City of Corvallis
Salmon Response Plan

Prepared for:

City of Corvallis, Oregon
Public Works Department
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Appendix 4

Methodology for Pathways Evaluation
Technical Memorandum
Natural Resource Planning Services, Inc.
October 18, 2004

technical memorandum

METHODOLOGY FOR PATHWAYS EVALUATION

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This document establishes the framework for evaluating the City's activities. As part of the City's submission for Endangered Species Act ESA 4(d) compliance, the National Marine Fisheries Service expects the City to evaluate the habitat baseline and effects analysis done in Phase 1 and 1) justify actions currently taken by the City as not having a negative impact on the habitat condition, 2) identify areas where the City's action have a negative influence on listed species, and 3) show the necessary activities to be undertaken to change the habitat trajectory from one moving away from properly functioning condition, to one attempting to achieve this condition, or at least as much as the constraints imposed by human habitation will allow**.**

1. Development will avoid inappropriate areas (e.g. slopes, wetlands, riparian areas).
2. Avoid stormwater discharge impacts to water quality, quantity and the watershed hydrograph.
3. Provide adequately protective riparian area management to maintain properly functioning conditions and mitigate unavoidable damage.
4. Avoid stream crossings by roads, utilities etc, when possible and minimize impacts where crossings are unavoidable through choice of mode, sizing, and placement.
5. Protect historical stream geomorphology and avoid hardening of banks and shorelines.
6. Protect wetlands and wetland functions
7. Preserve hydrologic capacity of all streams, permanent and intermittent, to pass peak flows.
8. Provide for and encourage use of native vegetation for landscaping to reduce water, pesticide and herbicide use.
9. Ensure water supply demands can be met without having a negative impact on flows, directly or through influences on groundwater. Any new diversions should be placed and screened in such a way as to prevent injury to and or death of salmonids.
10. Provide necessary enforcement, funding, reporting, and implementation mechanisms and formal plan evaluations at no greater than 5 year intervals.
11. Comply with all other state and Federal environmental and natural resource laws.
12. Provide the NMFS with annual reports regarding implementation and effectiveness.

As well, as part of its overall habitat improvement plans not necessarily associated with Compliance, the City of Corvallis desires a mechanism by which it can evaluate its potential rehabilitative/restorative activities, and establish priorities for projects. As a result, the document contains a number of factors not necessary for compliance with the ESA, but which may prove useful and/or informative for the City in this regard.

The document is organized in three main parts. The first classifies the various elements of the city's stream environments. It uses such already well-known designations found in the Corvallis Stormwater Master Plan, as well as the ESA habitat evaluation reaches from Phase 1 of this project.

Part II provides a scoring mechanism for assessing the impacts of present and future activities on the stream habitat baseline. The national Marine Fisheries Service has already concurred with the assessment that the major impact of Corvallis streams is on water quality. Therefore, the major focus of this document will be on pathways associated with contaminants and other water quality elements.

Part III addresses a framework for dealing with the effects of City activities. It contains BMPS for activities, as well as a decision analysis framework for rehabilitation activities. It also has a fiscal analysis associated with it, to better understand the benefits and costs associated with these activities.

The current classification procedure of the ESA compliance project is using maps of stormwater basins and zoning to assist in the classification, and has modified the existing Excel spreadsheets into a Microsoft Access database for ease of analysis and later use by the City. This database will be linked to the existing GIS layers, including an effective impervious surface layer created for this project by Alsea Geospatial.

I. CLASSIFICATION FACTORS

1. Determine the stormwater basin for each area of interest. Using these basins to organize the classification makes sense, in that the inputs to the streams fit into this model better than a strictly watershed-based system. This approach recognizes the urban reality of Corvallis' stream systems, and allows the classification to link the elements of the Stormwater Master Plan with the ESA baseline analysis conducted in Phase 1.

    a. Dixon Creek
    b. Squaw Creek
    c. Jackson-Frazier-Village Green
    d. Sequoia
    e. Oak Creek
    f. Garfield
    g. Mary's River
    h. Willamette River

2. Select an appropriate reach or meta-reach (one of the three or more major subdivisions of the stream and classify it using the geomorphic methodologies listed below (as input for rehabilitation decision tree). Again, using meta-reaches recognizes the changes in stream geomorphology resulting from urbanization. It also gets around the problem of what characteristics could be used to define a reach. For the purposes of this analysis, the most important reach characteristic becomes simply the ability to define an area where processes appear to be acting in a similar fashion. Meta-reaches are those used by the ESA Compliance Study to assess habitat. These meta-reaches are based on geomorphologic changes such as the presence of tributaries entering the main stem and gradient. The reaches are those used by the Corvallis Stormwater Master Plan. These reaches use man-made structures to determine geomorphologic changes.

3. Determine the related land use/zoning for the area in question. This characteristic will guide the assessment of the impacts of the various pathways, and accentuate those that may have the most impact and eliminate those that may not have an effect. This also provides a structure for both restoration and for the use of BMP. The zoning, for the purposes of the ESA Compliance Plan, may be kept at a more coarse scale. A great many of the effects detected in the analysis conducted in Phase 1 are citywide in their scope, and so may be dealt with, for the purposes of the Compliance Plan, at this greater scale. The NMFS is unlikely to want to evaluate City activities at a scale smaller than the reach level, with the exception of easily identified point sources. The tool being developed will provide the City with the capability of assessing impacts at the point source level, if desired.

    a. Residential
    b. Agricultural
    c. Commercial
    d. Municipal
    e. Industrial

4. Determine listed fish use. This establishes the baseline for evaluation of the impacts of pathways on listed populations, and also provides input into the rehabilitation decision tree elements of the plan. Habitat types of interest include spawning habitat, rearing habitat, and movement corridors. Spawning habitats generally consist of riffle or pool tail-out areas with a high percentage of gravel substrate. Rearing habitat consists of moderate-sized pools with overhead cover. Barriers include impassable culverts, pop-up or other dams, and de-watered areas. Other elements of habitat directly influenced by city activities include temperature, turbidity, and food supply.

    a. Spawning. Depth, velocity, and size of redd area are highly variable. The key requirement is large gravel. Chinook have been known to clean and spawn in areas containing as much as 25% fine sand/silt/clay substrates.

b. Rearing. Rearing generally occurs in smaller tributaries, well-developed riffle-pool systems with rubble type habitat. Chinook tend to avoid rearing in beaver ponds or off-channel sloughs.
c. Movement. The key element in movement is to ensure passage at times when listed species may be using a habitat. Blockage factors include direct blockages such as pop-up dams and compromised or poorly designed culverts.
d. Refuge from high-water winter flows. Access remains the issue here, as does water quality.

5. Identify any habitat-forming processes in stream.

   a. Floodplain/groundwater connectivity (level of incision and overland flow). Does the stream still overflow its banks? Are there streamside wetlands present? Is there still a connection with the groundwater system, both laterally and vertically?
   b. Hydrograph. Do 2 yr floods occur with a 1.5-3 yr periodicity? Is the major contributor to flows groundwater-based, such that the rising limb of the hydrograph is smaller than would be the case if the major contribution came from directed flow or overland flow? What level of floodplain water storage is available?
   c. Riparian community structure, width, and connectivity. Communities should be dominated by native species and should be a mosaic of the various seral stages appropriate for that area. Indications of non-functioning or impaired functioning include: Missing or broken up by large areas of infrastructure impingement. Communities heavily dominated by non-native vegetation, and climax or early seral stages (should be a mosaic which would adequately represent levels of disturbance necessary to maintain the stream in a dynamic equilibrium). There should be the capability for large wood supply to the stream, and leafy debris in the upper reaches.
   d. Pool-riffle ratios-reach-specific. Existing pools should be deep and broken up by riffle areas, rather than taking on the form of glides. The presence of glides suggests a system that is on a trajectory away from properly functioning condition.
   e. Substrate type. This is dependent upon the soils and bedrock present. Some reaches degrading (higher up in system, with greater gradients, larger substrates present. Fines should dominate aggrading reaches, lower down in the system with little or no gradient. Dominated by fines. When gravel present, heavily imbedded or low in the system, indicating high flows sufficient to transport bedload.
   f. Instream cover-undercut ban, instream boulders, and woody debris.

II. SCORING METHODOLOGY

The use of a methodology to score impacts and evaluate projects allows the City to make determinations as to the most important elements to fulfill various mandates. The assumption is that funds for rehabilitation are not limitless, and there is a desire to accomplish the necessary ordinance changes in as few steps as possible. This approach provides a mechanism for evaluating effects on any level desired by the City, as well as erecting a framework for later fiscal analysis in Phase 2 of the ESA Compliance project.

1. Determine the pathway(s) of interest and operating in that area (see Appendix X). For the City of Corvallis, Contaminants and Buffers should be major pathways in all reaches and all systems, for the purpose of ESA compliance. Therefore, it is not necessary to use the reach-related scoring in #6 for that pathway.

    a. Contaminants. Contaminants in the water may act as a direct effect, through toxicity to one or more life stages of the fish, or other elements of the food web, or through indirect effects, such a sublethal impacts on growth and vitality. These impacts are difficult to separate from background individual variation within a population, as well as from seasonal changes. They can, however, be highly important in the long-term survivability of the population, as their impact tends to be on lifetime reproductive output-usually through effects on growth, reproduction, sensory or motor functions, or food supply.
    b. Buffers. Changes in the riparian condition (decreased buffer width tends to act like impervious surface) cause an increase in instream erosion and an eventual loss of habitat structure and diversity .The increased Horton (overland) flow of water also contributes more sediment and contaminants. Other riparian condition pathways are: insufficient buffer size or structure, which diminishes the functions of infiltration and filtration. If the riparian zone consists of lawns or manicured grasses, it can act as a more impervious surface. The presence of large woody debris is diminished by lowered riparian connectivity, as is the structure of the riparian zone. A zone with no large trees will contribute no large woody debris to the stream channel. Riparian areas with shrubs or young trees provide less of a shade function to a stream. Grasses shade even less and manicured grasses provide no shade function. Any vegetation on the bank will provide protection against erosion, although quality varies. Properly functioning condition consists of buffer widths, continuity, and structure sufficient to provide stream bank erosion protection, large woody debris, filtration of overland flow, and shading. Densely vegetated riparian areas act as filters for contaminants and nutrients, as well as infiltration areas to regulate flows. Riparian areas also provide large woody debris, an important contributor to instream habitat structure and formation. Riparian areas also provide shade for the adjacent stream, prevent bank failure, and create instream bank cover for fish.

c. Barriers. Barriers to fish movement include such structures as culverts and pop-up dams. A great many culverts constructed in the years prior to the listing of salmonid species either stop or impede fish movement, causing a change in their normal behavior patterns, thus comprising a "take". Culvert characteristics considered to be impediments include excessive length, excessive velocity through the culvert, darkness, and an excessive vertical drop at the outlet of the culvert. Other impediments to movement include dams, diversion structures, and natural barriers (falls, beaver dams). Channelized sections of the stream also act as barriers to movement, with high velocities and little or no resting areas or cover.
d. Dams without fish passage, serve as blockage to movement during all flow regimes. Barriers are critical, as they don't allow adult fish access to spawning habitat, they don't allow juveniles access to rearing/refugia habitat and don't allow juveniles downstream passage.
e. Impervious surface/runoff. An increase in impervious surface leads to greater amounts of overland flow as opposed to infiltrated groundwater, as the source of water in the stream. Overland flows create a greater amount of water in the stream in a shorter period of time. Runoff from impervious surface causes increased in-stream erosion as the stream equilibrates to the new flow regime. This leads to loss of instream habitat features (e.g. under-bank cover) through erosion, and transport of large woody debris. It also increases fine sediments initially, while the stream is equilibrating (0-20 yrs). Once the stream reaches its new equilibrium, fines actually decrease (assuming no channelization-this activity stops the channel from reaching equilibrium). The principal effect of the increased flows is to widen the channel. This occurs because the stream must accommodate these greater flows. Bankfull width increases, pools tend to fill in. Stream flow slows and temperature increases, due to the slower passage, loss of riparian shading, and greater surface area to be heated. Continued erosion causes the loss of overhanging cover in the pool areas. The combination of increased sedimentation, and the subsequent slowing of flows and filling of pools by finer sediments, causes a loss of spawning and rearing habitat. As the channel reaches equilibrium, the sedimentation problem goes away as the higher flows act like flushing flows. This leaves coarser sediments, that may be better for spawning activities, but this activity is diminished if the connection between the groundwater flows and surface flows is severed as the result of changes in hyporheic zone activities. The higher flows may also wash fish away or lower lows may strand them in summer when rearing is important. The chief pathway for this change is through increased impervious surface contributing to greater surface runoff and less infiltration. This leads to higher flows and a "flashier' hydrograph. Secondary pathways could be the loss of riparian habitat and decreased groundwater flows-the latter as at least the partial result of reduced infiltration of stormwater. Increased impervious surface is the direct result of increased development of all types.

The more concentrated the development, the greater the amount of impervious surface. At a level of about 10% Total Impervious Surface, stream habitat begins to suffer. After a stream reaches equilibrium with its flows, riparian issues become more important.

f. Instream Habitat. The increase in the need for stormwater treatment as encroachment occurs in floodplain leads to channelization, as streams become stormwater conduits. Removal of large, woody debris (LWD) from channel increases channelization. Loss of floodplain and restriction of channel causes loss of off-channel habitat. Channelization causes increased velocity, increased down-cutting erosions, severing connections between stream flow and groundwater, causing problems in the hyporheic zone, and increasing problems for spawning and rearing fish. Channelization also degrades: instream cover, off-channel and other refugia habitat, riparian conditions, hydrologic connectivity, food resources, substrate and instream habitat quantity, diversity, and quality.

2. Determine the latitudinal/longitudinal extent of the pathway

    a. Within the riparian buffer/floodplain (3). Activities occurring within this zone have the capability of influencing the listed fish and their habitat without any need for a transport mechanism such as the stormwater system. Activities within this area also affect the riparian buffer characteristics.
    b. Outside the buffer/floodplain (1). This is scored lower simply because activities occurring outside the buffer require the intervention of a transport mechanism (such as the stormwater system).

3. Rank the location of the pathway or event (by meta-reach and basin)-use ESA reaches as a guideline. Each system should be weighted according to the pathway of interest. For the City of Corvallis, the Contaminant pathway should be the same for all streams, regardless of their position in the system, as should the riparian buffer (for purposes of water quality). Impervious surface and instream habitat should use the following system. The importance of the Buffer pathway varies with the desired function. In the case of Corvallis, the most important functions of the buffer are to maintain water quality. Buffer community structure and the mosaic of types are not so important, then, as are elements concerned with these functions. Width should increase in a downstream direction, as the amount of flow increases and the gradient decreases to the point that the stream can easily overflow its banks. Barriers should be addressed going upstream, with the greatest emphasis on those lower in the system.

4. Scoring for Instream Habitat and impervious surface reaches

    a. Upland tributaries-urbanized (4), non-urbanized (5)
        i. Intermittent stream area (2)
        ii. Perennial stream area (4)

b. Non-urbanized lowlands (2)
c. Urbanized lowlands (1)

5. Determine the spatial extent (magnitude) of the pathway's influence. Spatial extent plays an important role not only in the assessment of the level of influence, but also on the nature of the cure or rehabilitative activity. The greater the magnitude, the more likely that fixes will require some change in ordinances or the creation of new ones. This does not preclude the use of individual or point-related BMP.

    a. Point. Occurring at a single location or site. (1)
    b. Reach. Occurring at multiple locations throughout the designated stormwater reach (2).
    c. Meta-reach. Occurring at multiple locations throughout the designated ESA survey reach. (3)
    d. Basin/Watershed. Occurring throughout the basin as a whole. (4)

6. Determine the timing of the pathway. Timing has considerable influence upon the resilience of the system. Historic habitat-forming processes tended to be single-event or episodic in nature. The chronic nature of a great many anthropogenic changes in inputs to these processes is considered to apply more stress to the ability of the system to rebound.

    a. Single event (1) (occurs as the result of failure to implement BMPs or failure of BMPs).
    b. Chronic (occurs as the result of long-term action (e.g. stormwater runoff). (4)
    c. Periodic (occurs at regular intervals). (3)
    d. Episodic (intervals are not regular but occurs more than once). (2)

7. Determine intensity of the pathway or event. Intensity of an activity is related, to some degree, to the previous two categories (magnitude and timing) and has the least clear-cut predictive capability.

    a. Low (little or no mortality or habitat change expected). (1)
    b. Medium (some mortality; habitat changes occur but are within the resilience capability of the stream and within expectations for that particular time period in the evolution of the stream). (2)
    c. High (dramatic changes beyond the capability of the reach or stream to accommodate, forcing a change in steam geomorphology beyond that which could be expected from typical stream evolution; sufficient mortality to put populations in that area in jeopardy). (4)

8. Determine duration of pathway or event (not necessary for Corvallis). Duration take into account the ability of the pathway to influence multiple life stages of listed fish occupying the streams. There is also an element of seasonality in this factor as well, that needs to be added when specific activities and life stage presence are identified.

a. Short (0-3 months)(1). Short-term events are not likely to influence populations, or may only influence one life history stage.
b. Chronic (3.) Chronic events are more likely to influence several life history stages, or at least have the capability.
c. Medium 3-(6-9 months) (2). Medium duration events could influence two or more life history stages.
d. Long (9 months or longer) (3). Long-term events have a high likelihood of having an impact on several life history stages.

III. REHABILITATION DECISION CRITERIA

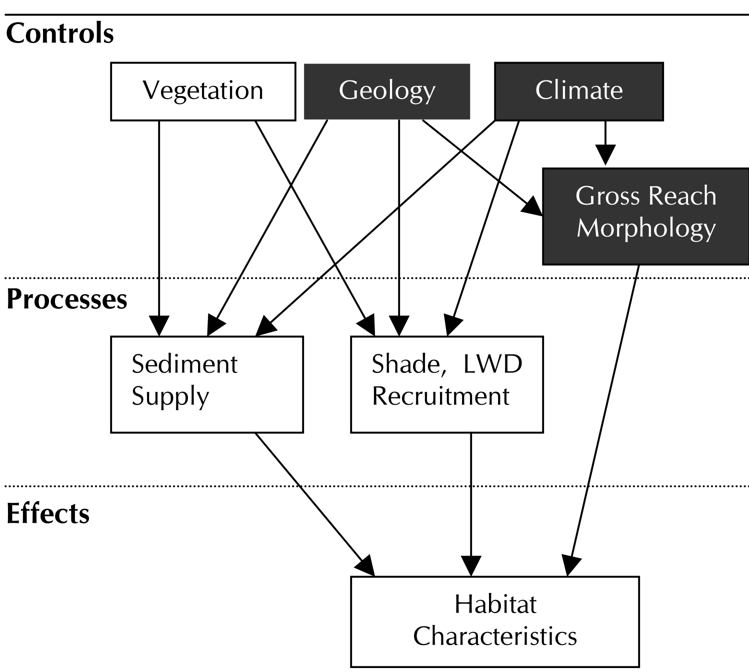
A watershed's land base controls its processes. Focusing all rehabilitative efforts within the stream channel ignores the effects of land use and riparian vegetation on the supply of water, sediment, shade, and wood to the streams. Past errors, based on doing things thought to be 'good' for salmon, like removing wood, would be less likely to occur if the restoration goal is to reestablish processes to which salmonids have adapted. In addition, by looking at watershed processes instead of individual salmon species habitat requirements, actions can be identified that restore habitat for all salmonid species. This approach requires analysis of habitat forming processes at the watershed scale in order to identify processes that have been disrupted, as well as the locations and timing of land use effects on those processes (Figure 1).

Recent efforts in salmonid recovery have shifted to an understanding of the dynamic nature of habitat within a watershed and the forces responsible for its production. Work by Benda, and others, on stream geomorphologic processes and the response of fish to dynamic habitat (Benda 1993, 2000; Reeves et al. 1995; Benda et al. 1996) has demonstrated that, in undisturbed watersheds, fires and subsequent landslides determined the nature of instream habitat by providing inputs of sediments and large woody debris that the stream then processed according to its geology and climatic regime. The periodicity of these disturbances was highly variable, with potentially as long a time as several centuries between them. Human influences have altered the type, frequency and magnitude of natural disturbances, perhaps to the point of affecting the resiliency, or ability of the system to return to some domain of its initial function.

In their discussion of the role of disturbance in salmonid recovery, Bisson et al. state, "Natural disturbances are an important part of the ecology of Pacific Northwest watersheds and create a diversity of aquatic environments to which different stocks of salmon and other native fishes have adapted over time. Objectives for managing habitat should be focused on maintaining the full range of aquatic and riparian conditions generated by natural disturbance events at landscape scales large enough to encompass the freshwater life cycles of salmon and other species. Because streams are dynamic, establishing fixed habitat standards for such parameters as temperature, fine sediment concentration, woody debris abundance, or pool frequency is not likely to protect the overall capacity of watersheds to produce fish or to recover from natural or anthropogenic disturbances. Attempting to make streams conform to an idealized notion of optimum habitat through legal regulations or channel manipulations will not easily accommodate cycles of disturbance and recovery, and may lead to a long-term loss of habitat and biological diversity. Desired future conditions can be derived by examining how natural disturbances influence the distribution of aquatic habitats and development of riparian communities within relatively pristine watersheds and by using these patterns as target conditions for watersheds in which management activities are planned. Although it is not feasible to return watersheds to a pristine state in most cases, a complete or nearly complete range of aquatic habitats can be maintained if anthropogenic disturbances are compatible with natural disturbances to the extent possible."

Processes are dictated by **controls** – the operations and rates of change of the biophysical world that generally occur at a hierarchical level greater than that of the landscape. **Processes** occur at the landscape scale and can include historic fire frequencies, sediment supply rates, growth and yield of riparian forests, stream temperature regimes, and frequencies and sizes of landslides and floods. It should be understood that the identification of these processes does not imply a return to them in restoration (Fig. 1)

Figure 1



Sediment supply: decreased forest cover, loss of root strength, increased water to soil

Stream temperature: decreased forest canopy density in summer

Large, woody debris (LWD) recruitment: altered species composition in riparian forests, decreased forest cover

Sediment supply: increased landslide rates, higher total sediment supply

Stream temperature: reduced shade levels

LWD recruitment: reduced LWD recruitment to stream

Sediment supply: channel widening, reduced pool depth

Stream temperature: increased maximum temperature, increased diurnal temperature fluctuation

LWD recruitment: reduced pool abundance, decreased pool depths

Figure 1 shows linkages among controls on watershed processes, the processes themselves, and habitat characteristics, with narrative descriptions for three habitat-forming processes Black boxes indicate controls that are not affected by land use. Gross Reach Morphology refers to average channel slope, approximate size of channel, and floodplain width (Source: Beechie, Tim and Susan Bolton. "An Approach to Restoring Salmonid Habitat-forming Processes in Pacific Northwest Watersheds." Fisheries Volume 24, No. 4 [April 1999]: pp. 6-13.).

Decisions on rehabilitation should be made according to a series of decision criteria. These encompass the socioeconomic and political as well as the biophysical.

The initial biophysical assessment should begin at the watershed level and should take into account the habitat-forming processes, at the various scales represented in that watershed. These include controls that function at the landscape or watershed-level and include such factors as vegetation, geology, climate, and stream geomorphology, processes occurring at the reach level (e.g. sediment supply. shade, large woody debris (LWD) recruitment, and effects (the habitat characteristics produced as a result of the above elements).

The failure of a great many rehabilitation efforts comes from not taking into account the various scales of the habitat-forming processes and not understanding that habitat is an effect of a dynamic, ongoing stream process. Equilibriums are attained in watersheds, but they are dynamic and shifting.

The processes necessary for successful rehabilitation will be ascertained through the habitat assessment process. Given the nature of watersheds in Corvallis, it is likely that habitat-forming processes will have both an intensely urban nature, as well as some of the aspects of a rural system.

Rehabilitation actions should be designed to protect, enhance, or restore the appropriate processes. It will not be possible to return the systems to the episodic fire and slide disturbance regime that existed prior to European civilization; however, processes should take into account the current geological and vegetation structures. This means, for instance, that urban areas need to be considered in light of the impervious "soil" materials and the chronic low-level inputs of sheet flow, punctuated by extremely flashy events that result from stormwater practices, and the changes from Douglas fir or oak gallery forest to agricultural field, turfgrass, and or thinner bands of smaller trees.

Actions will follow a format similar to that below (adapted from Beechie and Bolton 1999).

1. Estimate Historical Rates of Habitat-Forming Processes

This requires an understanding of the important processes in the watershed. Examples of important processes include historic fire frequencies, sediment supply rates, growth and yield of riparian forests, stream temperature regimes, and frequencies and sizes of landslides and floods.

2. Assess Changes in Rates of Habitat-Forming Processes

This requires identifying land use changes that have altered habitat-forming processes and determining, which changes most likely created a change in important processes. Examples of data that may illustrate changes include hydrographs, channel morphologies, stream temperatures and vegetation ages and types.

The next step is to identify land use changes that have altered habitat-forming processes and determine which changes most likely created a change in important processes. It also is critical to determine the nature of the habitat-forming processes currently operating in the system. This will aid in assessing the likelihood of changes having a positive influence on the habitat in question, and the nature of the trajectories of that change. Examples of data that may illustrate changes include hydrographs, channel morphologies, stream temperatures and vegetation ages and types.

1. Critical habitats.

   Habitat types of interest include spawning habitat, rearing habitat, and movement corridors. Spawning habitats generally consist of riffle or pool tail-out areas with a high percentage of gravel substrate. Rearing habitat consists of moderate-sized pools with overhead cover. Barriers include impassable culverts, pop-up or other dams, and de-watered areas. Other elements of habitat directly influenced by city activities include temperature, turbidity, and food supply.

2. Flow and Sediment.

   Threats to spawning areas include sedimentation, a “flashy” hydrograph (water flow over time), and temperature. Sediment originates from two sources – outside the system and instream erosion. Sediments influence spawning in two ways, by covering and smothering the eggs and by embedding the gravels, making it difficult or impossible for fish to dig redds (spawning sites). A “flashy” hydrograph, one with higher highs and lower lows, influences spawning by flushing spawning gravels with higher flows than normal, and by holding fish in a mainstem or lower in the system during low water periods. Salmonids prefer lower temperatures, so higher temperatures caused by a number of activities (high temperature inputs from outside the system, conversion of riffle areas to pools, removal of riparian cover) result in higher egg and larval mortalities, or at least in higher stress levels and resultant transfers of energy to metabolic maintenance and away from activities such as growth and reproduction.

   The major threats to rearing habitat consist of those changes in stream structure caused by higher and lower flows. The scouring and erosion caused by higher and more intense flows cause the stream to spread out and become more U-shaped (as opposed to a V-shape). This change in shape changes habitat structure as riffles and glides convert to pools. This results in higher temperatures, as the new pools have less depth and slower flows. Older pools also become shallower as the channel becomes wider. This decrease in depth also strands rearing fish in the summer as flows naturally drop. Increased fine sediments in the system embed the gravels and coarser sediments necessary for over-wintering, making them more difficult to use. Increased side-cutting leads to the loss of undercut banks that provide instream cover.

3. Vegetation.

   Loss of cover also contributes to changes in stream structure and threats to rearing habitat. Removal of riparian cover leaves stream banks susceptible to erosion from water entering the stream and instream erosion. Shade also disappears, causing water temperatures to increase, and removing sources of large woody debris.

4. Passage issues.

   A great many culverts constructed in the years before the listing of salmonid species either stop or impede fish movement, causing a change in their normal behavior patterns, thus comprising a "take". Culvert characteristics considered to be impediments include excessive length, excessive velocity through the culvert, darkness, and an excessive vertical drop at the outlet of the culvert. Other impediments to movement include dams, diversion structures, and natural barriers (falls, beaver dams). Channelized sections of the stream also act as barriers to movement, with high velocities and little or no resting areas or cover.

   Locate any present barriers-examine their extent at all flow regimes as could be barrier to small fish at high flow (large ones too if flow is too great), and to all fish at low flows if flow insufficient or culvert etc perched.

   Examine habitat above barriers for suitability. Restoration of passage could increase habitat and be looked upon favorably by NMFS.

5. Contaminants.

   Contaminants in the water may act as a direct effect, through toxicity to one or more life stages of the fish, or other elements of the food web, or through indirect effects, such a sub-lethal impacts on growth and vitality. These impacts are difficult to separate from background individual variation within a population, as well as from seasonal changes. They can, however, be highly important in the long-term survivability of the population, as their impact tends to be on lifetime reproductive output – usually through effects on growth, reproduction, sensory or motor functions, or food supply.

3. Identify Restoration Tasks

Decide on the physical and biological objectives for the site, and then identify the actions required to achieve each objective. In urban and agricultural areas, the types of actions may be severely constrained by current land use. Here the goal is to be sure that all actions will move towards the goal of restoring habitat-forming processes even if full restoration will not be possible given current land use.

Restoration may be passive or active. Passive restoration involves mapping sensitive areas and prohibiting activities in those areas. Active restoration includes actions such as removing culvert blockages for fish passage, identifying and repairing road failures, and identifying riparian areas for thinning or planting to enhance recovery of the desired size and species of trees.

4. Evaluate Effectiveness of Restoration Tasks

The methods used to evaluate options vary with the physical and biological objective and site. In some cases, habitat-based fish production models can be used. In other cases, the evaluation will be more qualitative and look at things like the effect of changing temperature, sediment, or hydrologic regimes on species of interest.

5. Prioritize Actions Based on Costs and Potential for Achieving the Biological Objective

Ideally, projects are ranked based on the greatest change in biological indicator per dollar cost. However, other factors often must be considered, such as recovery time, landowner willingness to participate, and funding availability for various projects.

1. Did these conditions of interest (habitat pathways) exist historically?
2. Are they currently maintained?
3. Can they be restored or protected?
4. Determine the influence of the pathway on the necessary habitat-forming processes as they relate to the watershed as a whole, and to the area in particular.
5. Identify the value and likelihood of modifying the habitat-forming process, in order to establish its precedence when considering rehabilitation.
6. Actions to cut pathway (see examples).
7. Actions to protect existing conditions (see example).
8. Actions to rehabilitate (see examples).