United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

# OPEN CHANNEL

## Code 582

## (Ft.)



## DEFINITION

An open channel is a natural or artificial channel in which water flows with a free surface.

## PURPOSE

Construct, improve, or restore an open channel to convey water required for flood prevention, drainage, wildlife habitat protection or enhancement, or other authorized water management purpose.

## CONDITIONS WHERE PRACTICE APPLIES

This standard applies to the construction of open channels or modifications of existing streams or, (ditches with drainage areas exceeding one (1) $mi^2$ (1.6 $km^2$)). This standard does not apply to Natural Resources Conservation Service (NRCS) Conservation Practice Standards (CPSs) Codes 362, Diversions; 412, Grassed Waterways; 388, Irrigation Field Ditches; 607, Surface Drain, Field Ditch; or 320, Irrigation Canal or Lateral.

This practice applies in stream restoration to modify a channel cross-section, construct an inset floodplain, or increase planform sinuosity. It is used often in combination with other practices such as Streambank and Shoreline Protection (Code 580), Channel Bed Stabilization (Code 584), and Stream Habitat Improvement and Management (Code 395). See **Additional Criteria for Stream Restoration**.

## CRITERIA

Design and install this practice in accordance with all Federal, State, and local laws and regulations. The landowner must obtain all regulatory permits to implement the practice. The landowner and contractor are responsible for locating all buried utilities within the work limits, including drainage tile and other structural measures.

The landowner is responsible for removing hazardous materials or point source pollution (e.g. *septic discharge)* within the work limits and attaining regulatory compliance prior to open channel construction.

Ensure that channel modifications do not increase the Base Flood Elevation (100-year) adopted into floodplain zoning ordinances, including (a) Special Flood Hazard Areas (SFHA) on FEMA flood insurance maps (FIRM), (b) dam breach inundation maps, and (c) floodplain storage maps. Maps and supporting data can be provided by the local zoning administrator or DNR Surface Water Data Viewer. The FEMA Map Service Center website only provides FIRM maps and models.

Use NRCS Engineering Technical Releases (TR), 210-25, Design of Open Channels; NRCS National Engineering Handbook (NEH), Part 653, Stream Corridor Restoration: Principles, Processes, and Practices; and NRCS NEH, Part 654, Stream Restoration Design, as applicable in surveys, planning, site investigations, and design of channel work.

Do not modify the horizontal or vertical alignment of a channel to the extent of endangering the stability of the channel or its laterals.

**Capacity.** Determine the capacity for open channels according to procedures applicable to the purposes of the channel and according to related engineering standards and guidelines in approved references and handbooks. Designs must consider low flows, average flows, frequent storm flows, and high (infrequent) storm flows.

Estimate stream flows using the USGS Flood Frequency Characteristics of Wisconsin Streams or hydrologic models such as NRCS WinTR-20, WinTR-55, or USACOE HEC-HMS.

Determine the water surface profile or hydraulic grade line for design flow using guidelines for hydraulic design in NRCS TR-210-25 and/or NRCS NEH, Part 654. Select a Manning's n value for the condition representing an aged channel. Base the selection on the expected vegetation and other factors such as the level of maintenance prescribed in the operation and maintenance plan. Establish the required flow capacity by considering volume-duration removal rates, peak flow, or a combination of the two, as determined by the topography, purpose of the channel, desired level of protection, and economic feasibility. Design conditions cannot result in flood impacts to adjacent properties without addressing through the appropriate authorities. Refer to the USACE HEC-RAS model for development of water surface profiles, when non-uniform, unsteady, or gradually varied flow make it difficult to evaluate floodwater impacts.

**Cross section.** Determine the required channel cross section and grade by the plan objectives, the design capacity, the channel materials, the vegetative establishment program, and the requirements for operation and maintenance. As necessary, provide a minimum depth to allow adequate outlets for subsurface drains, tributary ditches, or streams. In urban areas, consider the design impacts on high-value developments.

**Channel stability.** A stable channel has the following characteristics:

- The channel neither aggrades nor degrades beyond tolerable limits
- The channel banks do not erode to the extent that an appreciable change in channel cross-section results
- Excessive sediment bars do not develop
- Gullies do not form or enlarge because of the entry of uncontrolled surface flow to the channel.

Design all channel construction and modification (including clearing and snagging) to result in a stable channel with reasonable maintenance costs. Use vegetation, riprap, revetments, linings, structures, or other measures if necessary to ensure stability.

Use the methods in NRCS TR-210-25 and/or NRCS NEH, Part 654 to determine the stability of proposed channel improvements.

Bankfull flow is the discharge that fills a channel to an elevation where flow begins to spill onto the active floodplain. Bankfull flow can be identified by field indicators in alluvial channels that have adjusted to hydrologic conditions and sediment delivery. Over the long term, bankfull flow typically completes the most work in transporting sediment relative to the magnitude and frequency of other flows. Bankfull flow has a typical recurrence interval range of 1 to 3 years on an annualized frequency curve, with a predominance of values in the 1.2 to 1.8-year range, although exceptions may include urban areas, wetland streams, or settings influenced by colluvium or glacial features.

Channels must be stable under conditions existing immediately after construction (as-built condition) and under conditions existing during effective design life (aged condition).

Determine channel stability for discharges under the following conditions:

- As-built condition.—Bank-full flow, design discharge, or 10-year frequency flow, whichever is smallest, but not less than 50 percent of design discharge.
  - The designer may increase the allowable as-built velocity (regardless of type of stability analysis) in the newly constructed channel by a maximum of 20 percent if—
    - The soils at the site in which the channel is to be constructed are suitable for rapid establishment and support of erosion-controlling vegetation.
    - Species of erosion-controlling vegetation adapted to the area and proven methods of establishment are known.
    - The channel design includes detailed plans for establishing vegetation on the channel side slopes.
- Aged condition.—Bank-full flow or design discharge, whichever is larger, except that it is not necessary to check stability for discharge greater than the 100-year frequency.

Stability checks that are flow related are not required if the velocity is 2 ft/s (0.6 m/s) or less.

A stability check under the as-built condition evaluates velocity and shear stress in the channel for an unvegetated condition. A stability check under the aged condition evaluates the capacity of the channel for the well-established, vegetated condition.

For newly constructed channels in fine-grained soils and sands, determine the Manning's n values according to procedures in Chapter 6 of NRCS TR-210-25. Use caution selecting values greater than 0.25. In channels modified by clearing and snagging, determine the Manning's n value according to the expected channel condition following completion of the work. Guidance is also available in NRCS NEH, Part 654.

Refer to USGS Water Supply Paper 2339, "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains," or NRCS NEH, Part 654.0609(c). In straight, uniformly shaped channels, where vegetation plays only a minor role in resistance to flow, Manning's n can be estimated using the Strickler formula.

**Appurtenant structures**. Include all structures required for proper functioning of the channel and its laterals, as well as travel ways for operation and maintenance. Minimize the erosion or degradation from inlets and structures needed for entry of surface and subsurface flow into channels. Provide necessary floodgates, water-level-control devices, bays used in connection with pumping plants and any other appurtenances essential to the functioning of the channels. If needed, use protective structures or treatment at junctions between channels, to ensure stability at these critical locations.

Evaluate the effect of channel work on existing culverts, bridges, buried cables, pipelines, irrigation flumes, inlet structures, surface drainage systems, and subsurface drainage systems.

Assure that culverts and bridges modified or added as part of a channel project meet reasonable standards for the type of structure and have a minimum capacity equal to the design discharge or state agency design requirements, whichever is greater. Increase the capacity of culverts and bridges above the design discharge as necessary to assure the channel and associated floodway meet design capacity.

In natural channels, evaluate the effect of the grade control structure on channel and bank stability. Determine backwater effects and the effects of modification of sediment transport through the reach.

**Disposal of spoil**. Dispose of spoil material from clearing, grubbing, and channel excavation in a manner that will—

- Not modify flows or cause channel instability when the discharge is greater than the bank-full flow.
- Provide for the free flow of water between the channel and floodplain unless the presences of continuous dikes establish the basis for the valley routing and water surface profile.
- Not hinder the development of travel ways for maintenance.
- Leave the right-of-way in the best condition for the project purposes and adjacent land uses.
- Direct water accumulating on or behind spoil areas to protected outlets.
- Maintain or improve the visual quality of the site to the extent feasible.

**Vegetation of channel**. Establish vegetation on all channel slopes, berms, spoil, and other disturbed areas according to CPS Codes 342, Critical Area Planting; or 580, Streambank and Shoreline Protection.

**Cultural resources**. Consider existence of cultural resources in the project area and any project impacts on such resources. Consider conservation and stabilization of archeological, historic, structural, and traditional cultural properties when appropriate.

**Additional Criteria for Stream Restoration**

Conduct a site assessment to describe the watershed dynamics, identify impairments in the stream, develop integrated solutions, and assess the potential consequences of restoration activities.  At minimum, incorporate the following information into the design report. Refer to WI NRCS Supplements to the NEH, Part 650, Chapter 16 for assessment tools.

- Landowner's objectives for stream restoration, channel migration zone, available materials for bed and bank treatments, earthfill borrow and excavation spoil locations, existing and desired riparian land use, willingness to carry out maintenance activities, and special conditions.

- Geomorphic assessment of the existing stream which includes the following factors:
  - Past, present, future land uses in the watershed.
  - Description of the geomorphic setting and valley type. Refer to NRCS NEH, Part 654, Table 11-1 and TR-25-3.
  - Rosgen stream classification at existing representative crossovers locations. Refer to NRCS NEH, Part 654.0305(e).
  - Description of the bankfull channel's connection to a floodplain.
  - Channel evolutionary stage (i.e. down-cutting, widening, aggrading, or stable). Refer to NRCS NEH Part 654.0305(c). Include a direction of successional changes in channel evolution and indications of past, present, and future direction. Refer to NRCS NEH, Part 654, Fig. 11-15.
  - Description of the type and cause of streambank instability. Determine the type of bank failures such as a shallow slip failure, cantilever failure, or rotational shear failure. Describe causes of erosion such as concentrated flow around debris or sediment bars, seepage and soil piping, or high flow velocities along weak soil stratigraphy.
  - Measurements of planform sinuosity, meander wavelength, riffle spacing and width, deep pool proportions, and if applicable, the extent that the channel was artificially straightened.
  - Sediment transport conditions as described in NRCS NEH, Part 654,1302-1305.
  - Constraints to project completion, i.e. property lines, bedrock outcroppings, infrastructure, threatened and endangered species, cultural resources.
  - Historical meander patterns and lateral migration rates from aerial imagery.

- Log the soil profile from the top of high bank to a depth at least 2 feet below the channel bottom, or refusal, at representative locations or changes in soil type. Identify the location and elevation of observed seepage layers. Classify the bedload material using sieve analysis or pebble counts on the riffles and point bars.

- Document the location, type, and extent of existing bank protection or restoration work. Describe channel stability and effectiveness of those measures on improving water quality and fish and wildlife habitat. Examine past stabilization or restoration measures for success or failure.

- Assess aquatic and riparian habitat types, variability, and disturbances. Compile data on existing aquatic organism populations and water quality data. Summarize the ecological improvement potential.

- Describe the livestock type, number, riparian grazing period, stream crossing locations.

- Describe the type and density of riparian vegetation and invasive species.

- List waterway designations: Areas of Special Natural Resource Interest (ASNRI), Outstanding Resource Waters (ORW), Exceptional Resource Waters (ERW), trout stream classification, type (cold or warm water, fish habitat) and characteristics such as targeted aquatic species.

The primary objectives of alluvial channel design are to: (1) maintain sediment transport continuity, (2) reconnect the bankfull channel to a floodplain, (3) match stream type (hydraulic proportions and features) to the geomorphic setting, and (4) restore the natural planform to the extent possible.

Refer to Rosgen Geomorphic Channel Design as described in NRCS NEH, Part 654.11 or alluvial channel design as described in NEH, Part 654.0900, or combinations thereof. Portions of the stream may require a threshold channel design, or streambank protection, to prevent lateral migration due to physical site constraints such as property lines and buildings. Use the allowable shear stress approach as described in NEH, Part 654.0804 or streambank protection criteria in Streambank and Shoreline Protection (Code 580).

At minimum, incorporate the following analyses into the design:

- Develop a water surface profile model of the existing and planned channel. Refer to a flow model such as USACE HEC-RAS. Evaluate the shear stress, flow depth, and velocity for all flows from bankfull up to the 100-year flood. Calibrate the bankfull flow to field indicators. Match proposed vegetation with the frequency and duration of various flood surfaces.

- Design the cross-sectional geometry to match the dimensions of stable, natural channels in the same or similar geomorphic setting (e.g. bankfull width to depth ratios, floodprone width to bankfull width ratios).

- Evaluate the channel for sediment competence (*ability to move the largest particle made available to the channel)* at the riffle sections. Perform pebble counts or collect bar/riffle samples. Refer to NRCS NEH, Part 654.1102(c). Design the channel capacity, profile, and sinuosity to maintain the sediment transport capacity of the upstream and downstream channel reaches.

- Specify the location of artificial riffles if necessary to re-distribute grade and restore riffle-run-pool-glide sequences.

- If newly excavated channels will re-occupy former channel beds, verify the presence of suitable bed material. Where riffles are needed to re-establish vertical stability, specify the locations and dimensions of riffles to restore appropriate geomorphic conditions. Design pool geometry based on reference reaches or other empirical data.

- Where possible, design a planform indicative of historic or natural meander patterns, and incorporate variability within the channel as described in National Engineering Handbook, Part 654.1200.

- Conduct a soils or geologic investigation along the existing stream channel and planned alignment according to NRCS NEH, Part 631, Chapters 2 and 5 for Group B structures, or TR-25-3. Collect soil samples for index properties of bed and bank soils.

- Investigate the thalweg for at least 150 feet downstream to anticipate advancing headcuts or knickpoints.

## Additional Criteria for Conversion to Two-Stage Ditch

Agricultural drainage ditches are designed as threshold channels to resist movement. However, they often require sediment removal and bank repairs, particularly after large storm flows. These ditches can be converted to a two-stage ditch with a bench that functions as a floodplain, and a low flow (bankfull flow) channel to transport sediment and provide ecological benefits. Drainage benefits include increased ditch stability and reduced maintenance. Refer to NRCS NEH, Part 654.1000 for design. The typical cross section of a two-stage ditch is shown in Figure 1.

Determine the low flow channel capacity using the Cypress Creek equation in NRCS NEH Part 650.1403, regional curve method, or other accepted runoff method. The low flow channel typically carries between the 0.5 and 1-year frequency, 24 hour storm. It can be approximated in the ditch by the elevation of natural bench formations, or the start of sod-forming grasses.

Do not disturb the existing low flow channel. However, in cases where the existing low flow channel is over-widened with a sediment transport problem, evaluate the need to fill the low flow channel with compacted earthfill and excavate a channel with an appropriate cross-section.

Set the bench height at the top of the low flow channel. Use a total bench width between 2 and 4 times the top width of the low flow channel. Total bench width is preferred to be evenly split between the two sides, but can be distributed unevenly, or on one side only. Use one side only to avoid protected areas such as trees, wetlands, or cultural resources.

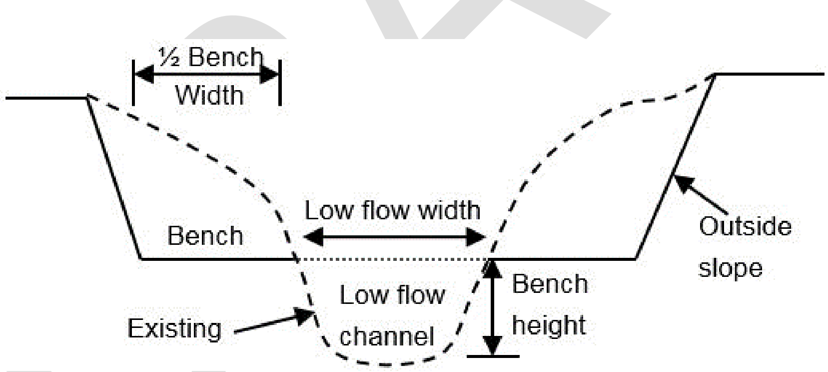


**Figure 1.** Typical two-sided two-stage ditch.

Use side slopes no steeper than those recommended in NRCS NEH, Part 650.1405, Fig. 14-14 and 14-15 which are based on the specific soils or geologic material in the ditch.

Outlet drainage tile on a bench to provide a free outlet. Install rock riprap or other erosion protection method at tile outlets to protect the bench. Appropriate cover must be maintained according to WI NRCS CPS Subsurface Drainage (Code 606) and Underground Outlet (Code 620).

Modify existing structures as necessary to fit the new ditch configuration.

Seed and mulch all bench and bank areas according to Critical Area Planting (Code 342) and Mulching (Code 484). Seed disturbed areas outside of top of bank within 15 days, or seed temporary cover if disturbed areas will be planted to a crop at a later time.

## CONSIDERATIONS

**Visual resource design.** Carefully consider the visual design of channels in areas of high public visibility and those associated with recreation. The underlying criterion for all visual design is appropriateness. The shape and form of channels, excavated material, and plantings are to relate visually to their surroundings and to their function.

Consider changes that may occur in the watershed hydrology, landuse, and sedimentation due to climate change. The magnitude and duration of rainfall and streamflow events may have increased from historical averages. Use local forecasts of climate change in the design if available.

**Fish and wildlife**. This practice may influence important fish and wildlife habitats such as streams, creeks, riparian areas, floodplains, and wetlands. Evaluate aquatic organism passage concerns (e.g., velocity, depth, slope, air entrainment, screening, etc.) to enhance positive impacts and minimize negative impacts.

Select project location and construction methods that minimize the impacts to existing fish and wildlife habitat.

Include measures necessary to mitigate unavoidable losses to fish or wildlife habitat in the design. Maintain the quality of the landscape by both the location of channel works and plantings, as appropriate.

**Vegetation**. Stockpile topsoil for placement on disturbed areas to facilitate revegetation. Consider placement and selection of vegetation to improve fish and wildlife habitat and species diversity.

**Water quality**. Consider the effects of—

- Erosion and the movement of sediment, pathogens, and soluble and sediment-attached substances that runoff carries.
- Short-term and construction-related effects of this practice on the quality of downstream watercourses.
- Wetlands and water-related wildlife habitats.

## PLANS AND SPECIFICATIONS

Prepare plans and specifications that describe the requirements for applying the practice according to this standard.

As a minimum, include the following items:

- A plan view of the layout of the channel and appurtenant features; include horizontal curve layout data.
- Typical profiles and cross sections of the channel and flood plain, as needed.
- Profile view along the improved channel reach. Include the thalweg, top of high bank, bankfull elevation, lateral and vertical extent (top and bottom key) of revetments, bed and bank treatments, habitat components, soil logs, and seepage locations.
- Appurtenant features as needed
- Structural drawings, as needed
- Requirements for vegetative establishment and/or mulching, as needed
- Safety features

- Site-specific construction and material requirements
- Ingress and egress locations for construction equipment.
- Work limits --- extent of protection, ingress and egress locations for construction equipment, parking areas, borrow and spoil locations, areas of habitat requiring protection or avoidance (e.g. wetlands, regulated floodplains, riparian and upland areas, instream habitat), property lines, and buried/overhead utilities.
- Pollution control, e.g. staged construction, floating silt curtains, silt fences, erosion control wattles and logs.
- Grading plans showing existing and proposed 1-foot contours. Include cut and fill volumes.

## OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for the operator.

As a minimum, include the following items in the operation and maintenance plan:

- Periodic inspections of all structures, channel surfaces, safety components and significant appurtenances.
- Prompt repair or replacement of damaged components.
- Prompt removal of sediment when it reaches pre-determined elevations.
- Periodic removal of undesirable trees, brush, and invasive species.
- Maintenance of vegetative protection and immediate seeding or replanting of damaged areas, as needed.

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