FACTSHEET

Rock chute spillways

Introduction

Photos 1 A and B : Rock chute spillway
Source : Bernard Arpin and Robert Beaulieu (MAPAQ)

There are numerous techniques for controlling the flow of water from a field to a stream and reducing bank erosion. A rock chute spillway installed at the edge of a field at the confluence of a grassed waterway or ditch and a stream is a way of directing surface water and reducing soil loss. The purpose of this fact sheet is to describe situations where a rock chute spillway is needed, along with the techniques for building such structures.

Definition

A rock chute spillway is a structure that allows for the safe flow of surface water in an outlet. This type of spillway helps stabilize banks by preventing retrogressive erosion of the bottom of waterways (furrows and ditches) and the formation of erosional gullies in fields. This flexible, low-cost and effective structure is readily adapted to the site and represents few drawbacks for agricultural practices. However, unlike a structure such as an inlet well with a sedimentation basin, it does not allow for water retention and the sedimentation of the soil particles contained in runoff water. The rock chute spillway is used to resolve erosion problems at the low end of fields, at the outlet of a furrow, an interception channel or a grassed waterway, or any other place where water flows into a stream.

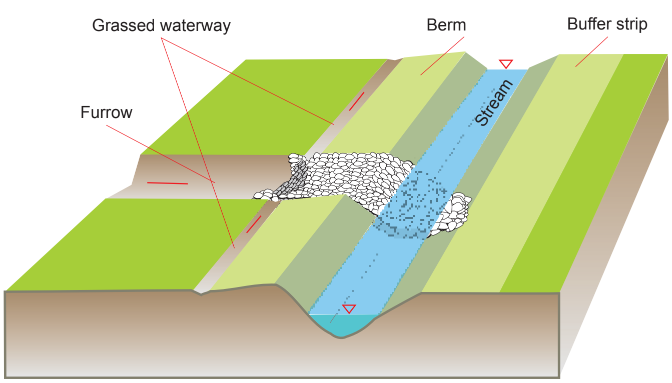

Figure 1 : Rock chute spillway
Source : Georges Lamarre, adapted by Pierre Caron (MAPAQ)

Design of a rock chute spillway

Step 1:
Assess surface erosion problems, locate site for structure and determine drainage area

The first step in designing a rock chute spillway is to clearly pinpoint the source of erosion. It is essential to evaluate overall field drainage and identify drainage areas along with the reasons for erosion. It is also important to ascertain whether an upstream problem needs to be corrected or whether installing a spillway alone will provide an adequate solution to the problem. The fact sheet entitled "Diagnosis and Solutions for Field Erosion and Surface Drainage Problems" could be useful for assessing erosion problems.

Photos 2A and B : Erosion at the edge of a field
Source : Georges Lamarre and Victor Savoie (MAPAQ)

Assessing the situation will involve interviewing the farm operator, applying the available assessment tools (aerial photographs, drainage plans, etc.) and conducting a field visit. The field visit also represents an opportunity to take measurements and collect data required to design the structure.

The following information will need to be collected and recorded during the field visit (ideally before vegetation growth in the spring), as well as in the discussions with the farm operator:

- **Field history**
Is the problem recent? Is it connected with a change in agricultural practices, grading or other work, etc.?

- **Behaviour of water in the spring**
Note whether any part of the field is flooded and how the water flows in the spring.

- **Soil texture**
The design of the structure will differ depending on soil type. With sandy soil, the risk of erosion is far greater, and the structure has to be built accordingly.

- **Condition of buffer strip, presence of vegetation and a berm**
This information indicates how the bank is protected and will help identify other potential areas where water flows into the stream. If so, a berm may need to be built to channel water laterally toward the spillway.

- **Field morphology**
A drawing depicting the morphology of the field is essential for determining whether an artificial funnelling structure needs to be created. The dimensions of gullies (depth, bottom width and slope) must be measured to size the spillway structure.

Photo 3 : Site where water flows into the stream
Source : Victor Savoie (MAPAQ)

- **Slope of drainage basin**
Determine the slope of the drainage basin that drains toward each structure (see Figure 1 in the fact sheet entitled "Evaluation of Peak Flows for Small Agricultural Drainage Basins in Quebec").

- **Drainage basin surface area**
This evaluation involves a number of elements:
— Visual site inspection;
— Assessment of available aerial photos, farm plans and subsurface drainage plans;
— Use of laser level with podometer;
— Use of precise topographical data (e.g., *Lidar*[1]), if available.

Step 2:
Determine peak flow for each spillway

The fact sheet entitled "Evaluation of Peak Flows for Small Agricultural Drainage Basins in Quebec" contains all the information needed to assess peak flows for individual spillways.

The most recent data from *Environment Canada* IDF curves[2] are to be used in these calculations.

Step 3:
Determine crest width of spillway: spillway entrance point

Use equation: $W_c = \dfrac{Q}{C \times h^{3/2}}$ (see Figure 2)

W_c : Crest width (metres)
Q : Drainage basin peak flow (m^3 / sec)
C : Constant = 1.8 (in metric system)
h : Water depth (metres), maximum of 0.3 m (0.2 m is generally a good choice).

(Commonly used formula for calculating water flow for trapezoidal as well as parabolic spillways.) See Figure 2.

[1] : LIDAR Light Detection and Ranging: System for accurately measuring land elevations using a laser mounted on an airplane.
[2] : *Environment Canada* IDF Files: http://www.climate.weatheroffice.ec.gc.ca/prods_servs/index_e.html Last consulted on August 6, 2009.

Table 1:
Crest width (m) in terms of peak flow (m^3/sec) and water depth (m)

Drainage basin peak flow (m^3/sec)	Crest width (m) for water depth of 0.20 m	Crest width (m) for water depth of 0.30 m
0.2 or lower	2*	2*
0.4	3.0	2*
0.5	3.5	2.0
0.6	4.5	2.5
0.7	5.0	3.0
0.8	6.0	3.0
0.9	6.5	3.5
1	7.5	4.0
1.5	11.0	6.0

* Crest width not less than 2 m

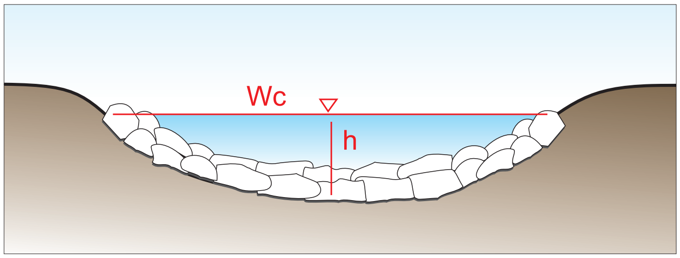

Figure 2 : Evaluation of crest width
Source : Roger Cloutier, adapted by M Pierre Caron (MAPAQ)

Step 4 :
Determine length of inlet apron

The inlet apron is the upstream part of the structure. It is even with the land and eases the transition between the subcritical flow from the outfall to be protected and the critical flow produced at the junction of the outfall and the steep slope of the spillway. The inlet apron must be at least 1.5 m long.

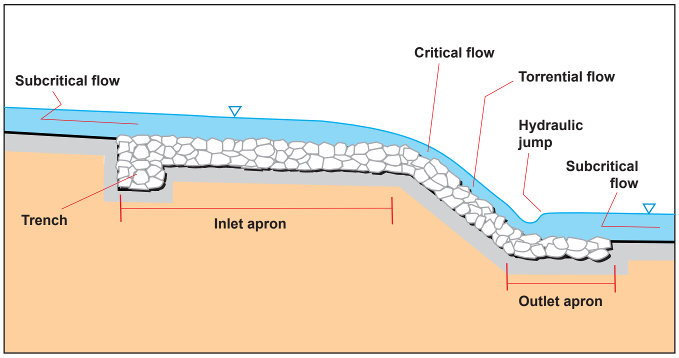

Figure 3 : Spillway inlet and outlet aprons
Source : Drawing adapted by Pierre Caron (MAPAQ)

Photo 4 : Inlet apron for rock chute spillway
Source : Mikael Guillou (MAPAQ)

Step 5:
Determine length of outlet apron

The outlet apron is in the transition zone between the supercritical flow generated by the spillway and the sub-critical flow at the base of the spillway. In this area, a hydraulic jump combined with strong turbulence occurs. The riprap at the foot of the spillway is therefore critical: it should be at least twice the D_{50} for the stone. The outlet apron should be at least 1 to 1.5 m long. However, there are various possible scenarios:

Photo 5 : Turbulence at outlet apron of rock chute spillway
Source : Ghislain Poisson (MAPAQ)

• **Case 1 :**
The spillway discharges water into a wide stream that never dries out even during low-flow periods (at least 30 cm of water during low-flow periods). In this case, a 1-m-long outlet apron on the stream bed is adequate.

Photo 6 : Rock chute spillway on the bank of the Yamaska River
Source : Ghislain Poisson (MAPAQ)

• **Case 2 :**
The spillway drains into a wide stream that is practically dry during low-flow periods. In such cases, the length of the outlet apron could be the same as the height of the spillway. A maximum length of 2 m is considered reasonable even if the height of the spillway is greater.

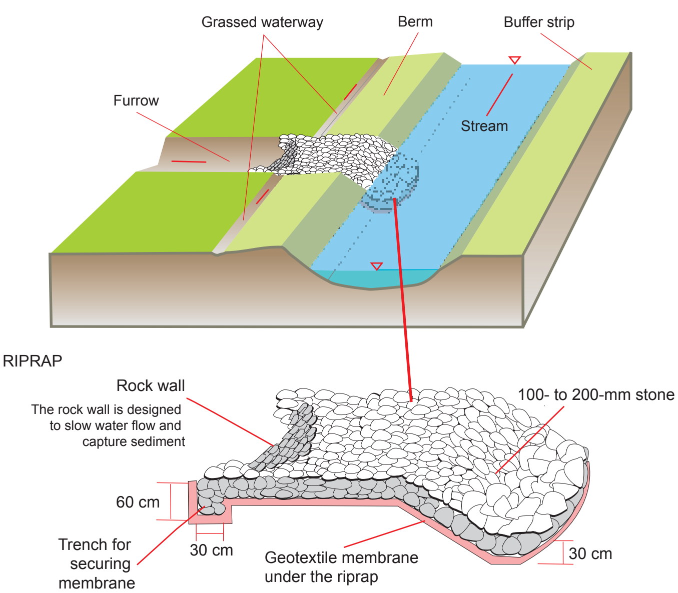

Figure 4 : Spillway draining into wide stream
Source : Drawing adapted by Pierre Caron (MAPAQ)

• **Case 3 :**
The spillway drains into a small stream. In this case, 30 to 60 cm of rip-rap is placed over the entire streambed at the site of the spillway as well as on the opposite bank of the stream.

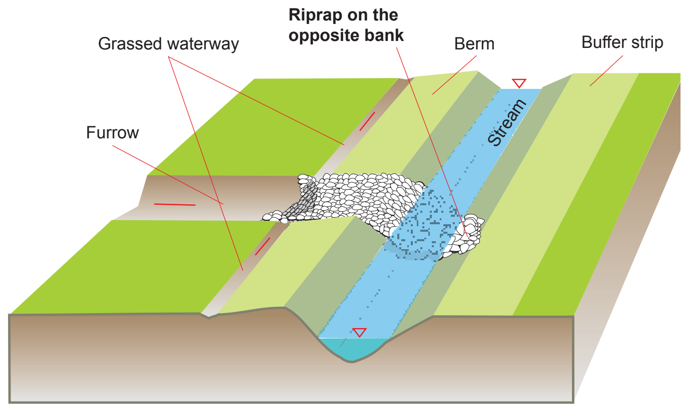

Figure 5 : Spillway draining into a small stream
Source : Drawing adapted by Pierre Caron (MAPAQ)

Step 6:
Determine slope of spillway

Generally, the slope of the spillway is the same as the slope of the bank. However, if the bank drops too steeply, a gentler slope will have to be created. It is recommended never to exceed a 1:1 slope.

The slope of the spillway will be determined by the type of rock used:

— Angular rock (rubble):
  slope of 1:1 or less

— Round rock (fieldstone):
  slope of 1:2 or less

Step 7:
Determine rock diameter

In the case of rock chute spillways for drainage basins of less than 10 ha, the average diameter of the riprap (D_{50}) will generally vary between 4 to 8 inches (100 to 200 mm). However, special attention should be paid to the height of the chute. If the drop is greater than 1.5 m, larger rock of 6 to 12 inches (150 to 300 mm) is recommended.

Rock from 6 to 12 inches (150 to 300 mm) is required for drainage basins greater than 10 ha. In these special cases, calculations will need to be done to determine the size of riprap needed for the structure to withstand peak flows. When spillways drain into steeply sloped or fast-flowing streams, the rock at the foot of the spillway and the outlet apron will need to be sized in terms of stream flow rather than field runoff. The base of the spillway and its toe trench (which is deeper still) can be riprapped with 4 to 24 inch (100 to 600 mm) rock or standard riprap.

In fast-flowing streams during snowmelt, ice can carry away overly light rock. It is therefore recommended to use larger rock that can withstand the impact of ice. In straight sections, angular rock is used on a minimum 1:1.5 (33°) slope instead of a 1:1 (45°) slope. This gentler slope will prevent ice from hitting and dislodging riprap and vegetation.

Step 8:
Calculating thickness of riprap

The thickness of the riprap should be equal to 1.5 times D_{50} for the slope of the spillway and twice the D_{50} for the entrance apron.

A minimum thickness of 0.30 m is required.

Step 9:
Calculate rock requirements

Once the spillway dimensions have been determined, the next step involves calculating rock and geotextile membrane requirements.

$$V = W_t \times d \times L_t$$

V : volume of rock (m^3)
W_t : total width of spillway (m)
d : mean depth of rock (m)
L_t : total length of spillway,
including inlet and outlet aprons (m)

Note :
The largest stones should be reserved for the outlet apron.

The total volume of rock can be estimated using the apparent density of the rock (including voids between stones), or 1.8 to 2.0 T/m^3.

Step 10:
Calculate geotextile membrane requirements

$S (m^2) = (W_t + 1{,}5) X (L_t + 2)$, adding 1.5 m and 2 m to the size of the membrane will allow for geotextile membrane to cover the sides of the spillway as well as the toe trenches.

S : Geotextile surface in m^2
W_t : Total width of spillway (m)
L_t : Total length of spillway,
including inlet and outlet aprons (m)

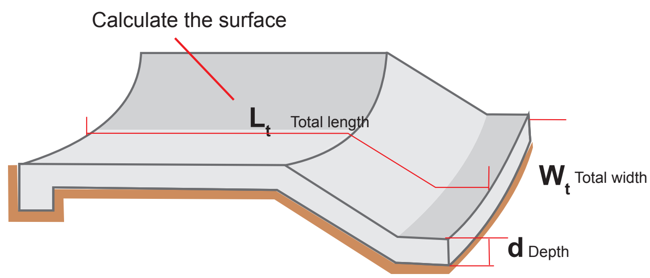

Figure 6 : Evaluation of rock volume and geotextile surface area
Source : Drawing adapted by Pierre Caron (MAPAQ)

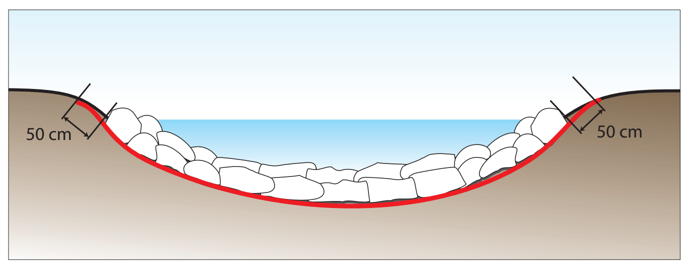

Figure 7 : Geotextile exceeding at least 50 cm on each side of the overflow
Source : Roger Cloutier, adapted by Sandra Hindson (AAFC)

Step 11:
Allow for undisturbed area upstream from spillway

In erosion-sensitive soils or when surface water is loaded with sediment, it is strongly recommended to refrain from working the soil or to seed grass in an area within at least a 5-m radius of the rock chute spillway.

Comment

In practice, spillways that drain areas greater than 10 ha or those at the mouth of grassed waterways require more elaborate sizing calculations. >>>

Comment (cont'd)

For drainage areas of less than 10 ha, the width of the spillway is often roughly 3 m, with the length corresponding to the hypotenuse of the bank plus 1 m for the inlet apron and 1 to 1.5 m for the outlet apron. The riprap tonnage is therefore equal to the length x width x depth (0.40 m generally) x 1.8 T/m^3 (riprap density) with rock size often varying from 4 to 8 inches (100 to 200 mm).

WARNING

Authorizations from the municipality or the RCM are required prior to undertaking work in streams or on stream banks. For some work, a certificate of authorization is required from the *Ministère du Développement durable, de l'Environnement et des Parcs* (MDDEP) in compliance with the *Environment Quality Act*, along with wildlife authorization from the *Ministère des Ressources naturelles et de la Faune* (MRNF), in compliance with the Act respecting the conservation and development of wildlife. As well, *Fisheries and Oceans Canada* regulates the protection of fish habitat and the free movement of fish under the Fisheries Act. Any work undertaken by a contractor in violation of the laws and regulations may expose the contractor to legal proceedings and heavy sanctions.

Building the spillway

Step 1:
Orienting the spillway

Spillways are built perpendicular to streams or drainage ditches.

Step 2:
Shaping the spillway

A hydraulic shovel or backhoe is used to remove vegetation from the surface of the soil and excavate a parabolic-shaped drop with a somewhat rounded or u-shaped bottom. Sufficient soil is removed to allow for the depth of the riprap to be installed for the spillway (generally 0.3 to 0.4 m of riprap).

This means that once the rock is installed, the surface of the riprap will be slightly above the soil surface without creating a barrier that would prevent water from flowing into the rock chute.

Photo 7 : Shaping a spillway
Source : Mikael Guillou (MAPAQ)

Step 3:
Shaping anchor trenches for the geotextile membrane at the top and bottom of the spillway

An anchor trench at least 30 cm wide and 45 to 60 cm deep (i.e., deeper than the average diameter of the rock) is excavated at the top of the spillway to secure the geotextile. The excavated soil can be deposited on either side of the spillway to increase the height of the berm and hence increase the capacity of the spillway and channel water to it. A similar trench is excavated at the foot of the spillway in the streambed or ditch.

Photo 8 : Anchor trench of inlet apron
Source : Mikael Guillou (MAPAQ)

Step 4:
Installing the geotextile

The geotextile membrane is selected in terms of its tear resistance (a function of rock size). Manufacturers indicate the geotextile membrane recommended for different rock sizes. *TEXEL 7612*, *Solmax 701* or *Soleno TX 170* is generally used.

The geotextile membrane is placed on the soil and in the upper and lower trenches then up the sides of the excavation over the berm. Water should never be allowed to infiltrate the sides of the spillway or under the trenches.

Photo 9 : Installing geotextile
Source : Georges Lamarre (MAPAQ)

Step 5:
Placing the riprap

Care should be taken in placing the riprap on the geotextile so as not to rip or dislodge the membrane. The toe trenches are filled with rock (soil can be used but only for the bottom of the upper trench). The level of the rock in the upper part of the spillway should be below the lowest part of the berm and field. The centre of the spillway can then be covered in rock. A hydraulic shovel positioned on the side of the spillway is used to shape the spillway into a parabolic form using the back of the bucket.

Photo 10 : Placing riprap
Source : Victor Savoie (MAPAQ)

Step 6:
Creating a berm, if necessary

When the goal is to concentrate the water at the edge of the field and direct it toward the spillway, a grassed waterway should not be installed too close to the buffer strip. Such a waterway could promote water infiltration and eventually crack the soil causing the slope to fail. This applies particularly to streams more than 3 m deep, as well as in cases where the waterway is weak.

It is preferable to build a 25- to 30-cm berm with a 1:8 slope on each side of the spillway to channel water toward the spillway. This structure will help limit the number of spillways needed on the banks of a stream. The length of the berm will depend on the topography of the site. Berms are built with soil and are grassed.

Photo 11 : Spillway with berm
Source : Mikael Guillou (MAPAQ)

Risks associated with poor design and construction

1. Water diverted around one or both sides of the spillway and soil erosion

Causes :

- Width of inlet apron crest undersized in relation to water flow and volume of water concentrated at that point;
- Poor positioning of spillway;
- Spillway poorly shaped, too flat, with not enough funnelling;
- Obstacle at spillway entrance (rocks, debris, waste, ice).

Photo 12 : Downcutting (Inlet apron too short and too low relative to the bottom of the furrow)
Source : Victor Savoie (MAPAQ)

2. Scouring under the spillway

Scouring can occur when water creates a channel under the structure, or field runoff seeps under the geotextile membrane.

Causes :

- Poorly formed trench, with rock inappropriately placed and poorly compacted;
- Inappropriate geotextile used (e.g., a woven, overly permeable geotextile);
- Geotextile not placed far enough up the sides;
- Entrance apron too short (the sandier the soil, the longer the apron needs to be).

3. Riprap on spillway sliding down to bottom of slope

If the slope is too steep or the rocks too round and small, water from the field can transport riprap to the bottom of the structure.

In the case of spillways built on the banks of fast-flowing streams, the water could also dislodge the structure.

Causes :

- Poorly constructed trench that is not deep enough;
- Geotextile poorly installed at the foot of the spillway and the lower trench;
- Rock too small for stream velocity or ice impact;
- Scouring of bank in various places on the spillway and water flow diverted around toe trench.

Maintenance

Regular or post-flood inspections are required to confirm the stability of the spillway and the accumulation of sediment and debris upstream from or in the spillway. An accumulation of material can redirect the flow of water and create gullies on the sides of the spillway, eventually rendering the spillway unserviceable. Debris and sediments have to be removed from time to time. If rock rolls down to the bottom of the structure, additional rock may need to be added manually.

Some farming practices such as direct seeding or other reduced tillage measures help maintain crop residues in the soil and hence slow down surface runoff and decrease sediment transport. Maintaining crop residues or a grass cover within a 5-m radius of the rock chute spillway will help trap sediments and prevent field runoff from undermining the structure.

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This fact sheet was prepared jointly by *Agriculture and Agri-Food Canada* (AAFC) and the *Ministère de l’Agriculture, des Pêcheries et de l’Alimentation du Québec* (MAPAQ). It is part of a series of fact sheets aimed at promoting hydro agricultural installations for improving surface drainage and arresting erosion in agricultural areas. The other sheets in the series are as follows: *Diagnosis and Solutions for Field Erosion and Surface Drainage Problems; Infiltration Wells; Permeable Trenches; Inlet and Drainage Wells; Evaluation of Peak Flows for Small Agricultural Drainage Basins in Quebec; Calculations for Sizing Inlet Wells; Diagnosis and Solutions for Bank Erosion Problems; Design of Drainage Outlets; Sizing Grassed Waterways; and Grassed Waterways and Interception Channels.*

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