Chapter 12
IRRIGATION FACILITIES

MONTANA
Department of Transportation

HYDRAULICS MANUAL

December 2023

Table of Contents

LIST OF FIGURES

Chapter 12
IRRIGATION FACILITIES

12.1 INTRODUCTION

In the *MDT Hydraulics Manual*, irrigation design refers to agricultural irrigation. This chapter provides guidance on the MDT design process when irrigation facilities are encountered on MDT projects. A qualified hydraulic engineer must design all irrigation channels, pipes and structures. Designs for irrigation pivot systems due to project impacts will be completed by others.

Irrigation systems are typically maintained to very specific operating water surface elevations and flow rates throughout the system. The established water surfaces are set to ensure that water users can obtain irrigation water to specific points for agricultural and livestock purposes. These established operational water levels must be maintained when irrigation features are impacted and altered by an MDT project.

Irrigation designs require more interaction with landowners/water users along project corridors than any other MDT hydraulic activity. Typically, interaction with irrigation water users is required from the beginning of the design process through the completion of project construction.

Some irrigation crossings may be encountered on projects that appear to have not been in use for many years. MDT's design practice is that all impacted irrigation facilities must be replaced unless explicit, written permission to abandon an irrigation crossing is obtained from the water rights holder(s). Contact the Right-of-Way Bureau to pursue formal abandonment of unused crossings.

This chapter is not intended to be an all-inclusive irrigation design guide. Some additional irrigation design resources available online include:

1. The USBR *Design of Small Canal Structures* (1) is a primary reference for designing irrigation structures that:

    - Describes engineering technology involved in the design of canal structures having discharge capacities up to100 ft^3/s;
    - Includes conveyance, regulating, protective, and water measurement structures; and
    - Discusses energy dissipators, transitions, pipes and pipe appurtenances, erosion protection, and safety devices.

2. The USDA, NRCS National Engineering Handbook, Part 623 "Irrigation," Chapter 4, "Surface Irrigation" provides detailed information on irrigation design.

3. The USDA, NRCS website contains a good collection of information on irrigation.

4. The Montana DNRC *Stream Permitting Book,* Chapter 4, "Irrigation Structures" provides guidance on irrigation features.

12.2 GENERAL CONSIDERATIONS

12.2.1 Irrigation Impacts

If an irrigation system will be impacted by a project and is functioning properly, it is usually best to perpetuate existing conditions when developing the proposed irrigation design. Give special attention to matching water surface elevations to the existing conditions.

Before conducting irrigation designs, meet with the impacted irrigators and document all discussions with these irrigators. See Section 12.4.7.

When impacting irrigation features, explore the possibility of a cost-to-cure replacement. A cost-to-cure is a payment from MDT to the irrigation owner. The irrigation owner then replaces their own impacted irrigation features. A cost-to-cure agreement is negotiated through the Right-of-Way Bureau.

12.2.2 Types of Irrigations Systems

Irrigation systems can typically be classified into two distinct types of systems — an open ditch (surface flow) system or a pressurized, subsurface piped system. Open ditch or canal systems are the most common type of system encountered. However, existing open-ditch systems are frequently converted to subsurface pressurized pipe systems to conserve water. These two systems use differing structures and methods to deliver irrigation water to agricultural fields. Sometimes, irrigation systems are a mixture of both open-ditch and closed-pipe systems.

Irrigation systems are typically maintained to very specific operating water surface elevations. These established water surfaces are set to ensure that water users can obtain irrigation water to specific points for agricultural and livestock purposes.

12.2.3 Irrigation and Roadside Drainage Interaction

In some cases, the existing condition intermixes roadside drainage and irrigation water and, on occasion, both may utilize the same pipes and ditches. MDT prefers to separate the drainage and irrigation water and to move irrigation ditches and structures to outside of the right-of-way.

Under some circumstances, it is difficult or infeasible to separate the irrigation and drainage. Separating roadside drainage and irrigation may not be feasible after years of current operational patterns, and/or the additional right-of-way requirements necessary for separation may be prohibitive. If unable to separate the irrigation and drainage, replicate the existing conditions.

12.2.4 Construction Timing

All irrigators operate on a yearly schedule. Typical irrigation seasons across the state will range from the beginning of April to the end of October and will vary depending on the specific owner/operator. Discuss the standard operating dates with the irrigation water users during the design process and include this

information in the Irrigation Owner/Operator Contact special provision that is discussed in Section 12.4.7. During construction, the preference is to not impede or impact the water users' standard operating dates.

12.3 DESIGN CRITERIA

12.3.1 Level of Design Analysis Required

Keep the design calculations and documentation commensurate with the importance of the structure. Most irrigation structures are designed with either HEC-RAS or HY-8:

- HEC-RAS models are required when designing the following:
    - For all irrigation culverts larger than 48 in. in rise,
    - For all irrigation bridge openings,
    - For long runs of ditch (> 1000 ft),
    - For a series of multiple culverts, and
    - For irrigation features such as division boxes or check structures.
- Use either HY-8 or HEC-RAS to model irrigation crossings 48 in. in rise and smaller.

Use the USBR *Design of Small Canal Structures* (1) for:

- Design of irrigation siphons; and
- Design of miscellaneous canal features (e.g., division boxes, flumes, headgates, water measurement, open ditch to closed system, alfalfa valves with hydrants, depressed pipe, and canal crossings).

Use HEC 14 (2) for:

- Design of subcritical flow transitions,
- Design of broken back culverts, and
- Design of stilling basins or other energy dissipation devices.

12.3.2 Irrigation Culverts

Chapter 11, "Culverts" is applicable to irrigation culverts, unless superseded by guidance provided in this chapter. In addition, design all irrigation culverts in accordance with Chapter 11 of the MDT *Road Design Manual*.

The following criteria are specific to irrigation culverts:

- Perpetuate all impacted existing irrigation culverts and features unless otherwise indicated and agreed upon by the water user. Before conducting irrigation designs, meet with the impacted irrigators and document all discussions with these irrigators. See Section 12.4.7.
- Hydraulically design all irrigation culverts 18 in. and larger with software to check capacity and

maintain backwater water surface elevations.

- Maintain the established operational water levels when irrigation features are impacted or altered by an MDT project unless otherwise indicated and agreed upon by the water user.
- Align culverts with existing irrigation ditches to minimize the need for irrigation ditch relocations and to avoid sediment build up.
- Maintain a minimum velocity of 2.5 ft/sec at the design flow to avoid unwanted sediment build up.
- Use single-barrel culverts unless there is documentation that the water user approves the use of a multiple opening culvert and is aware of the potential maintenance issues.

Use the largest culvert size based on the following criteria:

- Match the existing backwater elevation unless operational issues have been observed.
- On culverts larger than 48 in., provide a minimum of 1 ft of freeboard above design backwater to accommodate expected debris.
- Check the culvert headwater for a range of ditch Manning's n values to reflect varied vegetation conditions.
- Where an irrigation crossing also intercepts flood waters, size the crossing to convey the combined flood and irrigation discharges if both discharges reach the culvert.
- If the proposed design increases the culvert exit velocities, ensure that the velocities are not greater than the erosion limits of native ditch materials. Design proper ditch protection when necessary.

12.3.2.1 Irrigation Culvert Material Selection

MDT pipe material guidelines, including those for irrigation culverts and siphons, are presented in Figure 11.4-2, "Guidelines for Optional Pipe Material Selection." In addition, consider the following when designing irrigation systems:

- Watertight joints are required for all new irrigation culverts, pipelines, and siphons.
- Pressurized irrigation systems under MDT roadways may use PVC pressurized water pipe as described in MDT Standard Specification 708.06.1.
- For siphons over 20 ft deep, use concrete pressure pipe as described in MDT Standard Specification 708.02 or PVC Pressurized Water Pipe as described in MDT Standard Specification 708.06.1.
- Other pipe materials meeting the required service life guidelines and watertight joint requirements may be discussed with the State Hydraulic Engineer in special cases such as areas not under

pavement and irrigation waste outfalls.

12.3.3 Irrigation Canals and Ditches

When working with irrigation canals and ditches:

- Minimize the impact to all existing irrigation canals and ditches.
- If an irrigation canal or ditch must be relocated, design the ditch or canal to be in a cut condition.
- If a cut condition is not feasible, then the relocated section of the ditch must be lined or placed in a pipe to prevent leakage. Consult with the Geotechnical Section for additional design guidance.
- Design irrigation ditches to have a minimum of 6 in. of freeboard and canals to have a minimum 2 ft of freeboard for the operating flow. Also maintain the existing ditch capacity.
- In the plan set, include plan and profile details for all canal and ditch relocations, including field ditches. Show existing and proposed ground as well as any information pertinent to construction.

Modifications to ditches will require coordination with the ditch or canal owner(s) and operator(s).

12.3.4 Bridges Over Irrigation Canals

Consult Chapter 17, "Bridges" when designing a bridge over an irrigation canal.

In addition, when specifying a bridge over an irrigation canal:

- Clear span the irrigation canal where possible,
- Set the abutment walls behind the canal banks,
- Align the abutment slopes with the canal banks to minimize the contraction scour potential,
- Match the existing backwater surface elevations if there are irrigation take-outs upstream,
- Match the velocity of the existing canal at the design flow, and
- Provide sufficient freeboard for floating debris.

12.3.5 Piped Irrigation Systems

Piped irrigation systems adjacent to the roadway typically use pressure-rated plastic or steel irrigation pipe. Often, a piped irrigation system will pull water from a main delivery canal and use an open ditch or pumped system in some form for water delivery to specific locations and fields. Piped irrigation systems typically deliver water to the fields via alfalfa valves and hydrants (see Section 12.4.9) to either open ditches or gated plastic irrigation pipe (PIP).

If a piped irrigation system is located within an MDT project:

- Avoid impacting the system if possible, especially the pumps.

- If impacts are unavoidable:
    - Relocate the system outside of MDT's right of way.
    - Discuss system operation and replacement preferences with landowners.
    - Attempt to replace the system in-kind.
    - Explore the possibility of a cost-to-cure replacement.

12.3.6 Irrigation Design Limits – Right-of-Way Location

Standard MDT practice is to locate all irrigation ditches and structures outside of the new right-of-way limits of a project. Design irrigation culverts less than or equal to 30 in. in diameter span to extend a minimum of 24 in. beyond the proposed right-of-way limits. Design irrigation pipes larger than 30 in. to the same requirements as drainage culverts with respect to clear zone requirements and cover requirements.

12.4 DESIGN GUIDELINES

12.4.1 Design Flows

Irrigation design flows (operating flow, water right flow, and maximum flow) can be estimated from the following sources:

- Operating Flow
    - Discharges provided by ditch or canal owner(s) and operator(s),
    - Irrigation Study Report, which is prepared by the Right-of-Way Bureau,
- Water Right Flow
    - DNRC Water Rights Query System (available online),
    - County Water Resource Surveys (available online at DNRC website),
- Maximum Flow
    - Capacity of existing system or feature.

12.4.2 Irrigation Culverts

MDT practice for irrigation culverts is to perform the following:

- Discuss debris issues with the water users. If debris is present, trash racks may be necessary for smaller culverts, and additional freeboard may be necessary for larger culverts.
- Design new culvert widths to match typical operating water surface widths in the canal or ditch.

- Where an irrigation crossing also intercepts floodwaters, size the crossing to convey the combined flood and irrigation discharges.

12.4.3 Irrigation Culvert End Treatments

Irrigation culverts typically have different end treatments than drainage culverts. The selected end treatment depends on the size and type of the irrigation culvert and the transition needed between the canal and culvert.

For round or arch irrigation culverts and buried irrigation systems, use one of the following:

- MDT Standard Inlet and Outlet Irrigation Headwalls (MDT Detailed Drawing. No. 613-12).
- Irrigation Division Boxes or other structures (MDT Detailed Drawing No. 615-04).
- Concrete Irrigation Inlet and Outlet Transition (MDT Detailed Drawing No. 615-06) for siphons.
- When the culvert width approximately matches the canal width, a square pipe end can be used. In these situations, include a cutoff wall, per MDT Detailed Drawing No. 552-00.
- A standard flared end treatment section (FETS) is usually too wide to fit the ditch cross section. However, when the canal width is larger than the culvert width, a FETS can be used as a transition. A FETS is also useful where a trash rack is required.
- Specialty end sections.

For Reinforced Concrete Box (RCB) culverts, use one of the following:

- Concrete wingwalls (when the canal width is greater than the RCB width), or
- Sloped end sections.

In some instances, for both round and box culverts, specialty end sections may be required. In these cases, reference:

- USBR *Design of Small Canal Structures* (1) is recommended for use in the design of special transitions.
- HEC 14 (2) provides transition loss coefficients.

For entrance loss coefficients, see Figure 11.11-2 in Chapter 11, "Culverts."

12.4.4 Erosion Protection

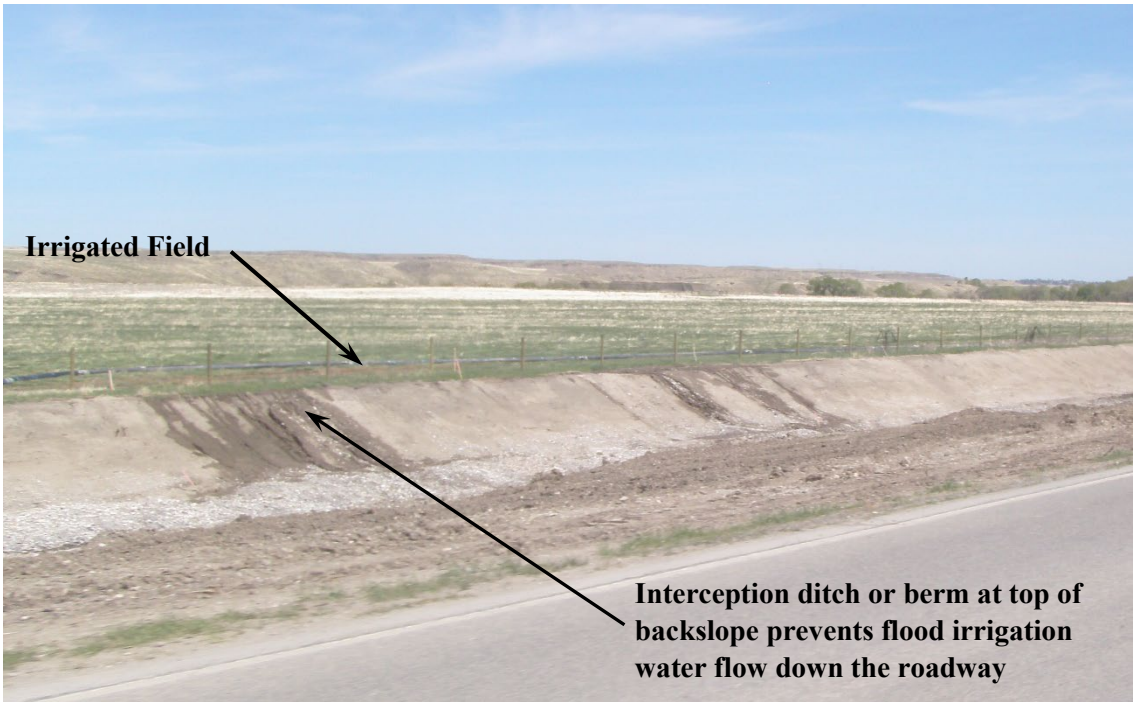
Check for erosion potential for the discharges in Section 12.4.1 at the outlets of culverts and division boxes. Additionally, check proposed irrigation canals for areas that may show high shear stress. Compare calculated velocities to the permissible velocities in Figure 10.5-2, and provide erosion control

protection where necessary. Evaluate bare earth conditions because irrigation operators often check the irrigation system's capacity immediately after construction before vegetation is established.

12.4.5 Irrigation Interception Ditches and Roadway Backslopes

If an MDT roadway is adjacent to an area where flood irrigation drains towards a road backslope, use a small ditch or berm to capture the water at the top of the backslope and direct the water to a culvert. See Figure 12.2-1. Failure to capture the irrigation runoff prior to the ditch backslope will lead to erosion on the backslope. Consult with the Geotechnical Section to select an appropriate solution based on the soil and site conditions.

Figure 12.2-1 — IRRIGATION INTERCEPTION DITCHES AND ROADWAY BACKSLOPES



12.4.6 Irrigation Siphon Culverts

Inverted siphons, referred to in this chapter as siphons, are used to convey water by gravity under roads, railroads, other structures, various types of drainage channels, and depressions. An inverted siphon is a closed conduit designed to run full and under pressure. Typically, MDT avoids siphons when possible.

Low roadway grades at an irrigation crossing will at times make it impossible to provide adequate pipe cover and maintain the necessary operating water surface elevations. Where this occurs, it is necessary to use an inverted siphon. Before designing a siphon crossing, evaluate a conventional culvert and check the cover to verify that a siphon must be used. Use siphons only when necessary due to the additional cost and maintenance.

For a better understanding of the siphon design process and associated hydraulic losses, see the USBR *Design of Small Canal Structures* (1), Chapter II, "Conveyance Structures," Part C, "Inverted Siphons."

Figures 12.4-1 and 12.4-2 illustrate two common siphon layouts. MDT's preferred option is to use transition structures as shown in Figure 12.4-1; however, the detail shown in Figure 12.4-2 may be encountered in the field for existing conditions. Use the 6H:1V transition structures shown in Figure 12.4-1 for all new siphon installations. The 6H:1V transition structure provides a more efficient flow transition between the ditch and the pipe. MDT has standard details for siphons and 6H:1V concrete transition structures.

Figure 12.4-2 — SIPHON WITH CONCRETE TRANSITION STRUCTURES

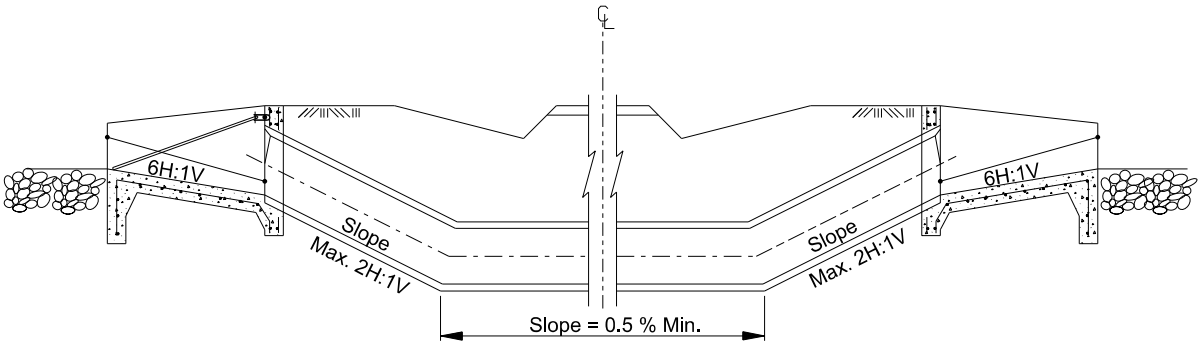
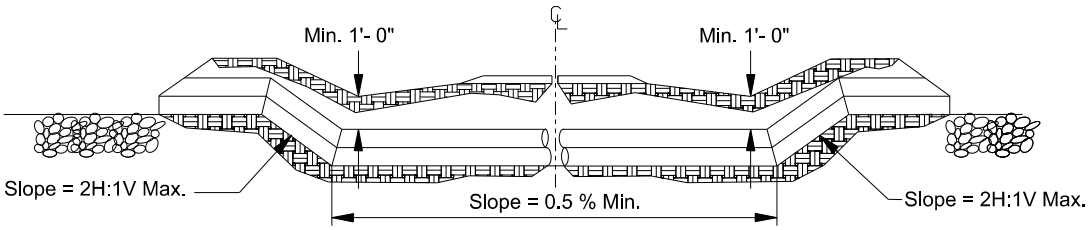


Figure 12.4-3 — SIPHON WITHOUT TRANSITION STRUCTURES



A maximum slope of 2H:1V is allowed for the pipe sections connected to the 6H:1V transitions, and a minimum 0.5% slope is required for the section of pipe under the roadway.

Allowable pipe materials for siphon pipes are the same as for standard irrigation crossings of a roadway. However, the maximum permissible head on a standard irrigation Class RCP is 20 ft, measured from the lowest bend of the siphon. When the head exceeds this value, other pipe and joint options will be required. ASTM C361 can be used to design pressure pipelines with low internal hydrostatic heads not exceeding 125 ft.

As with standard irrigation pipe crossings, all joints of a siphon must be watertight joints.

Trash guards are required on all siphon installations for two primary reasons:

- Because of their shape, siphons are extremely susceptible to plugging by floating debris.
- To prevent entry since siphons can be dangerous with or without water.

12.4.7 Irrigation System Owners and Operators

Irrigation systems are typically owned and/or operated by:

- A ditch company or irrigation district with a specific operator/regulator that manages the system (Ditch Rider);
- A government agency such as DNRC, USBR, BIA, NRCS, private dam owners, USACE, or BLM;
- A group of people with no central controlling entity; or
- A private party.

Owner/Operator Maintenance and Access are discussed in Section 12.4.6.1 and Contact and Coordination are discussed in Section 12.4.6.2.

12.4.7.1 Maintenance and Access

All irrigation features encountered and/or impacted along a project corridor will be maintained by the irrigation water users. The maintenance is conducted by individuals or by a central entity employed by an irrigation ditch company. MDT does not actively maintain any irrigation facilities nor does the Department pursue such negotiations.

Maintain access to existing irrigation ditches, structures, and pipes. Ensure that proposed designs provide access to new ditches, structures, and pipes when necessary or requested by water users. One of the primary maintenance considerations for the owners of the irrigation facility is access for:

- Operation (e.g., ditch rider roads, ditch flow monitoring flumes), and
- Maintenance (e.g., pipe cleaning),

Also, ensure culvert height is sufficient to accommodate cleaning equipment.

12.4.7.2 Irrigation Contact and Coordination

Coordinate all contact with irrigation water users along a project corridor with MDT district Right-of-Way personnel. If it is known that irrigation will be impacted on a project, include a request for an Irrigation Study Report from the MDT Right-of-Way Bureau in the LHSR and ensure that the LHSR is distributed to the proper district Right-of-Way personnel. Right-of-Way will typically complete a Preliminary Ownership Report at the beginning of the project and include the requested Irrigation Study

Report. This report will contain information on the irrigation water users and landowners along a project corridor, typically including contact information. Some reports may also contain information from initial discussions that Right-of-Way personnel previously had with irrigation water users.

Ensure that all irrigation water users on an impacted system are contacted. Some impacted water users may be located downstream of the project limits. Contact the irrigation ditch riders and foreman to determine if there are downstream water users that may be affected by the proposed work.

Document all contacts with irrigation water users and companies and include this information in the Irrigation Design Report. See Section 12.6.1. Provide copies of all irrigation water user contacts to district Right-of-Way personnel for use during right-of-way negotiations and acquisition.

Some important points of discussion to note include:

- Were any planned irrigation system improvements discussed?
- What are the standard operating flows and maximum design flows?
- What is the standard operating season for the irrigators?
- Does the user require specific products (such as valves) from specific suppliers?
- Are there any historic or existing erosion or capacity issues?
- Do any irrigation systems intercept drainage?
- Are any ditches used as irrigation waste ditches?
- What is the debris load on the system?
- Are trash guards desired?
- Are there existing trash guards or debris removal equipment?
- If a multiple barrel culvert is needed, is it acceptable?
- Are there any crossings that are not in use and can be abandoned?
- Is a cost-to-cure solution possible for impacted irrigation facilities?

Include an Irrigation Owner/Operator Contact special provision with all completed irrigation designs for inclusion with all project plan sets that involve irrigation impacts. This special provision contains contact information for the impacted irrigation owners or operators and the standard operating dates of the irrigation facilities.

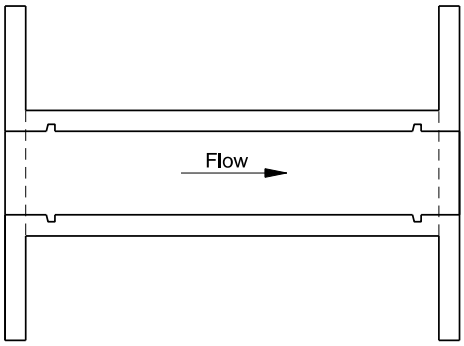
12.4.8 Irrigation Structural Design

In some cases, non-standard irrigation structures are necessary. If these structures include reinforced concrete, walkways, beams, or other structural elements, the structures must be designed by a qualified structural engineer.

12.4.9 Irrigation Structures and Features

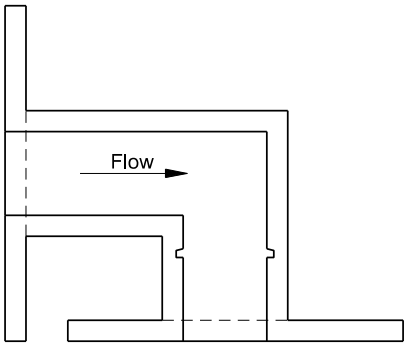
Following are some of the additional irrigation features and structures that may be encountered when irrigation systems are impacted by MDT projects:

- Division boxes or turn outs (see below and the MDT *Detailed Drawings*)



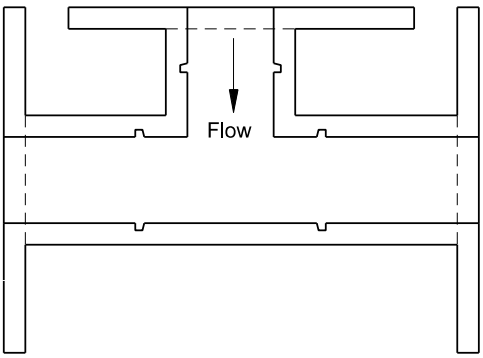
Type I

Modified Type I Division Box



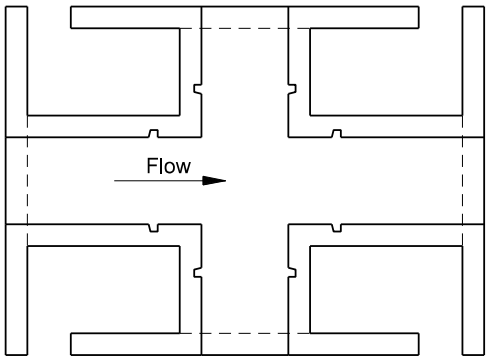
Type II

Type II Division Box



Type III

Type III Division Box

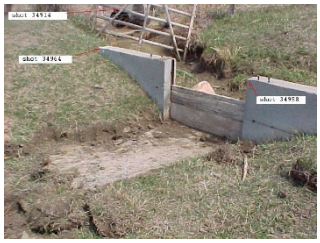


Type IV

Type IV Division Box

- Check structures

Check Structure



Check Structure with Boards

Check Structure with Gate

- Alfalfa valves

Alfalfa Valve

Alfalfa Valve in Field

- Air vent/vacuum relief valve

- Hydrants

Irrigation Hydrant

Irrigation Hydrant Connected to Gated Irrigation Pipe

- Gated plastic irrigation pipe (PIP)

- Slide gates

Slide Gate

Slide Gate in Field

In-line Plastic Slide Gate

Gated Pipe with Slide Gate

- Wheel gates/headgates

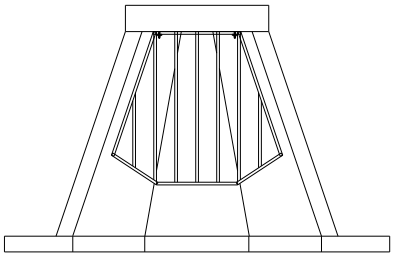
Aluminum

Cast Iron Wheel Gates

Cast Iron Wheel Gate

Wheel Gate

- Debris/trash guards (see the MDT *Detailed Drawings*)



- Flumes for flow measurement

Cipolletti Weir

Parshall Flume

Replogle Flume

12.5 DESIGN PROCEDURE

The following design procedure provides the general guidelines, steps, and documentation necessary for irrigation design on MDT projects. This procedure is not all inclusive; the hydraulic engineer must ensure the accuracy and completeness of the design. Each irrigation crossing or ditch/canal relocation requires that the hydraulic engineer perform a hydraulic analysis on a site-by-site basis. Irrigation culvert/system replacements demand a higher level of accuracy in the survey and design than drainage culvert crossings.

Step 1: Assemble site data and project file in addition to the material collected for the LHSR (see Chapter 5, "Location Hydraulic Study").

a. The minimum data are:

- LHSR;
- As-built plans;
- Project and hydraulic survey data;
- Topographic mapping;
- Proposed roadway alignment, profile, and cross sections;
- Aerial and ground photographs;
- Irrigation Study Report from Right-of-Way Bureau;
- Water Resource Study Reports; and
- Design data at nearby structures.

b. Studies by other agencies including:

- Canals — DNRC, USBR, BIA, or private irrigation districts;
- Small dams — DNRC, NRCS, private dam owners, USACE, BLM; and
- Floodplains — FEMA, DNRC, NRCS, independent community floodplain studies, USACE.

c. Historical performance of the existing culvert/ditch/canal:

- Contact MDT Maintenance, county/state/federal officials, local road maintenance, landowners, irrigators (users/operators), and/or residents concerning historical issues associated with the culvert/ditch/canal (e.g., flooding problems, culvert sufficiency, roadway overtopping, debris, previous channel alterations) to determine if there are any problems with the existing irrigation features. This information may also be used to help calibrate the existing hydraulic model.

d. Design criteria:

- Review Section 12.3 for applicable design criteria.

Step 2: Determine design flows for the crossing; see Section 12.4.1.

Step 3: Analyze the existing channel and culvert slopes.

a. Create a profile of the channel and determine an overall average channel slope. If needed, divide the ditch into segments to determine individual ditch slopes between irrigation features.

b. If there is an existing culvert, plot the culvert and compare the culvert slope to the average ditch slope.

Step 4: Develop a hydraulic model of the existing condition.

a. Model the existing channel and/or culvert in HY-8 or HEC-RAS as appropriate (see Section 12.3.1).

b. Calibrate the model to the recorded observed water surface elevations.

c. Determine the capacity of the existing ditch and culvert and compare the capacities to the design flows determined based on water rights information, water user supplied data, or ditch rider information.

d. Assess the culvert at the known water rights flows to determine standard operating water surface elevations. Compare calculated water surface elevations to observed or surveyed water surface elevations.

e. If there is a culvert crossing, compare the ditch capacity to the existing culvert capacity.

Step 5: Determine a preliminary proposed design layout and develop a hydraulic model replicating the existing conditions.

a. Ditches and canals:

- MDT hydraulic design practice is to locate all new irrigation ditches and canals outside of the proposed right-of-way limits unless this is impractical.
- Determine if the ditch can be constructed in a cut section (preferred) or if a fill section is required.
- If the relocated ditch must be constructed in fill, follow the criteria in Section 12.3.3.

b. Culvert crossings:

- Align the culvert with the skew angle of the ditch/canal.
- Set the proposed culvert slope to match the overall channel slope.
- Determine proposed culvert invert elevations:
  - Align the culvert inverts < 54 in. (equivalent) with the upstream and downstream channel flow lines, considering the overall channel slope and avoiding localized depressions or high points in the channel.
  - Embed larger culverts ≥ 54 in. (equivalent) a minimum of 10% of the culvert rise.
- Determine culvert length:
  - Extend irrigation pipes ≤ 30 in. in diameter or span a minimum of 24 in. beyond the right-of-way limits.
  - Design irrigation pipes > 30 in. to the same requirements as drainage culverts with respect to clear zone requirements and cover requirements.
- Determine allowable pipe materials following the guidance in Section 11.4 of Chapter 11, "Culverts."
- Select appropriate end sections. See Section 12.4.3.

c. Irrigation structures:

- If it is necessary to replace irrigation structures, replace in kind or work with the water users to determine an appropriate replacement structure type.
- Determine locations for any new irrigation structures desired by water users.

d. Check for erosion potential. See Section 12.4.4.

Step 6: Meet with the impacted water users (with the right-of-way agent if possible) to discuss the initial irrigation design including:

a. The interpretation of the existing condition based on the initial analysis;
b. The planned impacts from the roadway work;
c. The possible changes or improvements needed;
d. The draft proposed designs; include draft details for new structures; and
e. Documentation for all conversations and correspondence with water users.

Step 7: Modify the proposed designs as necessary based on discussions with concerned water users:

a. Ensure that the water users agree with the proposed designs, which may include multiple meetings and/or site reviews.

b. Verify with the water users that the modified proposed designs will meet their needs and their requests (e.g., are check boards or slide gates preferred on division structures?).

c. Provide the Right-of-Way Bureau with the information for the new structure for negotiation and acquisition.

Step 8: Finalize irrigation designs and ensure that all necessary information to construct the irrigation features is provided in the project plan set:

a. Develop final details.

b. Develop special provisions for any non-standard item including:

- Pipe materials;
- Valves, gates, and hydrants;
- Ditch liners;
- Construction methods; and
- Irrigation Owner/Operator Contact (irrigation contacts and standard operating dates).

c. Show the new ditch section in the roadway plan cross sections and include ditch invert elevations.

Step 9: Document analysis and assumptions.

a. See Section 12.6.

If requested by the Right-of-Way Bureau, hydraulic design personnel will accompany right-of-way negotiation and acquisition personnel during the right-of-way process to explain the design to concerned water users.

12.6 DOCUMENTATION

12.6.1 Irrigation Design Report

An Irrigation Design Report is required for all irrigation designs. The detail of documentation for each site must be commensurate with the importance of the structure. A report template is provided in Appendix 12A and includes the following:

- All information necessary to describe the proposed irrigation design;
- Documentation of existing conditions;
- Copies of all design calculations:
    - Design flows and how they were determined,
    - Model calibration,
    - Existing and proposed headwater elevations, and
    - Structural calculations if necessary;
- A comparison of the existing condition to the proposed condition, highlighting any changes that were made;
- Pertinent information from the landowner discussions; and
- Any cost-to-cure discussions.

12.6.2 Irrigation Recommendation Memo

An Irrigation Recommendation Memo is required for all irrigation designs. The recommendation will include all necessary design information required to accurately and adequately detail the irrigation design in the project plans. An Irrigation Recommendation Memo template is available in Appendix 12A.

Coordinate any cost-to-cure location with the Right-of-Way Bureau via separate correspondence from the Recommendation Memo. The intent of the Irrigation Recommendation Memo is a set of instructions to the Road Designer of features and descriptions to be added to the plan set.

12.6.3 Irrigation Data Summary Sheet

For all open-channel bridges and culverts that carry irrigation water and wastewater under the roadway, document the hydraulic data used in the irrigation crossing designs on an Irrigation Data Summary sheet in the plan set (see Standard Hydraulics Drawings). If the crossing contains both irrigation and drainage water, only include the crossing on the Hydraulic Data Summary sheet.

12.7 REFERENCES

1. **USBR.** *Design of Small Canal Structures.* Denver, CO: US Department of the Interior, Bureau of Reclamation, 1978.

2. **FHWA.** *Hydraulic Design of Energy Dissipators for Culvert and Channels, Hydraulic Engineering Circular No. 14.* 3rd Edition. Washington, DC : Federal Highway Administration, U.S. Department of Transportation, 2006. FHWA-NHI-06-086.

Appendix 12A IRRIGATION RECOMMENDATION MEMO AND DESIGN REPORT TEMPLATES

Montana Department of Transportation
PO Box 201001
Helena, MT 59620-1001

(Letterhead provided as an example and may be updated to current letterhead or consultant letterhead.)

Memorandum

To: "Click here and type name" P.E. *(Design Project Manager)*
"Click here and type title"

From: Name, P.E.
"Click here and type title"

Thru: Name, P.E.
State Hydraulics Engineer

Date: DRAFT until signed

Subject: [Project Number]
[Project Name]
UPN [UPN]
Irrigation Recommendation Memo

This memo describes the irrigation recommendations for the above project the design is described in more detail in the Irrigation Report. Please incorporate the following irrigation feature information into the plans and cross sections:

- The attached Hydraulic details: *(Following are provided as an example, not all inclusive)*
  - XXXXXXXHYDET001.DGN
  - XXXXXXXHYDET002.DGN
  - XXXXXXXHYDET003.DGN
  - XXXXXXXHYPBC001.DGN

- The attached Hydraulics Special Provisions:
  - XXXXXXXHYSPC001.DOCX.
  - *Include an Irrigation Owner/Operator Contact special provision.*

- The following Standard Special Provisions: This list will be customized for each project. Standard Special Provisions such as those listed below may be found at: https://www.mdt.mt.gov/business/contracting/standard-specials.shtml, and include:

  - *208-5 Montana Floodplain and Floodway Management Act*
  - *603-3 Precast Reinforced Box Culverts*
  - *603-7 Reinforced Concrete Pipes, Boxes, Inlets and Manholes*

(Then, starting at the beginning of the project, describe station by station the irrigation recommendations. The information in this memo will be used by the road designer as a checklist to enter the irrigation design into the plan set. In addition, at the end of the project, the checker will use this memo or a revised

version to ensure that the hydraulic design is accurately presented in the plan set. Some example text is included below but, because irrigation impacts are highly variable, the information presented in each recommendation memo will be project specific.)

Station 312+85 RT to Station 335+29 RT—Existing Irrigation Ditch
Label in plans, "Do not disturb existing irrigation ditch".

Station 356+90—New 24" RCP Irrigation Culvert

24-inch RCP-IRR, Class 3
Inlet Invert
Elevation = 4519.0′
Station = 356+47.5
Offset = 55.1′ RT
Outlet Invert
Elevation = 4518.4′
Station = 357+51.4
Offset = 79.2′ LT
Pipe Skew = 38° RT
Inlet and outlet end treatment = Inlet and Outlet Headwalls per Detailed Dwg 613-12
Length = 170'
(Note: A note may be included to describe critical site information regarding the pipe layout.)

Station 434+50—New 9′ × 7′ Irrigation RCB

9′ × 7′ RCB
Inlet Invert Elevation = 4513.2′
Outlet Invert Elevation = 4513.1′
Embedment Depth = 6″
Slope = 0.13%
No Skew
L = 78′
Culvert End Treatments Inlet and Outlet (See Detail)
30° Flat-Top Wing-walls
Cutoff Wall

Station 461+73, 114.5-ft RT—New Steel Replogle Flume

New Steel Replogle Flume
Invert Elevation = 4497.5′
See Hydraulics Detail, XXXXXXXHYDET001.DGN.
Add a cross-section cut at this location to show the new flume and invert elevation.

Station 462+35, 115.9-ft RT—New Type 3 Division Box

New Type 3 Concrete Irrigation Division Box, B = 2.5′ (See Det. Dwg. No. 615-04)
Invert Elevation = 4497.0′
Add a cross-section cut at this location to show the new irrigation structure and invert elevation.

Station 462+76, 116′ RT to Station 464+63, 116′ RT—New Irrigation Ditch

Station 462+76 Ditch Invert Elevation = 4497.0′
Station 464+63 Ditch Invert Elevation = 4495.3′
Slope = 0.9%
Ditch Typical Section; V-ditch: 3H: 1V side-slopes and 2-ft deep

Sta. 478+25—New 24″ RCP Encasement Pipe

24″ RCP IRR. (Class 3)
Inlet Invert Elevation =4570.50′ LT (2′ beyond ROW)
Outlet Invert Elevation =4570.00′ RT (2′ beyond ROW)
Skew =None
Cap/plug each end so landowner can tie into in the future. (See Special Provision *and/or* Detail)

Sta. 496+98—Remove and Abandon 24″ RCP

Label in plans, "Remove and Abandon 24″ RCP".

A copy of the Irrigation Report is attached. This memo, the Irrigation Report, details, and hydraulic special provisions are also available on DMS.

Recommendations for the drainage culverts will be submitted separately.

If you have any questions regarding this memo, please contact (person writing memo) or by e-mail (email address).

e-copies: *Distribution List may be adjusted as needed.*

Highways Engineer
Hydraulics Engineer
Hydraulics Operations Engineer
Road Design Engineer *(Headquarters Design)*
Road Design Designer
District Design Supervisor *(District Design)*
District Engineering Services Supervisor
District Projects Engineer
District Right-of-Way Supervisor
District Geotechnical Engineer
District Biologist
District Project Development Engineer
Highways File

Montana Department of Transportation
PO Box 201001
Helena, MT 59620-1001

Irrigation Design Report
Project Name:
Project Number:
UPN:
By:
Date:

INTRODUCTION

This report describes…

GENERAL PROJECT INFORMATION

(Can copy and paste this from the Hydrology report.)
Provide a brief description of the project location, route, project limits, and scope of work.
Include a general description of the project area (terrain, land use, etc.).

CULVERT SERVICE LIFE

Describe when the existing culverts were installed and the current condition of the culverts.
Describe the results of the soil and water testing and the allowable pipe materials and coating requirements for the project.
Include the corrosive soils spreadsheet in Appendix B.

HYDRAULIC DESIGN

Start at the beginning of the project and describe the existing irrigation feature, the past performance, and the proposed recommendation for that location.

Station XXX + XX
Write a description of the existing irrigation feature. Include photos if available and any information pertinent to the design including the ditch owner, water source, design flows, use, and whether the feature is inside or outside of right-of-way. Include descriptions from maintenance, local residents, or irrigators of historical performance. Include information from the Irrigation Study Report. Then describe the proposed irrigation features at this site.

If a culvert is at the site, include the table below with the existing culvert data and the proposed culvert sizes analyzed. Bold or highlight the recommended pipe in the table. List elevations to the nearest tenth of a foot. discharges to the nearest ft^3/s, velocities to the nearest tenth, and pipe slope to the nearest tenth of a percent.

Station XXX + XX

Pipe	Inlet Elev (ft)	Inlet Ke	Q Operating (ft^3/s)	WSE Q Operating (ft)	Q Water Right (ft^3/s)	WSE Q Water Right (ft)	Q Max (ft^3/s)	WSE Q Max (ft)	Q Operating Vel (ft/s)	Pipe Slope (%)
(Existing)										
(Proposed)										
(Proposed)										
(Proposed)										

Describe any additional proposed information that would be included in the recommendation memo for the site including allowable pipe materials, metal thickness, coating requirement, pipe class, culvert end treatments, skew, and outlet protection. Also describe any channel or ditch modifications. Include a discussion of the proposed hydraulic performance and why the recommended pipe size was selected (e.g., maintains existing hydraulics).

(May also include a plot of the proposed culvert cross section including the thalweg profile in and out of the culvert.)

APPENDICES

Appendix A. Irrigation Overview Map

Appendix B. Corrosive Soils Data

Appendix C. Proposed HY-8 Runs
Include runs for the recommended pipe size and the options.

Appendix D. Proposed HEC-RAS Runs (If needed)
Cross-section location plot, Profile, cross-sections, Tables 1, 2, Six Culvert Cross-Section, and Culvert Output.

Appendix E. Details

Appendix F. Irrigation Study Report (If provided)