River Restoration Toolbox
Practice Guide 8

Channel Defining Structures

IOWA DEPARTMENT OF NATURAL RESOURCES

Iowa Department of Natural Resources

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Executive Summary

Channel defining structures alter velocity distributions to reduce near bank stress and help define the low flow channel. They can also be used to maintain channel dimensions or induce channel narrowing. The following techniques are detailed in this report:

1. Cut-Off Sills
2. Engineered Log Jams
3. Longitudinal Peaked Stone Toe
4. Bendway Weirs
5. Stream Barbs
6. J-Hook Vane/Straight Vane

The *River Restoration Toolbox Practice Guide 8: Channel Defining Structures* (Practice Guide) has been developed to assist with the presentation of design and construction information for stream restoration in Iowa. It is intended to provide guidance to:

- Those responsible for reviewing and implementing stream restoration,
- Professionals responsible for the design of stream restoration projects,
- Others involved in stream restoration at various levels who may find the information useful as a technical reference to define and illustrate channel defining techniques.

The Practice Guide includes a written assessment of channel defining structures and describes a variety of channel defining techniques. Each technique includes design guidelines, a specifications list, photographs, and, when applicable, drawings.

The information in the Practice Guide is intended to inform practitioners and others, and define typical information required by the State of Iowa to be included with the use of channel defining techniques. The information and drawings are not meant to represent a standard design method for any type of technique and shall not be used as such. The Practice Guide neither replaces the need for site-specific engineering and/or landscape designs, nor precludes the use of information not included herein.

The Practice Guide may be updated and revised to reflect up-to-date engineering, science, and other information applicable to Iowa streams and rivers.

1.0 INTRODUCTION

Channel defining structures reduce bank erosion by altering velocity distributions and reducing near bank stress. These techniques can reduce the need for high cost, hardened banks and are often used with vegetative restoration methods for bank stabilization.

Channel defining structures are also used to define the low flow channel, which is critical for aquatic habitat. However, improper design or application of these techniques can result in undesirable movements of the thalweg, exacerbated stream bank erosion, or other instability. Design criteria must be followed carefully.

2.0 CHANNEL DEFINING STRUCTURES

2.1 CUT-OFF SILLS

2.1.1 Narrative Description

Cut-off sills are rows of stone that extend from the bank toe into the stream channel, angled in an upstream direction to better define the low flow channel. They are designed to allow sediment deposition along lateral and point bars. Generally, they are used in larger, gravel bed streams that have over-widened.

2.1.2 Technique Information

- **Use:** Cut-off sills are used in over widened streams to narrow and deepen the baseflow channel.
- **Other uses:** They may be used to define the low flow channel in a stream with active lateral or meander bar formation.
- **Best applications:** Used for larger streams with gravel beds that have experienced channel widening and as a result, shallow baseflow. (Brown 2000)
- **Variations:** Vegetative cut-off sills can be used in sand bed channels.
- **Computations:**
    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of cut-off sills. Hydraulic analysis is required to determine size and/or depth of rock materials that will resist becoming dislodged or undermined.

- Geometric calculations are required to properly size and situate the structure within the context of the stream flow. Cut-off sills require design by a professional.

- **Key Feature:** Installed in streams with sufficient sediment load available to allow sediment to accumulate behind the sills and create a narrower low flow channel. Cut-off sills are ineffective in bedrock channels or in channels with little sediment load.

2.1.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for cut-off sills. The data table includes design guidelines and sources, where applicable.

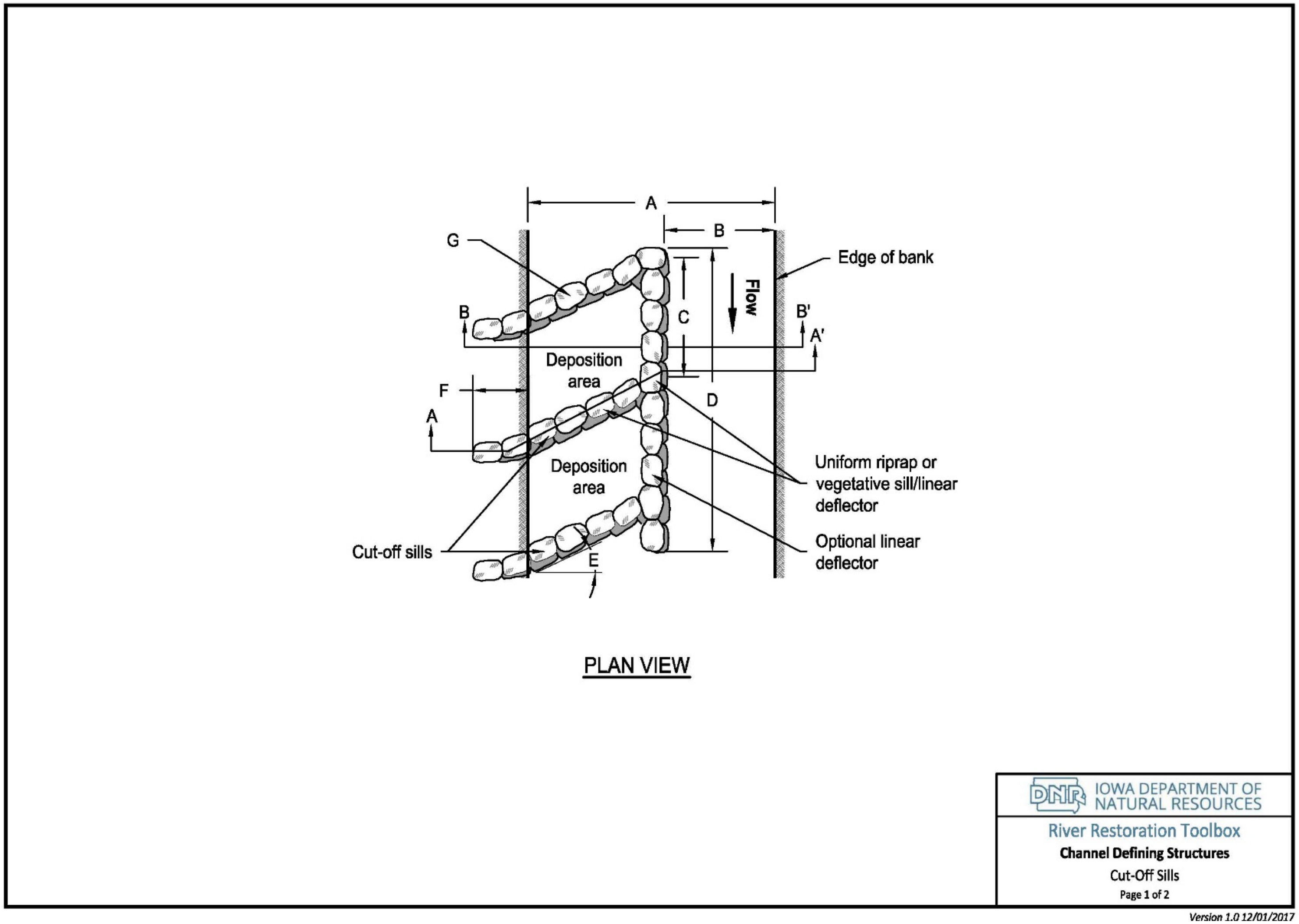
Table 1. Required Design Data for Cut-Off Sills

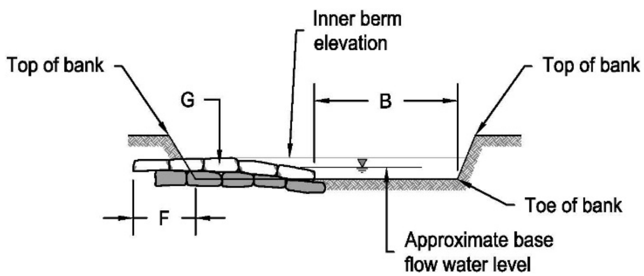
Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
A	Bankfull Width	Feet	Small to mid-sized streams	The channel width at bankfull stage, where discharge has filled the channel to the top of its banks and water begins to overflow onto a floodplain. In incised channels, bankfull is located vertically below the incipient point of flooding.
B	Low Flow Width	Feet	--	The width of the channel wetted during baseflow.
C	Sill Spacing	Feet	--	Distance between sills measured longitudinally along the stream.
D	Linear Deflector Length (optional)	Feet	--	Length of linear deflector measured from the upstream sill to the downstream sill.
E	Sill Angle	Degrees	20° - 30°	Measured between the sill and the perpendicular line from the bank where the sill intercepts the bank.

F	Length of Sill Buried in Bank	Feet	--	Length of the portion of cut-off sill extending into the bank. Sills are required to prevent out-of-bank flows from washing around the structure.
G	Boulder Dimensions	Feet	--	Boulder size will vary depending on the size of the stream system. Ideally, header and footing boulders should be rectangular as opposed to rounded and thick (“flat-shaped”).

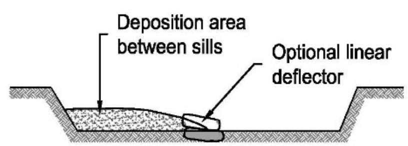
1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.

Drawing 1. Cut-Off Sills





CROSS SECTION A-A'



CROSS SECTION B-B'

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2.1.4 Specifications

The following information should be developed into specifications to accompany the use of cut-off sills:

- Materials:
  - Rock material, including cobble, riprap, and/or boulders. Boulders will be used for the sill portion of the structure, while smaller sized material will be used for structure fill.
  - Alternatively, vegetative sills constructed with woven live cuttings or emergent plant material tied together with wire or synthetic twine may be used in sandy channels with lower erosional forces (Virginia Department of Conservation and Recreation 2004).
  - Geotextile fabric.
- Equipment/Tools:
  - Excavator with thumb attachment.
- Sequence:
  - Excavate enough bed material to place footer rock and sill surface rock, such that the top of the surface rock closest to the bank is even with the inner berm elevation and the top of the surface rock furthest within the channel is even with the base flow elevation. Excavate deposition areas between sills to appropriate depth.
  - Place sills at appropriate angle and tie into bank as indicated in the design. Place linear deflector, if indicated by design.
- Workmanship: The structure elevations, angles, and slopes should match the design to avoid undercutting of the structure or bank erosion. Check the elevations of the invert in accordance with the plans.
- Maintenance: Cut-off sills generally require minimal maintenance; however, they should be inspected annually for movement that may indicate stability issues.

2.1.5 Photographs

Photo 1. Cut-off sill with sediment deposition on Thornton River. Source: Virginia Department of Conservation and Recreation.

2.2 ENGINEERED LOG JAMS

2.2.1 Narrative Description

Engineered log jams can be used for a variety of restoration goals; this Practice Guide will focus on their use to direct thalweg flows. Engineered log jams are built to mimic natural log jams that are absent from the reach due to riparian forest destruction and/or removal of in-stream wood. They are commonly built by stacking whole trees and logs in crisscross arrangements.

2.2.2 Technique Information

- **Use:** Intended to deflect and defuse stream energy away from a bank while providing exceptional aquatic habitat.
- **Other uses:** Engineered log jams can be used for a variety of restoration goals including bank protection, grade control, and habitat enhancement. Location in the stream and design may change depending on applicable goals.
- **Best applications:** Used in streams where natural wood load has been removed due to altered or diminished riparian area; and where inclusion of woody debris would enhance aquatic habitat.
- **Variations:** Engineered log jams can be used in combination with stone and living vegetation material.
- **Computations:**
    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of engineered log jams. Hydraulic analysis is required to determine required material size, and to verify that the velocities and shear stresses generated by streamflow do not exceed the strength of the structure. When used in stream restoration projects, engineered log jams require design by a professional. Inappropriate design and/or construction can cause significant instability.
    - Material size calculations are required. Minimum log dimensions and woody material size will vary depending on the size of the stream system.
    - Buoyancy calculations should also be performed to ensure the wood does not become buoyant and float away during the expected stream flows.
- **Key Features:** Can enhance habitat by adding critical woody material while achieving multiple goals such as bank protection.

2.2.3 Detail Drawings and Data Table

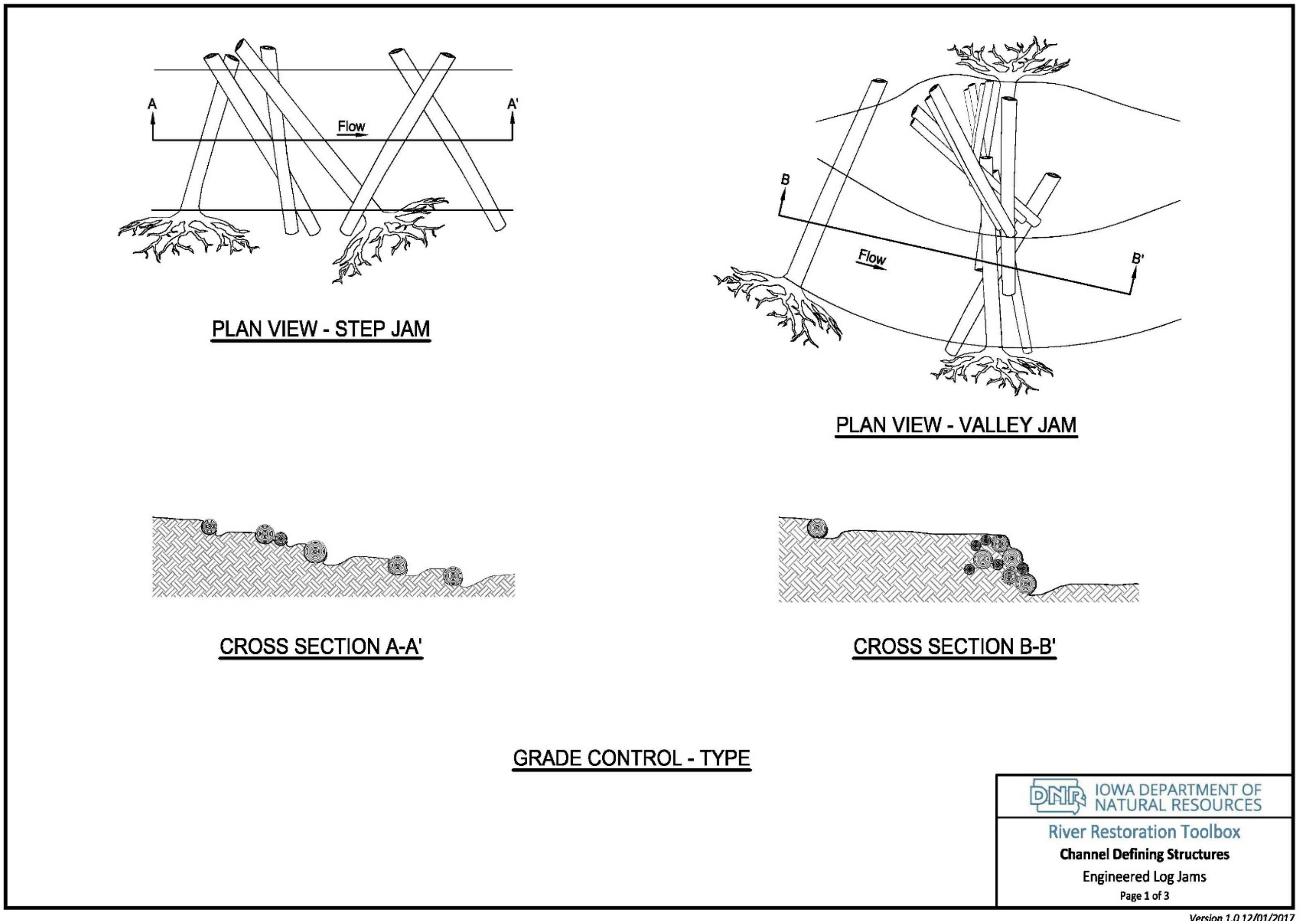
The following drawings and data table depict information that should be included in construction plans for engineered log jams. The data table includes design guidelines and sources, where applicable.

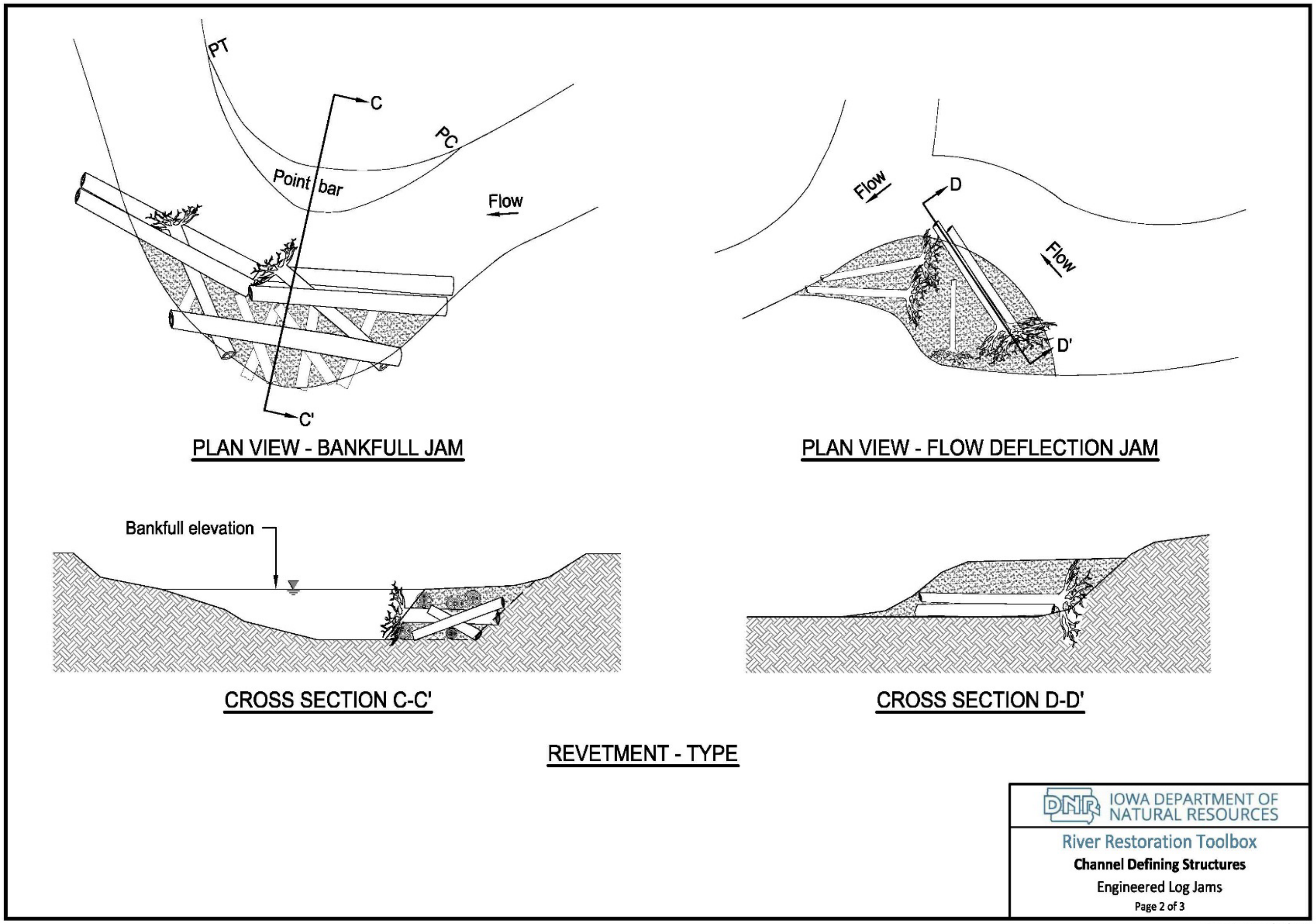
Table 2. Required Design Data for Engineered Log Jams

Dimension	Name	Typical Unit	Guidelines[1]	Description
N/A	Log Dimensions	Feet	Varies	Required log diameter and lengths will vary based on stream size, type of log jam, and how log will be used in the log jam.

1. Common guidance, values, or ranges are given unless they require computation using site-specific input.

Drawing 2. Engineered Log Jams




PT
C
PC
Point bar
Flow
C'
PLAN VIEW - BANKFULL JAM
Flow
D
Flow
D'
PLAN VIEW - FLOW DEFLECTION JAM
Bankfull elevation
CROSS SECTION C-C'
CROSS SECTION D-D'
REVETMENT - TYPE
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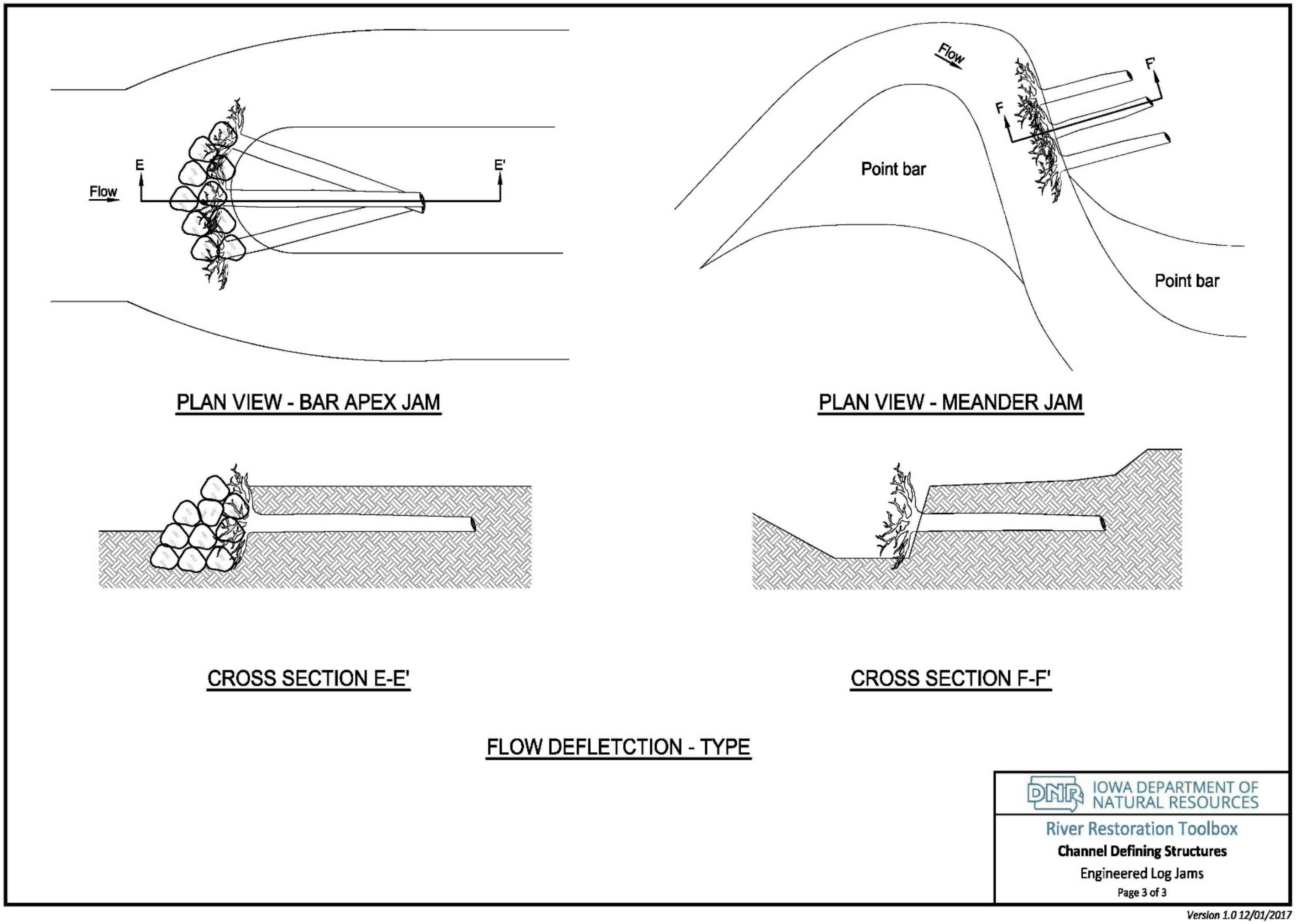
Flow
E
E'
PLAN VIEW - BAR APEX JAM
Flow
F
F'
Point bar
Point bar
PLAN VIEW - MEANDER JAM
CROSS SECTION E-E'
CROSS SECTION F-F'
FLOW DEFLETCTION - TYPE
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2.2.4 Specifications

The following information should be developed into specifications to accompany the use of engineered log jams:

- Materials:
    - Woody material of appropriate size consisting of root wads, logs, tree trunks, and smaller woody debris.
    - Live brush or bank vegetation may be incorporated.
    - Backfill material.
- Equipment/Tools:
- Sequence:
    - Sequencing will vary based on type of jam. Follow details indicated in design.
    - Excavate bed and bank as needed for buried portions of the log jam.
    - Place logs in interlocking or crisscross pattern according to design.
    - Place backfill material, compacting as needed, to build finished bank and bed surface around the log jam.
- Workmanship: The finished surface of the banks should be generally in accordance with the lines, grades, cross sections, and elevations of the design.
- Equipment:
    - Excavator with thumb attachment.
- Maintenance: Engineered log jams generally require minimal maintenance; however, they should be inspected annually for movement or flow around structures that may indicate stability issues.

2.2.5 Photographs

Photo 2. Engineered log jam on Rickreall Creek, Oregon. Source: Scottish Environmental Protection Agency, 2006.

Photo 3. Engineered log jam on Hoh River in Washington constructed by WSDOT. Source: Herrera Environmental Consultants, Inc.

Photo 4. Engineered log jam on Cispus River, Washington. Source: Southerland, 2010.

Photo 5. Engineered log jam on South Fork Nooksack River, Washington. Source: Southerland, 2010.

2.3 LONGITUDINAL PEAKED STONE TOE

2.3.1 Narrative Description

Longitudinal peaked stone toe is a continuous stone dike placed longitudinally at the toe, or slightly streamward of the toe of an eroding bank. A longitudinal peaked stone toe does not need to be parallel to the toe of the bank; it can be designed to smooth the curve of an outer bend. This technique is designed to allow stones to "launch" into scour holes, unlike stone toe protection, described in Practice Guide 7, which is designed to stay in place and hold the existing bank. This technique stabilizes the toe so that upper banks can attain a stable slope, while preserving much of the existing bank vegetation (USACE, 1997).

2.3.2 Technique Information

- **Use:** This technique is used to re-align, smooth alignment, or constrict an over wide channel.
- **Other uses:** This technique may be used in a stream restoration to help realign a bend.
- **Best applications:** This technique is typically used where upper bank slopes are relatively stable and erosion along the toe is the primary concern. Smaller streams are more suitable for this technique, as by design it does not protect upper or middle banks from high flow velocities.
- **Variations:**
  - Longitudinal peaked stone toe protection can be used in conjunction with planting or establishment of bank vegetation behind the structure.
  - The structure can be constructed with or without a backfill matrix.
- **Computations:**
  - Calculations are needed for volume or weight of stone required (often calculated per unit length of streambank). Computations are necessary to properly size rock material and should accompany any design using longitudinal peaked stone toe. This technique requires design by a professional.
  - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of longitudinal peaked stone toe. Geometric calculations are required to properly size and situate the structure within the context of the meander bend location. Proper location and transition can help prevent erosion around the edges of the toe treatment. Hydraulic analysis is required to determine size, thickness, and/or depth of rock materials that will resist becoming dislodged or undermined.

- **Key Features**: The volume of stone required for this structure can be determined by the estimated scour depth rather than by exact cross-section design, which simplifies the design.

2.3.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for longitudinal peaked stone toe. The data table includes design guidelines and sources, where applicable.

Table 3. Required Design Data for Longitudinal Peaked Stone Toe

Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
A	Channel Width	Feet	Mid-sized to Large Streams	The channel width near bankfull stage, prior to design.
B	Sill Spacing	Feet	--	Distance between sills measured longitudinally along the stream.
C	Key-in Length	Feet	--	Length of the portion of cut-off sill extending into the bank. Sills are required to prevent out-of-bank flows from washing around the structure.
D	Tieback Radius	Feet	--	The tiebacks of the stone toe shall be curved to transition smoothly into the existing banks.
E	Stone Toe Height	Feet	To approximate height of observed successful vegetation, OR, where vegetation not available to bankfull on small streams or 1/2 bankfull on mid-size to large streams.	Stone shall be placed up to the design elevation.

Table 3. Required Design Data for Longitudinal Peaked Stone Toe

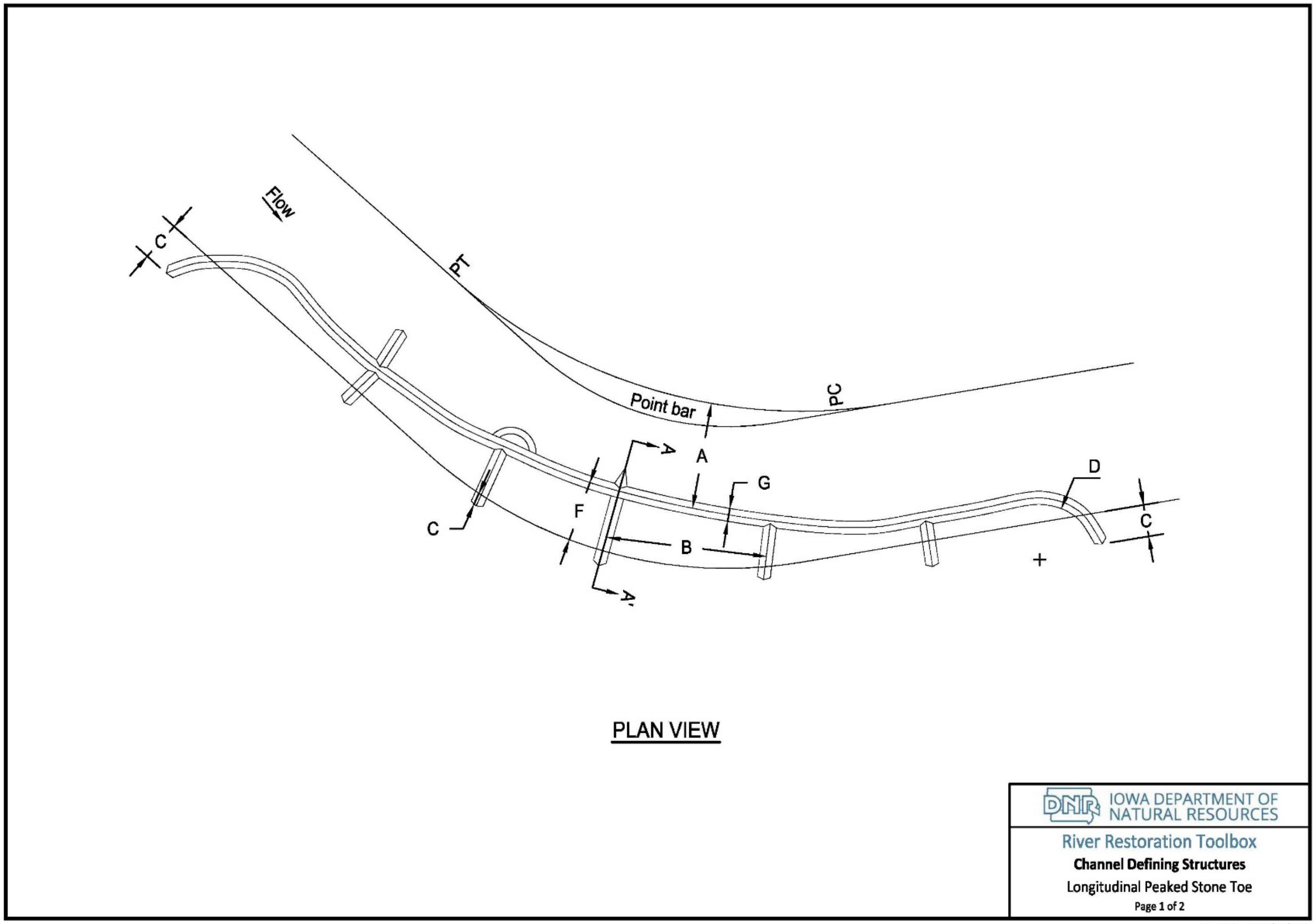
Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
F	Cut-off Sill Length	Feet	May vary along the bank	Distance from the peak of the stone toe to the existing bank.
G	Stone Toe Base Width	Feet	--	Base width.
H	Rock Gradation	Feet	--	The rock shall be graded in a way to allow the rock to self-adjust to fill scour holes created along the face of the stone toe.
I	Live Stake Length	Feet	3' (Iowa DNR 2006); 3-10' (NRCS 2007a)	Length of prepared dormant live cutting from woody plant to be used as live stake. Length should be sufficient to reach low-flow water table elevation.
J	Live Stake Protrusion	Feet	1/5 x live stake length (Iowa DNR 2006); taller than surrounding vegetation (NRCS 2007a)	Distance installed live stake should protrude from ground is about 20% of live stake length. At least two buds or bud scars should be present above the ground in the final installation, depending on the surrounding vegetation height.
K	Slope of Stone Toe Base	Foot:Foot, %	--	Slope of stone toe surface.

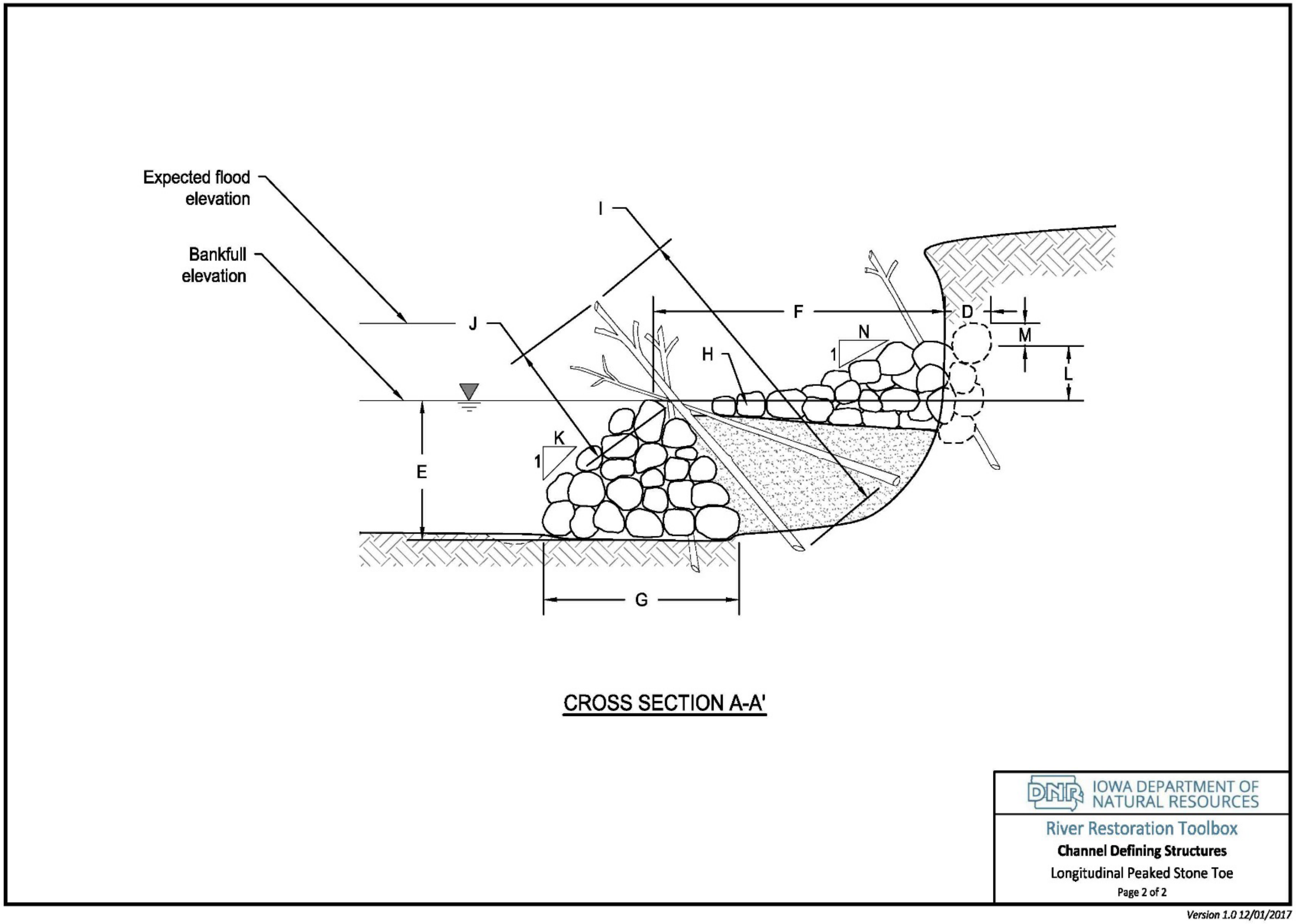
Table 3. Required Design Data for Longitudinal Peaked Stone Toe

Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
L	Height of Sill Stone Above Bankfull	Feet	--	Height of portion of sill buried in bank above the bankfull elevation.
M	Height of Stone Above Expected Flood Elevation	Feet	--	Height of portion of sill buried in bank that extends above the expected flood elevation.
N	Slope of Sill Stone	Foot:Foot, %	--	Slope of sill surface.

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.

Drawing 3. Longitudinal Peaked Stone Toe




Expected flood elevation
Bankfull elevation
I
J
F
D
M
N
1
H
L
K
1
E
G
CROSS SECTION A-A'
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2.3.4 Specifications

The following information should be developed into specifications to accompany the use of longitudinal peaked stone toe:

- Materials:
    - Well sorted, angular stone. Size determined by accepted riprap sizing methods.
    - Live stakes
    - Geotextile fabric
- Equipment/Tools:
    - Excavator with a thumb attachment
- Sequence:
    - Excavate enough bank and bed material to place the rock material at the toe.
    - Construct longitudinal peaked stone toe and backfill matrix (if used), placing coarse rock material with some smaller rock and fines on the bottom, followed by some smaller rock material on top of the coarse material to fill voids.
    - If required, place geotextile fabric above the stone toe, and install live brush or bank material to construct or repair bank as specified.
- Workmanship: The finished surface of the banks should be generally in accordance with the lines, grades, cross sections, and elevations of the design.
- Maintenance: Very little maintenance is required for this relatively simple technique as the rock material in the structure is designed to naturally shift into scour pools as the bank slope stabilizes.

2.3.5 Photographs

Photo 6. Recently constructed longitudinal peaked stone toe. Source: WES Handbook, USACE, 1997.

Photo 7 . Longitudinal peaked stone toe with tiebacks. Source: WES Handbook, USACE, 1997.

Photo 8. Recently constructed longitudinal peaked stone toe with tie backs; Red Banks, MS. Source: Dave Derrick

Photo 9. Longitudinal peaked stone toe with tie backs one year after construction; Red Banks, MS. Source: Dave Derrick

2.4 BENDWAY WEIRS

2.4.1 Narrative Description

Bendway weirs are low level, submerged stone structures placed on outside bends and angled upstream. They are designed to alter a river's secondary spiraling currents. Bendway weirs were developed for large rivers to maintain navigation. Flow over the weirs is directed perpendicular to the weir thereby moving the energy and thalweg away from the bank. Structures are self-maintained and because they are submerged and out of site they create a natural channel without obvious human intervention (U.S. Army Corps of Engineers 2012).

The St. Louis Army Corps of Engineers District has a comprehensive webpage dedicated to development and application of bendway weirs:
http://mvs-wc.mvs.usace.army.mil/arec/Basics_Weirs.html

2.4.2 Technique Information

- **Use:** Bendway weirs are used to control channel depth and divert stream energy away from a bank in navigational channels of large river systems. Some depositional effects can be observed along the toe of bank. This structure is not footed and is intended to be "self-launching", thus will not maintain its trapezoidal profile shape over time.

- **Other uses:** Bendway weirs help maintain navigation and have been found to provide diverse habitat for a number of fish species (U.S. Army Corps of Engineers 2012).

- **Best applications:** Bendway weirs are installed where the midstream tangent flow line intersects the bank. Bendway weirs do not perform well in degrading or sediment deficient reaches (FHWA 2001). Usually accompanied by bank shaping and vegetative restoration practices. Use caution in exceeding recommended ranges to avoid high velocity reverse flows, which can cause bank failure.

- **Computations:**

    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of bendway weirs. Hydraulic analysis is required to determine underlying scour conditions under design flows.

    - Weir length, spacing, and angles of weirs should target a thalweg that will form a stable radius of curvature for the individual river.

    - Geometric calculations are required to properly size and situate the structure within the context of the stream flow. Computations are necessary to properly size rock material and should accompany any design using rock. Bendway weirs require design by a professional.

- **Key Features:** The structures should be angled between 60º and 85º (Scurlock et al. 2012), with consideration of the angle at which flow enters the bend.

2.4.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for bendway weirs. The data table includes design guidelines and sources, where applicable.

Table 4. Required Design Data for Bendway Weirs

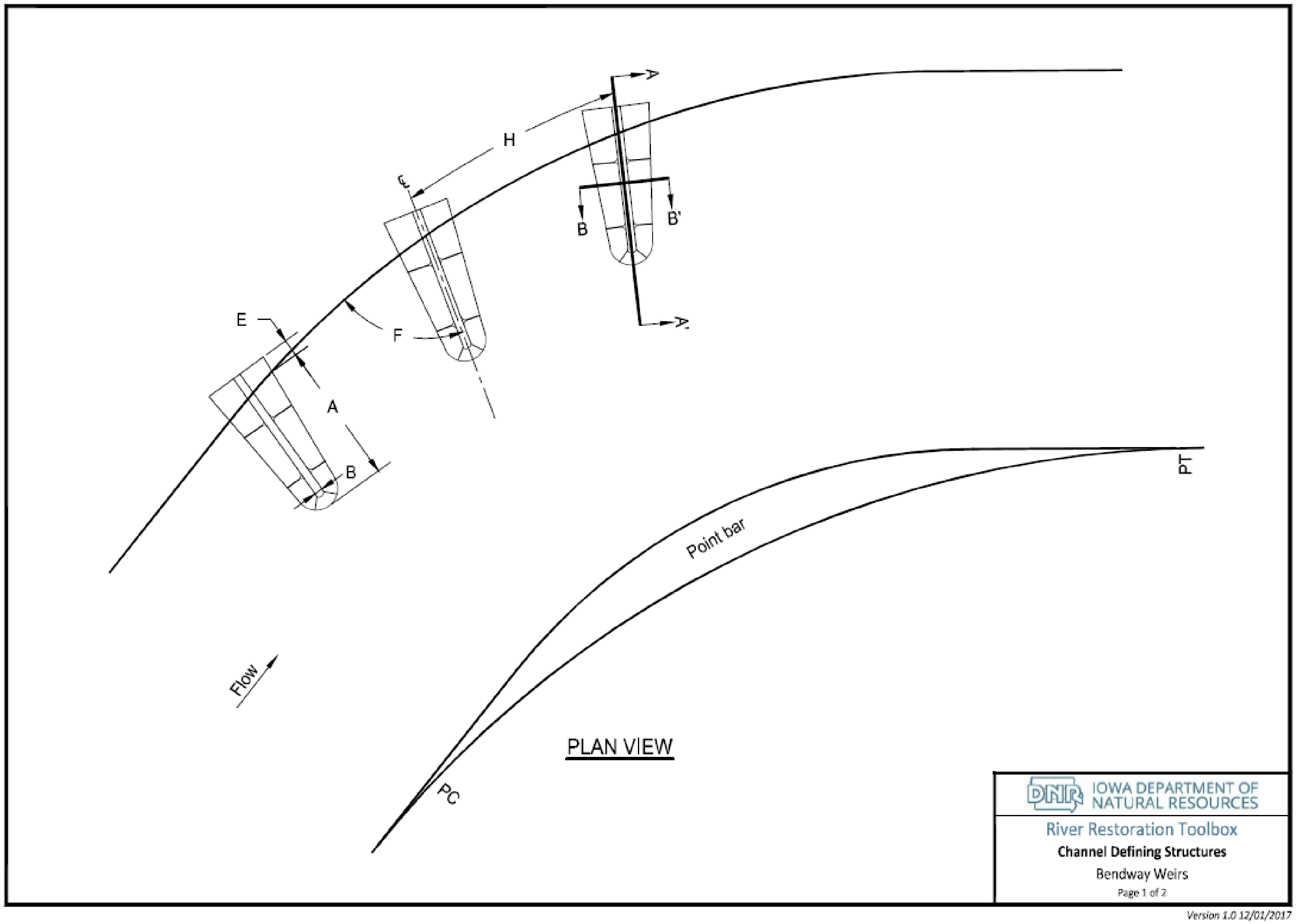
Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
A	Weir Length	Feet	Typically 10 percent of bankfull pool channel at the pool, and not to exceed 15 percent of width. Target length to desired located of new thalweg.	Length of weir from bank to end of weir buried in channel bed.
B	Top Width	Feet	2 times Dmax of Rock Material	Width of top of weir.
C	Side Slope	Foot:Foot, %	1.5 to 2 foot horizontal : 1 foot vertical	Slope of side of weir.
D	Bottom Width	Feet	Top width plus width needed to establish side slopes.	Bottom width of weir.
E	Sill Length	Feet	Carry to top of bank or stable floodplain. Trench in from design bank elevation to a depth that equals wetted height of the bendway weir. Width matches top width of the weir.	Length of sill portion of weir buried in the bank. Sills are required to prevent out-of-bank flows from washing around the structure. Often used only at point of curvature and point of tangency. Also known as keyway, or key.

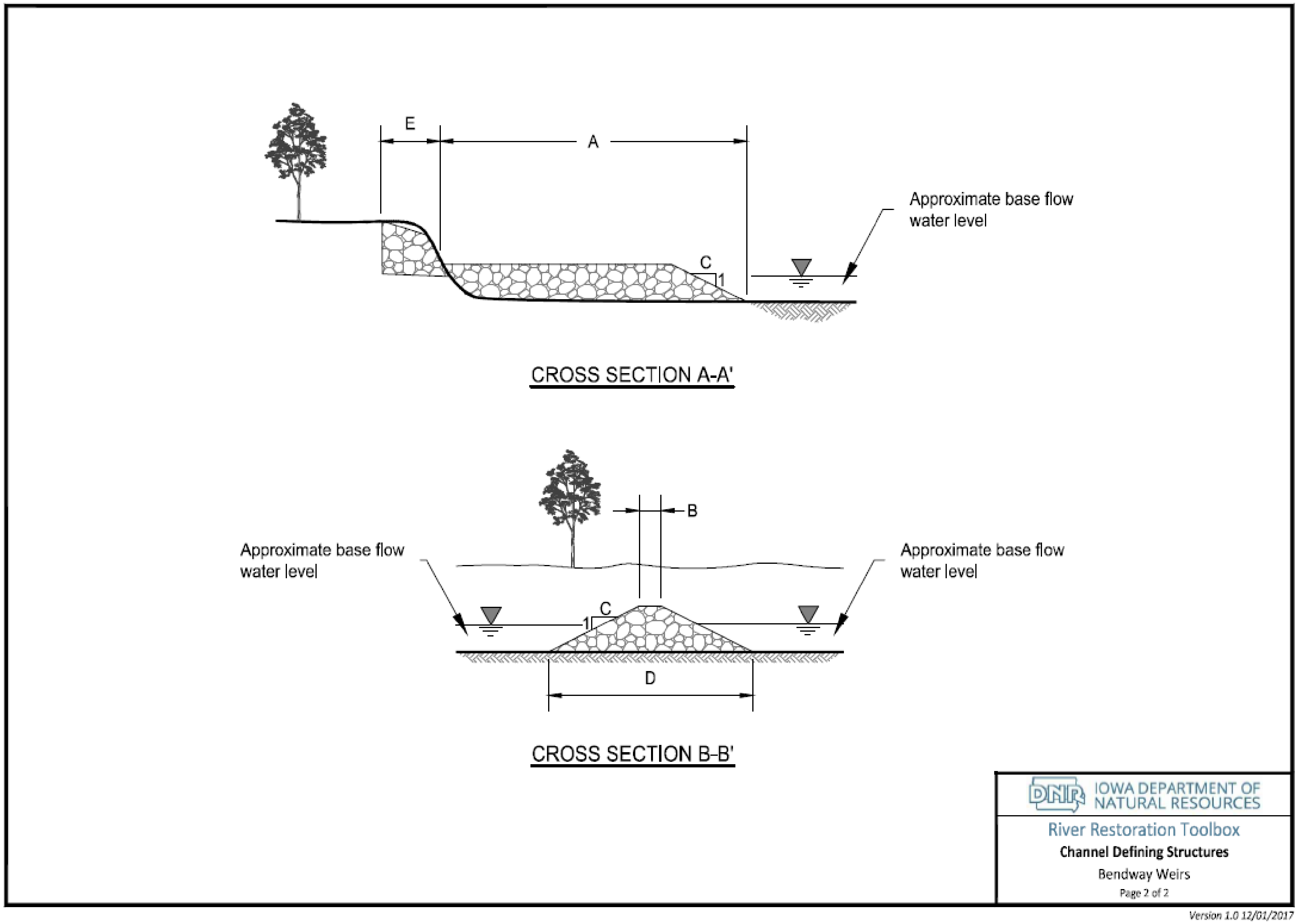
Table 4. Required Design Data for Bendway Weirs

Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
F	Weir Angle	Degrees	Typically placed at an upstream angle between 60 and 85 degrees.	Angle between streambank and weir.
G	Stone Size	Feet	Use Iowa DOT Class E revetment stone with the following gradation. Stone size percent larger than: 250 lbs. – 0% 90 lbs. – 50-100% 5 lbs. – 90-100% ½” Sieve 95-100%	Gradation of stone.
H	Weir Spacing	Feet	Ranges from 1/3 – 1/2 bankfull channel width. Closer spacer may be required based on field determined channel gradient.	Spacing from weir to weir on centers.

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.

Drawing 4. Bendway Weirs




E
A
C
1
Approximate base flow water level
CROSS SECTION A-A'
B
Approximate base flow water level
Approximate base flow water level
C
1
D
CROSS SECTION B-B'
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2.4.4 Specifications

The following information should be developed into specifications to accompany the use of bendway weirs:

- Materials:
  - Rock Material (size determined by location)
- Equipment/Tools:
  - Excavator with a thumb attachment.
- Sequence:
  - Installation should be performed during low flow periods with rock placement beginning at the upstream end of the structure.
  - The bank should be excavated so that the weir can be built into it to prevent water from flowing around and underneath the structure.
  - Excavate enough bed material to place weir rock. Excavate enough bank material to tie weirs into banks. Place weirs from downstream to upstream at appropriate angle and keyed into bank as indicated in the design. Small voids should be filled with backfill material.
- Workmanship: The finished surface of the banks should be generally in accordance with the lines, grades, cross sections, and elevations of the design.

2.4.5 Photographs

Photo 10. Bendway weirs and live bruch layering on Boone River, Iowa. Source: Iowa DNR.

Photo 11. Bendway weir on Boone River after construction. Source: Iowa DNR.

Photo 12. System of bendway weirs on Soldier Creek. Source: Iowa DNR.

Photo 13 . Construction of bendway weirs on Four Mile Creek. Source: Iowa DNR.

Photo 14. Bendway weirs visible at low flow. Source: Dave Derrick.

Photo 15. Flow over bendway weir with crest close to base flow elevation. Source: Dave Derrick.

2.5 STREAM BARBS

2.5.1 Narrative Description

Stream barbs are a low rock sill structure angled upstream to decrease flow stresses on a bank. They are designed to redirect streamflow away from the near bank region. Stream barbs are similar to bendway weirs but adapted for smaller streams. Stream barbs are usually placed in a series of two or more barb structures around a bend to direct flow. The barbs slope slightly downward away from the streambank.

2.5.2 Technique Information

- **Use:** Stream barbs are used to divert stream energy away from a bank.
- **Other uses:** Stream barbs can be used for habitat improvement for aquatic life.
- **Best applications:** Barbs are used alongside bioengineering in meandering, alluvial stream systems to relieve streambank pressure, while vegetation helps dissipate energy and encourages sediment deposition (U.S. Department of Agriculture 2013).
- **Computations:**
  - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of stream barbs. Hydraulic analysis is required to determine size and/or depth of rock materials that will resist becoming dislodged or undermined.
  - Geometric calculations are required to properly size and situate the structure within the context of the stream flow. Computations are necessary to properly size rock material and should accompany any design using rock. Stream barbs require design by a professional.
- **Key Feature:** Proper spacing is important to prevent flow from diverting between barbs and causing bank erosion. Stream barbs will not protect banks from erosion due to mass slope failure or rapid drawdown (USDA, 2013).

2.5.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for stream barbs. The data table includes design guidelines and sources, where applicable.

Table 5. Required Design Data for Stream Barbs

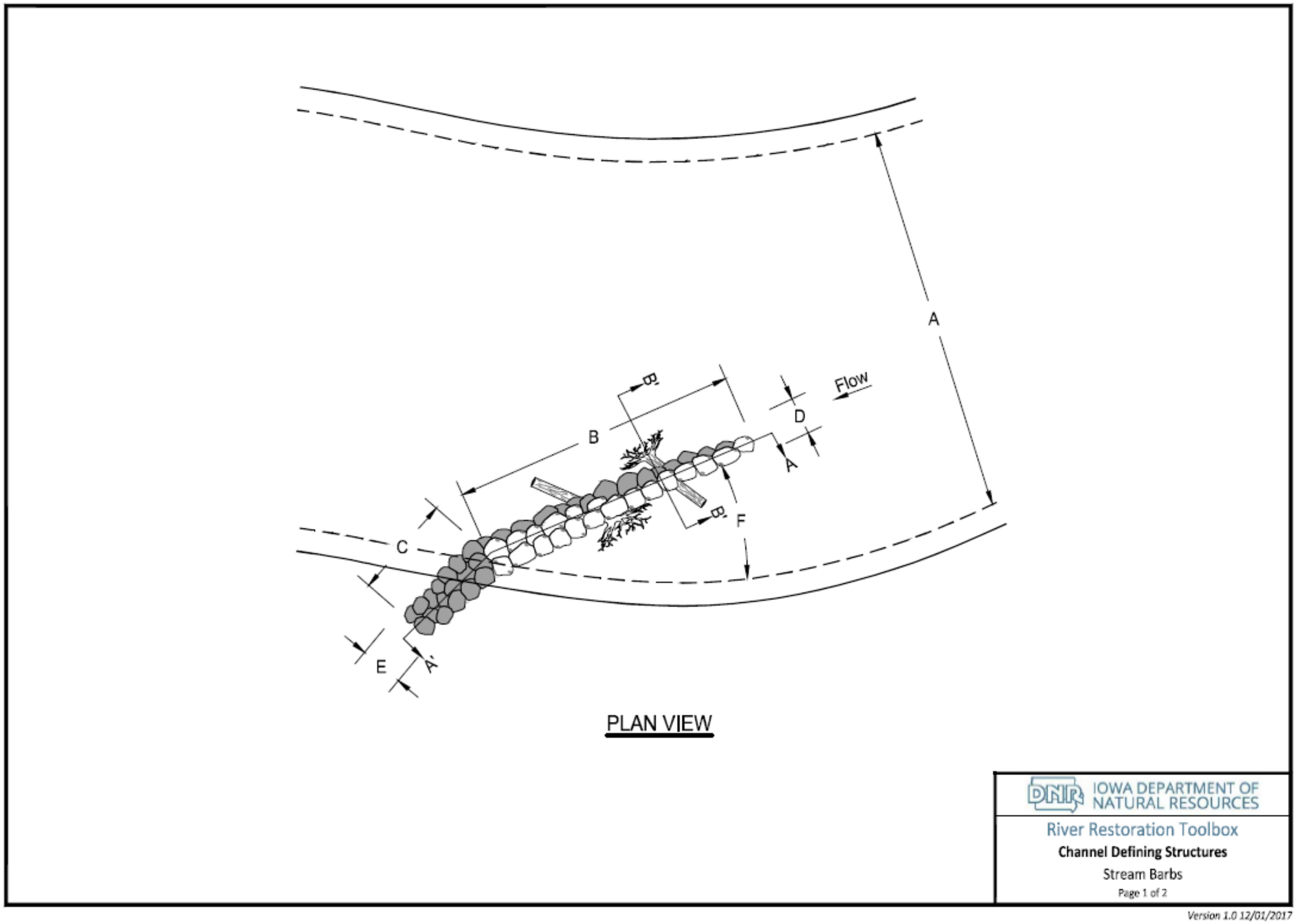
Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
A	Bankfull Width	Feet	--	The channel width at bankfull stage, where discharge has filled the channel to the top of its banks and water begins to overflow onto a floodplain.
B	Weir Length	Feet	Point of barb should not extend beyond 1/3 of the design pool width.	Length of stream barb from stream bank to end of barb in channel.
C	Sill Length	Feet	--	Length of portion of stream barb keyed into bank.
D	Barb Width	Feet	Base width matches height of structure at the sill intercept.	Width of barb crest, typically wider at stream bank and narrowing toward center of channel.
E	Sill Width	Feet	Match barb width	Width of portion of stream barb keyed into bank.
F	Barb Angle	Degrees	Upstream angle of departure from bank ranging from 20 to 40 degrees	Angle between stream barb and bank.
G	Barb Height	Feet	1/2 bankfull height	Height of barb from base buried in channel bed to crest at or near approximate base flow elevation.

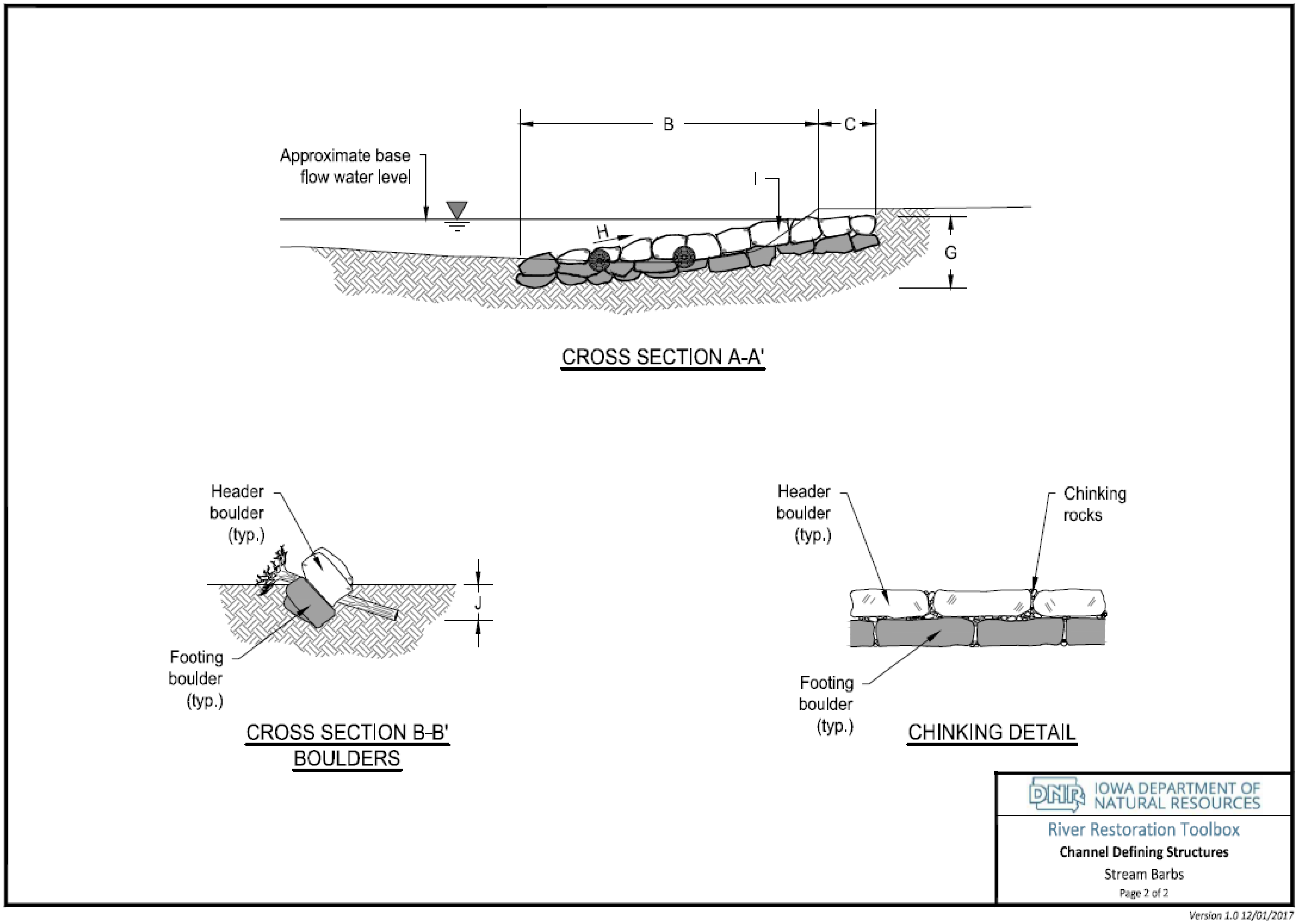
Table 5. Required Design Data for Stream Barbs

Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
H	Barb Slope	Foot:Foot, %	Maximum 10 percent	Slope of barb surface.
I	Boulder Sizing or Stone Gradation	Feet, Pounds	For boulders, minimum intermediate diameter of 3' with specific gravity of 2.6 or greater. For gradation, use Iowa DOT Class E revetment stone with the following gradation. Stone size percent larger than: 250 lbs. – 0% 90 lbs. – 50-100% 5 lbs. – 90-100% ½" Sieve 95-100%	Gradation of stone.
J	Footer Depth	Feet	Match thickness of boulder surface stone of thickness of rock gradation at surface. Verify depth based on scour calculations.	Depth of footing below bed of channel.

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.

Drawing 5. Stream Barbs




B
C
Approximate base flow water level
I
H
G
CROSS SECTION A-A'
Header boulder (typ.)
J
Footing boulder (typ.)
CROSS SECTION B-B' BOULDERS
Header boulder (typ.)
Chinking rocks
Footing boulder (typ.)
CHINKING DETAIL
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2.5.4 Specifications

The following information should be developed into specifications to accompany the use of stream barbs:

- Materials:
    - Boulders, large angular or subangular rock
    - Chinking rock
    - Logs with root wad (if using)
    - Live clumps or other vegetation may be incorporated
- Equipment:
    - Excavator with a thumb attachment.
- Sequence:
    - Place first barb in the downstream quarter of the meander bend (or near downstream end of instability) and proceed upstream with subsequent structures at appropriate spacing. Begin at streambank and construct outwards to allow the barb to support construction equipment.
    - Excavate enough bed material to place footer boulder and header boulder. Place barbs at appropriate angle and key into bank as indicated in the design. Small voids should be filled with backfill material.
    - Install geotextile fabric along barb structure as required by the design. Place backfill material on geotextile fabric against the upstream side of the structure and compact. Backfill area between the streambank and the structure on the upstream side.
- Workmanship: The structure elevations, angles, and slopes should match the design to avoid undercutting of the structure or bank erosion. Check the elevations of the invert in accordance with the plans.

2.5.5 Photographs

Photo 16. Stream barb. Source: Houston Engineering, Inc.

Photo 17 . Stream barb. Source: USDA NRCS, 2013.

2.6 J-HOOK VANE/STRAIGHT VANE

2.6.1 Narrative Description

J-hook and straight vanes divert stream flow away the bank. The straight arm of both types of vanes can be built with either stones or logs tied into the streambank and out from the bank in an upstream direction. The hook of a J-hook is built with stones. Rock vanes consist of both footer rocks and vane rocks. J-hook vanes also create a scour pool for fish cover (Rosgen 2006). Vane arms are similar to stream barbs but larger rock is used and stones are carefully locked together.

2.6.2 Technique Information

- **Use:** Intended to reduce near bank stress, reduce the need for bank armoring, encourage deposition along the bank, and maintain energy gradient near the center of the channel. Usually used in pool facets to maintain deep water, but sometimes used to train over-wide channels in high-fine-sediment-supply river systems by encouraging bank accretion.

- **Other uses:** Vanes can be used to protect bridge infrastructure (Johnson et al. 2001, 2002)

- **Best applications:** Work best in B, C, E, or F channel types (Rosgen 2006). Caution should be exercised with these structures in highly entrenched channels.

- **Variations:** Vanes may incorporate logs with rootwads.

- **Computations:**

  - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of J-hook or straight vanes. Hydraulic analysis is required to determine size and/or depth of rock materials that will resist becoming dislodged or undermined.

  - Geometric calculations are required to properly size and situate the structure within the context of the stream flow. Computations are necessary to properly size rock material and should accompany any design using rock. If logs are to be used, similar computations are required to determine required log dimensions. These structures require design by a professional.

- **Key Features:** The angle of the structure is critical to its proper function. Rocks should be as rectangular as possible to allow for solid rock to rock contact. If rocks are not flat, the thickest end should be placed downstream.

2.6.3 Detail Drawings and Data Table

The following drawings and data table depict information that should be included in construction plans for J-hook vane/straight vane. The data table includes design guidelines and sources, where applicable.

Table 6. Required Design Data for J-Hook Vane/Straight Vane

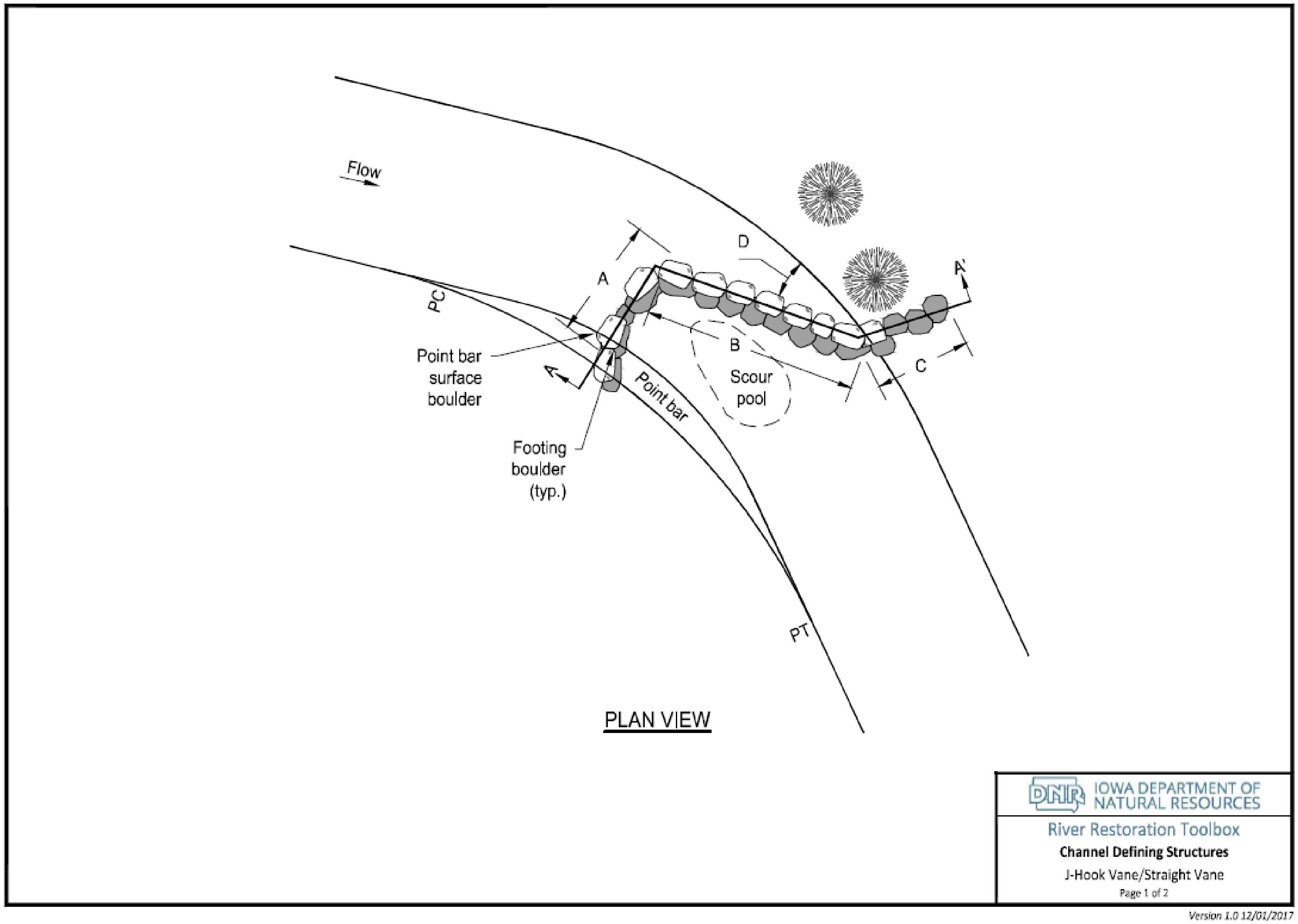
Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
A	Hook Width	Feet	Typically ≤ 1/3 Bankfull Width	Applicable to J-hook vanes; straight vanes have no hook.
B	Vane Length	Feet	Begins at design bank and ends approximately 1/3 of bankfull design width out from the bank of river facet, usually the pool.	Distance from the edge of the hook portion of the structure to the sill portion of the structure.
C	Sill Width	Feet	Matches width of vane. Width of sills extending into the floodplain where the vane arm intercepts the bank.	Sills are required to prevent out-of-bank flows from washing around the structure.
D	Vane Angle	Degrees	20° - 30°	Measure between the vane and the line tangent to the bank at the point where the vane intercepts the bank.
E	Vane Slope	Foot:Foot, %	2% - 7%	Measured along the surface of the vane from the vane-bank intercept down toward the stream bed.
F	Riffle Max Depth	Feet	--	The channel maximum depth above the riffle at bankfull stage, where discharge has filled the channel to

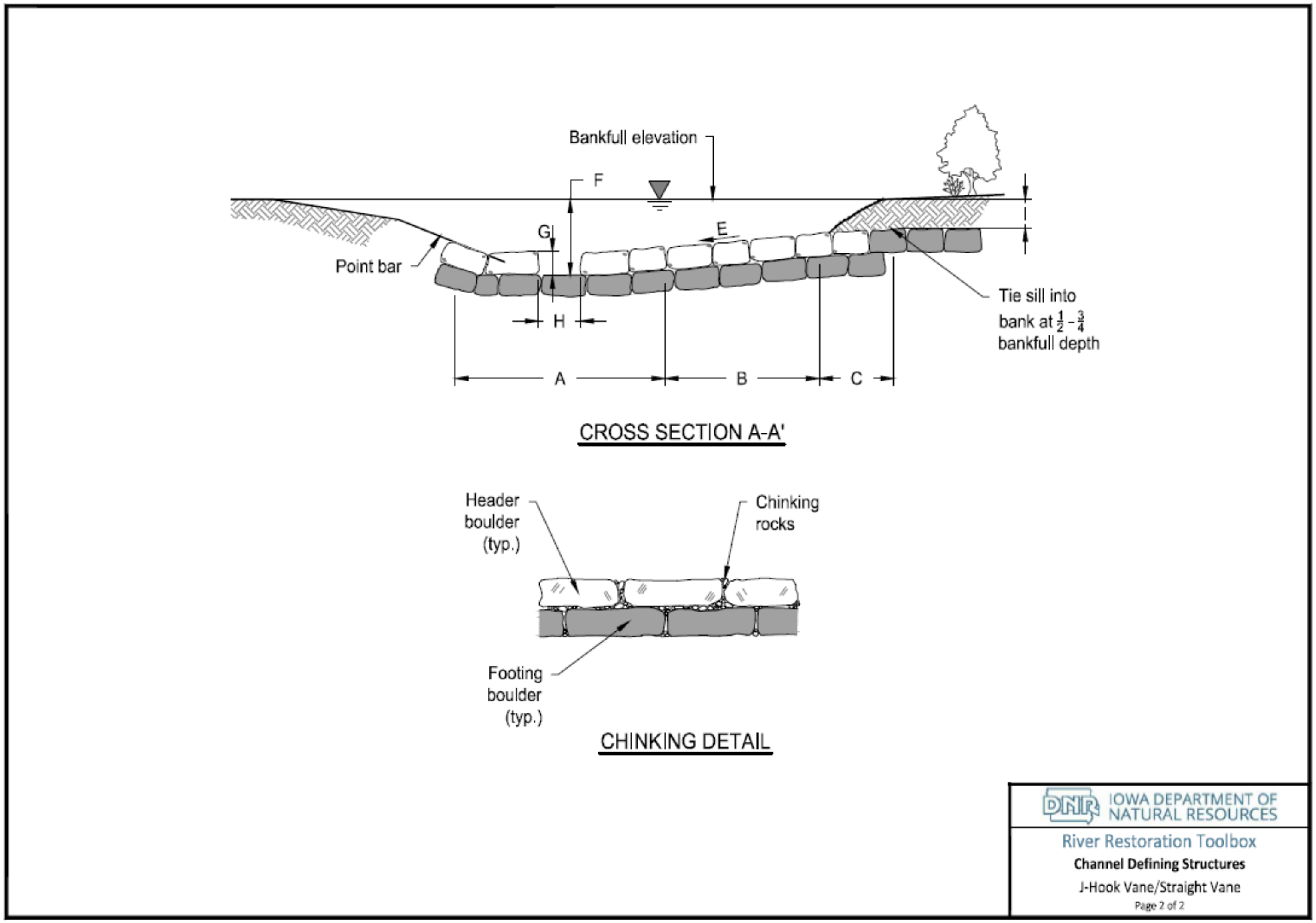
Table 6. Required Design Data for J-Hook Vane/Straight Vane

Dimension[1]	Name	Typical Unit	Guidelines[2]	Description
				the top of its banks and water begins to overflow onto a floodplain.
G	Boulder Protrusion Height	Feet, Inches	< Boulder Height	Height of boulders above the stream invert elevation.
H	Gap Width	Feet	1-2 feet	Width of gap left between hook boulders, if specified in design.
I	Depth Below Bankfull	Feet	Sill ties into bank at ½ - ¾ bankfull depth.	Distance from top of sill to bankfull elevation.
J	Pool Vane Spacing	Feet	Typically, vanes provide protection 2 vane lengths upstream and one vane length downstream of sill tie-in	Spacing for pool placement based on bankfull width and radius of curvature.
K	Boulder Sizing	Feet	Based on empirical data from rivers with bankfull discharge between 20 and 4,000 cfs depicting the relationship of bankfull shear stress to minimum rock size (Rosgen, 2006). Ideally, header and footing boulders should be longer than they are wide and thick ("flat-shaped") and be of a durable composition.	One of three measurements to describe size of cross vane boulder building materials, the thickness is typically the smallest dimension. It is also the vertical dimension.

1. Some labels are referenced in the detail drawings.
2. Common guidance, values, or ranges are given unless they require computation using site-specific input.

Drawing 6. J-Hook Vane/Straight Vane





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2.6.4 Specifications

The following information should be developed into specifications to accompany the use of J-hook vane/straight vanes:

- Materials:
    - Boulders and/or appropriately sized rock material
    - Relatively straight logs with diameters and lengths as specified in design
    - Backfill/chinking material
    - Geotextile fabric
- Equipment/Tools:
    - Excavator with thumb attachment
- Sequence:
    - Shape bankfull channel to specified grades including excavating scour pools. Excavate enough material to place log or boulders for sill, footing, and header.
    - Place the sill and vanes at angles and slopes according to design plans, with a portion of the vane extending into the bank and into the channel bed. Place footing logs and boulders first, followed by header logs and boulders. If used, rootwads of sill log and log vane should lock together.
    - Excavate enough bed material to place hook portion of the J-hook vane, and place footing and surface boulders at the appropriate elevation to form the proposed cross section. Fill small voids between boulders with rock that will not wash through.
    - Install geotextile fabric along entire length of vane structure as required by the design. Place chinking material on geotextile fabric against the upstream side of the structure to fill voids and promote flow over the structure.
- Workmanship: The structure elevations, angles, and slopes should match the design to avoid undercutting of the structure or bank erosion. Check the elevations of the invert in accordance with the plans.

2.6.5 Photographs

Photo 18. J-hook vane used to protect bank and direct stream flow through bridge infrastructure. Source: Stantec.

Photo 19 . Rock straight vane being constructed. Source: Stantec.

Photo 20 . J-hook vanes. Source: Stantec.

Photo 21 . Rock straight vane. Source: Stantec.

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