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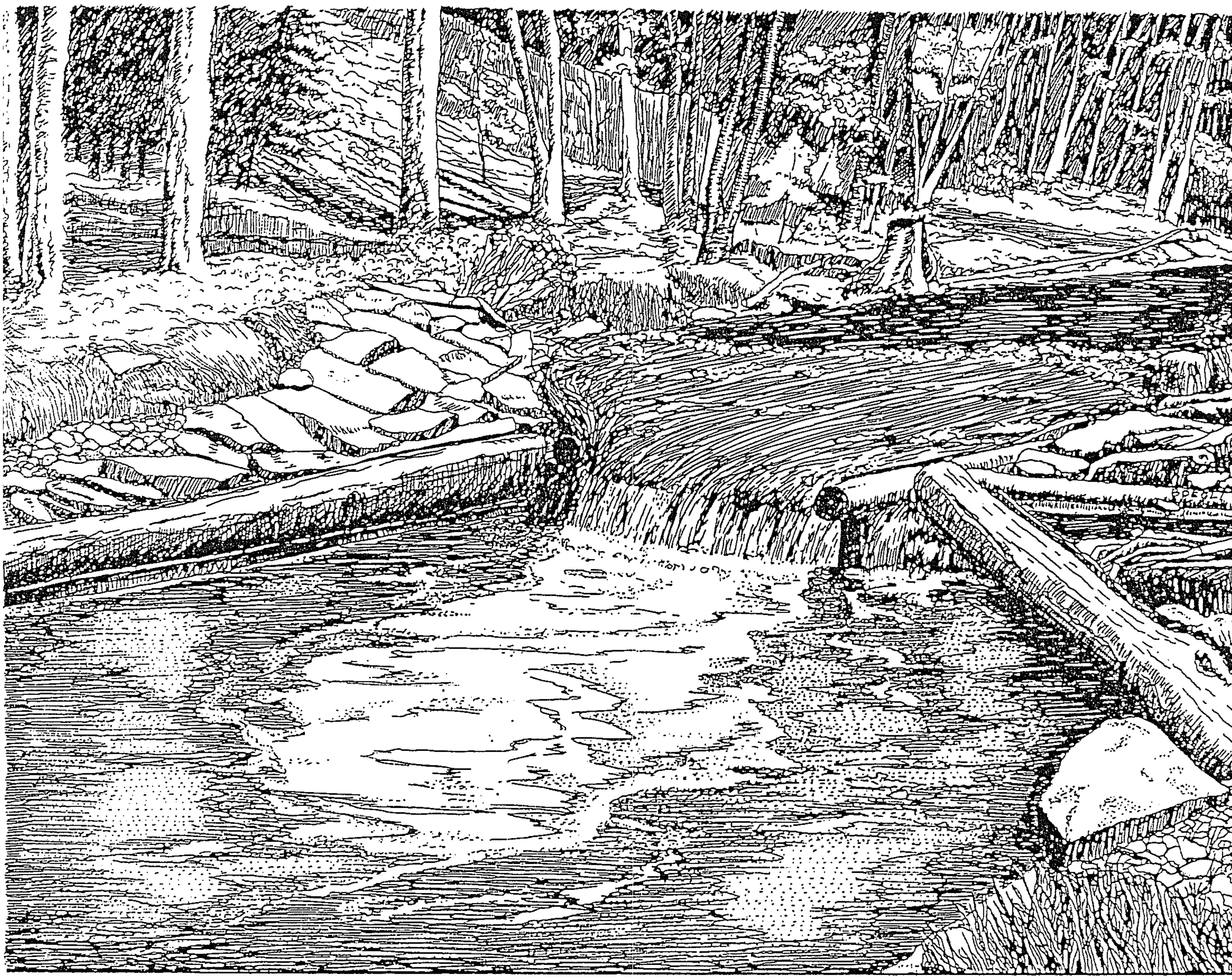

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THE 5TH TROUT STREAM HABITAT IMPROVEMENT WORKSHOP

AUGUST 12 - 14, 1986

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FISH HABITAT STRUCTURES - A SELECTION GUIDE USING STREAM CLASSIFICATION

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Abstract: Suitability guidelines are presented which evaluate various fish habitat improvement structures using a stream classification system. Results of fish habitat improvement structures often fall short of expectations due to adverse consequences of stream channel adjustments. These adjustments often result in accelerated stream aggradation, lateral migration, bank erosion, sedimentation, etc., creating actual reductions in habitat quality. Stream channels operate in a consistent and predictable manner and the knowledge of such channel response to artificially placed structures can be used to alter the design, placement or selection of various enhancement structures.

A universal stream channel classification system is used, based on the morphological criteria of gradient, width/depth ratio, sinuosity, nnel materials, channel confinement, entrenchment, soil, and landform. A guideline is developed which evaluates the suitability of a wide variety of commonly used structural enhancement designs over a wide range of stream types.

Fish habitat improvement projects are enjoying widespread application throughout the west. Trade-offs for proposed development involve mitigation focused on physical habitat enhancement. Flood damage as well as adverse impacts from land management activities are often responsible for deteriorated fish habitat conditions. Restoration plans generally include some type of structural fishery enhancement recommendations.

Often these structures meet with great success on certain streams and are total disasters on others. This occurs for a variety of reasons including, but not limited to; 1) poor understanding of river response as a result of installation of such structures, 2) lack of both field experience and/or documented procedural guidelines, 3) economic and time constraints which limit the amount of consultation and pre-project research, and 4) the lack of current state of the art knowledge in the applicability of those structures to various field conditions. All of these limitations serve to promote the "trial and error" method of application.

Integration of these stream enhancement projects with related disciplines such as hydrology, geomorphology, engineering, river mechanics, etc. has been slow due to the difficulty in the understanding and exchange of technical information. Many biologists have developed an "intuitive feel" after years of experience through trial and error. However, this knowledge is difficult to impart to others.

In order to bridge the communication and knowledge gap, all disciplines need a consistent frame of reference when describing channels. One such method is the channel classification system which catagorizes stream reaches into consistent descriptions of "channel types" based on morphological channel features (Rosgen, 1985).

A basic understanding of channel relations will assist fisheries biologists in selecting appropriate improvement designs for various streams. Channel patterns are self-developed and self-maintained such that any change in the variables responsible for such patterns sets up mutual adjustments within the channel. Changes in velocity, depth, width, channel materials, discharge, sediment supply, slope, etc., initiates a series of concurrent adjustments between these variables in order to seek an equilibrium or a "balance". Results of such adjustments often cause aggradation, degradation, lateral channel migration, accelerated bank erosion, floodplain and riparian vegetation encroachment, increased flooding with lower magnitude flows, increased sedimentation, and substrate material size shifts. These consequences of channel adjustments can often result in actual decreases in habitat quality, even though the initial adjustments were caused by in-channel structures designed to improve the habitat. Since streams follow the basic laws of physics, and habitat development is dependent on physical processes, the marriage of hydrological relationships and habitat enhancement is not only desirable but essential.

A guideline is presented which is designed to assist the fisheries biologist in evaluating suitability of various proposed fish habitat structures for a wide range of morphological stream "types". The main objective of the suitability guidelines is to bridge the gap between the "trial and error" methods and detailed engineering calculations for various installations. The guideline is not intended to determine what structure will be the most effective for improving a specific limiting factor, but rather insure the long term functioning of a particular structure. Within a given stream, the proper application for such a guideline is shown in the decision framework for habitat structure selection (Fig. 1).

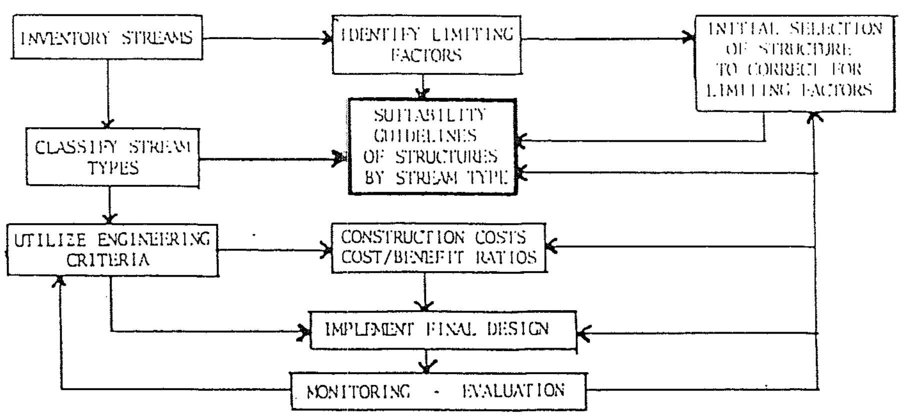

Fig. 1. Decision framework for habitat structure selection.

STREAM CLASSIFICATION

To predict a rivers behavior it is helpful to classify the stream in order to extrapolate data from streams of similar character. Data for the guidelines presented were obtained by classifying streams that contained a large assortment of enhancement structures in various hydro-physiographic regimes. The classification system was developed due to the need to; 1) predict a rivers behavior from its appearance, 2) extrapolate specific data collected on a given river reach to another of similar character and, 3) to provide a consistent and reproducible frame of reference for those working with river systems.

Since stream morphology is a result of an integrative process of mutually adjusting variables, those most directly measurable have been incorporated into the delineative criteria for stream types. Selection of the criteria for stream classification was developed from detailed analysis of hundreds of streams over many hydro-physiographic regions and from portions of existing classification schemes.

The stream type classification is summarized in detail in Table 1. Major stream types are classified, often from aerial photographs and topographic maps with some field measurements to verify the actual types. Stream sub-types or influences which alter patterns and interpretations are shown in Table 2. The guidelines presented utilize the major stream types only but may need further interpretations by using the sub-type criteria.

Interpretations such as sediment supply, ratio of bedload to suspended sediment, size of bedload transport, hydraulic geometry, stability, fish habitat potential, channel response to imposed changes, roughness coefficients and other river mechanics relations, etc., can be obtained from the classification procedure.

HABITAT IMPROVEMENT STRUCTURES

There is very little standardization for definitions of fish habitat improvement structures. Several names may be used to describe the same structure or a particular structure may have different design criteria in various locales. The descriptions below provide a standard frame of reference for the interpretations provided in the guideline.

Rearing Habitat Enhancement

<u>Low Stage Check Dam</u>.--One of the most common devices installed for fish habitat improvement are check dams (Fig. 2). Low stage dams are check dams that are placed low in the channel profile (generally less than 1/4 bankfull stage). These would more appropriately be termed a plunge or ledge rather than a dam because of their low height. These devices are not designed for pool formation above the structure but rather to form a plunge pool below. A variety of structures such as

Table 1. Delineative criteria for stream types

STREAM TYPE	GRADIENT	SINUOUSITY	W/D RATIO	DOMINANT PARTICLE SIZE OF CHANNEL MATERIALS	CHANNEL ENTRENCHMENT/ VALLEY CONFINEMENT	LANDFORM FEATURE - SOILS/STABILITY
A1	4-10	1.0-1.1	10 or less	Bedrock	Very deep/very well confined.	Deeply incised bedrock drainageway w/steep side slopes and/or vertical rock walls.
A1-a	10 +	(Criteria same as A1)				
A2	4-10	1.1-1.2	10 or less	Large & small boulders w/mixed cobble.	Same as A1	Steep side slopes w/predominantly stable materials.
A2-a	10 +	(Criteria same as A2)				
A3	4-10	1.1-1.3	10 or less	Small boulders, cobble, coarse gravel.	Same as A1	Steep, depositional features with predominantly coarse textured soils. Debris avalanche is the predominant erosional process. Stream adjacent slopes are rejuvenated with extensive exposed mineral soil.
A3-a	10 +	(Criteria same as A3)				
A4	4-10	1.2-1.4	10 or less	Predominantly gravel, sand, and some silts.	Same as A1	Steep side slopes w/mixture of either depositional landforms with fine textured soils such as glaciofluvial or glaciolacustrine deposits or highly erodable residual soils such as grussic granit, etc. Slump-earthflow and debris avalanche are dominant erosional processes. Stream adjacent slopes are rejuvenated.
A4-a	10 +	(Criteria same as A4)				
A5	4-10	1.2-1.4	10 or less	Silt and/or clay bed and bank materials.	Same as A1	Moderate to steep side slopes. Fine textured cohesive soils, slump-earthflow erosional processes dominate.
A5-a	10 +	(Criteria same as A5)				
B1-1	1.5-4.0	1.3-1.9	10 or greater ($\bar{X}$:15)	Bedrock bed, banks cobble, gravel, some sand.	Shallow entrenchment/moderate confinement.	Bedrock controlled channel with coarse textured depositional bank materials.
B1	2.5-4.0 ($\bar{X}$:3.5)	1.2-1.3	5-15 ($\bar{X}$:10)	Predominantly small boulders, very large cobble.	Moderately entrenched/well confined.	Moderately stable, coarse textured resistant soil materials. Some coarse river terraces.
B2	1.5-2.5 ($\bar{X}$:2.0)	1.3-1.5	8-20 ($\bar{X}$:14)	Large cobble mixed w/small boulders & coarse gravel.	Mod. entrenched/ Mod. confined.	Coarse textured, alluvial terraces with stable, moderately steep, side slopes.
B3	1.5-4.0 ($\bar{X}$:2.5)	1.3-1.7	8-20 ($\bar{X}$:12)	Cobble bed w/mixture of gravel & sand - some small boulders.	Mod. entrenched/ well confined.	Glacial outwash terraces and/or rejuvenated slopes. Unstable, moderate to steep slopes. Unconsolidated, coarse textured unstable banks. Depositional landforms.
B4	1.5-4.0 ($\bar{X}$:2.0)	1.5-1.7	8-20 ($\bar{X}$:10)	Very coarse gravel w/cobble mixed sand and finer material.	Deeply entrenched well confined.	Relatively fine river terraces. Unconsolidated coarse to fine depositional material. Steep side slopes. Highly unstable banks.
B5	1.5-4.0 ($\bar{X}$:2.5)	1.5-2.0	8-25 ($\bar{X}$:15)	Silt/clay.	Same as B4	Cohesive fine textured soils. Slump-earthflow erosional processes.

Table 1. Delineative criteria for stream types (continued).

STREAM TYPE	GRADIENT	SINUOUSITY	W/D RATIO	DOMINANT PARTICLE SIZE OF CHANNEL MATERIALS	CHANNEL ENTRENCHMENT/ VALLEY CONFINEMENT	LANDFORM FEATURE - SOILS/STABILITY
C1-1	1.5 or less ($\bar{X}$:1.0)	1.5-2.5	10 or greater ($\bar{X}$:30)	Bedrock bed, gravel, sand, or finer banks.	Shallow entrenchment, partially confined.	Bedrock controlled channel with depositional fine grained bank material.
C1	1.0-1.5 (X:1.3)	1.5-2.0	10 or greater ($\bar{X}$:18)	Cobble bed with mixture of small boulders & coarse gravel.	Mod. entrenched/ well confined.	Predominantly coarse textured, stable high alluvial terraces.
C2	0.3-1.0 ($\bar{X}$:0.6)	1.3-1.5	15-30 ($\bar{X}$:20)	Large cobble bed w/mixture of small boulders & coarse gravel.	Mod. entrenched/ well confined.	Overfit channel, deeply incised in coarse alluvial terraces and/or depositional features.
C3	0.5-1.0 ($\bar{X}$:0.3)	1.8-2.4	10 or greater ($\bar{X}$:25)	Gravel bed w/mixture of small cobble & sand.	Mod. entrenched/ slightly confined.	Predominantly moderate to fine textured multiple low river terraces. Unstable banks, unconsolidated, noncohesive soils.
C4	0.1-0.5 ($\bar{X}$:0.3)	2.5 +	5 or greater ($\bar{X}$:25)	Sand bed w/mixtures of gravel & silt (no bed armor).	Mod. entrenched/ slightly confined.	Predominantly fine textured, alluvium with low flood terraces.
C5	1.0 or less ($\bar{X}$:.05)	2.5 +	5 or greater ($\bar{X}$:10)	Silt/clay w/mixtures of medium to fine sands (no bed armor).	Mod. entrenched/ slightly confined.	Low, fine textured alluvial terraces, delta deposits, lacustrine, loess or other fine textured soils. Predominantly cohesive soils.
C6	0.9 or less ($\bar{X}$:.05)	2.5 +	3 or greater ($\bar{X}$:5)	Sand bed w/mixture of silt & some gravel.	Deeply entrenched/slightly confined.	Same as C4 except has more resistant banks.
D1	1.0 or greater ($\bar{X}$:2.5)	N/A Braided	N/A	Cobble bed w/mixture of coarse gravel & sand and small boulders.	Slightly entrenched/no confinement.	Glacial outwash, coarse depositional material, highly erodable. Excess sediment supply of coarse size material.
D2	1.0 or less ($\bar{X}$:1.0)	N/A Braided	N/A	Sand bed w/mixture of small to medium gravel & silts.	Slightly entrenched/no confinement.	Fine textured depositional soils, very erodable - excess of fine textured sediment.

Table 2. Delineative criteria for stream sub-types

ORGANIC DEBRIS/Channel Blockages (in Active Channel)

D-1 None

D-2 Infrequent debris, what's present consists of small, floatable organic debris.

D-3 Moderate frequency, mixture of small to medium size debris affects less than 10% of active channel area.

D-4 Numerous debris mixture of medium to large sizes - affecting up to 30% of the area of the active channel.

D-5 Debris dams of predominantly large material affecting over 30% to 50% the channel area and often occupying the total width of the active channel.

D-6 Extensive, large debris dams either continuous or influencing over 50% of channel area. Forces water onto flood plain even with moderate flows. Generally presents a fish migration blockage.

D-7 Beaver dams - few and/or infrequent. Spacing allows for normal streamflow conditions between dams.

D-8 Beaver dams - frequent. Back water occurs between dams - stream flow velocities reduced between dams.

D-9 Beaver dams - abandoned where numerous dams have filled in with sediment and are causing channel adjustments of lateral migration, evulsion, and degradation etc.

D-10 Man made structures - diversion dams, low dams, controlled by-pass channels, baffled bed configuration with gabions, etc.

RIPARIAN VEGETATION

V1 - Rock

V2 - Bare soil, little to no vegetative cover

V3 - Annuals, forbs

V4 - Grass - perennial bunch grasses

V5 - Grass - sod formers

V6 - Low brush species

V7 - High brush species

V8 - Coniferous trees

V9 - Deciduous trees

V10 - Wetlands

a. bog
b. fen
c. marsh

Note: Combinations of grass and brush understories with a coniferous overstory can be designated by combining sub-type numbers, i.e., (V4,7,8.)

Subscript letters may be used to identify specific vegetative associations, speciation, habitat types, or riparian types based on level of detail required by stream type user.

STREAM SIZE (S)

S-1 Bankfull width less than 1 foot.

S-2 Bankfull width 1-5.

S-3 Bankfull width 5-15.

S-4 Bankfull width 15-30.

S-5 Bankfull width 30-50.

S-6 Bankfull width 50-75.

S-7 Bankfull width 75-100.

S-8 Bankfull width 100-150.

S-9 Bankfull width 150-250.

S-10 Bankfull width 250-350.

S-11 Bankfull width 350-500.

S-12 Bankfull width 500-1000.

S-13 Bankfull width 1000+.

FLOW REGIMEN

<u>General Category</u>

E. - Ephemeral stream channels - flows only in response to precipitation.

S. - Subterranean stream channel - flows parallel to and near the surface for various seasons - a sub-surface flow which follows the stream channel bed.

I. - Intermittent stream channel - one which flows only seasonally, or sporadically. Surface sources involve springs, snow melt, artificial controls, etc.

P. - Perennial stream channels. Surface water persists year long.

<u>Specific Category</u>

1. Seasonal variation in streamflow dominated primarily by snowmelt runoff.
2. Seasonal variation in streamflow dominated primarily by stormflow runoff.
3. Uniform stage and associated streamflow due to spring fed condition, backwater etc.
4. Stream flow regulated by glacial melt.
5. Regulated stream flow due to diversions, dam release, dewatering, etc.

DEPOSITIONAL FEATURES (BARS)

B-1 Point Bars

B-2 Point Bars with Few Mid Channel Bars

B-3 Many Mid Channel Bars

B-4 Side Bars

B-5 Diagonal Bars

B-6 Main Branching with Many Mid Bars and Islands

B-7 Mixed Side Bar and Mid Channel Bars Exceeding 2-3X Width

B-8 Delta Bars

MEANDER PATTERNS

M-1 Regular Meander

M-2 Tortuous Meander

M-3 Irregular Meander

M-4 Truncated Meanders

M-5 Unconfined Meander Scrolls

M-6 Confined Meander Scrolls

M-7 Distorted Meander Loops

M-8 Irregular with Oxbows, Oxbow Cutoffs straight log weirs, diagonal log weirs, K dams, wedge dams, overpour ramps, etc., are evaluated under this description since the channel adjustments are similar. Low stage dams are normally placed in long shallow riffles on straight reaches and meanders.

Medium Stage Check Dam.--Another type of check dam are those placed higher in the channel profile (up to 3/4 bankfull). These are also plunge pool forming structures such as trash catchers, gabion dams, log dams, etc.

Boulder Placement.--A very common method of fish habitat improvement is the placement of boulders intended to provide instream cover(Fig. 3). Velocities are increased such that a scour pool develops around the structure. Boulders are often placed in groups or singly in a "random" fashion. Minimum size rock depends upon maximum velocities at the site but generally two to three feet diameter or larger boulders are utilized. They are generally placed in riffles and glides but are also occasionally placed in pools for added cover.

Bank Placed Material.--Bank placed materials (boulders, root wads, logs, etc.) are installed for dual purposes, i.e., to provide cover and pools similar to that provided by instream boulder placement and also to protect unstable banks. These structures act as small deflectors diverting high flows away from unstable banks and creating small pockets of back water that provide fish resting areas. Bank placed materials can be placed alone or in series along the bank, generally along the outside bend of meanders. They are keyed into the bank so that high velocity flows cannot scour behind or underneath them.

Single Wing Deflectors.--These commonly used devices are installed to direct stream flows, increase velocities and form small pools (Fig. 4). They are also used to direct high flow away from unstable banks. The guideline will evaluate deflectors built in a triangular shape. Single wing deflectors are often used in conjunction with other structures such as boulder placement and bank cover structures.

Double Wing Deflectors.--The objective of double deflectors is to narrow the channel and increase velocities such that a deep scour pool develops in the center of the channel. They are constructed by installing two single wing deflectors opposite each other reducing channel width by 40 to 80% (Fig. 5).

Channel Constrictor.--This structure is very similar to a double wing deflector in that it is designed to narrow and deepen the channel (Fig. 6). These structures are either paired or placed alone. Channel width is generally reduced up to 80%.

Bank Cover.--Bank cover structures are installed to create an undercut bank effect thus providing hiding cover for adult trout (Fig. 7). They are built along the outside bends or along straight reaches in conjunction with deflectors so that they always have adequate water depth below. They can be built with extensive planking as illustrated by White (1967), the modified version presented by Hunt (1980) or simply with log construction as shown by Seehorn (1985).

Floating Log Cover.--One simple method of cover development is the installation of floating logs (Fig. 8). These structures generally consist of two or more tree boles, fastened together and cabled to the bank, or to a streamside or instream boulder and are free to float and drift with rising and falling stage. They are generally placed over pools, backwater areas or along meanders to provide overhead protection.

Submerged shelters.--Submerged shelters such as whole trees, tree tops, shrubs, or brush piles are another simple structure placed in the channel to provide overhead cover (Fig. 9). These structures also provide ideal substrate for aquatic organisms (Seehorn, 1985). The guideline rates structures placed on meanders and straight sections separately due to different potential channel adjustments.

Half Log Cover.--Half log structures are used to provide overhead cover for adult trout (Hunt, 1977). They are built with 8 to 12 inch diameter logs split lengthwise, placed upon 6 inch spacer blocks and then anchored to the stream bottom (Fig. 10). They are placed parallel or at a slight angle to stream flow and positioned at or adjacent to the thalweg. They are generally placed in a riffle-run (deep glide) or a riffle with adequate depth to keep the structure submerged.

Migration Barrier.--These structures are installed to protect native fish populations in headwater streams from nonnative fish populations by blocking upstream fish migration (Fig. 11). They are designed to create an impassable falls generally 4 to 6 feet in height.

Spawning Habitat Enhancement

V Shaped Gravel Traps.--Gravel traps are used where streams have an adequate supply of gravel but have little instream structure such as fallen trees, debris, etc to trap gravel. Reeves and Roelofs (1982) described these structures used at Coos Bay, Oregon to retain spawning for anadromous fish (Fig. 12). The "V" shaped structures are placed with the apex downstream in a series of two or more. The upper structure dissipates water velocities and the lower collects and retains gravels.

Log Sill Gravel Traps.--Another type of gravel trap utilized by west coast biologists is the log sill (Fig. 13). These are very similar to low stage dams in design and materials but they are built for gravel accumulation rather than for pool formation. Thus, these structures are generally placed very low (less than 10% of bankfull stage).

Gravel Placement.--Another method of spawning habitat enhancement employed by several west coast biologist is the introduction of appropriate size gravel (Reeves and Roelofs, 1982). Clean river gravel is placed in riffles covering at least two square feet. This technique does not utilize any structural devices but is evaluated in regard to its applicability by channel type.

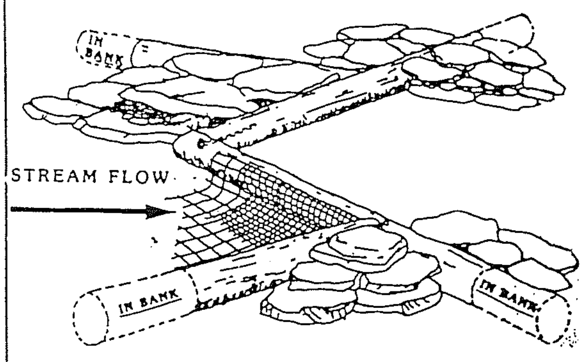

Fig. 2. Low stage check dam (Seehorn, 1985).

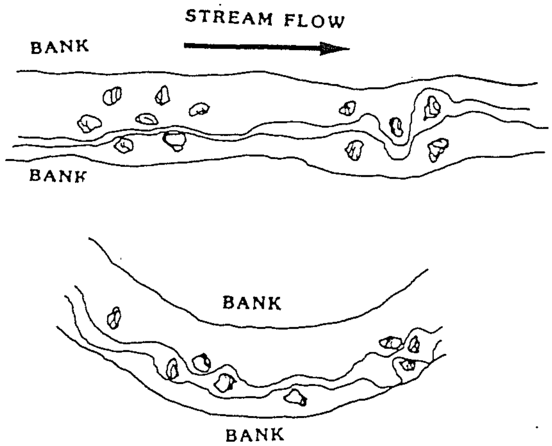

Fig. 3. Boulder placement (U.S. Dept. Transportation, 1979).

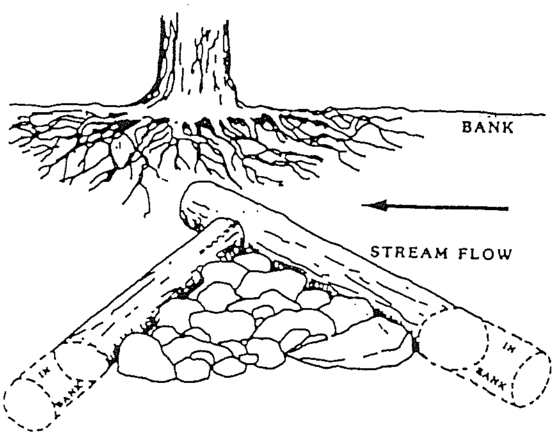

Fig. 4. Single wing deflector (Seehorn, 1985).

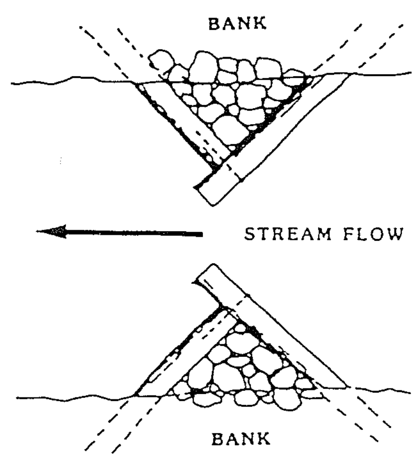

Fig. 5. Double wing deflector (Seehorn, 1985).

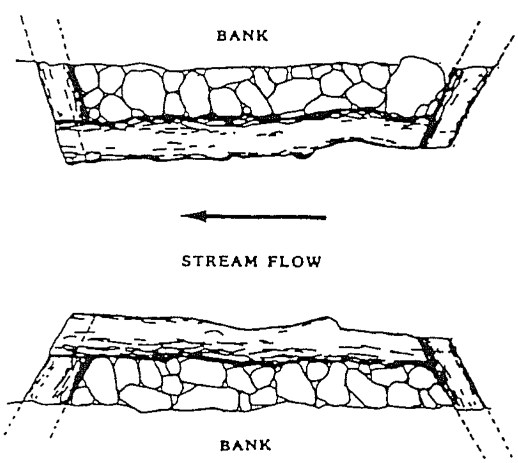

Fig. 6. Channel constrictor (Seehorn, 1985).

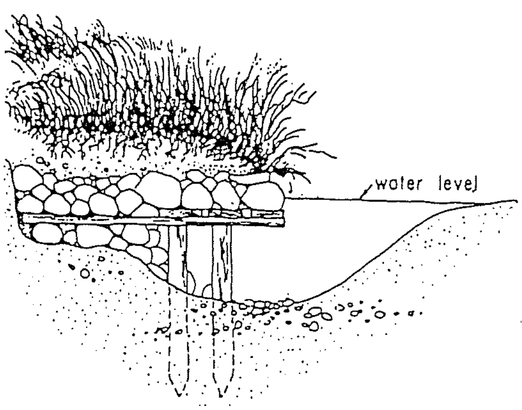

Fig. 7. Bank cover (White, 1967).

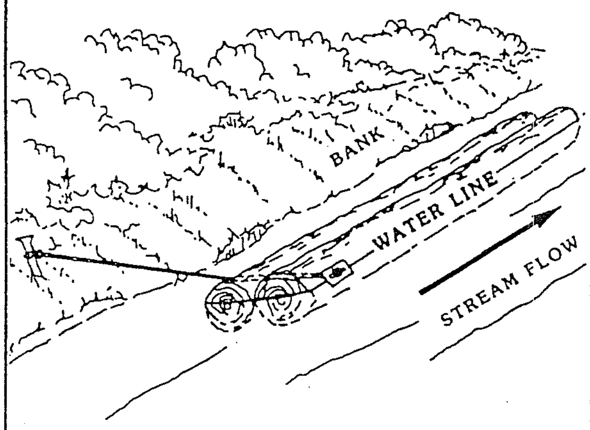

Fig. 8. Floating log cover.

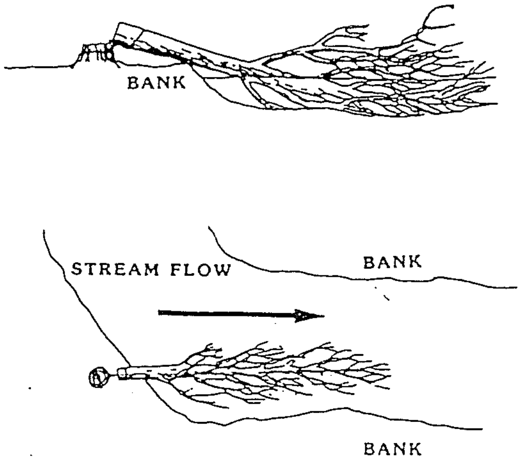

Fig. 9. Submerged sheltors (Seehorn, 1985).

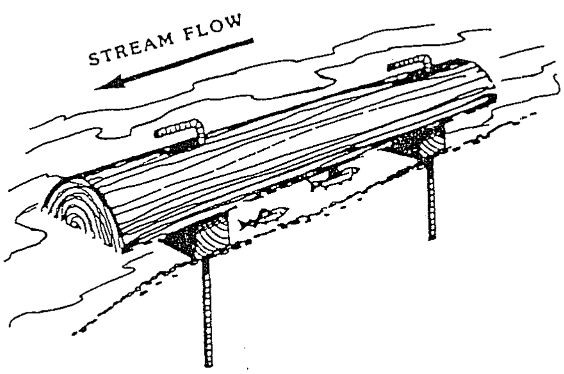

Fig. 10. Half log cover (Hunt, 1977).

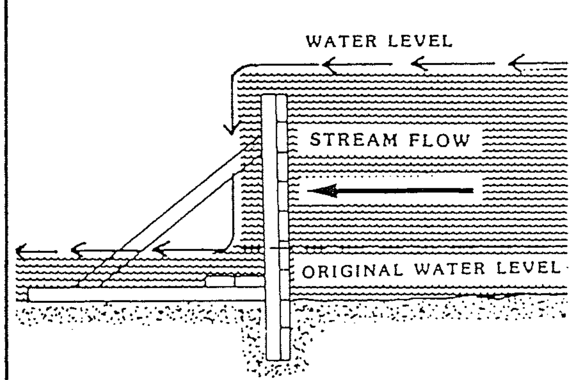

Fig. 11. Migration barrier (Culver, 1985).

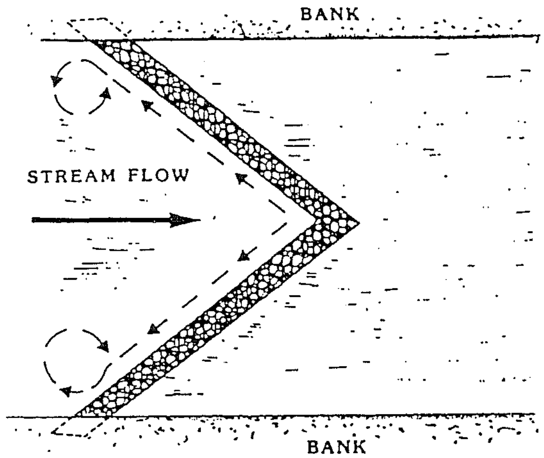

Fig. 12. V shaped gravel trap (Reeves and Roelofs, 1982).

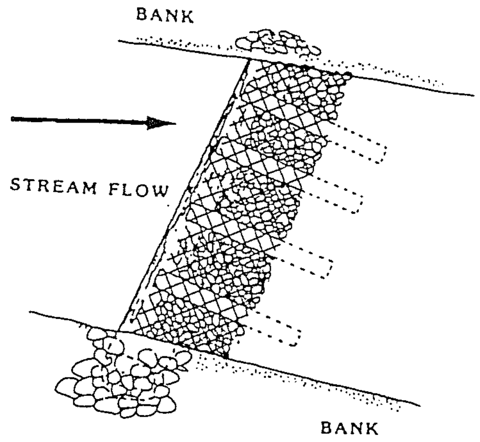

Fig. 13. Log sill gravel trap (Reeves and Roelofs, 1982).

APPLICATION OF GUIDELINES

The generalized rating scheme shown in Tables 3 and 4 evaluates the potential effectiveness of fish habitat improvement structures based on the morphology of the stream types involved. It is based on actual observations of such structures by stream type, reflecting both good and good applications of a given structure for a particular stream type. These are only guidelines and are meant to provide general direction or highlight potential problems. They are not intended to be "fixed" or evolve into "hard rules". They in no way substitute for the services of a fisheries biologist and hydrologist in planning enhancement projects. The guideline may, however, "red flag" some potential problem areas to necessitate more detailed, site-specific analysis prior to design selection.

The interpretations of this subjective rating scheme of excellent, good, fair and poor are described in Table 3. These ratings do not reflect on; 1) the biological effectiveness for meeting limiting factors of habitat, 2) costs or difficulty of construction or 3) cost/benefit relationships.

Table 3. Fish habitat improvement structures - suitability to stream types.

CHANNEL TYPE	LOW ST CH DAMS	MED ST CH DAMS	BOULDER PLACEMT	BANK PLC BOULDER	SINGLE WG DEFLECTOR	DOUBLE WG DEFLECTOR	CHANNEL CONSTRTOR	BANK COVER	HALF LOG COVER	FLOATING LOG COV	SUBMERGED SHELTOR MEANDER	SUBMERGED SHELTOR STRAIGHT	MIGRATION BARRIER	GRAVEL TRAPS 'V' SHAPED	GRAVEL TRAPS LOG SILL	GRAVEL PLACEMT
A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	EXC	GOOD	POOR	POOR
A2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	EXC	EXC	EXC	POOR
B1-1	POOR	POOR	GOOD	EXC	POOR	POOR	POOR	GOOD	GOOD	GOOD	GOOD	EXC	FAIR	GOOD	GOOD	FAIR
B1	EXC	EXC	N/A	N/A	EXC	EXC	N/A	EXC	GOOD	EXC	EXC	EXC	EXC	EXC	EXC	FAIR
B2	EXC	GOOD	EXC	EXC	EXC	EXC	EXC	EXC	EXC	EXC	GOOD	EXC	GOOD	GOOD	GOOD	GOOD
B3	FAIR	POOR	POOR	GOOD	POOR	POOR	POOR	POOR	POOR	FAIR	FAIR	FAIR	POOR	POOR	POOR	POOR
B4	FAIR	POOR	POOR	GOOD	POOR	POOR	POOR	POOR	POOR	FAIR	FAIR	FAIR	POOR	POOR	POOR	POOR
B5	FAIR	POOR	POOR	GOOD	POOR	POOR	POOR	POOR	POOR	FAIR	FAIR	FAIR	POOR	POOR	POOR	POOR
C1-1	POOR	POOR	FAIR	EXC	POOR	POOR	POOR	GOOD	GOOD	GOOD	GOOD	EXC	POOR	FAIR	FAIR	FAIR
C1	GOOD	FAIR	FAIR	EXC	GOOD	GOOD	FAIR	GOOD	GOOD	GOOD	GOOD	EXC	POOR	FAIR	GOOD	FAIR
C2	EXC	GOOD	GOOD	EXC	GOOD	EXC	EXC	GOOD	GOOD	EXC	EXC	EXC	POOR	GOOD	EXC	EXC
C3	FAIR	POOR	POOR	GOOD	FAIR	FAIR	FAIR	GOOD	FAIR	GOOD	FAIR	GOOD	POOR	N/A	N/A	N/A
C4	FAIR	POOR	POOR	GOOD	POOR	POOR	POOR	FAIR	POOR	GOOD	FAIR	GOOD	POOR	POOR	POOR	POOR
C5	FAIR	POOR	POOR	GOOD	POOR	POOR	POOR	POOR	POOR	GOOD	FAIR	GOOD	POOR	POOR	POOR	POOR
C6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	POOR	POOR	FAIR	FAIR
D1	FAIR	POOR	POOR	FAIR	FAIR	FAIR	FAIR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	N/A	POOR
D2	FAIR	POOR	POOR	FAIR	FAIR	FAIR	FAIR	POOR	POOR	POOR	POOR	POOR	POOR	N/A	POOR	POOR

Key:

EXCELLENT - No limitation to location of structure placement or special modification in design.

GOOD - Under most conditions, very effective. Minor modification of design or placement required.

FAIR - Serious limitations which can be overcome by placement location, design modification or stabilization techniques. Generally not recommended due to difficulty of offsetting potential adverse consequences and high probability of reduced effectiveness.

POOR - Not recommended due to morphological character of stream type and very low probability of success.

NOT APPLICABLE - Generally not considered since habitat components are not limiting.

NOTE - A3, A3-a, A4, A4-a, A5, A5-a channel types are not evaluated due to limited fisheries values.

Table 4. Limitations and discussions of various fish habitat improvement structures by stream types.

REARING HABITAT ENHANCEMENT

LOW STAGE CHECK DAM

Rating	Channel Types	Limitations/Discussion
Exc.	B1, B2, C2	No limitations.
Good	C1	Bank erosion due to lateral migration will occur unless bank stabilization is utilized.
Fair	B3, B4, B5, C3, C4, C5, D1, D2	Low dams must be constructed in conjunction with bank stabilization in these channel types. Use in conjuction with confinement measures and bank stabilization to reduce lateral migration.
Poor	B1-1, C1-1	Bedrock streambed limits the development of pools.
N/A	A1, A2, C6,	Pools not limiting in these stream types.

MEDIUM STAGE CHECK DAMS

Rating	Channel Types	Limitations/Discussion
Exc.	B1	No limitations.
Good	B2, C2	Stage increase will result in floodplain encroachment. Limit dam height to less than 75% of bankfull stage and select sites with high stable banks.
Fair	C1,	Banks must be adequately protected both up and downstream of structure.
Poor	B3, B4, B5 C3, C4, C5 D1, D2	Increased stream aggradation accelerated bank erosion, slope rejuvenation and floodplain encroachment can result. Extensive bank stabilization measures must accompany installation. Exceptions are on headwater streams in ephemeral channels to stop gully headcuts.
	B1-1, C1-1	Bedrock streambed limits pool scour depth.
N/A	A1, A2, C6	Pools not limiting factor in these channel types.

BOULDER PLACEMENT

Rating	Channel Types	Limitations/Discussion
Exc.	B2	No limitations.
Good	B1-1 C2	Lower gradient provides more opportunity for bar development up and downstream of rock - unless placed on meander points (See Bank Placed Rock). Use in conjuction with deflectors to increase velocity sufficient to create pools.
Fair	C1-1 C1	Bedrock limits bed scour. Potential bar deposition and lateral migration can be offset by stabilizing the banks and by strategic placement. Due to bed armor and flatter gradients, it is advantageous to create deep pools with a combination of deflectors, boulders and/or rock clusters.
Poor	B3, B4, B5 C3, C4, C5 D1, D2	The high sediment supply and highly unstable banks limit the effectiveness of boulders placed in the active channel (other than along banks). Bar deposition up and downstream of boulder and excessive bank erosion often occur. Deflectors can reduce sediment deposition.
N/A	A1, A2, B1, C6	Large boulder and/or pools are not a limiting factor in these channel types.

BANK PLACED BOULDER

Rating	Channel Types	Limitations/Discussion
Exc.	B1-1, B2, C1 C1-1, C2	No limitations.
Good	B3, B4, B5, C3, C4, C5	Boulders must be keyed into the bank on "confined" stream types.
Fair	D1, D2	Difficult to locate thalweg channel and where the banks will be inundated from one year to another.
Poor		
N/A	A1, A2, B1	Bank rock and streamside boulders naturally occur and banks are naturally stable.
	C6	Cover and pools not limiting in this channel type.

Table 4. Limitations and discussions of various fish habitat improvement structures by stream types (continued).

SINGLE WING DEFLECTOR

Rating	Channel Types	Limitations/Discussion
Exc.	B1, B2	No limitations.
Good	C1 C2	May need bank stabilization.
Fair	C3	Must be done with corresponding bank protection.
	D1, D2	Extensive construction may be needed to gain confinement of the active channel.
Poor	B3, B4, B5, C4, C5	Channel instability and high sediment supply reduces effectiveness.
	B1-1, C1-1	Bedrock bed limits effectness.
N/A	A1, A2, C6	Pools not a limiting factor.

DOUBLE WING DEFLECTOR

Rating	Channel Types	Limitations/Discussion
Exc.	B1, B2, C2	No limitations.
Good	C1	May need bank stabilization in conjuction with double deflector.
Fair	C3 D1, D2	Need bank stabilization. Extensive construction may be needed to gain confinement.
Poor	B3, B4, B5, C4, C5	Channel instability and high sediment supply reduces effectiveness.
	B1-1, C1-1	Bedrock bed limits effectness.
N/A	A1, A2, C6	Pools not a limiting factor.

CHANNEL CONSTRICTOR

Rating	Channel Types	Limitations/Discussion
Exc.	B2, C2	No limitations.
Good		
Fair	C1	Need bank protection downstream from constrictor.
	C3	Same as C1 except the reduced bed armor may create undercutting that could destroy the foundation of the structure.
	D1, D2	Extensive construction may be needed to gain confinement.
Poor	B3, B4, B5, C4, C5	Bank and bed instability and high sediment supply limits effectiveness.
	B1-1, C1-1	Bedrock bed limits effectness.
N/A	A1, A2, B1, C6	Not limiting due to existing low width/depth ratios.

BANK COVER

Rating	Channel Types	Limitations/Discussion
Exc.	B1, B2	No Limitations.
Good	B1-1, C1-1, C1, C2, C3	
Fair	C4	Lateral migration may result in undermining the structure.
Poor	B3, B4, B5, C5	Channel instability limits effectiveness.
	D1, D2	Change in annual thalweg position makes these structures impractical.
N/A	A1, A2, C6	Good cover generally available within these channel types.

Table 4. Limitations and discussions of various fish habitat improvement structures by stream types (continued).

HALF LOG COVER

Rating	Channel Types	Limitations/Discussion
Exc.	B2	No limitations.
Good	B1-1 B1, C1, C1-1, C2	Will have to use anchoring techniques compatable with coarse substrate.
Fair	C3	Increased sedimentation may cause bar formation which results in decreased channel capacity and increased bank erosion. Key is the use of deflectors in conjunction with half log structures.
Poor	B3, B4, B5 C4, C5, D1, D2	Extremely unstable bed conditions - degrading and aggrading reaches which limit the effectiveness of this structure.
N/A	A1, A2, C6	Cover generally not limiting.

FLOATING LOG COVER

Rating	Channel Types	Limitations/Discussion
Exc.	B1, B2, C2	No limitations.
Good	B1-1, C1-1, C1, C3, C4, C5	Overlapping logs reduces bank erosion.
Fair	B3, B4, B5	Undercutting will cause underming of the anchor and eventual loss of the structure. Take extra precautions to protect banks.
Poor	D1, D2	Shifting active channel makes this structure infeasible.
N/A	A1, A2	Instream cover generally not limiting. Steep gradient reduces effectiveness.
	C6	Instream cover not limiting.

SUBMERGED SHELTERS LOCATED ON MEANDERS

Rating	Channel Types	Limitations/Discussion
Exc.	B1, C2	No limitations.
Good	B1-1, B2, C1, C1-1	Because structures are located on meanders (high velocity areas of the channel), these channel types may be subject to some bank erosion.
Fair	B3, B4, B5, C3, C4, C5	Need bank stability measures on opposite bank to prevent accelerate bank erosion and lateral migration. Done in conjuction with bank stabilization, this structure can deepen and narrow C3, C4, and C5 channels in particular.
Poor	D1, D2	Shifting active and thalweg channel makes this structure ineffective.
N/A	A1, A2, C6	Not limited by cover.

SUBMERGED SHELTER LOCATED ON STRAIGHT REACHES

Rating	Channel Types	Limitations/Discussion
Exc.	B1-1, B1, B2, C1-1, C1, C2	No limitations.
Good	C3, C4, C5	Submerged shelters can be placed on straight reaches in these channel types.
Fair	B3, B4, B5	High bedload transport and high stream power of these types limits effectiveness.
Poor	D1, D2	Shifting active and thalweg channel makes this structure ineffective.
N/A	A1, A2, C6	Cover naturally available.

Table 4. Limitations and discussions of various fish habitat improvement structures by stream types (continued).

SPAWNING HABITAT ENHANCEMENT

V-SHAPED GRAVEL TRAP

Rating	Channel Types	Limitations/Discussion
Exc.	A2, B1	No limitations.
Good	A1, B1-1, B2, C2	
Fair	C1-1, C1	Higher sediment yields make invasion of fines possible. Use with pervious trap so intra-gravel flow rate is maintained.
Poor	B3	Unstable bank and bed with high sediment supply limits effectiveness.
	B4, B5, C4, C5, C6, D1	No source for suitable spawning gravel.
N/A	C3, D2	Gravel bed stream types.

Note: Downcutting often occurs at the point of the apex which can undermine the structure. Need bed stabilization in conjunction with this structure.

LOG SILL GRAVEL TRAPS

Rating	Channel Types	Limitations/Discussion
Exc.	A2, B1, C2	No limitations.
Good	B1-1, B1, B2	
Fair	C1-1	
	C6	Frequent bed scour may inundate gravel with fines.
Poor	B3	High bedload transport of sand results in unstable channel with both bed and bank instability.
	A1	High velocities and limited gravel source.
	B4, B5, C4, C5, D2	Gravel size bedload unavailable.
N/A	C3, D1	Gravel bed stream types.

GRAVEL PLACEMENT

Rating	Channel Types	Limitations/Discussion
Exc.	C2	No limitations.
Good	B2	Must select lower velocity areas within the reach - transition zones between pool and riffle.
Fair	B1-1, B1	May not be effective considering the limited area where critical shear velocities would not be exceeded.
	C1-1, C1	Can cause capacity reduction and increase bank erosion. Treat smaller percentage of the channel area and/or stabilize banks.
	C6	Potential for fine sediment invasion with minimal disturbance due to frequent bed shifts.
Poor	A1, A2	Ineffective due to steep gradient.
	B3, B4, B5 D1, D2	Will fill in with finer bed material.
	C4, C5	Effective for just one year.
N/A	C3	Gravel bed stream type.

MIGRATION BARRIER

Rating	Channel Types	Limitations/Discussion
Exc.	A1, A2, B1	No limitations.
Good	B2	Proper site selection must be made within the reach where banks are high and stable.
Fair	B1-1	Erodible banks and moderate confinement limit barrier placement.
Poor	B3, B4, B5	Bank and bed instability can result in structure failure.
	C1-1, C1, C2, C3, C4, C5, C6, D1, D2	Low banks - cannot create adequate height for falls.
N/A		

SUMMARY

An initial attempt is made to evaluate the suitability of a wide range of fishery enhancement structures for various stream types. These guidelines are intended for application in planning and designing enhancement structures over a wide variety of streams to reduce the "error" from the trial and error method. These guidelines are intended as an initial framework for technology transfer that others will improve upon as more data are derived from on-going monitoring and evaluation programs.

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