Erosion and Fine Sediment

Stream Bank Composition

Stream bank erosion contribute cobble and gravel to the channel which are important components in spawning substrate. Accumulation of instream fine sediment indicates a decrease in available spawning substrate. Roads, other land use activities, and naturally occurring background geologic disturbances contribute fine sediment.

The Outlet Creek Basin is on a list of water bodies for impairment or threat of impairment by sediments as required by Section 303(d) of the Clean Water Act. The 303(d) list describes water bodies that do not fully support all beneficial uses or are not meeting water quality objectives, and pollutants for each water body that impairs water quality. Because of the listing of the Outlet Creek Basin, the US EPA has developed numeric targets for sediment and established sediment allocations expressed as a total maximum daily load (TMDL) in tons of sediment per square mile per year. At the time of the listing, sediment was judged to be affecting cold water fishery and associated beneficial uses as described in the US EPA (2004). Nearly all aspects of the cold water fishery are affected by sediment pollution, including migration, spawning and reproduction, and early development of cold-water fish such coho and Chinook salmon, and steelhead trout.

Stream banks

The habitat inventory surveys data (1995) were analyzed to determine the stream bank composition of the subbasins and basin. Most of the stream banks in the Basin are dominated by sand/silt/clay (fine sediment), bedrock, and boulders. Most of the stream banks in the Northern Subbasin are dominated by cobble/gravel with almost equal amounts composed of bedrock, boulder, and sand/silt/clay. The stream banks in the Middle and Southern subbasins are dominated by sand/silt/clay (fine sediment) with some cobble/gravel areas and minor bedrock or boulder components (Figure X. Average composition of stream banks of the Outlet Creek Basin and subbasins).

The stream banks are contributing fine sediment and cobble gravel into the stream channels. It is likely that eroding stream banks in the Southern and Middle subbasins are contributing large amounts of fine sediment due to the very soft Alluvium found in Little Lake Valley. Fine sediment is being transported down stream into the Northern Subbasin and into the Eel River System. Fine sediment from stream banks in the Middle and Southern may be limiting the health and production of salmonids in the Outlet Creek Basin. This finding is supported by the TMDL (U.S. EPA 2005).

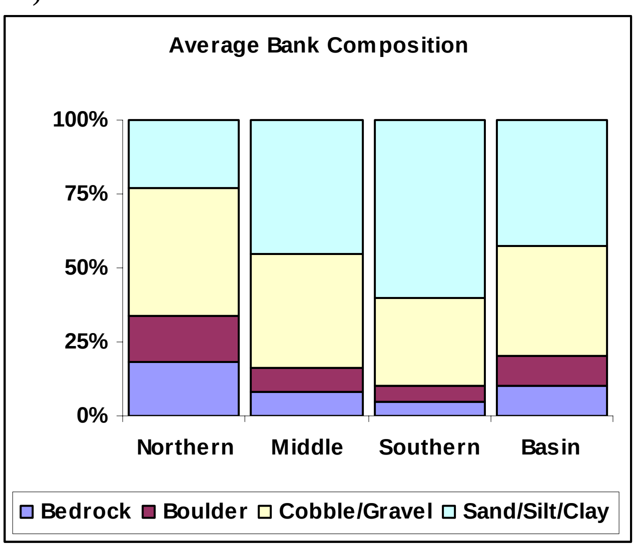


Figure X. Average composition of stream banks of the Outlet Creek Basin and Subbasins.

Embeddedness

The target value for embeddedness is to have 50% or more of the surveyed pool tail outs to be 50% or less embedded in fine sediment (sand, silt, or clay) (Flosi et al 1998).

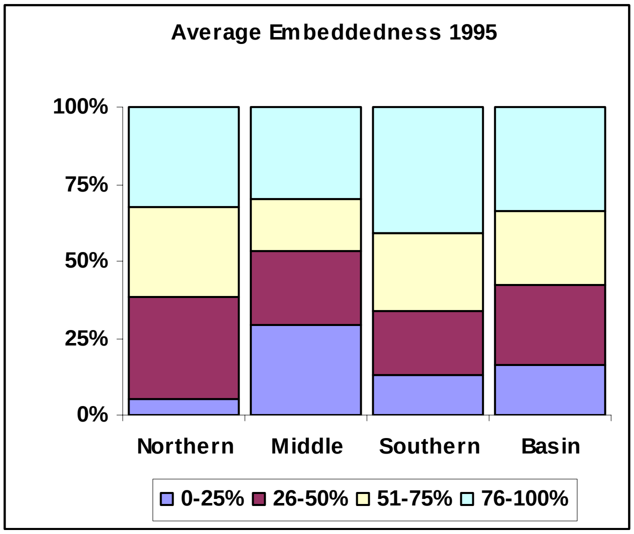
Fine sediment load is another important aspect of water quality. Salmonids cannot successfully reproduce when forced to spawn in cobble-gravel substrate embedded by excessive fine sediment. Eggs and embryos suffocate under excessive fine sediment conditions because oxygenated water is prevented from passing through the egg nest, or redd. Additionally, high fine sediment loads can cap the redd and prevent emergent fry from escaping the gravel into the stream at the end of incubation. High fine sediment loads can also cause abrasions on fish gills, which may increase susceptibility to infection. At extreme levels, fine sediment can clog the gills causing death. Additionally, materials toxic to salmonids can cling to sediment and be transported through downstream areas.

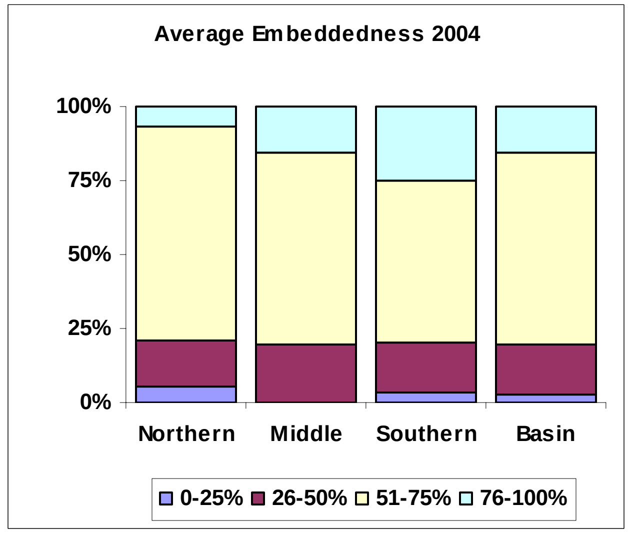
High embeddedness values indicate high fine sediment accumulation in the pool tail area where salmonids spawn, egg mature, and fry emerge. High embeddedness values and fine sediment accumulation indicates a lack of suitable spawning areas and low rates of egg survival to fry emergence. Cobble embeddedness is the percentage of an average sized cobble at a pool tail out embedded in fine sediment. Category 1 is 0-25% embedded, category 2 is 26-50% embedded, category 3 is 51-75% embedded and category 4 is 76-100% embedded. Category 1 is best, category 2 is supportive, and categories 3 and 4 are unsuitable for successful spawning and incubation of salmonids.

In 1995 and 2004, the Outlet Basin did not meet embeddedness target values. In 1995 and 2004, the basin 42% and 20% of the pool tail outs measured in the basin were 50% or less embedded, respectively. In 1995, most of the pool tail outs were 76-100% embedded, while in 2004, most were 51-75% embedded. However, in 1995, the pool habitat measurements were averaged for all of the streams surveyed in the basin, whereas in 2004, 50 random sites were surveyed throughout the basin.

In 1995 and 2004, the Northern Subbasin did not meet embeddedness target values and ranged between 40% and 24% of the pool tail outs were 50% or less embedded, respectively. In 1995, the Middle Subbasin had 51% and did meet embeddedness target values. In 2004, only 25% of the pool tail outs were 50% or less embedded, thus did not meet embeddedness target values. In 1995 and 2004, the Southern Subbasin did not meet embeddedness target values and ranged between 45% and 24% of the pool tail outs were 50% or less embedded, respectively. (Figure X and Y).

Overall, the embeddedness values in the Outlet Creek Basin have increased and the available spawning substrate has decreased between 1995 and 2004. The average embeddedness of pool tail outs in category 1 and 2 decreased between 1995 and 2004 indicating that spawning habitat conditions have become less suitable. This is most evident in the Middle Subbasin where spawning conditions have significantly declined. The increase in category 3 and decrease in category 4 may indicated that fine sediment is moving through the system. The increase in category 3 could also indicate that new sediment is being both contributed to the basin from natural sources and land use activities. The high percentage of pool tail outs with high embeddedness values indicate that fine sediment, possibly from eroding stream banks, may be impacting egg survival. Fine sediment is likely inhibiting spawning suitability and decreasing pool depths which limiting the health and production of salmonids in the Outlet Creek Basin.





Figures X and Y. Embeddedness in Pool Tails of the Basin and Subbasins in 1995 and 2004.

Riparian

The Target Values for Canopy Density is to have 80% or more of the stream channel covered by coniferous or deciduous canopy (Flosi et al 1998).

A functional riparian zone helps to control the amount of sunlight reaching the stream, provides vegetative litter, and contributes invertebrates to the local salmonid diet. These contribute to the production of food for the aquatic community, including salmonids. Tree roots and other vegetative cover provide stream bank cohesion and buffer impacts from adjacent uplands. Near-stream vegetation eventually provides large woody debris and complexity to the stream (Flosi et al. 1998).

Riparian zone functions are important to anadromous salmonids for numerous reasons. Riparian vegetation helps keep stream temperatures in the range that is suitable for salmonids by maintaining cool stream temperatures in the summer and insulating streams from heat loss in the winter. Larval and adult macro-invertebrates are important to the salmonid diet and are dependent upon nutrient contributions from the riparian zone. Additionally, stream bank cohesion and maintenance of undercut banks provided by riparian zones in good condition maintain diverse salmonid habitat, and help reduce bank failure and fine sediment yield to the stream. Lastly, the large woody debris provided by riparian zones shapes channel morphology, helps retain organic matter and provides essential cover for salmonids (Murphy and Meehan 1991).

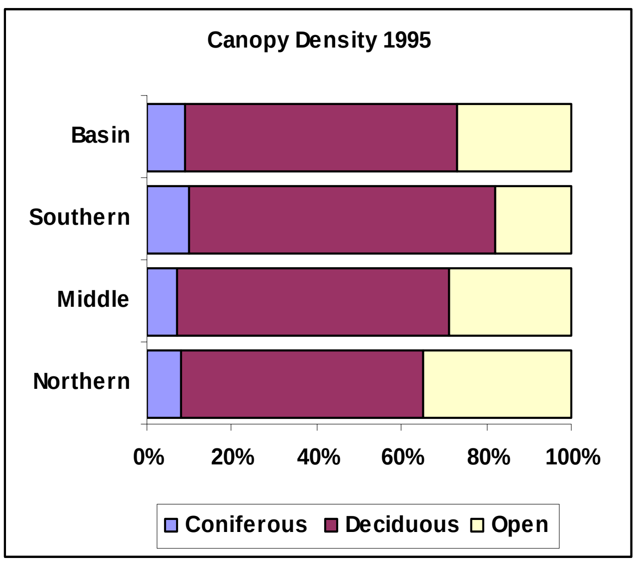
In 1995 and 2004, the average canopy density for the basin was 73%, which did not meet canopy density target values. In both 1995 and 2004, deciduous canopy dominates and coniferous canopy increases in 2004, with canopy density being provided by 65% and 45% deciduous and 8% and 27% coniferous species, respectively. Overall, the canopy density decreased and the open areas increased from the headwaters to the confluence with the main stem Eel, with the Southern and Middle subbasins providing more canopy than the Northern Subbasin. Most of the streams were covered by deciduous species with approximately one-third of the total basin canopy open (absent) Eel. The canopy was dominated by deciduous species in the all three subbasins, except for the Northern Subbasin in 2004, in which the coniferous composition increased significantly between 1995 and 2004. However, in 1995, the canopy values were averaged for all of the streams surveyed in each of the subbasins, whereas in 2004, 19, 7, and 24 random sites were surveyed throughout the Northern, Middle, and Southern subbasins, respectively.

In 1995 and 2004, the Northern Subbasin had an overall canopy density of 65% and 60%, respectively, which did not meet canopy density target values. In both 1995 and 2004, deciduous canopy dominated and coniferous canopy increased in 2004. The canopy density has not significantly changed between 1995 and 2004.

In 1995, the Middle Subbasin had an overall canopy density of 71%, which did not meet the canopy density target value. In 2004, the subbasin had an overall canopy of 88%, which does meet the target value. The canopy density appears to have increased, with both the deciduous and coniferous components increasing, between 1995 and 2004.

In 1995, the Southern Subbasin had an overall canopy density of 82%, which did just meet canopy density target values. In 2004, the canopy density was 68%, which did not meet target values. In both 1995 and 2004, deciduous canopy dominates. The canopy density appears to have declined between 1995 and 2004 (Figures X and Y. Percent of Canopy Density and Vegetation Type of the Basin and Subbasins in 1995 and 2004).

Overall, the average canopy density for the basin did not change significantly between the 1995 and 2004 surveys. Although there probably was some increase in coniferous species throughout the basin and in the Northern Subbasin, the rate of increase is likely incorrect and reflects the random sites surveyed. The 2004 GRTS sites were more frequently located on the tributaries to Outlet Creek which have smaller channel widths whereas in 1995, the entire stream length was surveyed resulting in a more complete data set and representation of the basin and subbasin conditions. Low canopy density is likely limiting the health and production of juvenile coho salmon and steelhead. Chinook juvenile salmon begin to migrate out of the Outlet Creek Basin prior to the increase in summer water temperatures, however they are likely affected by low canopy density and high water temperatures in the main stem Eel and possibly adverse water quality conditions in the estuary. Re-vegetation restoration projects should be planned and prioritization should be given to areas utilized or potentially utilized by juvenile coho salmon and steelhead trout.



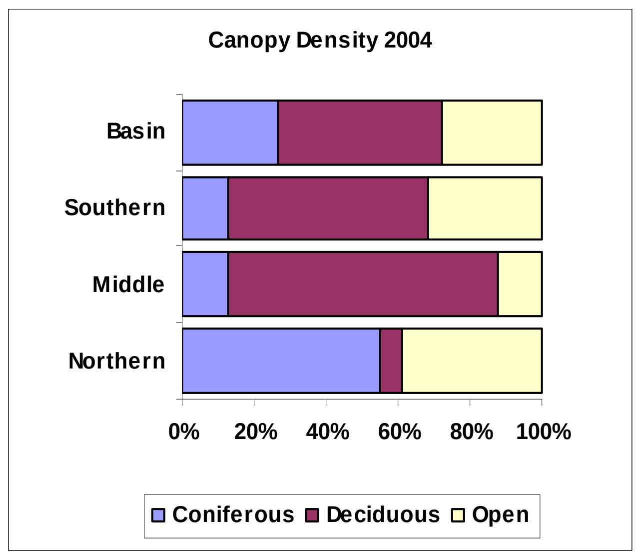


Figure X and Y. Canopy Density and Vegetation Type of the Outlet Creek Basin in 1995 and 2004.

Ecological Management Decision Support (EMDS) Canopy Density Conditions

The anadromous Subbasin EMDS evaluates the condition of the canopy density. EMDS calculations and conclusions are pertinent only to surveyed streams in 1995 and the GRTS sites in 2004 and are based on conditions present at the time surveyed. EMDS scores were weighted by survey length to obtain overall scores for the streams and survey sites.

In 1995 and 2004, the overall canopy density condition in the Outlet Basin was somewhat suitable. In 1995 and 2004, the overall canopy density condition in the Northern Subbasin was somewhat unsuitable and somewhat suitable, respectively. In 1995 and 2004, the overall canopy density condition in the Middle Subbasin was fully and moderately suitable, respectively. In 1995 and 2004, the overall canopy density condition in the Southern Subbasin was moderately and somewhat suitable, respectively. In 2004, 50 sites were surveyed, which include 19 in the Northern, 7 in the Middle, and 24 in the Southern subbasins. Out of the 50 sites, 21 were fully suitable, 6 were moderately suitable, 6 were somewhat suitable, 5 were somewhat unsuitable, 2 were moderately unsuitable, and ten were fully unsuitable (Figure X and Y. EMDS Canopy Density Suitability in the Outlet Basin in 1995 and 2004).

Though some areas have improved between 1995 and 2004, specifically in the Northern and Southern subbasins, the EMDS results show that the canopy density condition has remained relatively unchanged in the Outlet Basin overall. Restoration efforts focused on improving canopy should be located in areas with unsuitable EMDS ratings.

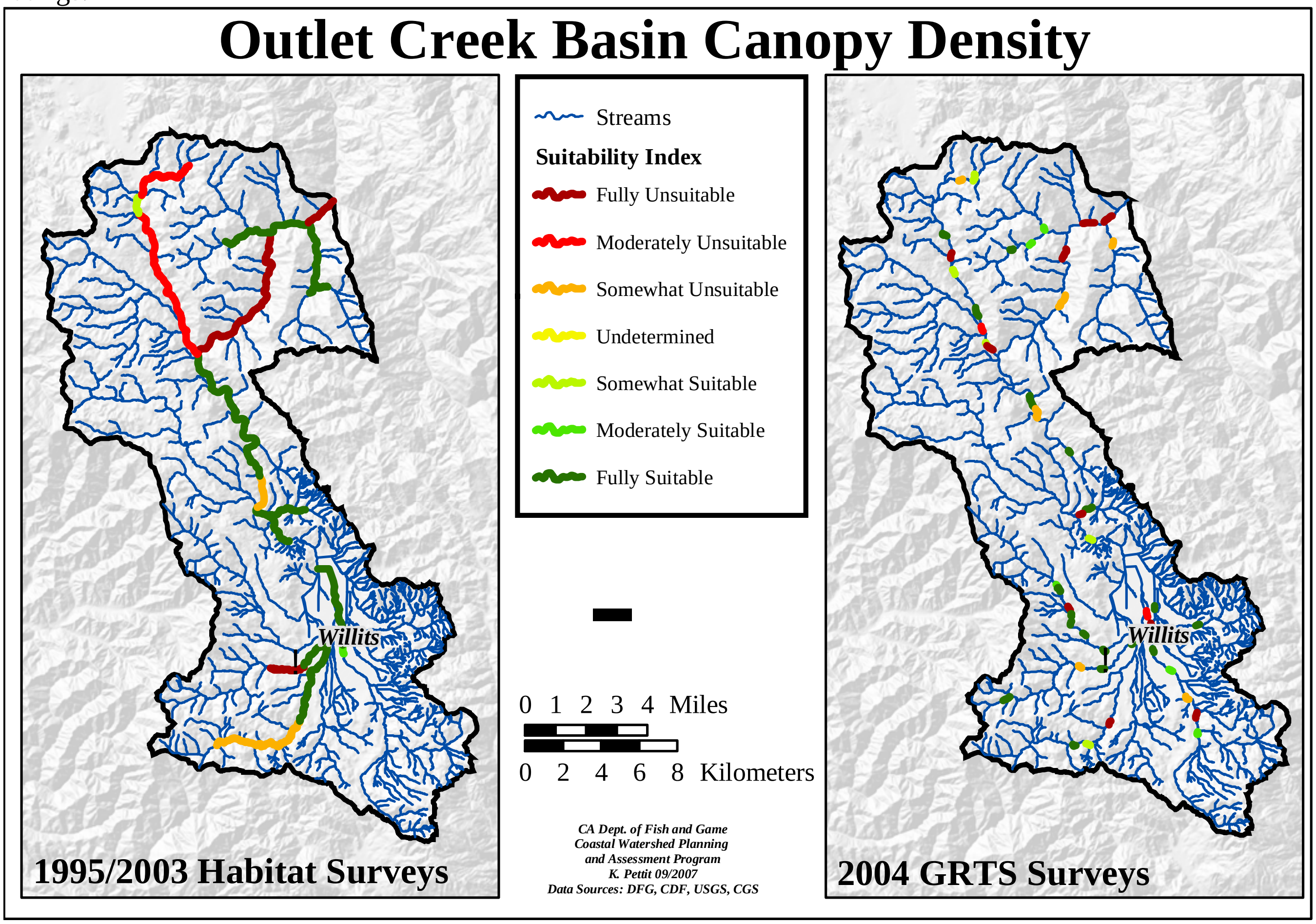


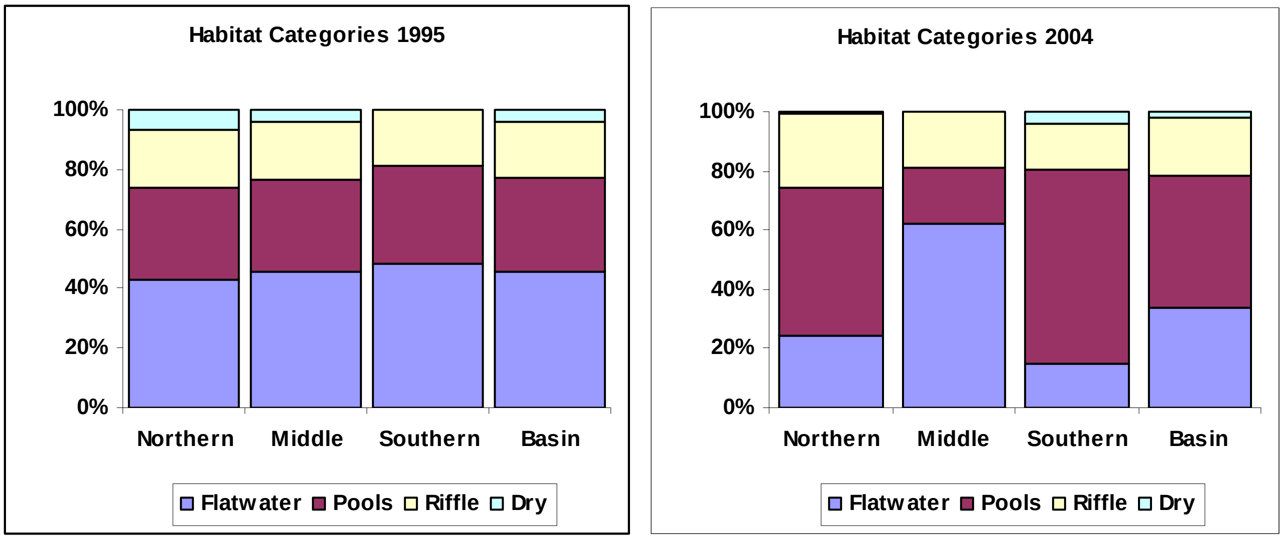
Figure X and Y. EMDS Canopy Density Suitability in the Outlet Creek Basin in 1995 and 2004

Habitat Categories

Streams with adequate amounts flatwater, pools, and riffles contribute to the health and productivity of juvenile salmonids (Flosi et al 1998).

Habitat diversity for salmonids is created by a combination of deep pools, riffles, and flatwater habitat types. Pools, and to some degree flatwater habitats, provide escape cover from high velocity flows, hiding areas from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas, particularly for young coho salmon. They are also necessary for adult resting areas. A high level of fine sediment fills pools and flatwater habitats. This reduces depths and can bury complex niches created by large substrate and woody debris. Riffles provide clean spawning gravels and oxygenate water as it tumbles across them. Steelhead fry use riffles during rearing. Flatwater areas often provide spatially divided pocket water units (Flosi et al. 1998) that separate individual juveniles, which helps promote reduced competition and successful foraging.

Between 1995 and 2004, the habitat ratio remained relatively unchanged overall in the Outlet Creek Basin. Between 1995 and 2004, pool habitat increased, while the flatwater, riffles, and dry units decreased in the Northern Subbasin. Between 1995 and 2004, flatwater increased, and pool, riffles, and dry units decreased in the Middle Subbasin. Between 1995 and 2004, flatwater decreased, pool habitat and dry units increased, while riffles remained unchanged. However, in 1995, the pool habitat measurements were averaged for all of the streams surveyed in the basin, whereas in 2004, 50 random sites were surveyed throughout the basin.



Figures X and Y. Percent of Habitat Categories in the Basin and Subbasins in 1995 and 2004.

Pool Habitat and Shelter

More frequent and deeper pools are associated with higher stream order. Target values are related to stream order and pool depth in that 1^{st} and $2nd^{t}$ order streams require 40% of the pools to be 2 feet deep and deeper and 3^{rd} order streams require to have 40% of the pools 3 feet deep and deeper. Pool shelter values of 100 are desirable. Large Woody Debris provides escape cover from predators (Flosi et al 1998).

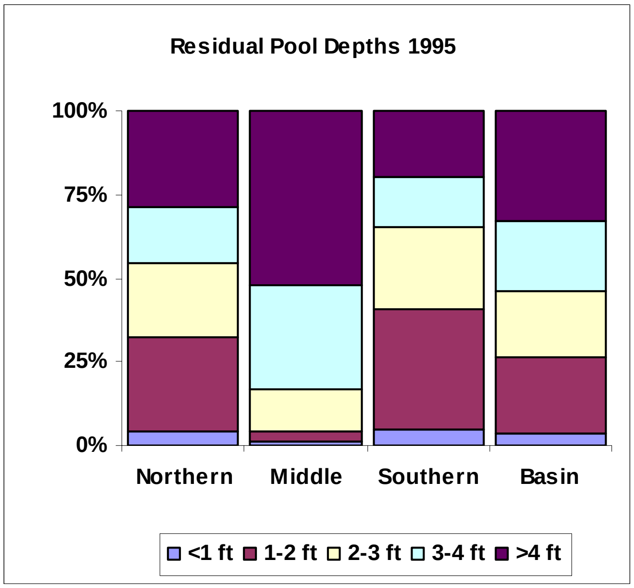
In 1995 and 2004, pools over 4 feet in depth were dominant in the Outlet Basin, while pools 1-2 feet in depth were dominant in 2004. Since pool frequency in relation to pool depth, is determined by individual stream order (40% of pools to be a certain depth), frequency cannot be assessed for Outlet Basin. However, overall pool depth percentages can be assessed. Between 1995 and 2004, the percentage of pools 3 feet and deeper has decreased, while pools 2 feet and less in depth have increased. However, in 1995, the pool habitat measurements were averaged for all of the streams surveyed in the subbasin, whereas in 2004, 50 random sites were surveyed throughout the basin.

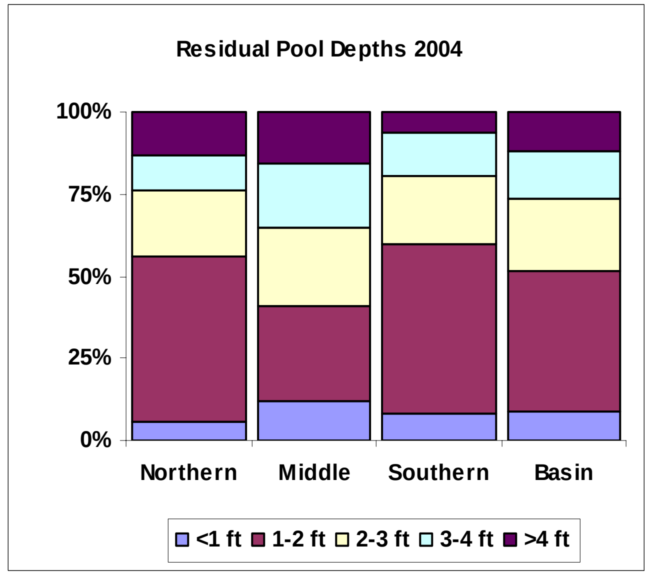
In 1995 and 2004, most of the pools surveyed in the Northern Subbasin surveyed were 1-2 feet. In 1995, pools 4 feet and over were prevalent where in 2004, pools 2-3 feet deep were common. Between 1995 and 2004, pool habitat appears to have decreased in the Northern Subbasin.

In 1995, pools over 4 feet in depth dominated the Middle Subbasin. In 2004, pools 1-2 feet in depth were prevalent while pools 2 feet and over were dominant. The overall depth of pools appears to have decreased between 1995 and 2004.

In 1995 and 2004, most of the pools surveyed in the Southern Subbasin were 1-2 feet deep. Between 1995 and 2004, the frequency of pools 2 feet and deeper decreased and pools 4 feet and deeper became uncommon.

Overall, the lack of deep pools is limiting the health and production of salmonids in the Outlet Basin. Pools 3 feet and deeper have decreased in each subbasin. In addition, pool depth does not incorporate water quality data. Poor water quality and high temperatures, as well as several legal and illegal sites where dewatering frequently occurred has reduced overall pool quality.





Figures X and Y. Average primary pools by maximum depth in the Basin and Subbasins in 1995 and 2004.

Ecological Management Decision Support (EMDS) Pool Depth Conditions

The anadromous Subbasin EMDS evaluates the condition of the pool depth. EMDS calculations and conclusions are pertinent only to surveyed streams in 1995 and the GRTS sites in 2004 and are based on conditions present at the time surveyed. EMDS scores were weighted by survey length to obtain overall scores for the streams and survey sites.

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In 1995 and 2004, the overall pool depth condition in the Outlet Basin was somewhat suitable and somewhat unsuitable, respectively. In 1995 and 2004, the overall pool depth condition in the Northern Subbasin was moderately suitable and somewhat unsuitable, respectively. In 1995 and 2004, the overall condition of the pool depth in the Middle Subbasin was fully and somewhat unsuitable, respectively. In 1995 and 2004, the overall conditions of pool depths in the Southern Subbasin were somewhat unsuitable. In 2004, 50 sites were surveyed, which include 19 in the Northern , 7 in the Middle, and 24 in the Southern subbasins. Out of the 50 sites, 18 were fully suitable, 1 was moderately suitable, 1 was somewhat suitable, 1 was undetermined, 1 was somewhat unsuitable, 4 were moderately unsuitable, and 24 were fully unsuitable (Figure X and Y. EMDS Pool Depth Suitability in the Outlet Creek Basin in 1995 and 2004).

The EMDS results show that the pool depth conditions in the basin have declined between 1995 and 2004. Major restoration efforts should be focused on improving pool depths and located in areas with unsuitable EMDS ratings.

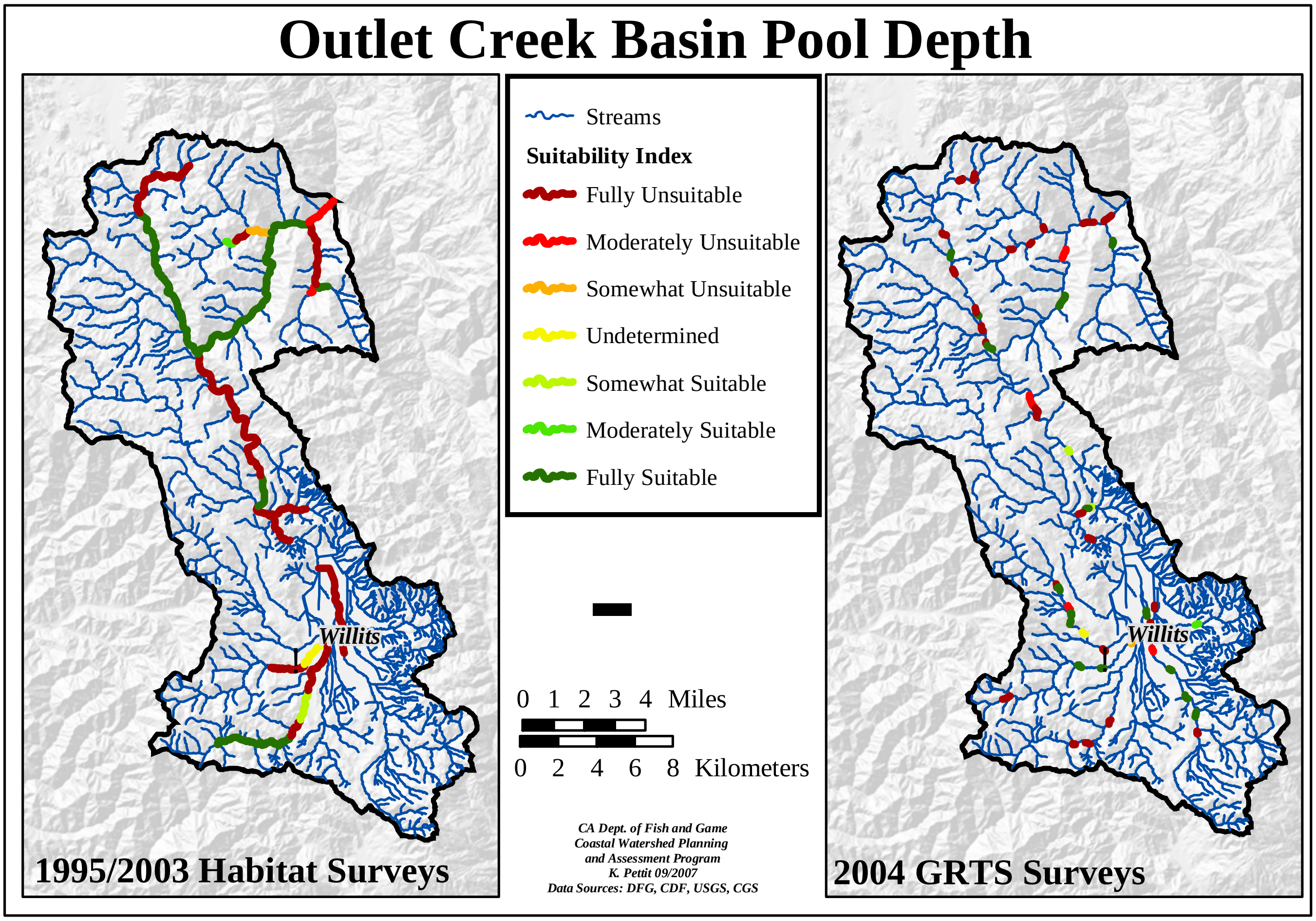


Figure X and Y. EMDS Pool Depth Suitability in the Outlet Creek Basin in 1995 and 2004.

In 1995 and 2004, the dominant sources of pool shelter were provided by terrestrial vegetation and boulders in the Outlet Basin. Bedrock ledges, aquatic vegetations, undercut banks, and small woody debris (SWD) were measured during both surveys. Large woody debris (LWD), white water and bedrock ledges provided the least shelter. However, in 1995, the pool shelter measurements were averaged for all of the streams surveyed in the subbasin, whereas in 2004, 50 random sites were surveyed throughout the basin (Figure X. Average frequency and source of pool shelter in the Outlet Creek Basin in 1995 and 2004).

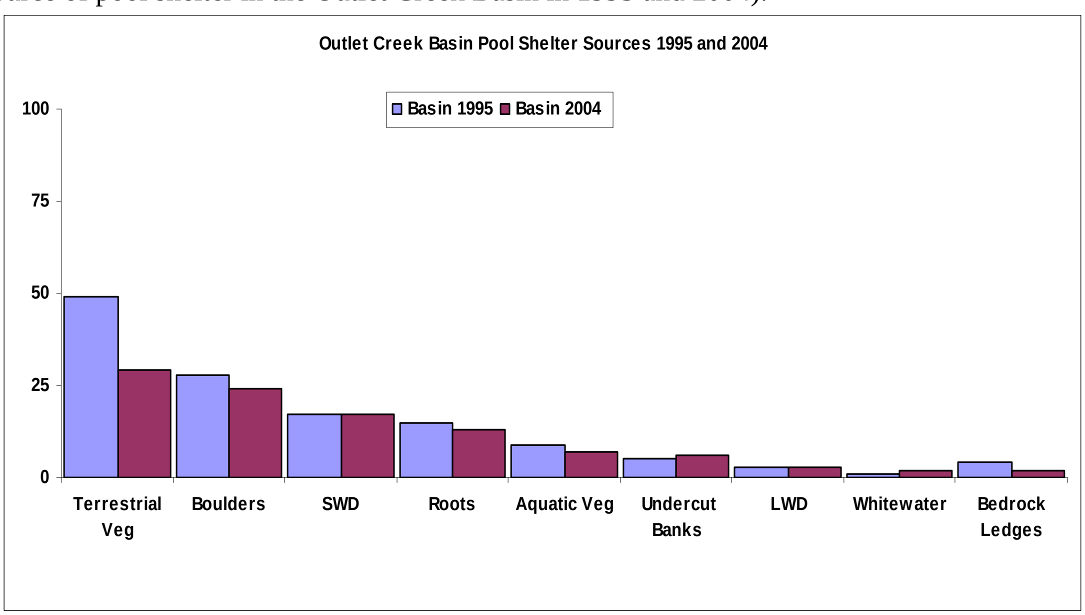


Figure X and Y. Average frequency and source of pool shelter in the Outlet Creek Basin in 1995 and 2004.

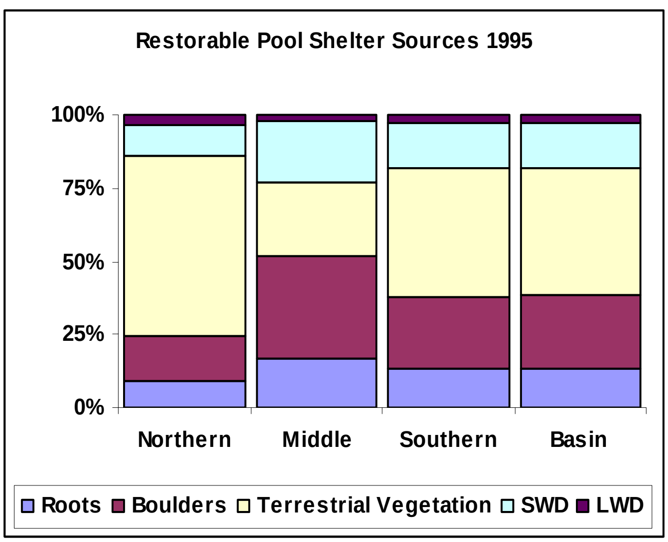
In both 1995 and 2004, the measured sources of pool shelter included boulders, terrestrial and aquatic vegetation, bedrock ledges, small and large woody debris, roots, undercut banks, and whitewater. Due to the restoration planning focus of this assessment, only restorable types such as roots, boulders, terrestrial vegetation, and small and large woody debris, were included in the below figures so that we could identify both the composition and dominate sources.

In both 1995 and 2004, boulders, terrestrial vegetation and SWD were dominant in the Northern Subbasin. The shelter values for the streams surveyed in both 1995 and 2004 were 28 and 34, respectively. The target values were not met in this subbasin during either of the years surveyed. This subbasin is lacking LWD and root wads, thus pool shelter composition could be greatly enhanced by adding these two types rather than boulders.

In 1995, boulders and terrestrial vegetation were dominant in the Middle Subbasin. In 2004, terrestrial vegetation and small woody debris (SWD) dominated the pool shelter. In 1995 and 2004, the Middle Subbasin did not meet pool shelter cover target values, with shelter values of 23 and 40, respectively. This subbasin is lacking LWD, pool shelter composition could be greatly enhanced by the addition of LWD in the subbasin.

In 1995, the dominant sources of pool shelter were provided by boulders and roots in the Southern Subbasin. In 2004, the dominant sources of pool shelter were provided by terrestrial vegetation and boulders. The shelter values for the streams surveyed in both 1995 and 2004 were 24 and 35, respectively. The target values were not met in this subbasin during either of the years surveyed. This subbasin is lacking LWD and root wads, thus pool shelter composition could be greatly enhanced by adding these two types rather than boulders (Figure X. and Y. Restorable pools shelter sources in the Outlet Creek Basin in 1995 and 2004).

Overall, since 1995, the target values were not met in the Outlet Basin. Although the target values were not met, the pool shelter has slightly improved in the basin. This may be indicative of recovery of the riparian since the adoption of the Forest Practice Rules. However, the amount of instream Large Woody Debris (LWD) has been very low. The lack of LWD is likely caused from legacy timber removal prior to the adoption of the Forest Practice Rules. The addition of this pool shelter type could greatly enhance the composition, as well as root wads, boulders, and terrestrial vegetation in areas where it is suitable. Pool shelter is limiting the health and production of salmonids in the Outlet Basin.



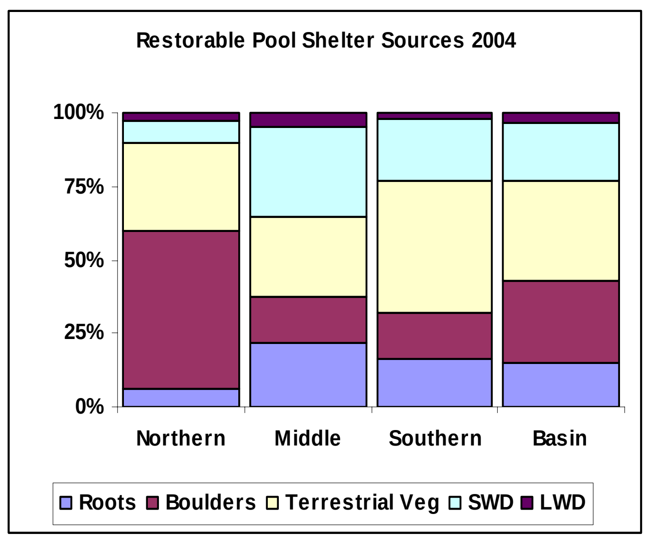


Figure X and Y. Restorable pools shelter sources in the Outlet Creek Basin in 1995 and 2004.

Ecological Management Decision Support (EMDS) Pool Shelter Conditions

The anadromous Subbasin EMDS evaluates the condition of the pool shelter. EMDS calculations and conclusions are pertinent only to surveyed streams in 1995 and 2003, and the GRTS sites in 2004 and are based on conditions present at the time surveyed. EMDS scores were weighted by survey length to obtain overall scores for the streams and survey sites.

In 1995 and 2004, the overall pool shelter condition in the Outlet Basin was moderately unsuitable. In 1995 and 2004, the overall pool shelter condition in the Northern Subbasin was moderately and somewhat unsuitable, respectively. In 1995 and 2004, the overall pool shelter condition in the Middle Subbasin was moderately unsuitable. In 1995 and 2004, the overall pool shelter conditions in the Southern Subbasin were moderately unsuitable. In 2004, 50 sites were surveyed, which include 19 in the Northern, 7 in the Middle, and 24 in the Southern subbasins. Out of the 50 sites, 6 were somewhat unsuitable, and 47 were moderately or fully unsuitable (Figure X and Y. EMDS Pool Shelter Suitability in the Outlet Creek Basin in 1995 and 2004).

The EMDS results show that pool shelter conditions in the basin have remained unchanged between 1995 and 2004. Most restoration efforts should be focused on improving pool shelter in areas with unsuitable EMDS ratings.

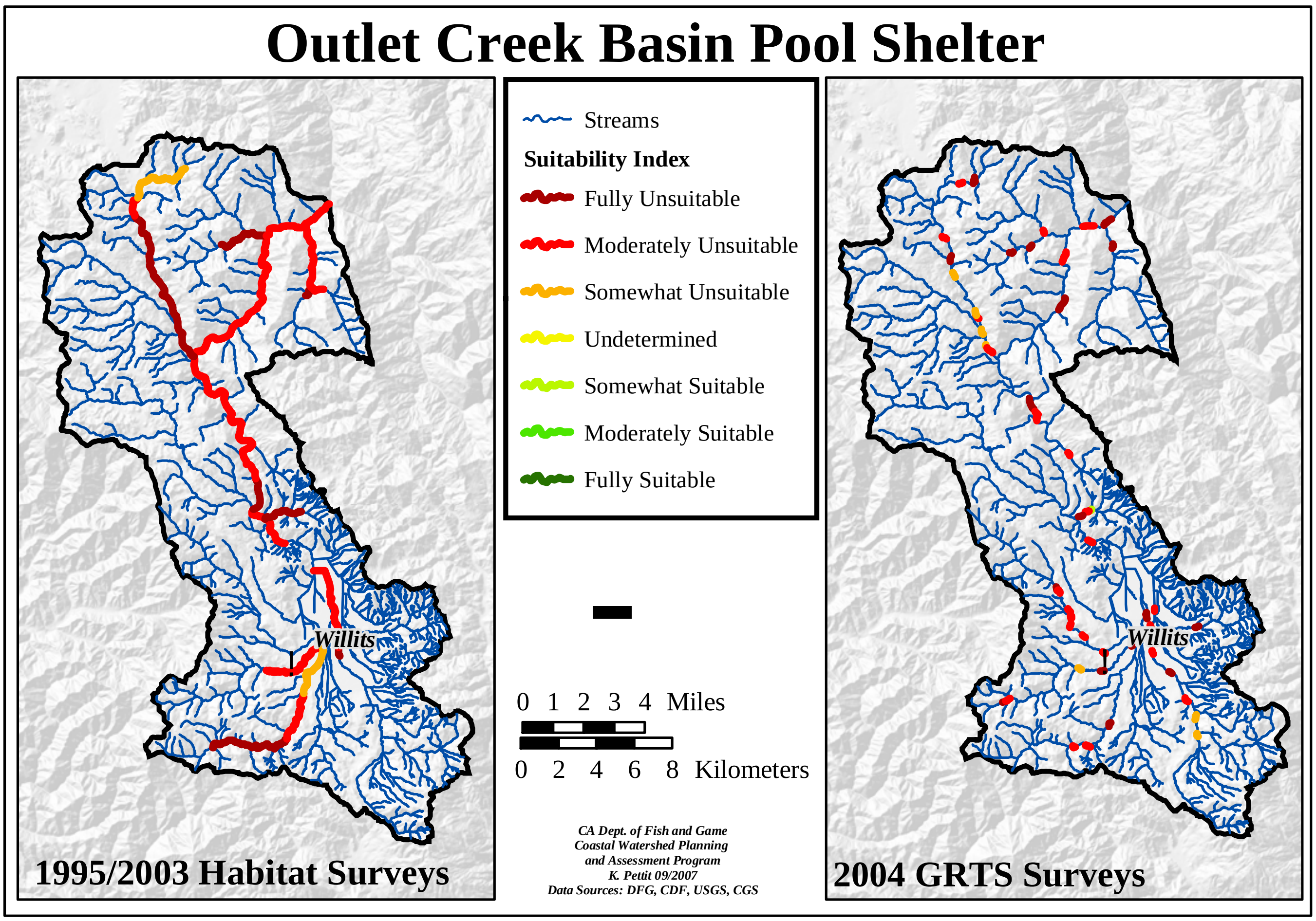


Figure X and Y. EMDS Pool Shelter Suitability in the Outlet Creek Basin in 1995 and 2004.

Ecological Management Decision Support (EMDS) Reach Conditions

The anadromous Subbasin EMDS evaluates the condition of stream reaches. EMDS calculations and conclusions are pertinent only to surveyed streams in 1995 and the GRTS sites in 2004 and are based on conditions present at the time surveyed. EMDS scores were weighted by survey length to obtain overall scores for the streams and survey sites.

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In 1995 and 2004, the overall reach condition in the Outlet Basin was somewhat unsuitable. In both 1995 and 2004, the overall reach conditions in the Northern, Middle and Southern subbasins were somewhat unsuitable. In 2004, 50 sites were surveyed, which include 19 in the Northern, 7 in the Middle, and 24 in the Southern subbasins. Out of the 50 sites, 3 were somewhat suitable, 1 was undetermined, and 46 were somewhat unsuitable (Figure X and Y. EMDS Reach Condition Suitability in the Outlet Creek Basin in 1995 and 2004)

The EMDS results show that the reach conditions in the Outlet Basin are unchanged between 1995 and 2004. Restoration efforts should be a high priority to improve conditions for juvenile salmonids, especially in Ryan Creek in the Middle Subbasin and Baechtel Creek in the Southern Subbasin due to the coho salmon populations there. Projects which focus on increasing canopy density, pool depth and pool shelter should be the highest priority. The introduction of LWD, anchored or not, would scour substrate thus deepening pools while simultaneously increasing shelter cover.

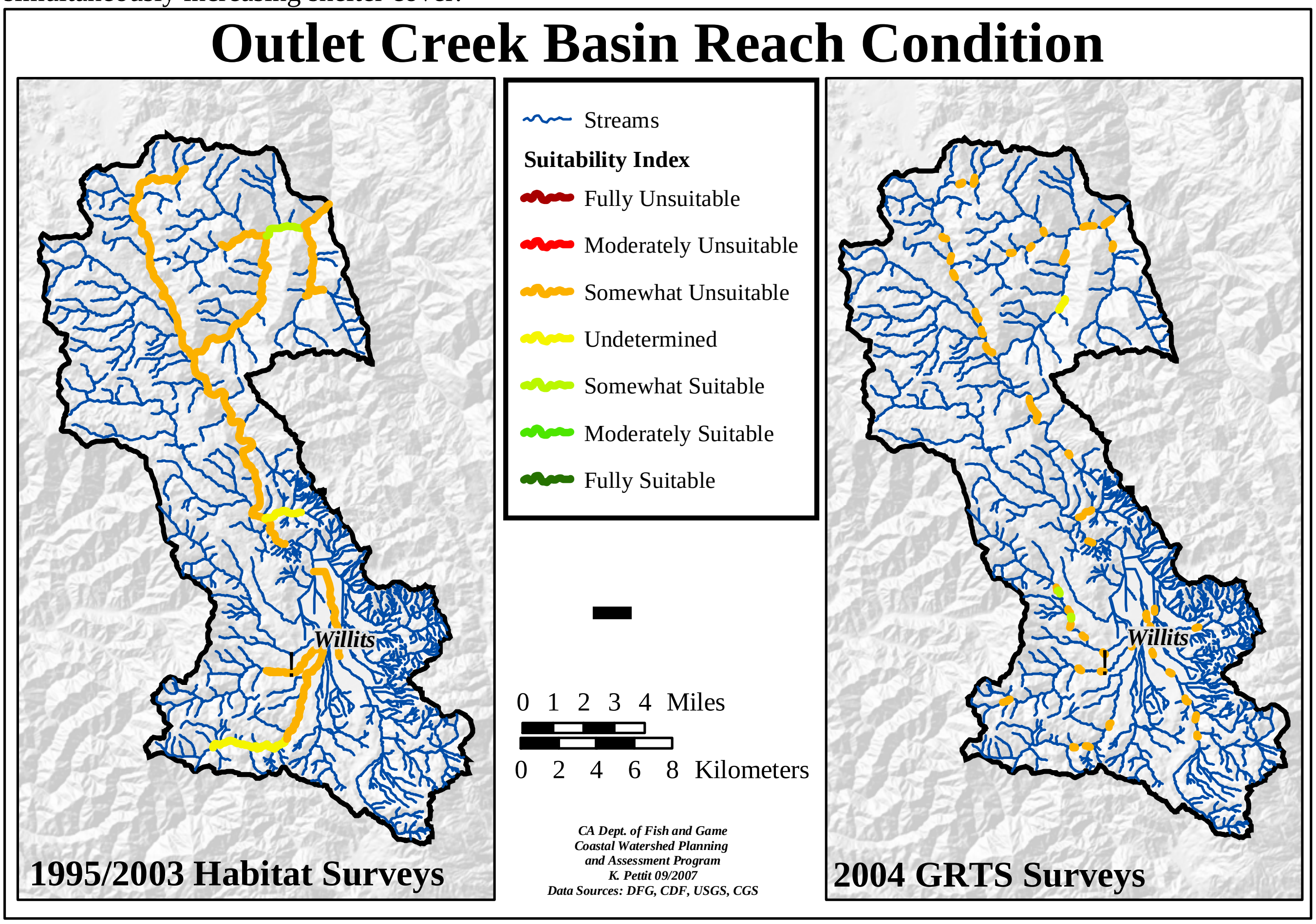

Figure X and Y. EMDS Reach Condition Suitability in the Outlet Creek Basin in 1995 and 2004.

Ecological Management Decision Support (EMDS) Basin Conditions

The anadromous Basin EMDS evaluates the condition for juvenile salmonids based upon overall water temperature (MWAT and/or instantaneous), canopy, pool quality, pool depth, pool shelter, and embeddedness conditions. EMDS calculations and conclusions are pertinent only to surveyed streams and are based on conditions present at the time surveyed.

EMDS scores were weighted by survey length to obtain overall scores for the tributaries, subbasins, and the entire Basin. Suitable conditions exist for canopy in both of the streams surveyed. Unsuitable conditions exist for reach, in channel, and pool shelter in all tributaries evaluated.

Table X: Ecological Management Decision Support (EMDS) Reach Model Scores anadromous reach condition model results the Outlet Creek Basin

Subbasin	***Canopy***	***Pool Depth***	***Pool Shelter***	***Embeddedness***
Northern	Somewhat Suitable	Somewhat Unsuitable	Somewhat Unsuitable	Somewhat Unsuitable
Middle	Somewhat Suitable	Somewhat Unsuitable	Somewhat Unsuitable	Fully Unsuitable
Southern	Fully Suitable	Somewhat Unsuitable	Somewhat Unsuitable	Fully Unsuitable
Basin	Somewhat Suitable	Somewhat Unsuitable	Somewhat Unsuitable	Somewhat Unsuitable