Assessment Team Considerations for Emergency Stabilization

Primary Treatment Use

Checkdams trap sediment and slow water velocities slowing the sediment pulse entering streams.

Description

Checkdams can be constructed from straw, log, or rock depending on the location and availability of materials. Strawbale checkdams are a temporary erosion control measure built with three to five strawbales depending on the size of the channel. Strawbale checkdams are placed in ephemeral channels with a moderate gradient to trap and reduce sediment delivered to channels. Log checkdams are built from logs within the fire area. The size, slope, and space between logs determines the amount of material trapped. Rock checkdams are used where there are high values at risk and a rock source is close by.

Figure 48—Strawbale checkdam with energy dissipater.

Purpose of Treatment

Checkdams are designed to trap and store sediment mobilized from the hillslope and channel. Properly constructed checkdams prevent downcutting and attenuating peak flows as water is routed through a series of small basins created by the checkdams. The moist deposits of soil, ash, and organic material can serve as fertile sites for vegetative recovery.

Emergency Stabilization Objective

Objectives are to reduce water quality deterioration and encourage recovery of vegetation.

Suitable Sites

The treatment is intended for use in one or more of the following locations:

- Swales with gentle gradient that allow for sediment storage.
- High-burn severity areas with highly erodible soils.
- Areas with less than 20-percent ground cover, or ineffective cover for that ecosystem.
- Areas with high values at risk.
- Watersheds with small drainage areas, generally less than 5 acres.

Cost

Checkdams are inexpensive to construct and range in price from $150 to $600 each.

Cost factors include the following variables:

- Treatment location and access.
- Construction material used (log, straw, or rock)
- Movement of bales from the staging area to the treatment sites.
- Availability of strawbales that are certified weed free.
- Maintenance and reconstruction needs.

Strawbale checkdams were popular in the 1990s. They were one of the most common channel treatments implemented. Treatment success varied with ratings of good to poor. However, properly located and installed strawbales can be effective. Strawbale checkdams placed in first order streams with a stream gradient of less than 5 percent were rated favorably by implementers. However, poor ratings were given for improperly installed treatments or when located in large drainages. Strawbale checkdams are more successful in a 2- to 5-year design storm return period where design storm magnitude is within the capacity of the structure.

Problems with strawbale and log checkdams include filling to capacity from only small storms. A large storm event can cause the entire structure to fail requiring reconstruction or maintenance. Successive and frequent storm events can wash out structures. Inspection of the strawbales after storms is recommended to reduce catastrophic failure. It is not uncommon for up to 20 percent of the structures to fail even under good conditions. Failure of structures often resulted in more damage occurring from the treatment.

Figure 49—Strawbale checkdam that filled, overtopped, and created a gully below the structure.

Some implementers found the single-log check dams or log-sill dams to be effective in seasonal and small perennial streams and less risky than the multi-log structures. Field review found up to 20 percent of the structures failed during the first runoff season (Ruby, unpublished paper). More catastrophic failures occurred with larger multi-log structures especially in streams that quickly aggraded (Hubbert, unpublished paper). Water formed a new channel around the end of the log dam even in places where the logs were keyed in 3 feet into the streambank. Failure mechanisms included undercutting and end-runs around the structure.

Rock checkdams are more permanent and can be effective when properly implemented. All types of checkdams appear to work better when implemented in gentle gradients, high in the watershed, and placed in a series. Any checkdam changes the channel gradient and works only to meter out the sediment in a channel rather than preventing it from getting into the channel in the first place.

Assessment teams should consider the burn severity, vegetative response, design storm, values at risk, and ability to implement, inspect, and maintain channel treatments prior to prescribing this work.

Project Design and Implementation Team Information

Design

After the BAER assessment team has designated potential treatment areas, review these field sites with the hydrologist and soil scientist to ensure suitability. Key design considerations include watershed size, channel type, slope gradient, burn severity, space requirements, and materials needed.

Identify site access and hazards in and around the work area to determine appropriate mitigation measures.

Construction Specifications

Implementation of a strawbale checkdam includes the following steps:

1. Survey the site to identify the appropriate placement for each strawbale checkdam.
2. Build strawbale checkdams in a series. Construct the dams upstream from a natural nickpoint (point resistant to erosion). Ideally, the crest of the second spillway below should be at the elevation of the base of the first dam above it. However, water has more energy to undermine the structure if it is dropped from a high elevation. Armor outlets to reduce water’s erosive force.
3. Look upstream to determine the existing channel width. The strawbale dam must extend well beyond the existing channel width because the new grade control established by the dam will be higher than the preexisting grade.
4. Place the spillway bale(s) on the flat side after smoothing a shallow trench.
5. Ensure the bales are seated properly, preventing water flow from under the dam.
6. Use wooden stakes to anchor the spillway bales securely into the ground.
7. Use an appropriate hammer to pound the stakes at an angle until they are 2 inches below the surface.
8. Place the side bales upright at a slight skew, to create a “smile” shaped structure. Ensure that the bales extend well beyond the preexisting active channel. The soil surface beyond the end bales must be higher than the maximum depth of flow anticipated over the center of the structure.
9. Push the bales together tightly to prevent gaps between the bales.
10. Use rocks and woody material to close any gaps between the side bales and the spillway bales.
11. Construct an energy dissipator at the base of the spillway bales by anchoring logs with U-shaped rebar or using onsite rocks piled at least two deep against the bales. (Bend the rebar in advance or bend in the field by wrapping it around a small tree trunk.) The energy dissipator should be large enough to receive all water flowing over the dam.
12. Pound the U-shaped rebar into the ground using the hammer.
13. Secure the rebar to the log with 2-inch fence staples.
14. Place any small branches, woody debris, or pine needles on the upstream side of the dam. The small material will be picked up by the water and plug any gaps in the dam.

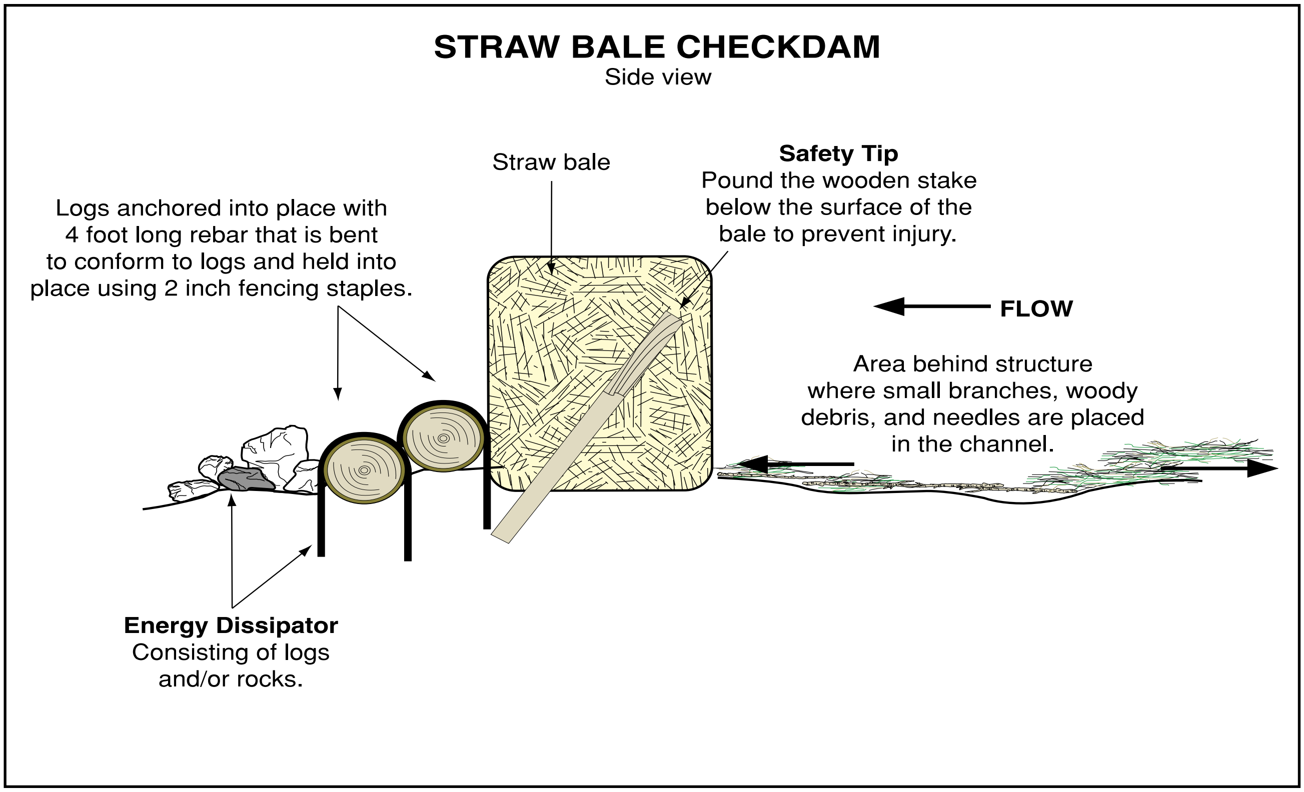

Figure 50—Strawbale checkdam (sideview).

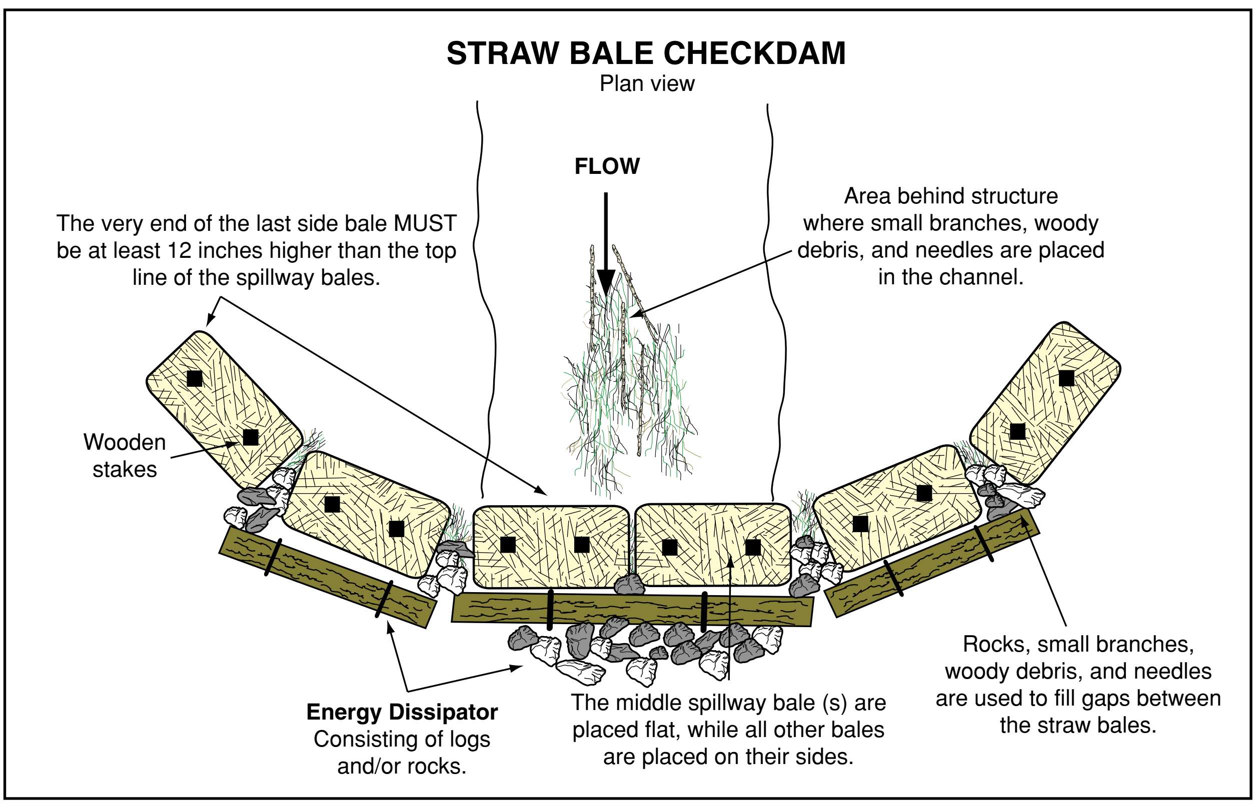

Figure 51—Strawbale checkdam (planview).

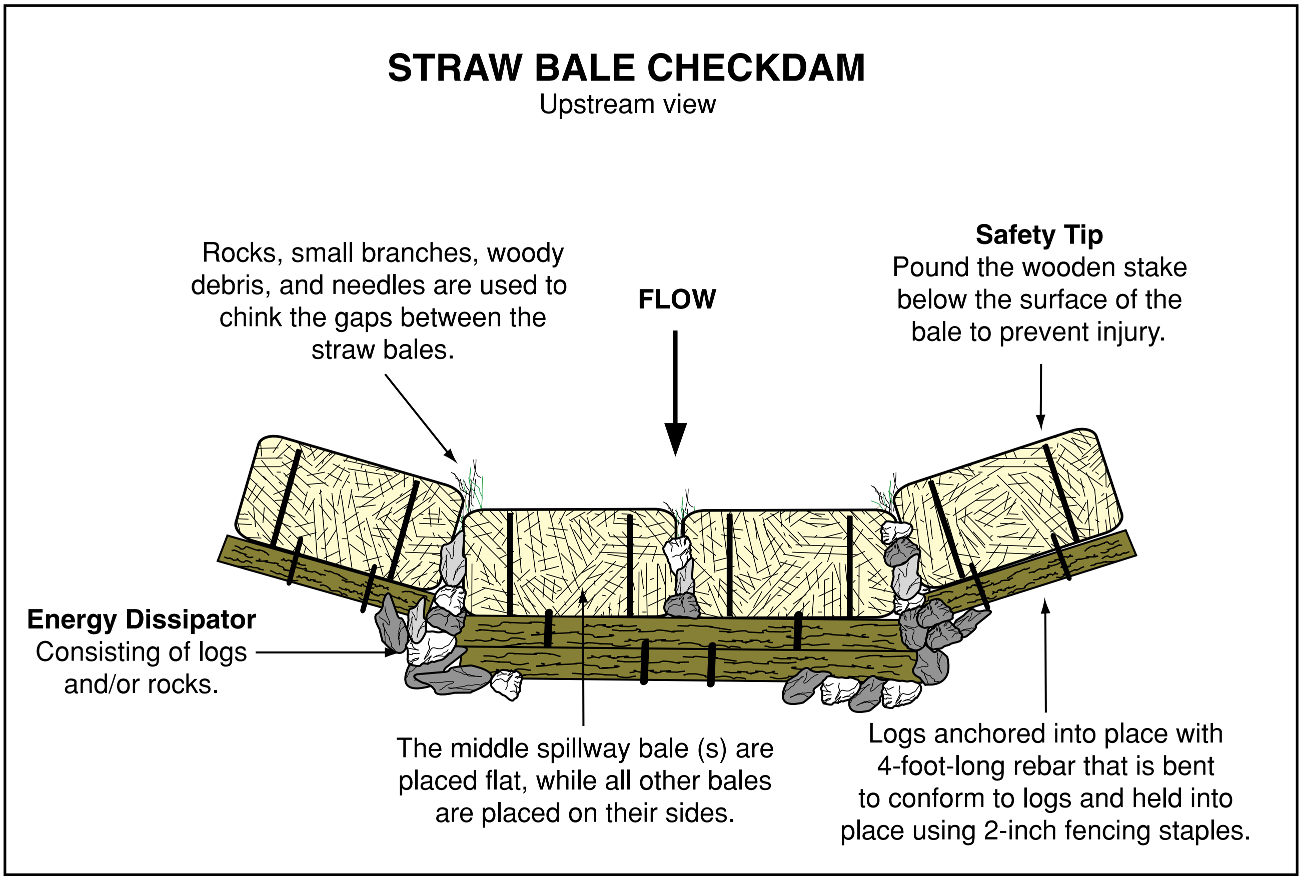

Figure 52—Strawbale checkdam (upstream view).

Inspection

To ensure the checkdam functions properly, review the following:

1. The crest of the spillway bale must be lower than the bottom edge of the last side bale to trap sediment and prevent water from going around the structure.
2. The energy dissipator must use large enough material to withstand the storm runoff.

Material/Tools

Items required for a strawbale checkdam include:

Materials

1. Certified weed-free strawbales (meet State requirements for noxious and invasive weeds).
2. Wooden contractor stakes, 24 inches long.
3. Rebar to anchor log dissipater, 3/8 inch (See drawing).

Tools

1. McLeod rakes.
2. Shovels.
3. Hammer.
4. Eye protection.

Log Checkdam Construction Specifications

1. Determine the channel width and cut the log 3 to 4 feet longer to key the log into the channel bank. Streams should not be wider than 6 to 7 feet at bankfull.
2. Excavate a trench 2 to 4 inches deep in the channel.
3. Key the log 2 feet into the channel bank and lay it in the trench.
4. Place two posts on the downstream side of the log to hold it firmly in place.
5. Attach filter cloth to the structure's upstream side to prevent undercutting. Filter cloth should extend up the channel approximately 3 feet and be buried at least 6 inches.
6. Notch the log to provide a spillway and armor the spillway with rocks to serve as an energy dissipator.
7. Inspect and maintain all dams after the first runoff event.

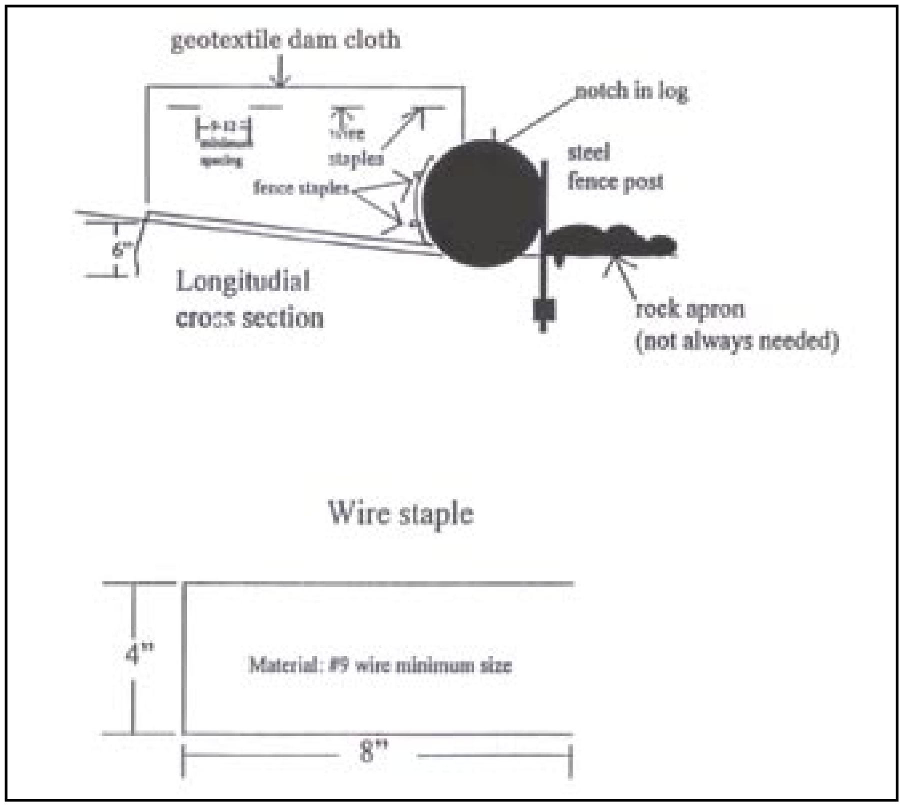

Figure 53—Typical log checkdam structure.

Safety

Strawbale checkdams are implemented safely if all hazards are mitigated. Review, update, and include the following items in the JHA.

- Hazard trees and snags within treatment areas.
- Stump holes and unstable footing.
- Strawbale lifting and moving.
- Eye protection.
- Allergic reactions from straw.

Treatment Monitoring Recommendations

Implementation

- Was the project implemented as designed?
- Were the strawbales properly located?
- Were energy dissipators installed?
- Were there gaps between bales?

Figure 54—Checkdams should be inspected and maintained.

Effectiveness

- Did the strawbale checkdam fill with sediment?
- Did vegetation grow in the deposits behind the dam?
- Did any downcutting occur downstream from the dam?
- Does the structure need any maintenance for subsequent storm events?

Figure 55—Install checkdams to avoid endruns.

Assessment Team Considerations for Emergency Stabilization

Primary Treatment Use

In-channel tree felling is prescribed to maintain channel stability and provide fish habitat. In-channel tree felling replaces woody material consumed by the fire. It also is used to treat steep drainages to reduce the risk of in-channel debris flow bulking for several years after a fire (Fitzgerald, unpublished paper).

Description

In-channel tree felling involves directionally felling trees upstream so the tops of the trees are in the channel. The trees are felled at a diagonal along designated channel reaches. The trees are staggered from side to side along the stream in a herringbone design (Ruby, unpublished paper; Fitzgerald, unpublished paper).

Purpose of Treatment

In-channel tree felling traps floatable debris and suspended sediment. Over time, woody material can cause sediment deposition and channel aggradation. Large woody material dissipates stream energy, provides cover for fish, and forms rearing and resting habitats. For seasonal channels the in-channel trees serve as dams to stabilize existing prefire bed material and to trap and store post fire sediment in the short term, while providing long-term channel stability (Fitzgerald, unpublished paper).

Emergency Stabilization Objective

In-channel tree felling reduces effects to critical natural resources (sensitive aquatic species) or downstream values (water quality and or road crossings) by restoring large woody debris to the channel and dissipating stream energy.

Suitable Sites

This treatment is intended for use in one or more of the following locations (Ruby, unpublished paper):

- Areas of high-burn severity where woody material has been consumed.
- Channels where energy dissipation is necessary.
- Channels with high values at risk such as road crossings or sensitive aquatic species.
- Channels with unstable bedload and high sediment-loading potential.

Cost

Little cost data is available for this treatment. The unit cost for directional felling in the Southwest Region (R3) for FY 2000 to 2003 ranged from $3,500 to $4,000 per mile of treatment, based on approximately 100 trees felled per mile of channel.

Cost factors include the following variables:

- Number of trees designated per mile.
- Hazard associated with felling trees.
- Location of treatment area.
- Amount of large woody material available.

Treatment Effectiveness

The Shasta Trinity National Forest has reviewed the effectiveness of in-channel tree felling for 5 years. The treatment is successful when properly located in a series along the channel. Structures reduce the risk of debris flow bulking and stream channel destabilization, yet are flexible to shift as the stream channel recovers (Fitzgerald, unpublished paper).

Other effectiveness monitoring of this treatment are by visual observations identifying if the trees are still there and if sediment was trapped.

Project Design and Implementation Team

Design

After the BAER assessment team has designated potential stream reaches for in-channel tree felling, review the areas in the field to ensure the sites are suitable. Key considerations are the availability of suitable trees, ability to safely implement the treatment, and channel characteristics favorable to this treatment (increased sediment load, gradient, and loss of woody material from the fire).

Construction Specifications

- Define the treatment areas by staking, GPS coordinates, or flagging.
- Candidate trees are dead and size class is representative of the stream reach.

For perennial streams:

- Leave felled trees in one piece with the top attached.
- Space 2 trees per 50 to 100 feet of channel, with 1 tree on each side of the channel for approximately 106 to 212 trees per mile.
- Fell two trees from each side of the channel on top of each other to improve stability.
- Fell trees such that the top quarter to half of the tree is within the high-water level for that channel (Ruby, unpublished paper).

For seasonal channels:

- Fell the primary tree across the channel to “plug” the channel.
- Buck the primary tree so the log touches the channel bottom.
- Fell secondary trees to support the primary tree.
- Use trees large enough to hold the expected runoff and debris load (Fitzgerald, unpublished paper).

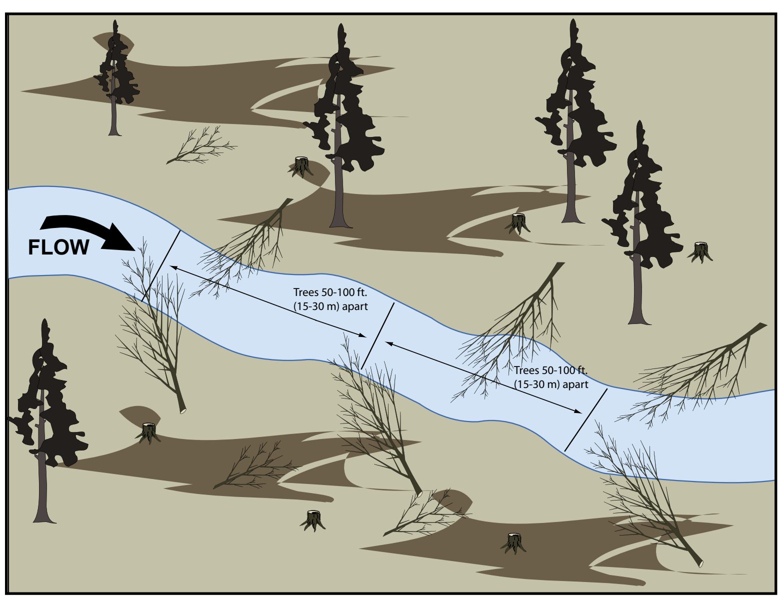

Figure 56—Directional tree felling.

Tools/Equipment

Tools necessary for implementing in-channel felling include chain saws and PPE.

Safety

In-channel tree felling is implemented safely when hazards are identified and mitigated. Review and update the JHA daily to avoid injuries. Include the following in the JHA.

- Work in and around streams with unstable footing.
- Muscle and back strain from chain saw operation.
- Hazards associated with tree felling of potentially unstable trees.

Treatment Monitoring Recommendations

Implementation

- Was the treatment implemented as designed?
- Were guidelines followed regarding the spacing, diagonal placement, and percentage of the tree within the high water level?
- How many trees per acre were placed in the channel?

Effectiveness

- Did the woody material trap sediment?
- Did the woody material protect identified downstream values (culvert or aquatic habitat)?
- Were the in-channel trees tested at the time of review according to the design storm parameters?

The following tool was developed by hydrologists Bob Blecker and Terry Benoit in 1985 during the Gorda-Rat fire. This dichotomous key modified an earlier debris stability key by Bilby.
Review of channels and literature determined that firmly anchored log jams plus large logs should remain in the channel for channel stability, fish habitat, and to stabilize instream bed material.

Stream Channel Debris Removal Key and Guidelines

Debris removal key (use as a dichotomous key starting with couplet 1)

1). a) Debris anchored or buried in the streambed or bank at one or both ends or along the upstream face – LEAVE
b) Debris not anchored – Go to 2

2). a) Debris longer than 30 feet – LEAVE
b) Debris shorter than 30 feet – Go to 3.

3). a) Debris greater than 18 inches in diameter – Go to 4.
b) Debris less than 18 inches in diameter – Go to 5.

4). a) Debris longer than 15 feet – LEAVE
b) Debris shorter than 15 feet – Go to 5.

5). a) Debris braced on downstream side by boulders, bedrock outcrops, or stable pieces of debris – LEAVE
b) Debris not braced on downstream side – REMOVE.

Assessment Team Considerations for Emergency Stabilization

Primary Treatment Use

Grade stabilizers are designed to prevent channel incising and downcutting. Grade stabilizers provide grade control to systems that may become destabilized from increased storm runoff and velocities.

Description

Grade stabilizers are constructed from various materials, including logs, rocks, and wood. BAER assessment teams may recommend this treatment in areas where the loss of soil cover and increased runoff would result in channel downcutting. If grade stabilizers are proposed as an emergency treatment, a hydrologist familiar with their design, implementation, and effectiveness should design them to meet the particular site specifications.

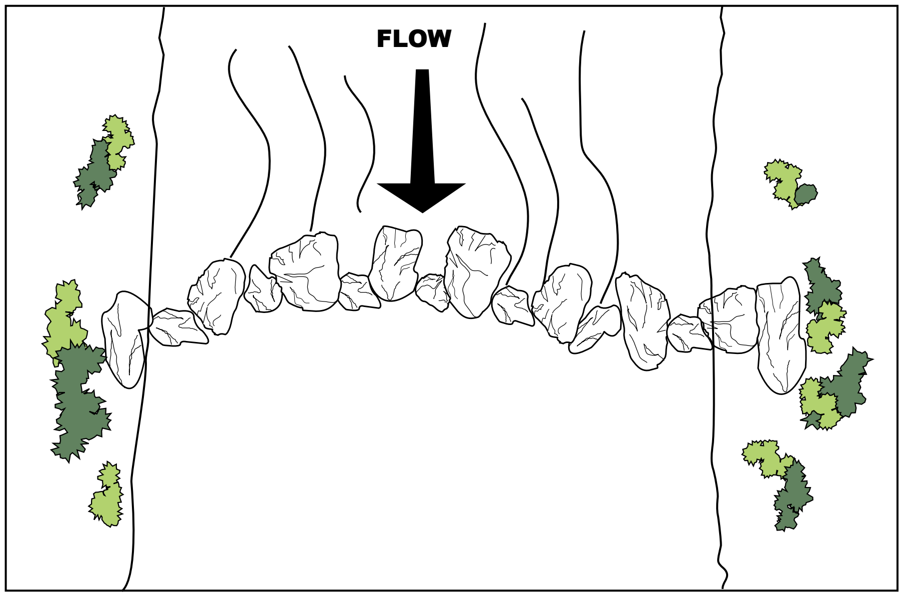

Figure 57—Grade stabilizer is placed at grade to prevent channel incision.

Purpose of Treatment

Grade stabilizers maintain channel gradient and reduce channel scouring or downcutting from increased overland runoff.

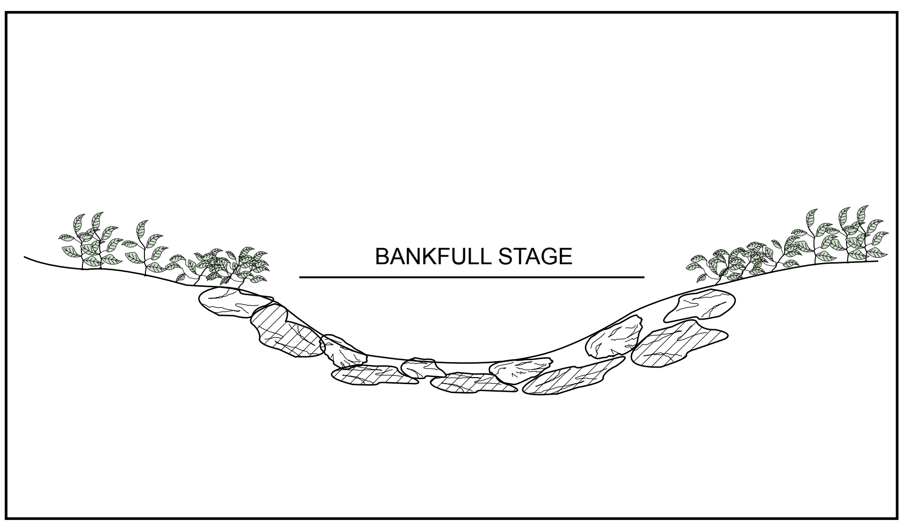

Figure 58—Bankfull view of grade stabilizer.

Emergency Stabilization Objective

Objectives are to reduce water quality deterioration and establish grade control in seasonal channels.

Suitable Sites

This treatment is intended for application in one or more of the following situations:

- Downstream beneficial uses are high.
- Channel indicators of instability exist.
- Watershed has high percentage burn throughout.
- Soil cover loss and woody debris.
- Presence of persistent hydrophobic condition in watershed.
- Seasonal channels with low to moderate flows.
- Channel gradient less than 6 percent.

Cost

Limited data exists on this treatment because it is seldom used. Costs range from $250 to $4,000 per structure depending on materials and installation method.

Cost factors include the following variables:

- Material available.
- Access to sites.
- Availability of skilled workforce.
- Mechanized equipment use (backhoe/excavator).

Treatment Effectiveness

Little quantitative data is available on grade-stabilizer effectiveness as a BAER treatment. Data collected on BAER treatment effectiveness (Robichaud 2000) found no evidence that grade stabilizers were effective in stabilizing the channel gradient.

In some cases, scouring and downcutting of seasonal channels has occurred after wildfires, but our ability to predict where downcutting may occur is limited. Much of the downcutting that does occur could result from short-duration stormcells over a particular drainage that can be missed easily during the BAER assessment phase.

Occasionally, assessment teams recommend grade stabilizers. This treatment may be most effective for areas of low or moderate flows.

Project Design and Implementation Team Information

Design

After the BAER assessment team has designated potential treatment areas, review these field sites with the hydrologist to ensure suitability. Key design considerations include channel gradient, morphology and stability, adjacent hillslope conditions (soil burn severity), and available materials. Obtain any needed State or Federal streambank alteration permits prior to implementation.

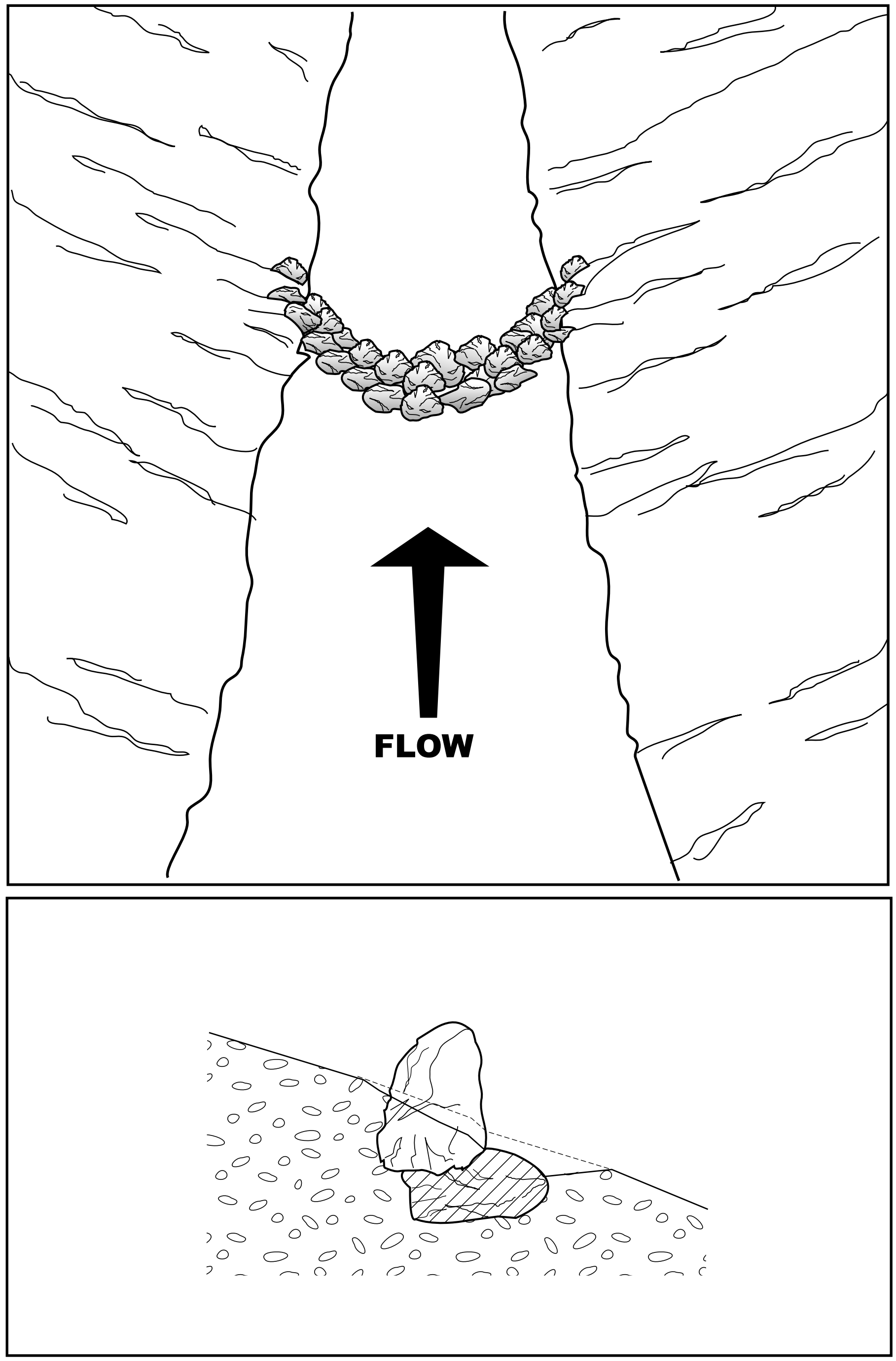

Figure 59—Stream grade can be adjusted and maintained by careful placement of boulders.

Construction Specifications

Proper design and planning is required when implementing a treatment. Each rock- or log-grade stabilizer will vary depending on the site but basic requirements include:

1. Identify each treatment area by staking, flagging, and marking GPS coordinates.
2. Estimate the size and amount of material required for each structure.
   a. If using rock for the structure, ensure it is large enough to withstand the erosive force of the stream channel.
   b. If using wood or logs, estimate the width of the channel for the targeted high flows to ensure the structure is not outflanked with higher flows.
3. Construct the structure at grade, which requires excavation, depending on the materials used.
4. Spread excavated material on the slopes and/or use it to fill around the rocks.
5. Inspect and monitor the structures for any signs of erosion after the first storm event.

Tools/Equipment

Tools will vary depending on the type of material used.

- Chain saws for use on wood and log structures.
- Backhoes or excavators for placing rock structures.

Safety

Grade stabilizers are safely implemented when hazards are identified and mitigated. Review and update the JHA daily to avoid injuries. Include the following items in the JHA.

- Hazard trees and snags within treatment areas.
- Work around heavy equipment.
- Rocks or logs on site.
- Chain saw use.
- Road access to the site.

Treatment Monitoring Recommendations

Implementation

- Was the treatment implemented as designed?
- Is the structure at grade?
- Is the structure long enough to avoid outflanking?
- Were State or Federal streambank permit final reports submitted?

Effectiveness

- What type of storm events did the structure receive prior to monitoring?
- Are there indications of channel downcutting? If so, are more structures needed?
- Did the structure function as designed?

Assessment Team Considerations for Emergency Stabilization

Primary Treatment Use

Streambank armoring reduces impacts from increased peak flows from the fire's effects on unstable stream reaches. In some hydrologic systems, streambanks are a major source of sediment after a wildfire.

Description

Armoring is the placement of rock along the streambank to reduce erosion. Armoring may include placement of boulders, riprap, or gabion baskets.

Purpose of Treatment

Streambank armoring is prescribed to reduce erosion and sediment in stream channels.

Emergency Stabilization Objective

Armoring of streambanks moderates the severity of streambank erosion and reduces degradation of water quality.

Suitable Sites

This treatment is intended for use in one or more of the following locations:

- Highly erodible streambanks.
- Areas with high values at risk.

Cost

Streambank-armoring cost data is unavailable because this treatment is used seldom. However, the forest engineering staff may have identified rock sources.

Cost factors include the following variables:

- Proximity to suitable rock source.
- Haul distance.
- Size of material required.

Treatment Effectiveness

No quantitative effectiveness monitoring data exists for this treatment. Qualitative monitoring of streambank-armoring using gabion baskets to protect a well house and pump station performed well (Kuyumjian, personal communication). Assessment teams that prescribe this treatment should consult with the forest watershed and engineering staff to evaluate whether this treatment meets the emergency treatment objectives. When streambank armoring is prescribed, ensure that properly sized material is used. Well-intentioned prescriptions have accelerated streambank erosion downstream of the structure. Assessment and implementation teams should use caution when prescribing this as an emergency treatment.

Project Design and Implementation Team Information

Design

After the BAER assessment team has designated potential treatment areas, review these field sites to ensure suitability and determine the material required.

Key design considerations include material size and amount. Designers also need to ensure that no erosion occurs at the end of the armoring treatment. Design considerations for transitioning may include energy dissipators and in-channel felling. Obtain any State or Federal stream alteration permits prior to implementation.

Tools/Equipment

Backhoe.
Dumptruck.
Excavator with a thumb attachment for precise boulder placement or moving large rock.
Gabions for necessary mass when large boulders are unavailable.

Safety

In-channel tree felling is implemented safely when hazards are identified and mitigated. Review and update the JHA daily to avoid injuries. Include the following in the JHA.

- Working with heavy equipment.
- Working in and near a stream zone with unstable footing.
- Working near hazard trees.

Treatment Monitoring Recommendations

Implementation

- Was the treatment implemented as designed?
- Were guidelines followed for rock and boulder sizing?
- Were treatment transitions (energy dissipators) incorporated in the design and implemented?
- Were stream alteration permit final reports submitted?

Effectiveness

- Did the stream-channel armoring prevent streambank erosion?
- Was the armoring tested at the time of review according to design storm parameters?
- Were transition structures effective in preventing downcutting and streambank scouring, if used?

Assessment Team Considerations for Emergency Stabilization

Primary Treatment Use

Channel deflectors protect a structure or infrastructure from increased streamflows caused by the effect of the fire.

Description

Channel deflectors include methods such as j-hooks, rock barbs, and single- or double-wing deflectors (Rosgen 1996). The treatment is designed to direct streamflows and velocities away from unstable banks or high values at risk.

Purpose of Treatment

Channel deflectors protect structures or the transportation infrastructure from increased streamflows and/or flooding.

Emergency Stabilization Objective

Channel deflectors reduce the potential loss or damage to property or infrastructure.

Suitable Sites

This treatment is intended for use in one or more of the following locations:

- Roads which may parallel stream channels.
- Facilities at risk from streambank erosion or flooding.

Cost

Treatment costs are highly variable depending on the structure installed. Once a structure is selected, consult with the forest watershed staff to obtain cost estimates.
Cost factors include the following variables:

- Structure type installed.
- Availability of material (rock, jersey barriers, riprap, logs).
- Site location and access availability.

Treatment Effectiveness

There is no documented effectiveness monitoring data for this treatment, because this treatment is seldom prescribed. If a BAER assessment team prescribes this treatment, a well-developed design is required prior to implementation. In many cases there is inadequate time to conduct surveys and design this treatment prior to the first damaging storm event.

Project Design and Implementation Team Information

Design

After the BAER assessment team has designated potential treatment locations, review the area in the field to ensure site suitability. Key considerations are available streamflow data, values at risk (if flows increase, what impact is there on a campground, building, or road), availability of materials, and experienced personnel to design and implement the treatment. Use established protocols for the treatment selected and match the treatment to the channel characteristics (Rosgen 1996).

Identify appropriate permits required for implementation. Channel deflectors should be in compliance with both State and the United States Army Corps of Engineers Nationwide Permit 37 “Emergency Watershed Protection and Rehabilitation” and Nationwide Permit General Conditions (Kuyumjian, personal communication).

Tools/Equipment

Most channel deflectors are installed with an excavator or backhoe. Excavators with a thumb attachment enable the operator to pick up and place boulders with less impact to the stream. Other equipment includes dumptrucks to haul boulders to the site.

Safety

If this treatment is implemented, work with the forest watershed staff and other resource professionals experienced with implementing these treatments to ensure proper installation.

Channel deflectors can be implemented safely if all hazards are mitigated. Review, update, and include the following items in the JHA.

- Heavy equipment working in area..
- Vehicle traffic on roads to and from the site may require a traffic management plan.

Treatment Monitoring Recommendations

Implementation

- Was the treatment implemented as designed?
- Were guidelines followed regarding the size of the material placed and the spacing between channel deflectors?
- Were stream alteration permit final reports submitted?

Effectiveness

- Did the structures function as designed and help to move the stream flow away from the identified values at risk?
- Were the structures tested at the time of review by the design storm?
- Was there damage to the structures (campground, building, road)? If so, are additional treatments necessary?
- Was there damage to the stream environment?

Assessment Team Considerations for Emergency Stabilization

Primary Treatment Use

Debris basins are emergency structures for areas where a threat to human life and property is identified and an opportunity exists to contain and control expected material. Constructing new debris basins are considered a last resort due to cost, maintenance, and timeframes for engineered design and permit approvals.

Description

Debris basins vary in size and type. The basin type refers to whether it is in-channel or off-channel. The type influences the design, construction and operation, and reclamation needs (Van de Water, unpublished paper). In some cases, existing debris basins are cleaned out or enlarged to provide additional capacity.

Figure 60—Small basin created to trap sediment.

Purpose of Treatment

Debris basins are constructed to treat either the loss of runoff control and deterioration of water quality or threats to human life and property.

Emergency Stabilization Objective

The objectives provide immediate protection from floodwater, floatable debris, sediment, boulders, and mudflows.

Suitable Sites

This treatment is intended for use in one or more of the following locations:

- Areas of moderate- to high-burn severity.
- Areas identified with prefire debris flow and landslide hazards.
- Areas where high-value resources are imminently threatened.
- Sites with the capacity to trap the estimated debris flow volume.
- Sites with access available for construction and maintenance.

Cost

Debris basins are expensive and costs vary from location to location.

Cost factors include the following variables:

- Access to site.
- Size of debris basin.
- Availability of material.
- Frequency of maintenance.
- Proximity to spoils area.
- Type of debris basin, new or existing.
- Site characteristics.

Treatment Effectiveness

Because debris basins seldom are implemented as a BAER treatment by the USDA Forest Service, no such quantitative information is available on their effectiveness. Current research by the U.S. Department of the Interior, U.S. Geological Survey is working to define treatment effectiveness.

Project Design and Implementation Team Information

Design

After the BAER assessment team has designated potential treatment locations, review the area in the field to ensure site suitability. Prior to designing the structure, explore all other potential treatments that reduce the emergency to an acceptable level (FSH 2509.13 Chapter 26.4).

If a major structure is required, a certified, professional engineer should design the structure. Obtain any State or Federal permits and approval and design the structure to no less than the minimum acceptable design probability of a 100-year flood.

The level of detail of the investigation, design, design reports, and drawings to construct a safe dam depends on the size and hazard assessment classification of the dam (FSM 7500 Chapter 7510).

Current design standards (FSM 7500, Chapter 7520) require the following investigations for all new dams or enlargement of an existing dam.

- Test appropriate size and hazard of the dam.
- Ensure that the factors of safety and allowable shear stresses in the design are appropriate for the construction and operating conditions.
- Identify earthquake hazards, including fault displacement, soil liquefaction, and cracking potential; structure type; structure, abutment, and reservoir slope stability; overtopping effects; and required defensive measures including emergency action plans.
- Use geosynthetic fabric for the dam's structural stability only after consultation with other Federal agency or private engineering consultants experienced in their application.
- Use of outlet works depends on the type of dam and hazard class. Consider requirements for reducing reservoir capacity in the design.
- Use of flashboards with shear pins or failure supports are not permitted in uncontrolled spillways.
- Provide all weather road access for operation and maintenance of high hazard dams.
- Provide instrumentation, where necessary, for measurement of physical changes that could affect dam safety.

Figure 61—Ensure that material from the debris basin can be removed.

Figure 62—Large debris basins may be constructed where there are high values at risk.