recovery plan.

Key improvements to development of the White River Spring Chinook harvest management portion of an integrated Puyallup watershed recovery plan include:

- Develop exploitation rate guidelines based on local data and an updated assessment of the expected responses in VSP characteristics of the population (i.e. relationships to abundance, productivity, and considerations for potential effects on diversity and spatial structure).
    - For example, White River (Boise Creek) straying data from White River and Voight's Creek hatcheries needs to be used to update natural origin exploitation and escapement estimates.
    - The assertion that the maximum 20% exploitation rate is appropriate to recovery is not linked to hypotheses for any VSP characteristics.
- Develop some discussion of the potential effects of harvest management on diversity and spatial structure.
- Utilizing existing local data to develop an updated harvest management strategy that explicitly follows from a recovery hypothesis relating harvest management, integrated with the habitat and hatcheries sectors, to responses in all four population VSP characteristics.
- Develop a harvest management strategy for achieving watershed recovery goals that explicitly follows from a recovery hypothesis relating harvest management, integrated with the harvest and hatcheries sectors, to responses in all four population VSP characteristics.
    - What is the basis for the n = 200 critical threshold for the White River Chinook stock? How does that relate to VSP needs for the White

population? Are late returning White River Chinook managed as part of the White population, the Puyallup population, or a separate stock?

Addressing the key items above would greatly increase the certainty of success for this plan.

Was the analysis based on one or many models?
One.

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

Low.

- The harvest management plan is apparently based on the hypothesis that maintaining the overall exploitation rate below 20% will not impede the ability of the population to respond positively to habitat and hatchery actions to promote recovery. However, this hypothesis is not clearly stated in the materials the TRT reviewed.
- There is no discussion of the effects of harvest on diversity and spatial structure.
- Development of exploitation rate guidelines based on local data and an updated assessment of the expected responses in VSP characteristics of the population (i.e. relationships to abundance, productivity, and considerations for potential effects on diversity and spatial structure) could significantly reduce this uncertainty.

Ways to improve certainty in plan outcomes:

- Develop exploitation rate guidelines based on local data and assessments of the population's abundance, productivity, and other VSP characteristics (i.e. relationships to abundance, productivity, and considerations for potential effects on diversity and spatial structure)
- Develop some discussion of the potential effects of harvest management on diversity and spatial structure.

How well supported is the recovery hypothesis with watershed specific data? (Watershed Data Quality)

Low.

- The support is highly uncertain because there is no explicit discussion relating how a harvest hypothesis supports an overall recovery hypothesis. Although reasonably good exploitation rate estimates are available, accurate escapement estimates for the populations and hatchery returns are hard to obtain. Thus, management for an exploitation rate target is a good idea, but this has to somehow be related to the populations' productivity and other VSP characteristics. In addition, resolution of the remaining uncertainties on the population structure of Chinook in the White River, as identified in the habitat section and the consolidated comments, will be necessary to reduce the harvest management uncertainties discussed here.

- The exploitation rate guideline, based on an assessment of the population's VSP characteristics, could probably be accomplished using the SHIRAZ or EDT habitat-based models and the available fishery, escapement, and genetic data. An update of the co-managers' White River Recovery plan, synthesizing the recent genetic stock identification results with other analyses and data, is one potential approach that has been discussed.

Ways to improve certainty in plan outcomes:

- Utilize existing local data to develop an updated harvest management strategy that explicitly follows from a recovery hypothesis relating harvest management, integrated with the habitat and hatcheries sectors, to responses in all four population VSP characteristics.

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

No.

- It is not clear whether the population has sufficient productivity to sustain the exploitation rate. The need for documentation of the basis for a strategy that is integrated with an overall recovery strategy is addressed above. Once an explicit integrated strategy is developed, an adaptive management plan, including harvest strategies, can further reduce uncertainties.

Ways to improve certainty in plan outcomes:

- Develop an integrated recovery adaptive management plan, including harvest strategies, to reduce weaknesses in the current escapement and productivity data and to test whether the exploitation rate guidelines are effective (i.e. can be sustained under current conditions and allow for population growth with improved habitat conditions).

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

No.

- The harvest management strategy is not clearly related to either a recovery hypothesis or the VSP characteristics of the population. It is not clear if the intrinsic productivity of naturally-spawning White River Chinook will be sufficient to support the current exploitation rates. Naturally-spawning White River Chinook will be much more likely to support exploitation rates derived from a harvest management strategy that is better linked to a hypothesis and analytical support for the abundance, intrinsic productivity, diversity, and spatial structure of the population.
- Development of an expanded hypothesis explicitly including the relationships between harvest actions and expected diversity and spatial structure responses of the population will further improve the likelihood that the strategy will be consistent.

Ways to improve certainty in plan outcomes:

- Develop a harvest management strategy for achieving watershed recovery goals that explicitly follows from a recovery hypothesis relating harvest management, integrated with the habitat and hatcheries sectors, to responses in all four population VSP characteristics.

How certain is the empirical support for the effectiveness of the recovery actions?
Moderate

- The effects of the harvest plan on diversity and spatial structure have not been evaluated. There is no evidence that reduction in exploitation rates in recent years has resulted in increased escapements, as escapements have been quite variable with no significant trend. Both exploitation rates and escapement were higher in the early nineties than now.

Are the harvest management recovery actions consistent with the plan's all-H recovery strategy?
Yes.

- Actions are determined to be potentially consistent with a hypothetical integrated recovery strategy based on EDT modeling results provided. As in the habitat section, the strength of the empirical and modeling evidence demonstrated for the effectiveness of the proposed actions will have a significant influence on the implementation certainty of a recovery plan.

Ways to improve certainty in plan outcomes:

- The near term steps identified above will also improve the certainty that harvest management recovery actions are consistent with the all-H recovery strategy as intended.
- Actions listed for the other questions will also improve the empirical support for the harvest actions, thereby enabling implementation of harvest actions for recovery that are consistent with an all-H recovery strategy.

II. **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.

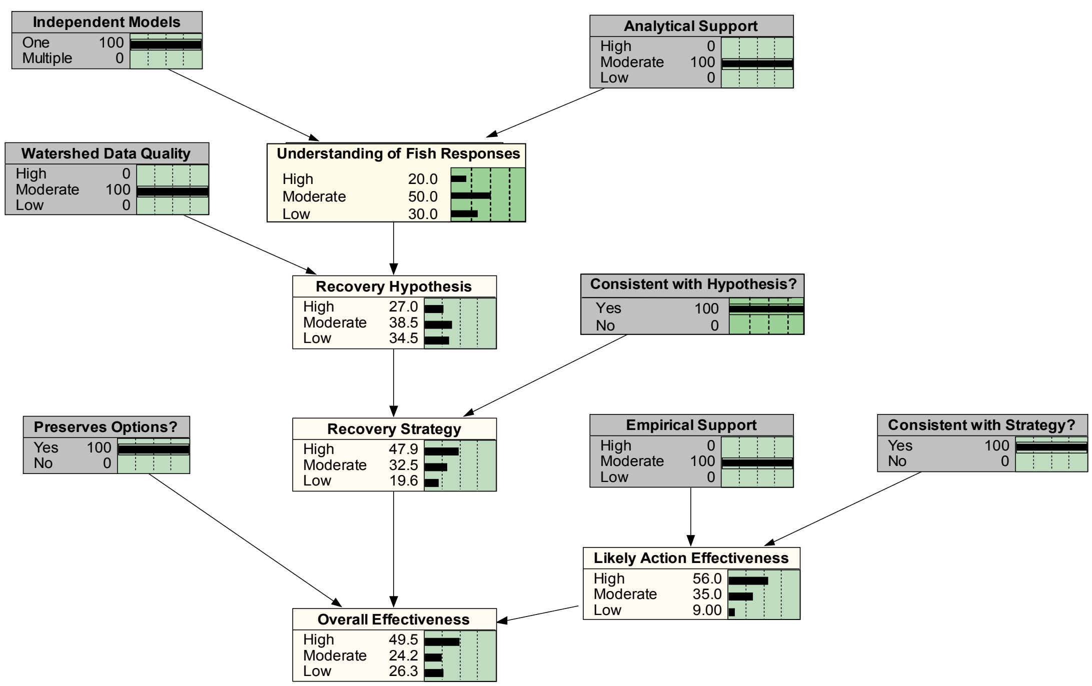

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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.

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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)
Harvest 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

Nisqually Plan: Nisqually Chinook Salmon Population
May 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the 2001 Nisqually Chinook Recovery Plan and the memorandum from the Nisqually Tribe, which is leading the recovery planning effort that described changes to the plan and clarification of issues raised by the TRT in their 2004 review. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies

or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the Nisqually Plan is an excellent start for recovery of this population. Revisions to the Plan should provide better integrated strategies for habitat, hatchery, and harvest recovery actions. Proposed improvements to Plan include new goals. A major strength of the plan that provides certainty towards achieving the goals is the adaptive management approach and framework. A major weakness of the plan is the many of the proposed details and changes to the plan remain undeveloped and not yet incorporated into the plan.

Habitat Strategy

Key Technical Gaps

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

- Complete revision of the Plan to incorporate changes described in the May memorandum from the Nisqually Tribe.
- Continue refinement of the implementation details for consistent, integrated strategies in all the 'Hs', including 1) sequencing of actions in habitat, hatcheries, and harvest management, 2) incorporating what is known about spatial structure and diversity, and 3) and the monitoring and evaluation needed to evaluate and adjust the integrated, all-H recovery strategy as needed.
- Include an adaptive management decision framework in the plan that highlights where information from monitoring and evaluation of habitat projects and fish population responses will affect decisions about the overall recovery strategy.

Based on our analysis, developing and implementing the key items above would greatly increase the likelihood of a "high" level of certainty for this plan.

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

The certainty of the analytical approaches used to understand fish responses to actions in the Nisqually Plan was "moderate." Nisqually Plan relied on both qualitative and quantitative models. The quantitative model was the primary tools used to evaluate the potential responses of the Chinook population to changes in habitat conditions and qualitative models developed from research in the basin were used to ground truth the quantitative model.

The Ecosystem Diagnosis and Treatment (EDT) model was used to estimate quantitatively the effects of changes in habitat conditions on all four viable salmon population (VSP) attributes of the Nisqually population. The EDT model did not incorporate quantitative estimates of the effects of changes in habitat-forming processes (e.g., sediment dynamics, riparian function, floodplain dynamics); land use/land cover conditions on in-stream habitat conditions or on Chinook salmon; or the potential effects of climate change. The Nisqually plan included a good description of the methods for the EDT model. The memorandum from the Nisqually Tribe received in May 2005 described in better detail the assumptions for how the EDT model was parameterized for the Nisqually population and provided citations for many of the research studies that were used to parameterize the model and to translate modeled projects into habitat conditions. These need to be included in the next revision of the Plan. No sensitivity analyses for EDT have been conducted, so it is not clear how modeled results of the effects of habitat restoration and protection projects on habitat conditions might change under different assumptions. Similarly, no analyses have been conducted exploring the sensitivity of the EDT model results to assumptions about how habitat conditions affect Chinook population status. No calibration of the EDT model in the Nisqually watershed was conducted for current habitat conditions or current Chinook abundance, productivity, or diversity data. No calibrations of the model occurred for the effects of habitat restoration projects or for how Chinook diversity might respond to modeled actions.

Key Issues to Improve Certainty:

- Conduct sensitivity analyses for EDT so that the relative importance of assumptions and model inputs for estimated effects of recovery actions can be understood. These could help prioritize critical areas of uncertainty and monitoring.
- Include documentation of supporting research in the next revision of the Plan.

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?

The support for these hypotheses was "low". The stated hypothesis in the draft Nisqually recovery plan is that juvenile survival and capacity are key life stages limiting population recovery, and if a number of habitat factors (e.g., estuarine capacity, floodplain channelization) are corrected, the Chinook in the Nisqually will recover. The memorandum from the Nisqually Tribe provided citations for research studies that provided watershed-specific information for the habitat factors estimated to be limiting recovery of the Nisqually population. The current condition of habitat in the Basin is relatively well understood, but information on the function of habitat-forming processes is not provided. We are aware that some information is available on the VSP status of the Chinook population, especially for abundance at the adult stage, loss of diversity (extinction) of the indigenous population (Appendix 3 and new genetics results), and spatial distribution of spawners. New or previously uncited information should be incorporated in the next revision of the plan. Life-stage specific Chinook productivity data were not available, nor were natural-origin spawning, spatial structure or diversity information for juveniles. In addition, there was very little information in the Basin on the interactions among habitat-forming processes and land use attributes and how they affect the in-stream habitat conditions used in their modeling.

Key Issues to Improve Certainty:

- Include what is known in the Nisqually Basin about the mechanistic links between habitat-forming processes, land use, and in-stream habitat conditions in the next revision of the Plan.
- Document assumptions made about the VSP status of the Nisqually population in the next revision of the Plan.
- Collect data on hatchery and wild juvenile use and survival in different habitat types (lower main stem, estuary, and nearshore).
- Monitor natural-origin and hatchery-origin Chinook salmon use at different life stages throughout the Basin.
- Monitor and study linkages between habitat-forming processes, land use, and in-stream habitat conditions so that mechanistic links among those can be better understood, protected and restored.

Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?

Yes. The Nisqually Plan has made significant progress in developing a recovery strategy that is consistent with the recovery hypothesis for habitat factors limiting recovery and the hypotheses and strategies for hatchery management and harvest management. The revised goals and summary of revisions to the plan provided by the Nisqually Tribe indicate much better integration of habitat, hatchery, and harvest strategies and actions, although the details of how these will be implemented and refined remain to be developed. In particular, details of the goals were not explicit enough for us to evaluate quantitatively the consistency of the Nisqually goals with the TRT's planning ranges. The watershed group has been using the All 'H" Hatchery Analyzer model (AHA), which was developed by the Hatchery Scientific Review Group (HSRG), to examine strategies for better integration of the H's and consistency with the dominant recovery hypothesis. This model should provide a good tool for addressing abundance and productivity goals and the actions over time. The model and the Plan still does not address two VSP characteristics—diversity and spatial structure---as well as it could.

Key Issues To Improve Certainty:

- Revise Plan to include information in May memorandum to Shared Strategy
- Continue refinement of the implementation details, such 1) sequencing of actions in habitat, hatcheries, and harvest management, 2) incorporating what is known about spatial structure and diversity, and 3) and the monitoring and evaluation needed to evaluate their success.

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

No. The existing adaptive management plan for Nisqually Chinook does not yet state how it will preserve options for implementation of the overall recovery strategy, although the memorandum from the Nisqually Tribe indicates that this is a focus of refinements to the Plan.

The habitat recovery strategy in the draft Nisqually Chinook Recovery Plan contains one of the best adaptive management plans we reviewed in the Puget Sound. Nevertheless, the plan is not yet fully developed, and the authors acknowledge there are missing pieces yet to be completed. The habitat recovery strategy protects existing VSP structure and opportunities for future improvements in the "all-H" condition for the Nisqually population. In contrast, there is not yet a well-developed adaptive management and monitoring program that preserves options for implementation of the all-H strategy.

Key Issues To Improve Certainty:

- Include an adaptive management decision framework in the plan that highlights where information from monitoring and evaluation of habitat projects and fish population responses will affect decisions about the overall recovery strategy.
- Use information from monitoring over time to adjust the integrated, all-H recovery strategy as needed.

How well have the habitat recovery actions been shown to work?

The empirical support for the habitat recovery actions identified in the Nisqually recovery plan is “moderate.” There is some empirical evidence of the effectiveness of the proposed habitat restoration actions in similar settings, but there are few tested applications of projects. Although model predictions about the effects of individual actions are available, some conflicting empirical results could occur. Very little is understood about how the cumulative effects of the actions interact to affect habitat-forming processes or in-stream habitat conditions. Furthermore, the modeling analysis of the effects of habitat recovery actions did not incorporate uncertainty in assessments. Finally, evidence for the effects of habitat protection measures (e.g., critical areas ordinances, shoreline management plans) is not discussed.

Key Issues to Improve Certainty:

- Incorporate summaries of existing modeled or empirical support for the effectiveness of habitat protection and restoration actions identified in the plan.
- Continue to implement a comprehensive monitoring and evaluation program that can track the integrated, cumulative effects of habitat recovery actions over time.
- Systematically analyze the potential cumulative effects of protection measures. Specifically,
    - Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
- Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.

Are the habitat recovery actions consistent with the recovery strategy?

Yes. A clear and logical relationship exists between the “all-H” recovery strategy and the proposed habitat recovery actions in the Nisqually recovery plan. The major habitat protection and restoration actions identified clearly reflect the major elements of the recovery strategy. The habitat recovery actions logically derive from the spatial and temporal elements of the recovery strategy, and the actions have clear and logical outcomes that are predicted to be consistent with achieving the recovery strategy.

Nisqually Hatchery Strategy

Key Technical Gaps

This review is based on the 2001 Nisqually Chinook Recovery Plan and the May 2005 memorandum from the Nisqually Tribe.

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

1. Complete revision of the 2001 Nisqually Chinook Recovery Plan incorporating the proposed changes described in the memorandum from the Nisqually Tribe in May 2005.
2. Continue to use the AHA model and other modeling tools developed by the co-managers and conduct sensitivity analyses of these models to refine and incorporate the details of recovery actions and how they will be integrated with harvest and habitat actions
3. Include an adaptive management decision framework in the plan that highlights where information from monitoring and evaluation of hatchery actions and fish population responses will affect decisions about the overall recovery strategy.
4. Develop and implement a monitoring program

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 (BRAP) cited in co-managers' resource management plan) to understand the potential affects of hatchery actions on populations. The model addressed all VSP criteria. Documentation is 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 Nisqually River population. The co-managers also used two quantitative models. They used EDT as a quantitative model to examine the affects of habitat conditions and restoration actions on population productivity and abundance. The plan included documentation for the EDT model. The memorandum from the Nisqually Tribe indicates that they are also using the AHA model to examine the interaction of improvements in habitat and changes in abundance and productivity resulting from hatchery and harvest management actions. Most of the analyses were based on weak inference.

Key Issues to Improve Certainty:

- Revise the Plan with the new goals and strategies developed by using the AHA and other independent models and document model assumptions and analyses.
- Develop ways to obtain and use better local information to assess the effects of hatchery actions
- Refine modeling results so managers can understand how different factors affect the certainty of the results from hatchery management decisions (e.g. through a sensitivity analysis of the AHA and EDT models).

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

Support for the recovery hypothesis using watershed specific data for was low. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. The plan and references cited contained few examples of watershed specific data that supported the recovery hypothesis. This may reflect the logistical difficulties in obtaining accurate demographic information, genetic information, and information in ecological interactions in this river system. We believe this will improve as marking of fish and sampling of adults and surveys of juveniles continue.

Key Issues to Improve Certainty:

- Use available data from other watersheds to increase the analytical support and to document the assumptions that would be part of that and begin collecting information from the Nisqually River.

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

Yes. The plan does a good job of identifying objectives, such as maintaining genetic diversity and minimizing ecological interactions, which address general concerns from hatchery programs that might limit recovery. Changes indicated in the May 2005 memorandum from the Nisqually Tribe indicated that the revised strategy will be to operate an integrated hatchery program with gene flow between hatchery and wild components of the population and to greatly reduce the fraction of hatchery-origin spawners in the wild. This general strategy is consistent with the Nisqually goal of promoting a locally adapted population. Other strategies include minimize the ecological effects on natural-origin fish through improved release strategies.

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

Yes. The TRT concluded the plan preserves options for two reasons. First, the Nisqually Chinook Plan outlines one of the best adaptive management plans we examined. Technically, it is lacking an adequate monitoring program for the effects of the hatchery strategy and actions on VSP characteristics of the population (see recommendation below). However, the TRT was impressed by the structure of plan outlining management goals and tasks to achieve the goals and make management decisions. The TRT felt the current process of revising the plan to implement a better strategy given new information was evidence that the adaptive management plan could work. Second, the native Nisqually Chinook salmon is assumed to be extinct and much of the genetic diversity of the extant Nisqually Chinook salmon is maintained in the current hatchery program.

Key Issues to Improve Certainty:

- Develop and implement a monitoring program

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

No. The proposed actions are very general. As far they go, they may be consistent with the strategy but many important details remain to be worked out. In particular, the details of actions effecting spatial structure and diversity are not yet available. For example, we are aware that the Nisqually Tribe is experimenting with seasonal weirs as one method to control the proportion and spatial distribution of hatchery-origin spawners in the wild, but they have not decided on this tool or others that might be used. We expect that some of these alternatives could impact harvest management actions and strategies and the integration of these hatchery and harvest actions is not well described. In addition, although the plan identifies minimizing ecological interactions of hatchery and wild fish as a strategy, it does not provide adequate information on the actions to determine whether they will be consistent with the strategy.

Key Issues to Improve Certainty:

- Continue to use the AHA model and other modeling tools to refine and incorporate the details of recovery actions and how they will be integrated with harvest and habitat actions
- Include ecological interactions in the analyses
- Include an adaptive management decision framework in the plan that highlights where information from monitoring and evaluation of hatchery actions and fish population responses will affect decisions about the overall recovery strategy.

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

Empirical support for the proposed actions is moderate. Some evidence exists that these recovery actions may work, although the evidence is not overwhelming. Especially uncertain is the effectiveness of actions to 1) minimize domestication in production hatchery programs such that it minimizes effects on productivity of natural origin fish and 2) to limit potentially negative ecological interactions of hatchery fish (all species) and natural fish.

Key Issues to Improve Certainty:

- Develop and implement a monitoring program

Nisqually Harvest Management Strategy

Key Technical Gaps

This evaluation is based on the Nisqually Management Unit profile, pages 68-171, of the *Comanagers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the Plan submitted by the Nisqually watershed group, and responses to the 2004 TRT review that were provided in a memorandum from the Nisqually Tribe in May 2005.

The most important ways to improve the certainty of an effective harvest recovery strategy in this plan are to:

1. Update Plan to provide details of harvest actions that are consistent with revised goals and harvest strategy
2. Expand the strategy (including the adaptive management plan) to include the effects of harvest on diversity and spatial distribution. .

3. Gather and analyze population data to support EDT or other modeling efforts predictions of the effects of harvest actions on VSP characteristics.

Did the analysis use one or multiple independent models to understand potential fish responses to actions?
The Plan used one model, EDT, to determine escapement goal under current conditions. In addition, the memorandum from the Nisqually Tribe indicates that they are also using the AHA model to explore implications of integrated strategies for habitat, hatchery, and harvest actions.

How well supported is the understanding of the links between harvest actions and population viability (VSP) characteristics used in the planning (Analytical Support)?
Moderate. The EDT model includes qualitative and quantitative descriptions of the link between harvest management and abundance and productivity, but the effects of harvest on diversity and spatial distribution were not well described. Although the general framework of the model was well documented, the sensitivity of the results to variation in the parameter values is unknown. This is especially important because although the model was calibrated using local habitat data, it did not use demographic data. AHA uses productivity and capacity estimates from EDT, a heuristic model for domestication impacts of hatchery fish on natural productivity, and watershed specific details of hatchery and harvest production to examine joint effects of hatchery, habitat, and harvest actions on abundance and productivity but it does not address spatial structure and diversity. The sensitivity of the results to variation in the parameter values is also unknown. The co-managers have concluded that managing for differences in diversity and spatial distribution is not possible or necessary because of the small spatial distribution of Chinook spawning areas make it biologically unreasonable and logistics of such management difficult. Although we appreciate these logistical difficulties, it appears from the EDT analyses that watersheds such as the Mashel and Ohop are second only to the Puget Sound nearshore and estuary in importance for diversity.

Key Issues to Improve Certainty:

- Revise Plan to 1) incorporate new goals and strategies developed from analysis using AHA and other models with documentation of the assumptions and 2) document the assumptions that support conclusions about spatial structure and diversity.
- Incorporate sensitivity analyses into the results

How well supported is the recovery hypotheses with watershed specific data? (Watershed Data Quality)
Support for the recovery hypothesis with watershed specific data is low. The harvest objective (a fixed escapement) is based on EDT only, and not supported with empirical data. If appropriate data were available, the hypothesis for the role of harvest in recovery could be strengthened by presenting independent analyses (e.g. spawner-recruit curves, density dependence relationship, spatial distribution information) that would support

EDT analyses. This information should improve as marking and sampling of fish continues.

Key Issues to Improve Certainty:

- Collect watershed specific data to test harvest recovery hypothesis.

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

Yes. The revised harvest management strategy, as indicated in the memorandum from the Nisqually Tribe, includes control of hatchery-origin spawners, reductions in harvest rates, and revised escapement goals as habitat productivity and capacity increase. These strategies are generally consistent with the recovery hypothesis. Many important details of the strategy, including how and whether it can be successfully implemented, remain to be worked out. In addition, although the co-managers have concluded that managing for differences in diversity and spatial distribution is not necessary because of small spatial distribution of Chinook spawning areas makes it biologically unreasonable and logistics of such management are difficult, the TRT remains concerned that the harvest management strategy does not address these VSP parameters.

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

No. The Nisqually Plan has a good adaptive management framework, which should help preserve options for recovery, although it is lacking implementation details. Uncertainty in any of the harvest, hatchery, or habitat results was not incorporated into the analyses. In addition, under the logic which the TRT used for evaluating this question, all VSP characteristics need to be addressed. The harvest strategy in the Plan assumes that management for diversity cannot be done and is relatively unimportant compared to other VSP characteristics. This assumption needs to be supported and tested. Although the proposed strategy may be consistent with current management not to jeopardize the population given the status and history of the stock, the TRT concluded that diversity does need to be considered for the long term goal of recovering a locally adapted population throughout the basin. This is also suggested by the EDT analysis. We recommend that the planners approach managing diversity in harvest management as both short tem and long term objectives that may change priority over time and that can be incorporated and monitored in the adaptive management plan.

Key Issues to Improve Certainty:

- Address the uncertainty about the importance of diversity in the short term by documenting empirical support for minimizing diversity in the harvest management in the short term and in the long term by collecting data to test the diversity hypotheses suggested by the EDT analysis.
- Develop a truly all-H integrated strategy in the Nisqually plan.

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

No. The proposed actions may be consistent with the proposed strategy and some of short-term objectives, but we could not really evaluate this. Adequate details of the actions needed for us to evaluate this question were not described in the Plan and or the proposed revisions.

Key Issues to Improve Certainty:

- Address the uncertainty by fitting a production curve to data on recruits per natural origin spawner to test the appropriateness of the escapement goal developed form the EDT analysis.

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

Support for the recovery actions is moderate. There is good empirical evidence that harvest management can achieve a specified escapement goal, assuming that sufficient abundance is available to the fishery being managed for the goal.

II. 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

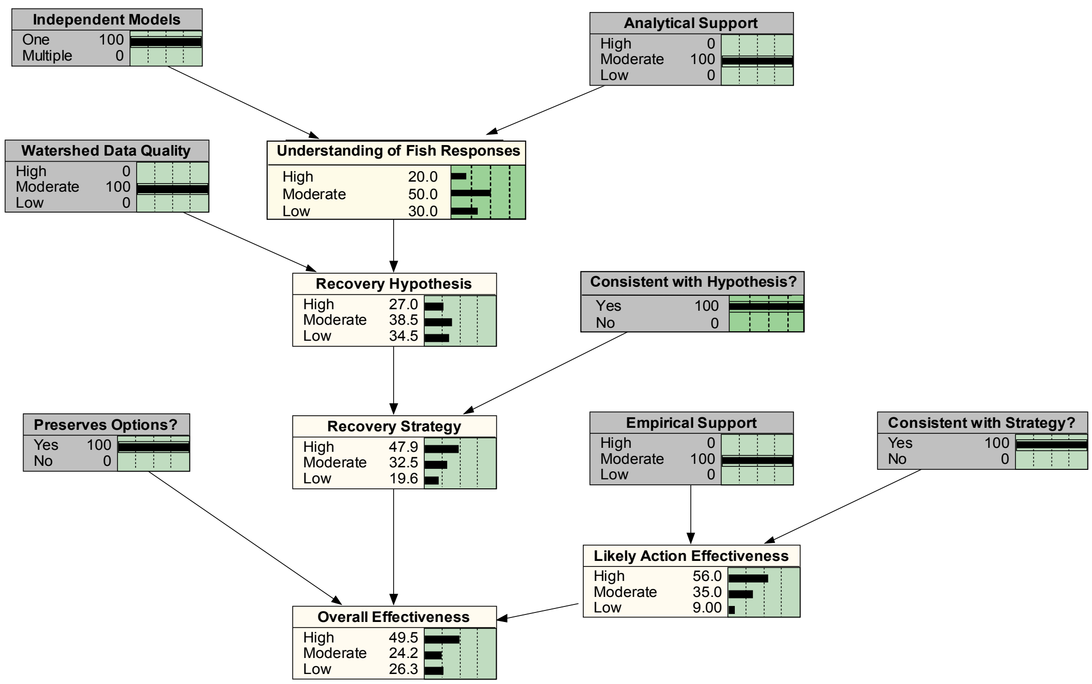

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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*.

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.

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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, landuse, 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)
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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

South Sound plan
May 2005 Technical gap analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the South Sound recovery plan submitted to the Shared Strategy in April 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information

from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the South Sound plan provides a good guidance framework with maps identifying priority protection and restoration locations and good, scientific bases for their priorities.
A major source of uncertainty in the plan's outcome is that there is no consideration of how hatchery fish use the South Sound habitats and affect their strategy to recover Chinook.
Furthermore, conducting the next step of identifying specific actions and who will implement them will increase the plan's certainty.

Habitat strategy

Key technical gaps

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

- Further develop explicit conceptual life stage specific linkages relating habitat conditions to responses in population viability characteristics, better document the data used and the conceptual model as it becomes available.
- Further develop a detailed and specific habitat recovery strategy tiered down from more explicit hypotheses on conceptual linkages relating habitat conditions to salmon viability via life stage specific potential responses.
- Develop an adaptive management plan that integrates the habitat, hatchery and harvest management strategies.

Based on our analysis, developing and implementing the key items above would increase the likelihood of a greater level of certainty for this plan.

Did the analysis use one or multiple independent models to understand potential fish responses to actions? What is the nature of the analytical support for the model linking salmon population status to changes in habitat-forming processes and marine habitat conditions?

A conceptual model was used for the South Puget Sound to evaluate the potential responses of Chinook populations to changes in nearshore and freshwater habitat conditions. The South Sound plan provides documentation for their qualitative model linking hypotheses for what factors are impaired through proposed mechanistic links to VSP in Chapter 4. Documentation of the qualitative model is provided. Also general information on nearshore processes and some specific information on habitat conditions were provided to support the approach taken. The certainty in the analytical model used to link changes in habitat conditions and processes to fish population response in the South Sound plan is low/moderate.

Ways to improve certainty in plan outcomes:

- Include hypothesized effects of habitat conditions on food web structure and function (e.g., competition, predation, non-indigenous species); and in turn, the hypothesized effects of changes in food web elements on the likelihood of salmon recovery through VSP.
- Include hypothesized interactions among the H's in their effects on the South Sound environment and salmon populations.

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?

The stated hypothesis in the draft South Sound recovery plan is that nearshore and freshwater habitat conditions and processes (physical and biological) are limiting recovery of the populations using south Puget Sound, and if a number of these habitat factors are corrected, the Chinook using South Puget Sound waters will recover. Support for these hypotheses is low. There is a good discussion of nearshore processes and how they function (especially for water quality). There is little watershed-specific data to validate the nearshore and freshwater habitat factors estimated to be limiting recovery of the Chinook populations using south Puget Sound. The plan includes local habitat assessments for each region, and linked the changes in habitat conditions to hypothesized changes in VSP. However, the plan does not link the effects of impaired processes to habitat, and to VSP.

Ways to improve certainty in plan outcomes:

- Given the alterations in nearshore habitat, an estimate of the capacity of these habitats to support both wild and hatchery salmonids (Chinook and other species) would increase the certainty in strategies. Such an estimate can provide the basis for analyzing the effects of other H activities on VSP.
- Include support for an hypothesis for how disruption to the food web—e.g., competitors, predators, forage fish, non-indigenous species—could affect VSP. It is a strength of the plan that forage fish spawning beaches are included as a key habitat type used in prioritizing protection and restoration actions in Ch. 5. The rationale for this inclusion should be included through hypothesized food web effects.
- Freshwater tributaries also are included in their prioritization scheme in Ch. 5. Include the hypothesized mechanistic links among habitat-forming processes and land-use attributes; and how they affect freshwater and nearshore habitat quality or quantity in the hypotheses and strategy. Monitor and study these linkages so that mechanistic links among those can be better understood, protected and restored.
- Document assumptions made about the VSP status of Chinook using south Puget Sound waters, the data used and the conceptual model.
- Continue to coordinate and collect data on juvenile use of and survival in different habitat types.
- Monitor natural-origin and hatchery-origin Chinook use at different life stages throughout the south Puget Sound.

Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery?

The habitat recovery strategy in the draft South Puget Sound recovery plan is not completely consistent with the hypotheses for what population status and habitat, harvest and hatchery problems are limiting recovery.

- The strategy is to improve condition of degraded nearshore habitat areas and protect natural shorelines.
- The habitat hypotheses are specific and employ an ecological process-based approach, which is a very important base to start from to help increase the certainty that management actions will have sustainable results. The hypothesized relationships between stressors and VSP characteristics are a good start.
- Hypotheses specific to VSP characteristics or ESU persistence (in Chapter 4 tables) can be used to conceptually relate recovery actions to more explicitly defined habitat recovery strategies for protection and restoration that, in turn related to expected responses in VSP.

- The habitat strategy describes priority protection and restoration actions in Chapter 5 maps for each sub-region.

Ways to improve certainty in plan outcomes:

- Clearly state the hypotheses for what freshwater and nearshore habitat factors are most important in limiting the status of populations using south Puget Sound.
- Provide more detail and justification in the habitat strategy for the sequence in which specific areas will be protected or restored.
- Provide a description for how the habitat recovery strategy is consistent with the strategies and objectives for hatchery and harvest management for the south Puget Sound Chinook stocks.
- Include in the strategy ways to address the role of food web disruption in limiting salmon recovery.
- Develop more explicit qualitative linkages between each of the specific protection and restoration action plans for nearshore or shoreline areas and the hypothesized VSP responses.

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

The existing habitat recovery strategy does not state how it will preserve options for implementation of the overall recovery strategy. Preserving options requires an adaptive management plan to respond to changes and uncertainty as they occur.

Ways to improve certainty in plan outcomes:

- Include an adaptive management decision framework in the plan that highlights where information from monitoring and evaluation of habitat projects and fish population responses will affect decisions about the overall recovery strategy.
- Use information from monitoring over time to adjust the integrated, all-H recovery strategy as needed.

How well have the habitat recovery actions been shown to work?

There is moderate empirical support for the habitat recovery actions identified in the south Puget Sound recovery plan. The tables in Chapter 6 that identify the tool boxes available, potential parties that have that authority, and needed next steps will be useful for implementing the protection and restoration needed in priority areas identified in Ch. 5.

- The experience of many practitioners suggests that nearshore protection and restoration actions may be successful, although there are conflicting results and much uncertainty. The goal of protecting existing habitat is a good primary step. Fee-simple purchases and conservation easements along with public education are listed as the centerpiece for habitat protection strategies. Given the experience of the plan developers, how successful do we expect this strategy to be? If this is the primary strategy, what is the certainty that remaining habitat will not be lost? How long will it take to protect the remaining habitat under this strategy?

Ways to improve certainty in plan outcomes:

- Be more specific on what actions are envisioned under each general protection measure. Also, indicate which threats are not addressed with existing authorities.
- Design and implement a comprehensive monitoring and evaluation program that can track the integrated, cumulative effects of habitat protection and recovery actions over time.
- Systematically analyze the potential cumulative effects of protection measures. Summarize existing modeled or empirical support for the effectiveness of habitat protection and restoration actions identified in the plan. Areas that are especially uncertain are 1) the effectiveness of shoreline regulatory protection programs, 2) validation that habitat actions to rehabilitate or enhance nearshore habitats increase the capacity of the nearshore to support chinook and chum salmon life stages.

Specifically,

- o Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
- o Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
- o Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.

Are the habitat recovery actions consistent with the recovery strategy?

The actions described in the plan are very general, so it is difficult to evaluate whether a clear and logical relationship exists between the "all-H" recovery strategy and the proposed habitat recovery actions.

Ways to improve certainty in plan outcomes

- Provide more specific definitions of protection and restoration actions.
- Focus the recovery actions through a more defined habitat recovery strategy. Particularly emphasize the relationships among restoration actions and protection actions.
- Develop better empirical and analytical support for the above relationships between protection and restoration actions and hypotheses specific to VSP characteristics.

South Sound Hatchery Management Strategy

The South Sound nearshore region is used by wild and hatchery Chinook salmon from multiple independent populations and hatchery fish released from hatcheries on the small, independent tributaries or bays of the Puget Sound in this region that do not have independent, spawning populations. No comprehensive hatchery strategy was included in the South Sound Plan. The TRT reviewed individual hatchery strategies for the Nisqually River and Puyallup and White rivers, which contain the three independent populations most closely associated with this region. The other programs in this region by their locations have assumed a strategy of isolating hatchery fish from wild population to limit impacts. These programs were reviewed by the Hatchery Scientific Review Group (HSRG) but the HSRG recommendations were based on the current objectives for the hatchery stocks and did not consider their effects on ESU recovery. The omission of a comprehensive hatchery strategy from the plan adds uncertainty in the overall ESU recovery strategy that could be addressed with the following actions:

The most important ways to improve the certainty of effective hatchery strategies in this plan are to:

- Evaluate the effects of current hatchery management activities on capacity of the nearshore environment for wild Chinook (hatchery-wild interactions)
- Evaluate the potential straying of hatchery fish from this region into independent populations
- Develop a comprehensive monitoring and adaptive management plan.

South Sound Harvest Management Strategy

This plan, appropriately, does not include a harvest management strategy because harvest is addressed in the watershed plans for the areas where the where the populations spawn. Chinook populations that contribute the most to the habitats addressed in the South Sound plan are Nisqually and Puyallup/White.

II. 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.

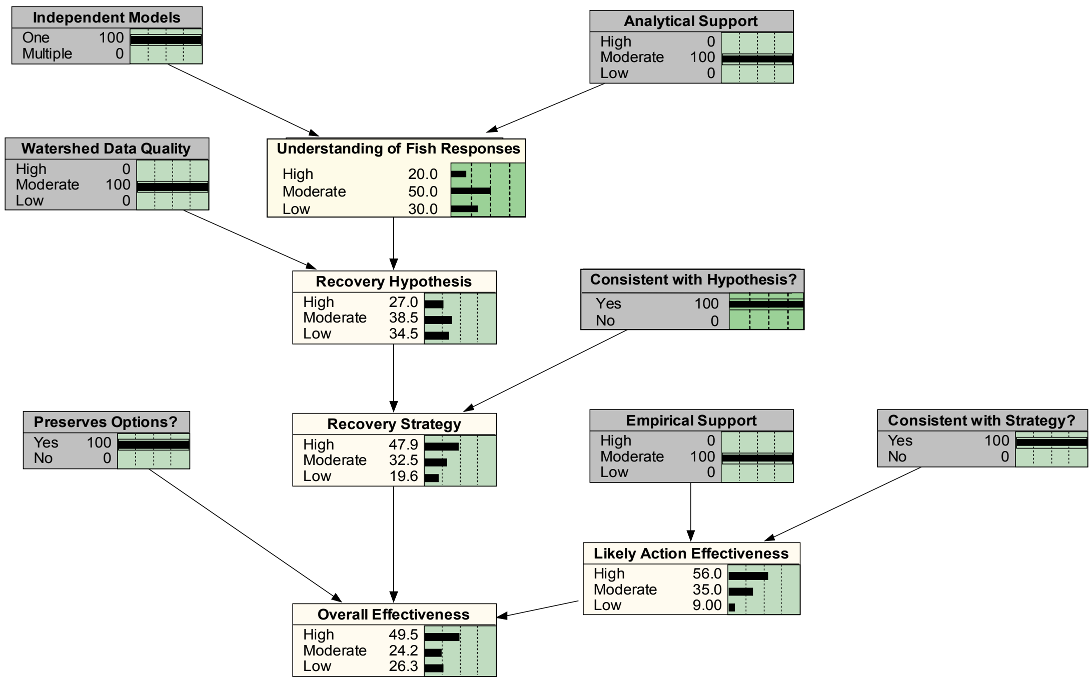

Figure 2. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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.

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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

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Hood Canal Plan: mid-Hood Canal Chinook Salmon Population
May 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the 2005 mid-Hood Canal Chinook Recovery Plan. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
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plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the mid-Hood Canal Plan is a good start for recovery of the mid-Hood Canal Chinook population. The plan treats the 3 mid-Hood Canal streams (i.e., the Duckabush, Hamma Hamma and Dosewallips rivers) as separate populations, and the TRT considers these to be a single historical population of chinook salmon. The separate recovery strategies for the habitat portions of these 3 streams is potentially consistent with recovering the single population that occurred there—but until the rationale for this assumption is clearly stated, the certainty of the plan's outcomes will remain uncertain. The plan does not include a submittal for Skokomish watershed, so integration among the H's and how the mid-Hood Canal and Skokomish populations help to achieve the ESU viability criteria for the Hood Canal region are highly uncertain.

- Provide a recovery plan for the Skokomish watershed and how the recovery strategy in the Skokomish preserves options for habitat and salmon recovery.
- Discuss the implications of treating the mid-Hood Canal streams as 3 separate populations—what are the consequences for the overall population status as identified by the TRT (e.g., how are spatial structure and diversity goals for the population likely to be achieved by having three separate streams restored)?

- Assess the ecological effects of hatchery and wild salmon interactions on VSP, including Chinook and other salmonid hatchery species in Hood Canal.
- Integrate the strategies to protect and restore land uses, processes, freshwater habitat conditions and the nearshore habitat quality and quantity.
- Integrate the H-strategies so that habitat restoration and protection actions are consistent with hatchery and harvest management strategies.
- Explicitly include food web effects in the Hood Canal nearshore habitats in the recovery strategies.
- Describe how the harvest objectives and recovery goals will be made consistent.
- Develop a comprehensive adaptive management and monitoring plan.
- Develop a comprehensive adaptive management and monitoring plan.

Habitat Strategy - Skokomish

No recovery plan for Chinook in the Skokomish River Basin was provided for technical review.

Key Issues to Improve Certainty

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

- Present short- and long-term recovery goals for the Chinook population(s) in the Skokomish River.
- Present hypotheses for which of the 4 VSP parameters are most limiting the recovery of the Chinook population(s) in the Skokomish.
- Present hypotheses for which habitat-forming processes or conditions, if protected or restored, have the greatest potential to recover the population(s).
- Provide a description of a habitat recovery strategy that will address the hypothesized problems with population status and habitat factors.
- Provide a description for how the habitat recovery strategy is consistent with the strategies for hatchery and harvest management for Hood Canal salmon.
- Develop an adaptive management plan that integrates the habitat, hatchery and harvest management strategies.

Based on our analysis, developing and implementing the key items above would increase the certainty for this plan.

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

- No model was presented for the Skokomish chinook population(s) to describe the potential responses of the population(s) to changes in habitat conditions.

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)?

- No hypotheses for VSP attributes or habitat factors limiting recovery of the Skokomish Chinook population(s) were provided.

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)

- No hypotheses for VSP attributes or habitat factors limiting recovery of the Skokomish Chinook population(s) were provided.

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

- No habitat recovery strategy was presented for the Skokomish Chinook population(s).

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

- No habitat recovery strategy was presented for the Skokomish Chinook population(s). There was no description of an adaptive management plan for the Skokomish Chinook population(s).

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

- We cannot determine whether a clear and logical relationship exists between the "all-H" recovery strategy and the proposed habitat recovery actions, since no strategy was presented.

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

- Since no habitat recovery strategy for the Skokomish Chinook population(s) was presented, we cannot evaluate whether actions are consistent with the strategy.

Habitat Strategy – Mid-Hood Canal

Key Issues to Improve Certainty

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

- Present hypotheses for which of the 4 VSP parameters are most limiting the recovery of the Chinook population in mid-Hood Canal.
- Present hypotheses for which habitat-forming processes or conditions, if protected or restored, have the greatest potential to recover the population.
- Provide a description of a habitat recovery strategy that will address the hypothesized problems with population status and habitat factors.
- Provide a description for how the habitat recovery strategy is consistent with the strategies for hatchery and harvest management for Hood Canal salmon.
- Develop an adaptive management plan that integrates the habitat, hatchery and harvest management strategies.

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

The Mid-Hood Canal Chinook plan uses a qualitative model to describe habitat conditions and processes in the watersheds. Preliminary results from the EDT model were presented for the Mid-Hood Canal chinook population to describe the potential responses of the population to changes in habitat conditions.

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)?

There is moderate analytical support for the hypotheses for VSP attributes and habitat factors limiting recovery of the Mid-Hood Canal Chinook population.

The qualitative model presented in the plan provides a good discussion of processes and habitat conditions within the 3 mid-Hood Canal streams (although processes and habitat conditions are not linked). Documentation for the EDT model is poor—what assumptions were made for this application? No sensitivity analyses are provided, and there is no discussion of empirical support (i.e., calibration) for the quantitative model.

Ways to improve certainty in plan outcomes:

- Provide better 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, habitat conditions, and all four VSP characteristics relevant to the recovery planning would also strengthen support.

- Further develop life stage specific linkages relating ecological processes, land use, and habitat conditions to responses in population viability characteristics, and to potential responses of the population.
- Include information about environmental conditions in the nearshore Hood Canal in assumptions and hypotheses about potential VSP responses to recovery strategies.

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)

Watershed Data Quality is Low. Habitat factors limiting recovery of the Mid-Hood Canal Chinook population are discussed for both processes and conditions (although their potential linkages are not). There are no hypotheses presented for population- or stage-specific key factors limiting recovery.

Ways to improve certainty in plan outcomes:

- Provide clear statements of the life stage specific factors limiting overall population recovery; the likely H factors contributing to this are lacking—i.e., where are the bottlenecks for each population?
- Develop a more explicit and quantitative life stage model(s) with watershed specific data that relates the interactions among land use, habitat forming processes, habitat conditions in freshwater and nearshore to the population response.

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

No overall habitat recovery strategy was presented for the Mid-Hood Canal Chinook population. There is no link provided between the hypotheses for VSP limitations and the habitat actions that are suggested (from HCCC). The basis for the proximity (1 mile) rule for prioritizing actions is not clear, and it is not consistent with other technical conclusions. There is a good discussion of the predicted fish population results as predicted by EDT, but specific uncertainties remain:

- Time lags for response—25 years is probably not realistic. If they use NRC continuum from rehabilitation, restoration, etc from the Summer Chum plan—could make a stronger argument for how long to expect habitat and population response.
- It is not clear why the in-channel projects ranking is so high.

There also is no H-integration strategy.

Ways to improve certainty:

- Specify habitat goals in freshwater and nearshore to meet the VSP targets;
- Provide rationale for the questions above about time lags and in-channel project rankings.

- Link the harvest and hatchery management programs for this population and evaluate their assumptions and implications for the habitat strategy. Adjust the habitat strategy if necessary and provide the rationale;
- Link the all-H strategy in the mid-Hood Canal streams to the recovery strategy for the Skokomish population.

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

There was no description of an adaptive management plan for the Mid-Hood Canal Chinook population(s). Preserving options requires an adaptive management plan that more comprehensively addresses all habitat factors and associated protection and restoration actions for the watershed and that provides a means to respond to changes and uncertainty as they occur.

Ways to improve certainty in plan outcomes:

- Develop a more comprehensive habitat recovery strategy that explicitly relates the interactions among land use, habitat forming processes, habitat conditions in freshwater and nearshore to population VSP responses.
- Develop and implement an adaptive management plan including more detailed qualitative and quantitative interactions among a comprehensive list of land use, habitat forming processes, habitat conditions and population responses for specific protection and restoration action plans.

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

Yes. Given the habitat strategy presented, the proposed protection and restoration actions are generally consistent with the strategy.

Ways to improve certainty in plan outcomes:

- More specific definitions of protection and restoration strategies are needed to better evaluate consistency.
- Develop better empirical and analytical support for the above relationships between protection and restoration actions and hypotheses specific to VSP characteristics or ESU persistence.

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

Support for the proposed actions is moderate.

Linkages between actions aimed at improving habitat processes or conditions and VSP characteristics, and the potential population responses from these actions would strengthen the overall analytical support for that aspect of the recovery plan. For other protection and restoration actions in the watershed, our experience suggests that the protection and restoration actions proposed have some utility; however, there are some conflicting results and uncertainties that remain. Areas that are especially uncertain are 1) the effectiveness of shoreline regulatory protection programs, 2) the cumulative effects from the various conservation efforts of other agencies; and 3) validation that habitat actions to restore, rehabilitate, or enhance floodplain, estuary, and nearshore habitats are coordinated with protection efforts intended to support chinook life stages.

Ways to improve certainty in plan outcomes:

- Use available data and document assumptions for floodplain, estuary, and nearshore habitat protection and restoration actions by type to strengthen the empirical support.
- Systematically analyze the potential cumulative effects of protection measures. Specifically,
    - Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
- Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.

Hood Canal Hatchery Strategy

Hood Canal contains two historical independent populations. No recovery plan for Chinook in the Skokomish River Basin was available for technical review. A plan was available for the mid-Hood Canal. In the absence of integrated planning across the different populations and habitat, hatcheries, and harvest management sectors, the TRT examined the actions and strategies outlined in the co-managers resource management plans for hatcheries.

Key Ways to Improve Certainty

- Develop a recovery plan for the Skokomish River Chinook salmon that integrates strategies and actions for habitat, harvest, and hatcheries to meet the recovery goals.
- Refine the recovery hypothesis for the mid-Hood Canal Chinook salmon population, including the strategy for the Hamma Hamma supplementation program.
- Integrate the recovery strategy for the mid-Hood Canal Chinook salmon population across all management sectors (habitat, harvest, and hatcheries) to achieve VSP characteristics of the population.
- Develop and implement an adaptive management plan that includes monitoring and evaluation programs for the effects of hatchery actions.

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 (BRAP) cited in co-managers' resource management plan) to understand the potential effects of hatchery actions on populations. The model addressed all VSP criteria. Documentation is 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 assessments for the Skokomish River and mid-Hood Canal populations. Although these assessments were done, an explicit recovery hypothesis for the mid-Hood Canal population was not well defined. Based on the recovery plan, it was unclear to the TRT what factors are hypothesized to be limiting viability of this population and how that might be relevant for identifying a recovery hatchery strategy.

Since the original assessments using the BRAP, addition tools and assessments have been developed that could refine understanding, including the Hatchery Scientific Review Group's All 'H' Hatchery Analyzer (AHA) model and quantitative models developed to evaluate domestication, effects of small population size, and competition and predation by WDFW and the NWIFC as part of the hatchery risk assessment modeling project (RAMP). In addition, the SHIRAZ population dynamic model could be adapted the model to include a quantitative analysis of hatchery effects. The EDT model, which has been parameterized for habitat conditions, could potentially also be used. Use of these or similar tools would allow planners to evaluate how their decisions might be affected by uncertainty in different management sector factors that drive recovery. Most of these models do not included ecological interactions, but studies are underway to examine potential ecological interactions in the estuary. Until such results are available, assessment of ecological affects is based on weak inference.

Key Ways to Improve Certainty:

- Use or refine existing models (above) to assess the genetic and ecological interactions of hatchery fish and wild fish and to refine hypotheses for the different hatchery strategies in Hood Canal and their role in recovery
- Use available data from Hood Canal and other watersheds to increase the analytical support and to document the assumptions of the hypotheses.
- Test 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 for was low. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. Few data are available from the mid-Hood Canal population to support the recovery hypothesis. Most of the information appeared to be inferential or based on local knowledge.

Key Ways to Improve Certainty:

- Develop an explicit recovery hypothesis for the effects of hatcheries on recovery of the Hood Canal populations that considers the status and functioning of the habitat and uses the most recent available local data on abundance, contribution of hatchery fish to natural spawning, productivity, and spatial distribution.
- Use available data from other watersheds to increase the analytical support and to document the assumptions that would be part of that and begin collecting information on hatchery-wild interactions at different life stages.

Is the recovery strategy consistent with the recovery hypotheses for population status and key habitat factors limiting recovery? (Consistent with Hypothesis)

No. The proposed strategy is to use hatchery supplementation to restore natural spawning and recovery in conjunction with producing fish for harvest. The plan did not provide enough details to show how the interactions of different hatchery programs, their objectives, harvest, and available habitat were an integrated strategy for recovering a viable population. In particular, the hypothesis that the Hamma Hamma supplementation program is necessary for the population recovery and the choice of its size, given habitat capacity, productivity, and the relative sizes of the integrated harvest programs, needs better analytical support using available analyses (see above) and EDT model results.

Key Ways to Improve Certainty:

- Provide better rationale for the strategy in the Hamma Hamma supplementation program and how it relates to recovery of the mid-Hood Canal Chinook population.
- Provide more detail on how the recovery strategy integrates across all management sectors (habitat, harvest, and hatcheries) to achieve VSP characteristics of the population.

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

No. Many of the changes in hatchery management undertaken by the co-managers in recent years will help preserve and increase options for recovery. Preserving options also requires an adaptive management plan to respond to changes and uncertainty as they occur.

Ways to improve certainty in plan outcomes:

- Develop and implement an adaptive management program.

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

No. The operation of integrated harvest programs in Skokomish and mid-Hood are consistent with co-manager objectives given the current habitat, but for recovery planning this need to be integrated with habitat objectives for recovery of those populations. Many of the changes in hatchery management undertaken by the co-managers in recent years are consistent with the recovery strategy. Those hatchery management actions that are consistent include managing for population structure between Skokomish River and Mid-Hood Canal regions, use of local brood stock for a supplementation program, reductions in production, elimination of net pens, and delayed release of other hatchery species that could prey on listed populations. However, the hatchery management strategy in mid-Hood Canal does not appear completely consistent. It is not clear that the Hamma Hamma supplementation program is sized consistent with what the natural habitat can support. Using eggs or brood stock from George Adams Hatchery in the Hamma Hamma program does not appear consistent with allowing local adaptation to the mid-Hood Canal. Likewise, the effectiveness of the integrated harvest programs for allowing recovery remains unclear.

Key Ways to Improve Certainty:

- Following reevaluation of the strategies, as the existing hatchery management plans become consistent with the recovery goals of the plan, revise the actions to be consistent the strategies.

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 especially uncertain are 1) the actions to reduce competition or predation, if it occurs, 2) the actions to reduce straying of other stocks into the natural population, 3) actions to reduce domestication and loss of productivity in hatchery fish spawning in the wild, and 4) the size of the programs given the capacity of the habitat and ability to support natural spawners.

Hood Canal Harvest Strategy - *Skokomish*

NOTE: This evaluation is based on the Skokomish Management Unit profile, pages 172-177 of the *Comanagers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the plan submitted by the Hood Canal watershed group.

The harvest management portion of the recovery plan is based on the hypothesis that decreased exploitation rates are contributing to increased escapement levels and that a current escapement goal of 3,650 fish supports current habitat conditions; this includes both hatchery and in-stream spawners.

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

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

Was the analysis based on one or many models?

One – qualitative relating exploitation rates estimated from FRAM using the George Adams indicator stock with escapement estimates.

-

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

Low

- The model includes qualitative descriptions of the link between harvest management and abundance and productivity. The effects of harvest on diversity and spatial distribution are not addressed.
- Quantitative estimates of a rebuilding exploitation rate for the Skokomish Chinook population have not been developed. There is also no information presented on the breakout of escapement into natural-origin and hatchery-origin components.
- Integrated H-modeling, for example by including harvest and hatchery effects with an EDT assessment, 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 plan states that a spawner abundance of "50% of the current MSY estimate…represents a level necessary to ensure in-system diversity and spatial distribution (Magnuson-Stevens Act, National Standard for Overfishing Review Threshold)." Certainty could be increased by discussing the derivation of this guideline and the rationale for its application to the Skokomish Chinook population.
- Data are available for total escapements, but are not calculated for hatchery versus natural components; therefore, no estimations are made as to effect of harvest on the natural component.

Is the recovery strategy consistent with the recovery hypotheses? (Consistent with Hypothesis)
No

- The strategy places a limit on the exploitation rate in Southern US fisheries, 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 whether the natural component of the escapement is being protected or 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

- o Recent trends for the George Adams hatchery indicator stock for the Skokomish River suggest that the actions taken to limit incidental impacts in fisheries affecting Skokomish River Chinook result in reduced exploitation rates.

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.

Harvest Strategy – Mid-Hood Canal

NOTE: This evaluation is based on the Mid-Hood Canal Management Unit profile, pages 178-180 of the *Comanagers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the plan submitted by the Mid-Hood Canal watershed group.

The harvest management portion of the recovery plan is based on the hypothesis that the stocks comprising this population are all at low levels and cannot withstand much harvest. It is not stated how the harvest management will change to accommodate recovery objectives for the Mid-Hood Canal and Skokomish populations.

Ways to improve plan certainty:

- Develop exploitation rate guidelines based on productivity and abundance estimates of the Mid-Hood Canal Chinook population.
- Broaden the hypothesis to include the effects of harvest on diversity and spatial distribution.
- Broaden the strategy to also address diversity and spatial structure.
- Incorporate 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 / none

- There is no indicator stock to estimate exploitation rates, although George Adams is used as a surrogate.

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

- The model includes qualitative descriptions of the link between harvest management and abundance and productivity. The plan uses predicted distribution of habitat productivity from the EDT model to estimate the potential effects of harvest on spatial structure. The effects of harvest on diversity are not addressed.

Ways to improve certainty in plan outcomes:

- Develop quantitative estimates of a rebuilding exploitation rate for the Mid-Hood Canal Chinook population.
- Present information on the breakout of escapement into natural-origin and hatchery-origin components.

- Incorporate diversity and spatial structure in integrated H-modeling, for example by including harvest and hatchery effects with an EDT assessment, and make a quantitative assessment of the effects of harvest management.

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

Moderate

- There is no indicator stock for the Mid-Hood Canal population and it is not known if George Adams is an adequate indicator stock. The plan states that the terminal harvest rates for Mid-Hood Canal and Skokomish would be different due to location of fisheries within Hood Canal, but this has not been tested.
- There is no estimate of hatchery versus wild component of the natural spawners so that the effects of harvest on natural origin fish can be assessed.

Ways to improve certainty in plan outcomes:

- Indicate how it will be possible to assess the natural- and hatchery-origin components of natural escapement and how this will be applied to revised assessment for the harvest management model.

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

No

- The strategy places a limit on the exploitation rate in Southern US fisheries but not on the total exploitation rate.
- The strategy does not address the effect of harvest on the diversity and spatial structure VSP parameters.
- Lacking an analysis of the appropriate rebuilding exploitation rate for this population, it is not possible to determine whether the exploitation rate on this population, including fisheries both north and south of the US/Canada border, is sufficiently low that the population will be likely to respond positively to the hatchery and habitat actions in the plan.

Ways to improve certainty in plan outcomes:

- Expand the strategy to include the effects of harvest on diversity and spatial distribution.
- Develop a strategy for managing both southern U.S. and northern fisheries to allow recovery of these populations
- Incorporate results from analytical tools to document integration of habitat, harvest, and hatchery strategies

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

No

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

Ways to improve certainty in plan outcomes:

- Develop and implement an appropriate adaptive management plan.

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

- o Recent trends for the indicator stock for the Skokomish River suggest that the actions taken to limit incidental impacts in fisheries affecting Chinook from the Hood Canal region result in reduced exploitation rates.

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

- It is not clear from the information presented that spawning escapements have increased as exploitation rates were reduced. Therefore, it isn't clear that the proposed action (tight control of exploitation rates on mid Hood Canal Chinook south of the border; only broadly-based limits on Chinook interceptions north of the border) will provide sufficient, or any, overall control of exploitation rates to levels appropriate to allow rebuilding.

II. 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*.

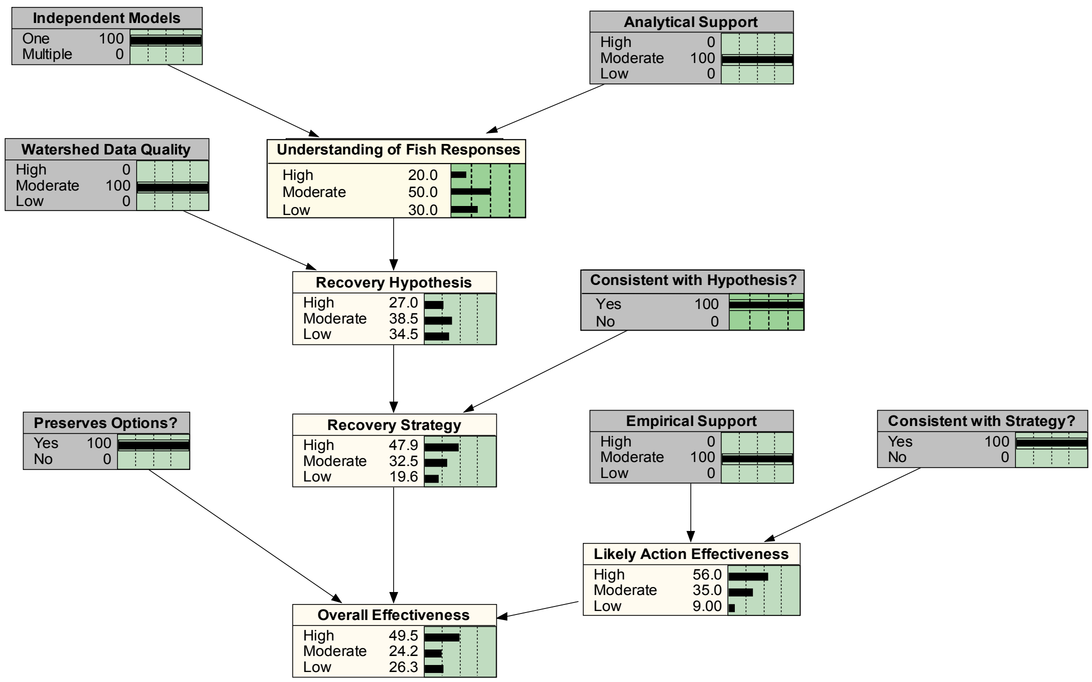

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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.

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Table 5. 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, landuse, 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 6. Attributes for different states of the quality of watershed data

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

Dungeness Plan
May 2005 Technical Gap Analysis
Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the 2005 Dungeness Recovery Plan. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the

plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the Dungeness Plan is an excellent start for describing a strategy and set of actions necessary to recover the Dungeness Chinook population. The Plan does a comprehensive job of organizing and summarizing the status of the population and what is known about the historical and current limiting factors and impacts on the population based on qualitative and quantitative assessments. The plan general strategy outlined in the plan is to continue to supplement the Chinook population with hatchery fish until the habitat protection and restoration has proceeded sufficiently so that a naturally self-sustaining population can be supported. The TRT supports such an approach, given the very low abundance of Chinook in the watershed under current conditions. The TRT liked the approach of using EDT to look at spatial variation in reach productivity and to use that information to focus restoration strategies. Nevertheless, the ability of the hatchery-origin chinook to locally adapt to the watershed is limited by habitat conditions in the watershed (therefore, there is a high domestication risk in the short term). This uncertainty in the strategy should put a priority on habitat restoration and protection actions in the integrated strategy, as the plan states.

The monitoring and adaptive management portion of the plan is improved, especially the revisions to the hatchery portion of the plan. The certainty in the plan's outcomes will be greater when the adaptive management plan describes how information on habitat-forming processes and ecosystem functioning is expected to proceed as recovery does. Furthermore, explicit prioritization of monitoring needs will greatly increase the certainty that monitoring will be funded and information critical to adapting the strategy will be available.

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. For example, as is the case for all plans that adopted co-manager targets for their recovery goals, the likelihood that the population will be able to achieve recovery targets is uncertain because it was assumed in the EDT analyses that the estuary was fully functioning in EDT.
- Provide a summary of any empirical support used to relate the flow management regime, land use, ecological processes, and habitat conditions, to all four VSP attributes 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 empirical data on the effectiveness of the protection actions described.
- Further develop an adaptive management plan for the habitat recovery strategy that more explicitly and quantitatively relates the interactions among the flow management regime, land use, habitat forming processes, habitat conditions to population responses.

Based on our analysis, developing and implementing the key items above would increase the current certainty of the plan outcomes.

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/high.

- Certainty could be increased to a higher level over the long-term by 1) better documenting in a more transparent manner what has been accomplished in defining these relationships to date, and 2) further developing the 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 to population responses relating to all 4 VSP parameters. The model does not account for the fundamental processes that control habitat structure. 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 characteristics 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 of sensitivity testing and how such results could increase plan certainty. Nor does the plan discuss empirical testing and validation of the models.
- Key gaps in hypotheses for habitat factors limiting recovery of the Dungeness population include: poor linkages between habitat restoration and predicted effects on diversity and spatial structure; and poor descriptions of how the HCP for instream flows are likely to affect the likelihood of recovery of the Dungeness population.

Ways to increase certainty in plan outcomes:
- Improve documentation of the data, assumptions, and models used as they relate to the existing VSP characteristics and potential responses of the population. In particular, clarify the hypothesized effects of habitat restoration projects on spatial structure and diversity (the current linkages either do not make sense—for example, for spatial structure, or have not used existing data—for example, the current diversity in return-timing);
- Provide the empirical support used to relate ecological processes, land use, flow management, and habitat conditions to all four VSP attributes. In particular, from the information provided, it is uncertain how the HCP for instream flows is consistent with a flow regime necessary for the Chinook population to recover, since the HCP flow standards are based on habitat recovery objectives and not directly on salmon recovery needs. The flow levels proposed in the current plan are not consistent with the IFIM study results, and it appears as if

side channel habitats are omitted from the analyses (*in p 2 responses to TRT comments*), which would make the estimates of sufficient flows overly optimistic;
- Conduct sensitivity analyses on the EDT model to test assumptions.
- 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 to confirm the applicability of models to the local habitat regime.

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.

- Multiple lines of evidence were presented to support the hypothesis. Habitat data are generally good; fish data--particularly life stage distributions--are weak. The available data could be more explicitly applied to the hypotheses and to potential VSP responses to increase the strength of the analytical support.

Ways to increase certainty in plan outcomes:
- Develop more explicit and quantitative life stage model(s) (using watershed specific data) relating the interactions among ecological processes, land use, flow management, habitat forming processes, habitat conditions to the potential population VSP responses.

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

Yes.

Ways to increase certainty in plan outcomes:
- 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 uncertainties as they occur. The monitoring and adaptive management plan is improved from the previous draft of the plan but could benefit from the following: describe how information on habitat-forming processes and ecosystem functioning will be collected as recovery proceeds, a prioritized list of monitoring needs (this may increase the chances that such monitoring will occur), and a decision-making system using the monitoring information.

Ways to increase certainty in plan outcomes:

- Further develop an adaptive management plan for the habitat recovery strategy that explicitly relates the interactions among land use, the proposed flow regime, habitat forming processes, habitat conditions and population VSP response.
- Develop a prioritized list of monitoring needs as a basis for formulating a specific monitoring plan.
- Implement an adaptive management plan including more explicit 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 actions proposed in the plan.

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

No. The description of the requirements for low flows in the plan is not consistent with the IFIM analyses.

Ways to increase certainty in plan outcomes:

- Develop stronger empirical and analytical support for the relationships among protection and restoration actions, the hypotheses and strategies, and specific VSP characteristics or ESU persistence.
- Provide a scientifically sound basis for the low flow requirements that are necessary for the population to achieve recovery targets.

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 can be successful, although there are conflicting results and many uncertainties.. These uncertainties arise from: 1) the effectiveness of shoreline regulatory protection programs; 2) assumptions that the habitat actions to restore, rehabilitate, or enhance floodplain, estuary, and whether nearshore habitats will support chinook life stages as predicted.

Ways to increase certainty in plan outcomes:

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

- 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.
- Systematically analyze the potential cumulative effects of protection measures. Specifically,
    - o Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    - o Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    - o Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
- Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.

Dungeness Hatchery Management Strategy

Key Ways to Improve Certainty

The ability of the hatchery supplementation program to promote local adaptation to the watershed is limited by habitat condition in the watershed. This may lead to risk of domestication in the short term. Limiting this risk puts a high priority on habitat restoration and protection actions in the integrated strategy, as the plan states.

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.

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 (BRAP) 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.

Since the original assessments using the BRAP, addition tools and assessments have been developed that could refine understanding, including the Hatchery Scientific Review Group's All 'H' Hatchery Analyzer (AHA) model and quantitative models developed to evaluate domestication, effects of small population size, and competition and predation by WDFW and the NWIFC as part of the hatchery risk assessment modeling project (RAMP). In addition, the SHIRAZ population dynamic model could be adapted the model to include a quantitative analysis of hatchery effects. The EDT model, which has been parameterized for habitat conditions, could potentially also be used. Use of these or similar tools would allow planners to evaluate how their decisions might be affected by uncertainty in different management sector factors that drive recovery. Most of these models do not included ecological interactions, but studies are underway to examine potential ecological interactions in the estuary. Until such results are available, assessment of ecological affects is based on weak inference.

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.

Key Ways to Improve Certainty:

- Efforts with AHA model are a good step; but develop and use treatments of ecological interactions or the spatial context of hatchery and habitat actions.
- Explicitly include considerations of the effects of interactions between hatchery and wild fish on the predicted outcomes of recovery strategies on wild Chinook.
- 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 planners have available and used local data to support the hypotheses that have been formulated. 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.

Key Ways to Improve Certainty:

- Continue to collect demographic, genetic, and ecological information and then use it 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 an important addition to the plan to increase its certainty. 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.

Key Ways to Improve Certainty:

- 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 the natural population; and 3) actions to reduce domestication and loss of productivity in hatchery fish spawning in the wild.

Dungeness Harvest Management 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. The harvest mgt approach is based on very low quality data, and also considers two populations in the Dungeness watershed, which is inconsistent with the TRT population structure. The implications of this for population recovery are unclear.

Ways to improve certainty in plan outcomes:

- 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 harvest management 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.
- Explicitly discussing the implications of the harvest management strategy based on the presumed two populations for the recovery prospects of the single population of Chinook in the TRT documents.

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)?

Moderate.

- 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 was used to help inform harvest management. In Addendum A, estimates of location-specific productivities can be used to adjust ER over time.
- 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)

Low

- 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.
- Lacking an analysis of the appropriate rebuilding exploitation rate for this population, it is not possible to determine whether the exploitation rate on this population, including fisheries both north and south of the US/Canada border, is sufficiently low that the population will be likely to respond positively to the hatchery and habitat actions in the plan.

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

- It is clear from the information presented that spawning escapements have not increased as exploitation rates were reduced. Therefore, it isn't clear that the proposed action (tight control of exploitation rates on Dungeness Chinook south of the border; only broadly-based limits on Chinook interceptions north of the border) will provide sufficient, or any, overall control of exploitation rates on Dungeness Chinook to levels appropriate to allow rebuilding.

II. 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*.

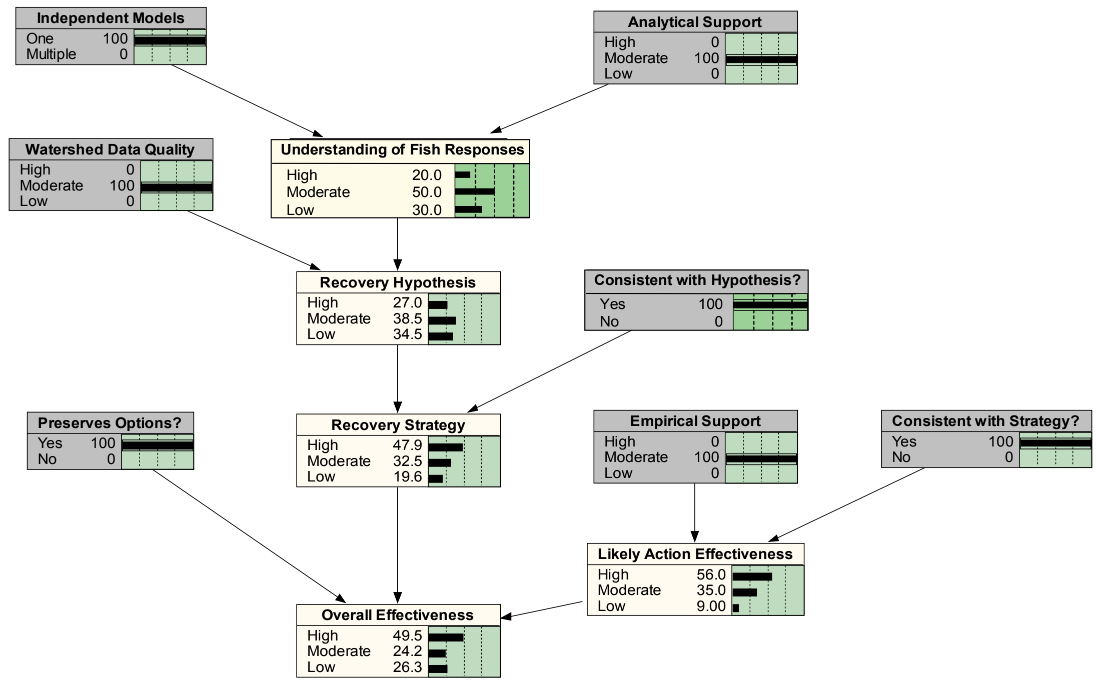

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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.

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Table 7. 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, landuse, 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)
Harvest 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

Elwha Plan: Elwha Chinook Salmon Population
May 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the 2005 Elwha Recovery Plan. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. SUMMARY OF CERTAINTY ANALYSIS

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall, the Elwha Plan is an excellent start for recovery of the Elwha Chinook populations. The scope of the plan is based on the assumption that the two dams on the Elwha River are the most important factors limiting recovery of the Elwha River Chinook populations. The recovery strategy thus consists of removing the two dams and conducting habitat restoration to help recover the Elwha watershed ecosystem. There also is a hatchery management strategy designed to maintain the population during dam removal effects and to help restore the population after access to the upper watershed is restored. The revisions to the monitoring and adaptive management plan are good—it is moving in the right direction. The Elwha system is exceptionally well suited to conducting experiments for the integrative effects of the H's. It is very important to expect surprises in this big restoration experiment, and thus the planners are wise to make sure the adaptive management and monitoring plan accounts for such surprises.
In particular, using habitat and process functioning information to help design hatchery outplantings, etc. for the hatchery supplementation program is a rare opportunity that the monitoring plan should continue to describe and track.

The key technical gaps remaining in the Elwha plan are:

1. The treatment of ecosystem recovery in the monitoring and adaptive management plan is still very brief and incomplete. The regional research potential is important here—this question should be one of the higher priorities for the regional monitoring and adaptive management plan.
2. The assumed productivity from habitat in the Elwha River Basin to support harvest is very uncertain
3. The land use planning in the lower floodplain outside the boundaries of the park and the potential effects of the estuary restoration plan on the likelihood of Chinook recovery in the watershed are uncertain.
4. The effects of protection and restoration measures on VSP are not described.

Habitat Strategy

Key Issues to Improve Certainty

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

- Better document the data, assumptions, and models used in the plan to relate habitat conditions to the VSP characteristics and potential responses of the population.
- Provide the available empirical support used to relate ecological processes, habitat conditions, and all four VSP attributes relevant to the recovery planning to strengthen the analytical support for the recovery plan.
- Further integrate the habitat strategy with hatchery and harvest management strategies in the planning area
- Document assumptions for floodplain, estuary, and nearshore habitats protection and restoration actions by type to increase the strength of the empirical support for the actions. Addressing the *Analytical Support* key near-term action item will address this action in regard to the Elwha Project.
- Develop a more comprehensive habitat recovery strategy that explicitly relates the interactions among land use, habitat forming processes, habitat conditions and population VSP responses.
- Provide a more detailed adaptive management plan consistent with the revised habitat recovery strategy.

Based on our analysis, developing and implementing the key items above would increase the certainty of the plan's outcomes.

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

The Elwha chapter utilizes multiple models to assess the affects of dam removal on fish status and potential VSP responses.

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.

- A well developed *qualitative* model was used to relate ecological processes, habitat conditions, and all four VSP characteristics. Quantitative models were applied to develop understandings of Abundance and Productivity (R:S and capacity estimates), flow and sediment transport processes and sediment effects from dam removal. It is not clear to what extent, if any, the effects of the restoration projects have been modeled for the estuary. Lower river floodplain land use management assumptions and diversity and spatial structure characteristics of the population are also not clear. A summary of the key assumptions for habitat and VSP in the plan itself would make the supporting evidence more readily available and transparent to various users. Similarly, a synthesis of the empirical support would strengthen the analytical support. Reviewers found no empirical support for productivity or for other VSP hypotheses. While there is some empirical support for the sediment transport and flow process hypotheses, linking these processes to VSP characteristics would strengthen the overall analytical support for the recovery plan. There is no explicit discussion provided of sensitivity testing, though some exists in the associated records. The plan also does not discuss empirical testing and validation of the models. Finally, habitat factors beyond the scope of the restoration project have clearly not been assessed.

Ways to improve certainty in plan outcomes:

- Provide better documentation of the data, assumptions, and models used as they relate to the VSP characteristics and potential responses of the population;
- Provide the empirical support used to relate ecological processes to land use and habitat conditions, and to all VSP characteristics.
- Further develop explicit life stage specific linkages relating ecological processes, land use, and habitat conditions to responses in population viability characteristics, and potential responses of the population.

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.

Ways to improve certainty in plan outcomes:

- The support for the hypotheses could be strengthened by linking available data, the strategy, and potential VSP response.
- Develop more explicit and quantitative life stage specific model(s) with watershed specific data relating the interactions among land use, habitat forming processes, habitat conditions and population response.

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

Yes.

- The strategy is to restore ecological processes, habitat and access to habitat by removing the dams.

Ways to improve certainty in plan outcomes:

- 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 that more comprehensively addresses all habitat factors and associated protection and restoration actions for the watershed and that provides a means to respond to changes and uncertainty as they occur.
- Hypotheses beyond the scope of the restoration project and specific to VSP characteristics or ESU persistence will be needed in the long-term to complete the habitat recovery strategy and actions plan.

Ways to improve certainty in plan outcomes:

- Develop a more comprehensive habitat recovery strategy explicitly relating the interactions among land use, habitat forming processes, habitat conditions and population VSP responses.
- Develop and implement an adaptive management plan including more explicit detailed qualitative and quantitative interactions among a comprehensive list of land use, habitat forming processes, habitat conditions and population responses for specific protection and restoration action plans.

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

Yes.

Ways to improve certainty in plan outcomes:

- Provide more specific definitions of protection and restoration strategies are needed to better evaluate consistency; many of the actions listed could be applied as detailed strategy statements.
- Develop better empirical and analytical support for the above relationships between protection and restoration actions and hypotheses specific to VSP characteristics or ESU persistence.

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

Support for the proposed actions is moderate.

- Dam removal has been both theoretically and practically shown to exert strong influences over sediment and hydrologic processes. Thus, there is some empirical support for the sediment transport and flow process hypotheses for the Elwha Project. However, the linkages to VSP characteristics and population responses to this action are less clear. Providing hypotheses for these relationships would strengthen the overall analytical support for that aspect of the recovery plan.
- For other protection and restoration actions in the watershed, our experience suggests that their effectiveness is uncertain and outcomes are somewhat inconclusive. Areas that are especially uncertain are 1) the effectiveness of shoreline and other regulatory protection programs, 2) support for the proposed regulatory actions to act in concert with actions to restore, rehabilitate, or enhance floodplain, estuary, and nearshore habitats.

Ways to improve certainty in plan outcomes:

- Use available data and document assumptions for floodplain, estuary, and nearshore habitat protection and restoration actions by type to strengthen the empirical support.
- Systematically analyze the potential cumulative effects of protection measures. Specifically,
    - Identify what groups have the authorities to address each threat through regulation. Assess whether there are any gaps in which threats are identified and there is no mechanism to address them. If so, identify approaches to filling the gaps.
    - Estimate the degree to which these regulations (protection measures) are being implemented across the landscape. Are there any gaps in implementation, variances, etc.? If so, identify approaches to filling the gaps.
    - Evaluate the effect of the protection measures on habitat and VSP. Are there gaps in the predicted and observed effect on habitat or VSP? If so, identify approaches to filling the gaps.
- Increase consistency between pre-existing agreements (e.g. Federal consultations—HCPs, Sect. 7, others) and content of recovery plans.

Elwha Hatchery Management Strategy

Key Ways 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 plan.

Based on our analysis, of the draft plans we examined, 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 the adaptive management programs, the certainty for biological effectiveness for their strategies would greatly increase.

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 (BRAP) cited in co-managers' resource management plan) to understand the potential affects of the current hatchery actions on wild populations. The model addressed all VSP criteria. Documentation is 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 Elwha River population. The TRT is unaware of a similar systematic analysis for the proposed actions to maintain populations, fisheries, and reintroduce salmon to the upper watershed after the dams are removed.

Key Ways to Improve Certainty:

- Develop and use models that will allow managers to understand how different factors affect the certainty of the results from hatchery management decisions (e.g. through a sensitivity analysis). This is especially important for the reintroduction programs and deciding the risks and benefits of different strategies (e.g. natural colonization, adult supplementation, juvenile supplementation) to accomplish it.

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

Support for the recovery hypotheses using watershed specific data for was moderate. This question asks if the watershed planners have available and used local data to support the hypotheses that have been formulated. The current recovery hypotheses for hatcheries in the Elwha River watershed is that hatcheries can provide a demographic buffer until habitat recovers and the salmon have access to habitat above the dams. The second recovery hypothesis is that hatcheries can be used to reintroduce viable populations of salmon to the upper watershed. Demographic data from historical operation of the hatchery indicate that the programs are capable of maintaining abundance. Hypotheses about the potential genetic and ecological affects on productivity, spatial structure, and diversity and the certainty of successful reintroduction are more inferential.

Key Ways to Improve Certainty:

- Use available data from other watersheds to increase the analytical support and to document the assumptions.

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

Yes. Overall, using the hatchery to maintain abundance and as a refuge while the dams are being removed to allow access is consistent with the recovery hypothesis. Likewise using hatcheries to buffer populations against catastrophic losses during the removal of the dams and to reintroduce salmon to new habitat are consistent with the recovery hypothesis. The TRT had a number of questions about how recovery planning integrates actions in the different H sectors, such as harvest, that planners should consider.

Key Ways to Improve Certainty:

- Although there will be no directed fisheries during the removal of the dams, planners should make more clear how non-directed fisheries and international fisheries were factored into the recovery strategy.
- Document information and assumptions for how the level of hatchery production and release strategies after the dams are removed will be consistent with what is known about the capacity of the habitat.

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

No. Many of the actions taken to implement the recovery strategy are clearly intended to preserve options. Preserving options also requires an adaptive management plan to respond to changes and uncertainty as they occur. Hatchery and genetic management plans (HGMPs) contain a brief description of current monitoring and evaluation, but we would assume that this would change and be expanded during the reintroduction program. There is little detail in the draft plan on this. Reintroducing viable populations in this river will be a major undertaking, with a great deal of uncertainty. This will require significant attention to monitoring and adaptive management to be able to make mid-course corrections in management actions. Although the TRT is aware that watershed planners and co-managers have given considerable thought to many aspects of adaptive management, these are not well described in the recovery plan.

Key Ways to Improve Certainty:

- Further develop and implement an adaptive management program.

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

Yes. The recovery strategy is well supported by appropriate actions. The TRT was concerned about whether the overall hatchery strategy included enough redundant backups to catastrophic losses for all life history stages during the period the dams are being removed. For example, maintaining a small population in Morse Creek alone may be assuming an unnecessarily high exposure.

Key Ways to Improve Certainty:

- Describe how the mix of hatchery strategies will provide redundancy for catastrophic losses.

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 hatcheries might be used to maintain populations for time periods longer than should be necessary to remove the Elwha River dams and provide access to good habitat. Likewise, evidence exists that reintroductions into unoccupied, high quality habitat can successfully establish viable populations, although the results are mixed.

Elwha Harvest Management Strategy

NOTE: This evaluation is based on the Elwha Management Unit profile, pages 184-186 of the *Co-managers' Puget Sound Chinook Harvest Management Plan*, as well as material presented in the plan submitted by the Elwha watershed group.

The harvest management portion of the recovery plan states that current habitat cannot support current returns, returning adults are spawned in a hatchery, and that harvest should be kept low to maintain current return levels until habitat is restored.

Ways to improve certainty in plan outcomes:

- Develop exploitation rate guidelines based on productivity and abundance estimates of the Elwha Chinook population.
- Broaden the hypothesis to include the effects of harvest on diversity and spatial distribution.
- Broaden the strategy to address diversity and spatial structure.
- Incorporate 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. The derivation of rebuilding exploitation rates is not clear.

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

Low

- The model includes qualitative descriptions of the link between harvest management and abundance and productivity. The effects of harvest on diversity and spatial distribution are not addressed.
  - It is not apparent that quantitative estimates of a rebuilding exploitation rate for the Elwha Chinook population have been developed. No information was presented on the breakout of escapement into natural-origin and hatchery-origin components.

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

Moderate

- Escapements are estimated, but the hatchery- versus natural-origin fraction of naturally spawning fish is not determined. A coded-wire-tagged (CWT) indicator stock is used to determine exploitation rates.

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

No

- The strategy places a limit on the exploitation rate in Southern US fisheries but not on the total exploitation rate.
- The strategy does not address the effect of harvest on the diversity and spatial structure VSP parameters.
- Lacking an analysis of the appropriate rebuilding exploitation rate for this population, it is not possible to determine whether the exploitation rate on this population, including fisheries both north and south of the US/Canada border, is sufficiently low that the population will be likely to respond positively to the hatchery and habitat actions in the plan..

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

- It is clear from the information presented that spawning escapements have not increased as exploitation rates were reduced. Therefore, it isn't clear that the proposed action (tight control of exploitation rates on Elwha Chinook south of the border; only broadly-based limits on Chinook interceptions north of the border) will provide sufficient, or any, overall control of exploitation rates on Elwha Chinook to levels appropriate to allow rebuilding.

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II. 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.

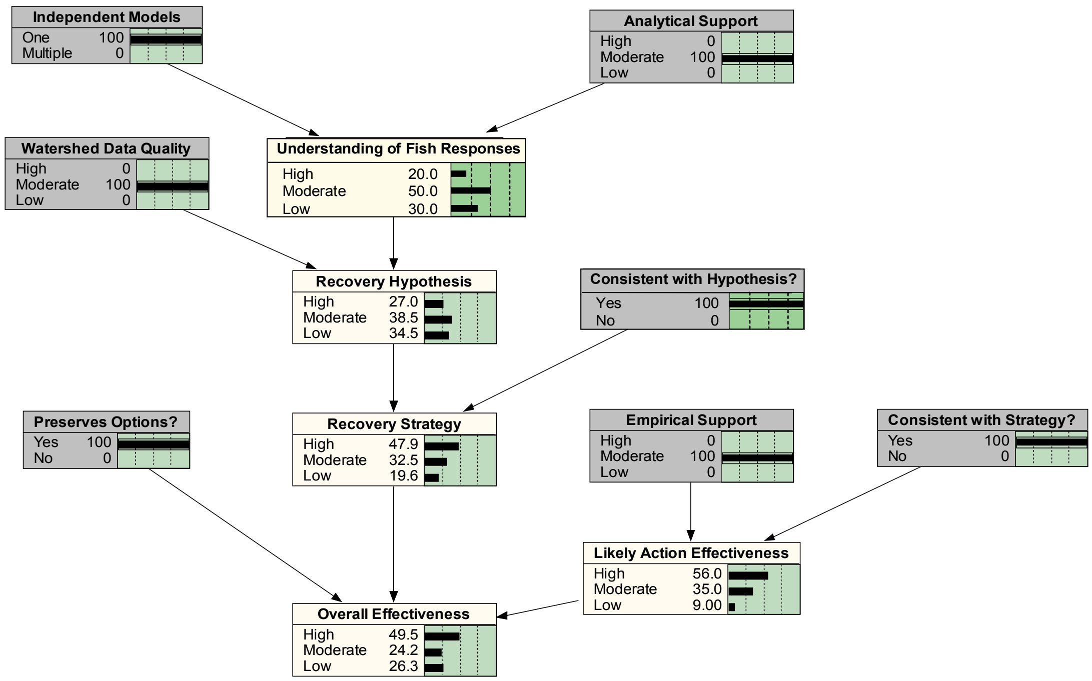

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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

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

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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.

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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, landuse, 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)
Harvest 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
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Table 3. Attributes for different states of consistency of recovery strategy with recovery hypothesis.

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

States	Attributes
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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

Regional Nearshore and Marine Chapter: Puget Sound Chinook Salmon and Hood Canal Summer Chum Regional Issues
May 2005 Technical Gap Analysis

Puget Sound Technical Recovery Team

The Puget Sound Technical Recovery Team (TRT) reviewed the Regional Nearshore and Marine Chapter submitted to the Shared Strategy in May 2005. The general question we asked in our review was "What is the certainty that the actions described in the plan will result in the estimated outcomes for salmon?" NOAA Fisheries' Regional Office and the Shared Strategy directed the TRT to assume that the strategies and actions described in the plan were to be implemented (i.e., **our certainty analysis does not include a judgment about how likely it is that particular strategies or actions will be implemented**). The TRT used the probabilistic network framework to describe the certainty in technical elements of the plan, similar to our technical review conducted on an earlier draft of the plan in the summer of 2004. The primary questions guiding our technical review of plans are summarized in Table 1. The results from the summer 2004 review were intended to support the iterative review process designed by the Shared Strategy and NOAA Fisheries, and these results are available on the Shared Strategy web site. The TRT reviews at that time were designed to provide technical feedback to plan authors so that its revisions could include those elements that were most likely to increase the certainty of the plan's outcomes for salmon. The methods and a brief description of our certainty analyses are provided in section II of this write-up.

Table 1. Questions asked in the TRT review to elucidate the technical certainty in outcomes from salmon recovery plans. More detailed descriptions of methods used in the certainty analyses are provided in Section II.

- Did the analysis use one or multiple lines of evidence to understand potential habitat, hatchery and harvest (i.e., the 'H's') factors limiting salmon recovery?
- How well supported is/are the qualitative or quantitative model(s) used to predict salmon population responses?
- How well supported are the recovery hypotheses with watershed-specific data?
- Is the recovery strategy for all H's consistent with the recovery hypothesis?
- Is the recovery strategy robust by preserving options for recovery? (e.g., is there an adaptive management plan?)
- Are the recovery actions consistent with the all-H recovery strategy?
- How well have the recovery actions been shown to work?

The purpose of the 2005 technical review was to summarize what elements in the plan were well described and where significant technical uncertainties in the plan's strategies or actions still remained. Together, the TRT and Shared Strategy used the information from the technical review to explicitly identify the strengths and remaining gaps in the plan, and the means through which such gaps can be filled. The elements in the plan, plus the clearly stated approaches for filling any remaining gaps, constitute a recovery plan for submission to NOAA Fisheries for their consideration. A description of the gaps and recommended approaches for how to address them are included in the individual watershed profile sections of the regional plan submitted by Shared Strategy.

This review has two components:

- Brief summary of results of our review concerning certainty, and discussion of factors we believe are critical to address in order to improve the certainty of this plan; and
- A description of the methods by which we performed the certainty analysis (i.e., the probabilistic network analysis).

I. Summary of Certainty Analysis

The content of this section summarizes the results of the probabilistic network analysis (for description of the approach, see *Section II* of this document.) This analysis will help in tracking key strategic elements of the plan and how information at each step affects the overall certainty that the proposed actions in the plan will contribute to population and ESU recovery. The technical gaps that emerged from our review were discussed with the Shared Strategy, and were flagged in the regional plan as issues needing special attention during implementation. This section is divided into separate discussions of the certainty in habitat, hatchery and harvest management elements of the plan that we used to identify these key gaps. In addition, several questions within each "H" ask how well the habitat, hatchery and harvest strategies are integrated in the plan. The certainty in the plan's outcomes can be increased by clearly documenting the basis for current strategies and adapting the strategies and actions as implementation proceeds.

Overall conclusions:

1. This element of the regional plan is in the early stages of development and needs more work to bolster the scientific basis for the strategy and the policy vetting. The complexity of the ecosystem and the scope of the task are large, and therefore the outcomes of this plan, even including the actions below to fill gaps, are uncertain.
2. Integration of the nearshore chapter approach with the strategies contained within watershed plans and across all of the Hs at the local and regional levels will also increase the certainty of the outcomes of all the individual watershed plans and the Regional Recovery plan.
3. We support the direction in which the nearshore plan strategy is heading.

Notes: Some revisions to the chapter occurred between this review and printing of the Draft Puget Sound Salmon Recovery Plan at the end of June. The draft plan may, therefore, already reflect some additional progress in filling the gaps described above and elsewhere in this review.

The objectives of the draft nearshore plan are not well described. We applaud the ecosystem-based approach that they cite, but it is not clear what is meant by such an approach for describing hypotheses or formulating strategies to protect and restore the ecosystem. The certainty in the plan's outcome will be increased if it more specifically discusses actions and commitments. The sub-basin discussions are much farther along than the overall regional discussion of hypotheses/strategies. Nevertheless, because the rationale for the sub-basin strategies is not clearly laid out, the technical evaluation of the hypotheses, strategies and actions is difficult. A clear articulation of the regional strategy that summarizes the effects of the sub-basin strategies, and their overall regional consistency will improve the likelihood of success of the nearshore plan.

Key Gap: the nearshore plan does not contain a systematic analysis at the regional level —What connectivity or regional strategies are needed to improve the outcomes of strategies at the sub-basin scale? For example, the zoning approach described in the San Juan County plan would be helpful to discuss at the regional scale. It holds promise for marine-ecosystem-based management approaches as a coordinating mechanism for managing human needs and all impacts in a spatially explicit way.

- We suggest that the nearshore chapter include an analysis similar to Table 6-7 in the South Sound plan that links the 'tool box' of protection and regulation measures to threats that can be addressed with each and the authorities for the protection measures. If such protection measures are then linked to their predicted effects on salmon VSP characteristics, as in table 7 in the Island County plan, the certainty in this regional plan would be increased. The tables also make very explicit what potential threats may not yet be addressed with existing authorities. They are a good means of linking hypothesized threats with strategies and actions.

Nearshore Habitat strategy

Key technical gaps

The most important actions to fill remaining gaps and improve certainty of effective regional nearshore habitat strategy outcomes are to:

- Further develop explicit and spatially distinct life stage linkages relating habitat conditions to responses in population viability characteristics.
- Further develop a specific habitat recovery strategy tiered down from explicit hypotheses relating habitat conditions to population viability to life stage-specific responses across spatially distinct habitats.
- Better relate recovery actions to the more well-defined recovery *strategies* for protection and restoration. In turn, relate these actions to ecological processes, the resulting habitat conditions, and the expected population level VSP responses.
- Develop an adaptive management plan.

Based on our analysis, developing and implement the key items above would substantially increase the certainty for this plan.

Did the analysis use one or multiple independent models to understand potential fish status and responses?
The Nearshore chapter utilizes one model to assess the relationships among ecological processes, land use, habitat conditions, and potential VSP responses of the populations in aggregate. A conceptual model was used for nearshore and marine environments of Puget Sound to evaluate the potential responses of Chinook populations to changes in nearshore and freshwater habitats.

Ways to improve certainty in plan outcomes:

- Include hypothesized interactions among the H's in their effects on the nearshore and marine environments of Puget Sound and resulting responses in VSP characteristics of the salmon populations.

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

The analytical support was low.

- A *qualitative* model was used to relate ecological processes, land use, and habitat conditions to all four VSP attributes. Documentation is from draft nearshore guidance documents. General information on nearshore processes and some specific information on habitat conditions (e.g. water quality) were provided to support the approach. No quantitative models were used.
- Coordination of nearshore assessment approaches and methods across the region was noted as a significant issue. Collaboration with others will facilitate progress on this important regional element.

Ways to improve certainty in plan outcomes:

- Further develop explicit conceptual life stage linkages that relate ecological processes, land use, and habitat conditions to responses in VSP characteristics,
- Provide clear documentation of the model(s) as it becomes available, particularly, documentation of the relationships between habitat condition and salmon juvenile life stage dispersal and utilization, and VSP responses.
- Assess how protection and restoration strategies, if implemented, would contribute to recovery for the region and each subbasin.
- Over the first ten year implementation schedule, develop a more refined and spatially explicit model of the relationships among life history types and habitat types for the nearshore environment.

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

Support for the recovery hypothesis using watershed specific data was low.

- Habitat quality and condition data are generally good; habitat process data are poor; fish use data are poor and, therefore, VSP characteristics data are not available or reliable.

Ways to improve certainty in plan outcomes:

- Develop example application(s) of available habitat quality and fish utilization data to increase analytical support for the hypothesized linkages among habitat conditions and VSP responses.
- Further develop explicit life stage specific relationships among ecological processes, land use, habitat conditions, and responses in population viability characteristics.
    - Include habitat sub-hypotheses to understand how salmonids use habitats in the nearshore and how their numbers relate to nearshore capacity.
- Further develop applications of available habitat quality and fish utilization data to increase qualitative or quantitative analytical support for the hypothesized linkages among habitat conditions and VSP responses.
- ▪ Compile data from each subbasin on juvenile nearshore habitat use, both spatial distribution and productivity. Develop a mechanism to share these data so that people from each subbasin catchment area (sub-region) can access the data and use it in their analyses. This data gap precludes a more quantitative treatment of hypotheses, and also limits our ability to predict the effects of actions (or the magnitude of response required) in the nearshore.
- ▪ Address food web interactions and the effects on the likelihood of recovery for salmon in the nearshore.

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

No.

- The strategy is to restore processes, reduce stressors, restore specific types of priority areas (habitats?), and protect specific types of areas (habitats?). Organization of the strategy around marine sub-basins and key point areas (e.g., Admiralty Inlet) is a good start toward addressing population VSP characteristics and ESU diversity and spatial structure characteristics. The strategy is also incorporating hatchery releases into each sub-basin as a start to integrating the H's.
- The habitat strategies presented appear well thought out and are consistent with the habitat hypotheses. The habitat hypotheses are specifically stated within an ecological, process-based approach, which will help increase the certainty that management actions will have sustainable results. However, the hypotheses for the relationships between stressors and VSP characteristics are not well developed.

Ways to improve certainty in plan outcomes:

- Further develop the habitat recovery strategy from more explicit hypotheses about relationships among ecological processes, land use, habitat conditions, and the potential responses in population level VSP characteristics and ESU persistence.
- Continue to develop more explicit qualitative linkages between each of the specific protection and restoration action for nearshore and shoreline areas and the hypothesized VSP responses.
- Over the first ten year implementation horizon, move toward defining quantitative linkages among these elements above (again, in collaboration with others).

- Include freshwater flows explicitly in the strategy, i.e., how does the amount and timing of stream and groundwater flows into estuaries and the nearshore affect productivity, or the distribution of prey items, or the distribution of juvenile salmonids? (e.g., Table 7 strategies do not include water quantity issues).
- Include nearshore capacity considerations for all species, including salmonids, hatchery and wild fish, and food web interactions in the strategies. Also, spell out how nearshore recovery strategies will be coordinated with other species directed (e.g.Orca, forage fish, non-indigenous species, etc.) conservation efforts.

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

No.

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

Ways to improve certainty in plan outcomes:

- Develop an adaptive management plan that includes indicators, triggers for actions, and criteria for decisions.

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

Support for the proposed actions is moderate.

- In general, the evidence suggests that nearshore protection and restoration actions have some utility although there are conflicting results and many uncertainties. Areas that are especially uncertain are 1) the effectiveness of shoreline regulatory protection programs at maintaining nearshore habitat functions that support early migrant Chinook and chum salmon, 2) the degree to which existing nearshore habitat degradation may be constraining population viability characteristics, 3) validation that protection and recovery actions to rehabilitate or enhance nearshore habitats actually increase the capacity of the nearshore to support Chinook and chum salmon life stages.

Ways to improve certainty in plan outcomes:

- Gather available data, examples of successful outcomes, and list basic assumptions for the actions (by type) as a step to increase the strength of the empirical support.

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

No.

- Specific sets of actions are not explicitly related back to expected regional ecological outcomes through the recovery strategies.
- Some of the actions are clearly consistent with improving the ability of the nearshore to support a recovered ESU. Nevertheless, the actions stated still are not generally consistent—some key actions are not included thoroughly (e.g., for water quality, quantity issues, the list of actions is a mix of very specific sources and then some

appear to be missing, such as storm/wastewater discharges) or are not specific enough to evaluate whether they are consistent with the strategy.

Ways to improve certainty in plan outcomes:

- Relate each type of protection and restoration action more explicitly to a specific habitat recovery strategy.
- Relate specific suites of actions explicitly to expected regional ecological outcomes through the recovery strategies.

Nearshore Hatchery Strategy

Key technical gaps

The most important actions to fill remaining gaps and improve certainty of effective recovery plan hatchery strategy outcomes are to:

- Integrate hatchery strategies with the nearshore habitat strategies and harvest strategies at the sub-basin and regional scales. Preliminary assessments have posed questions relating to potential competition and predation in nearshore/marine environments that remain unresolved. See technical comments on certainty in hatchery and harvest strategies for each of the watershed plans for further discussions.

Ways to improve certainty in plan outcomes:

- Assess ecological effects of hatchery-wild interactions on VSP, including Chinook and other species (especially hatchery steelhead and coho). This issue is probably most pressing for strategy development and how to build an "integrated" hatchery program that accounts for ecological interactions. Conduct multi-jurisdictional collaboration between the co-managers and other interested parties at the watershed and regional levels to fully integrate the nearshore and Hs strategies of the regional plan. (See table 2, #s 5-8).
    - For example, decisions on hatchery supplementations to reduce short term risks to viability (largely expressed in terms of abundance, productivity, and genetic integrity) continue to be made without evaluation of the effects on population status throughout its' life stages and range, particularly during early marine residence. Resulting changes in these characteristics may be increasing risks to the population and ESU persistence.

Nearshore Harvest Strategy

Harvest strategies, by their inherent nature, have largely been addressed relative to this chapter in harvest management recovery plans and watershed recovery plans. The reader is referred to harvest management 4d rules and supporting harvest management planning and technical documents and to the watershed recovery plans for descriptions of the harvest management actions and their affects on populations.

Key technical gaps

The most important actions to fill remaining gaps and improve certainty of effective recovery plan harvest strategy outcomes are to:

- Synthesize and translate the descriptions of the harvest management actions and their effects on populations (See table 2, #s 5-7).
- Integrate harvest strategies with the nearshore habitat strategies and hatchery strategies at the sub-basin and regional scales. Preliminary assessments have posed questions particularly relating to potential competition and predation that remain

unresolved. See technical comments on certainty in the harvest and hatchery strategies for each of the watershed plans for further discussions.

- As in the hatchery Strategy, conduct multi-jurisdictional collaboration between the co-managers and other interested parties at the watershed and regional levels to fully integrate the nearshore and Hs strategies of the regional plan. (See table 2, #s 5-8).
- Continue to implement adaptive management to ensure harvest management implementation is consistent with all-H recovery strategies and their implementation.

II. 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.

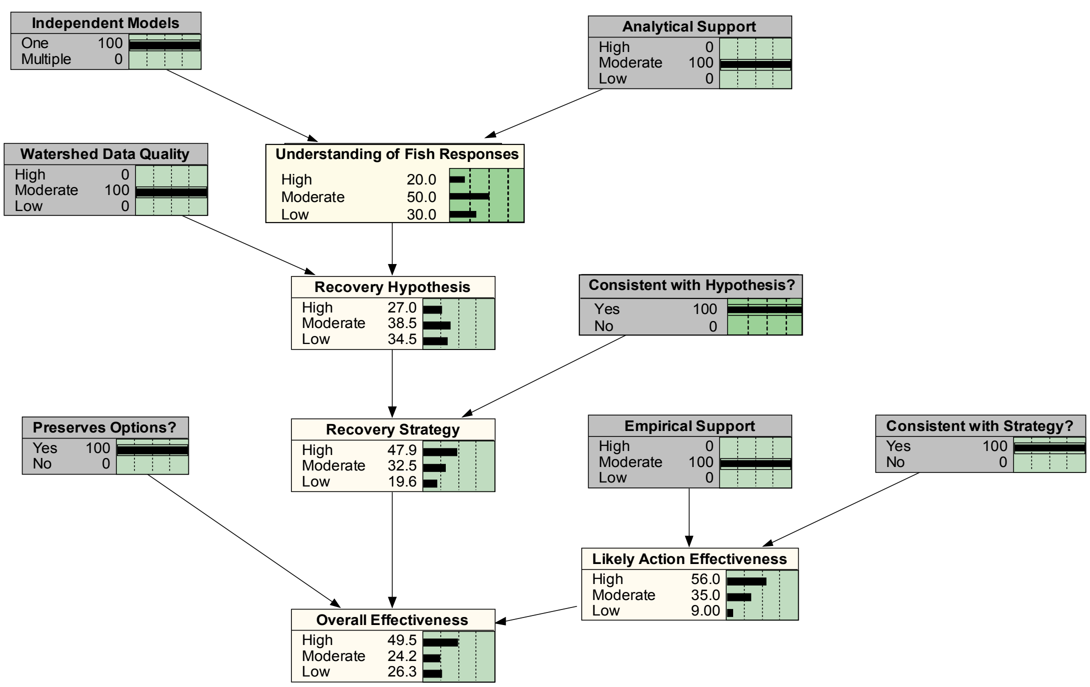

Figure 1. Probabilistic network for evaluating the biological certainty of effective recovery plans illustrating the results of a hypothetical review. Diagnostic nodes are shaded. Numbers at each node are the probabilities for each and the bars show the distribution of the results.

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.

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

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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