The University of Iowa | Office of Outreach and Engagement

## FINAL DELIVERABLE

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|---|---|
| **Title** | Don Williams Lake Spillway Fish Barrier |
| **Completed By** | Brian Cummings, David Millmeyer, Trenton Wilson |
| **Date Completed** | December 2018 |
| **UI Department** | Civil and Environmental Engineering |
| **Course Name** | CEE:4850:0001<br>Senior Design |
| **Instructor** | Paul Hanley |
| **Community Partners** | Boone County Conservation |

This project was supported by the Provost's Office of Outreach and Engagement at the University of Iowa. The Office of Outreach and Engagement partners with rural and urban communities across the state to develop projects that university students and faculty complete through research and coursework. Through supporting these projects, the Office of Outreach and Engagement pursues a dual mission of enhancing quality of life in Iowa while transforming teaching and learning at the University of Iowa.



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# Fish Barrier at Don Williams Lake Spillway

Project Design Report – December 2018

# Corn Belt Engineering

# Contents

# Executive Summary

Don Williams Lake is the primary attraction at Don Williams Recreational Area in Boone County. Iowa Department of Natural Resources (IDNR) and Boone County Conservation stock walleye and catfish annually in an effort to improve lake quality and reestablish desired fish population. According to the County, roughly half of the stocked fish are lost over the spillway due to fish migration. In addition, invasive gizzard shad and carp have overpopulated the lake, leaving less food for catfish and walleye to thrive. The Don Williams Lake Spillway Fish Barrier Project will maximize stocking efforts by retaining stocked fish, preventing invasive species from migrating into the lake, and improve overall lake quality. Successful completion of this project will make Don Williams Lake a more attractive destination for fishing and recreation, bringing in more visitors and increasing revenue generated by Don Williams Lake. This design was performed by students at the University of Iowa. The following design alternatives were evaluated in this report:

- Alternative 1 – Fence-Type Barrier with Maintenance Walkway, Lower Spillway Barrier and Security Fence
- Alternative 2 – Rotating Drum Screens with Maintenance Walkway and Security Fence
- Alternative 3 – Electric Strip Barrier

Evaluation of the three alternatives included determining if design alternatives are feasible, practical, and consideration of maintenance requirements. Alternative 1 – Fence-Type Barrier with Maintenance Walkway, Lower Spillway Barrier and Security Fence was deemed feasible, practical, and having moderate maintenance requirements. Alternative 2, rotating drum screens, was deemed not feasible due the high cost of construction. Alternative 3, electric strip barriers, was deemed not feasible due to the high cost of construction and operation. Design Alternative 1 was is the recommended alternative due to lower capital cost while effectively mitigating fish migration.

Design of Alternative 1 required hydrological, hydraulic, and structural analysis. The physical barrier consists of rigid vertical members welded to a base plate and mounted to the crest of the spillway structure. The barrier also has horizontal members with small vertical spacing to minimize water resistance while retaining small stocked fish from escaping over the spillway. The barrier is designed to span the spillway crest at a height of 6 feet. Design height was determined using a 100-year design event which would result in 5.45 feet of water over the top of the spillway at 6,700 cubic feet per second (cfs). Additionally, a maintenance walkway will be constructed on the upstream side of the spillway to remove accumulated debris during safe working conditions. The lower spillway barrier will be constructed at the 100-year event elevation for the downstream side of the spillway to prevent invasive gizzard shad from entering Don Williams Lake. Finally, a security fence would be constructed to prevent unauthorized visitors from accessing the spillway structure, maintenance walkway, or fish barrier.

Construction of this project for is estimated to cost $75,000; this cost includes material, labor, a 20% contingency, and 10% administrative costs for the primary barrier, walkway, lower barrier and security fence. Iowa Department of Natural Resources (Iowa DNR) and Boone County stocked 5,215 fish (catfish and walleye) in 2017 at an estimated cost of $8,344. With a modest estimate of 50% efficiency (recovering half of the current losses), the Don Williams Spillway Fish Barrier Project would save Iowa DNR $2,085 in the last year and likely more in lost revenue. These savings could be used for improvements elsewhere, rebuilding, maintaining, and upgrading Don Williams Lake and many other sites across Iowa.

## Organization Qualifications and Experience

**Our Company**
Corn Belt Engineering is a team of senior engineering students at the University of Iowa in the capstone design class. We are a team of civil engineers with a focus in Structural, Environmental, and Water Resources Engineering.

**Organization Location and Contact Information**
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**Organization and Design Team Description**

**Description of Experience with Similar Projects**
**Brian Cummings, Project Manager**
Brian is in his last semester at the University of Iowa studying civil engineering focusing on civil and environmental engineering practice. Over his time studying civil engineering, he has had a mix of structural, environmental and water resource classes including principals of hydrology, hydrology and water resource engineer. Brian has had multiple summer internships varying from project management to material testing. He spent the first summer working for the City of Iowa City engineering department as an engineering inter focusing on installation of drain tile throughout the city. The second internship was working for a general contractor, Norcon Inc. in Chicago. While there for the summer, Brian was working in a field office for the construction of a 125,000 sqft health club as a project intern helping manage the subcontractors. Most recently Brian worked for Shive-Hattery architecture and engineering firm in their construction services department doing material testing such as concrete testing, compaction testing, and construction inspections.

**Trent Wilson**
Trent Wilson is a senior engineering student at the University of Iowa, with a focus in Water Resources and Environmental Engineering. Trent, who remains interning throughout 2018 with an engineering firm, has contributed to several engineering reports presented to various municipalities, counties, and government agencies. Prior to pursuing a career in civil engineering, Trent worked in industrial construction as a journeyman millwright and carpenter through the United Brotherhood of Carpenters and Joiners of America.
Related Experience

- City of Tipton, Iowa Antidegradation Alternatives Analysis Report
- Village of Benton City, Missouri Facility Plan Report
- Taum Sauk Lower Reservoir Dam – Outlet Gate Improvements Project

**David Millmeyer**

David is in his final semester at the University of Iowa studying civil engineering focusing on Transportation Engineering. He has completed coursework in areas including structural design and fluid dynamics. David has completed multiple internships in the asphalt construction industry. There he completed materials testing, project management, and site plan creation tasks. David has done work with water runoff and site design of construction zones.

## Proposed Services

**Project Scope**
Corn Belt Engineering was contracted to design a barrier that will keep walleye, bass and other fish species from being lost over the spillway of Don Williams Lake, while the barrier meets all applicable design standards and Iowa DNR standards that apply. The scope of this project included the following tasks:

- Design of fish barrier and maintenance walkway.
- Design of lower barrier.
- Hydraulic analysis for fence height, force on fence members, fence fasteners and brackets.
- Construction cost estimates and Project cost estimate.

## Constraints, Challenges and Impacts

**Constraints**
The fish barrier has been designed with consideration of construction constraints. Throughout the life of the structure the fish barrier will be mostly submerged. To facilitate construction of the fish barrier the lake would have to be drawn down to a safe water level. Draw-down of Don Williams Lake poses an additional time constraint considering the recreational area will remain open during the Spring, Summer, and Fall. Temperatures below freezing and frozen work surfaces could create additional constraints for this project. The top of the spillway is away from level surfaces and would require erecting temporary platforms (such as scaffolding) to access the spillway where the structure will be mounted. Fall protection is also a construction constraint for this project. To eliminate additional forces on the structure and to prevent additional accumulation of debris, the fish barrier walkway will not have a handrail or guard on the upstream side. For this reason, fall protection is recommended while working on the walkway.

**Challenges**
In addition to construction constraints, the fish barrier poses an environmental issue with interruption natural migration of wildlife. This challenge is seen twice in design of this project with preventing walleye, panfish, and largemouth bass from escaping over the spillway, as well as preventing gizzard shad from traveling up the spillway into the lake. The county suggests, this is a unique situation, in which fish migration leads to degradation of Don Williams Lake.

**Societal Impact within the Community**
Boone County, Iowa has a population of 26,643 residents with much of the population residing in Boone, Iowa. The Median Household Income (MHI) is $40,763 which is this 27.5% lower than the state average of $56,247. The improvement of Don Williams Lake will provide a more desirable space for Boone County residents to enjoy. The improved lake will also attract more outside visitors and economic activity to the area. Per discussion with the Conservation Board, the estimated costs associated with stocking fish in 2017 was $8,344. The Conservation Board suggests approximately half of the stocked fish escape the lake over the spillway.

Don Williams Recreational Area is a key attraction and contributes to tourism in Boone County. Improvements to the lake will create a more desirable recreational experience and increase tourism thus justifying these improvements. In meeting with the Conservation Board, the county is optimistic that the Iowa Department of Natural Resources will prioritize a large-scale lake restoration project and provide funding over the next decade.

# Alternative Solutions

## Alternative 1 – Fence-Type Barrier with Maintenance Walkway, Lower Spillway Barrier and Security Fence

Alternative 1 used strategically spaced horizontal members as a barrier to prevent fish from escaping over the spillway. The barrier is to be mounted to the lake-side of the existing spillway structure. Horizontal members are to be secured with narrow vertical spacing to allow water to flow without significant resistance. The vertical spacing is specified to prevent smaller fish from escaping over the spillway. This alternative also includes a maintenance walkway to accommodate debris removal or member replacement as needed. Boone County Conservation Board suggests that large debris is not typical, however occasionally a large branch or other debris has been observed at the spillway. Alternative 1 includes lower barrier prevent invasive species from traveling up the spillway and into the lake. In years, past, Don Williams Lake has become overpopulated with gizzard shad. Gizzard shad have invaded Don Williams Lake from the receiving stream from the spillway and consume much of the available food needed for panfish to thrive. Additionally, a security fence will be installed to prevent visitors from accessing the walkway and barrier. This alternative has advantages and disadvantages as listed. An example of a fence-type barrier can be seen below in Figure 1.

Advantages

- Maintenance could be performed as needed, but not expected very often.
- Fence members, walkway, and other materials are products that are typically stocked items, and can be installed without custom fabrication.
- The Conservation Board and Iowa DNR have had success with similar barriers at other locations.
- Design can be modified for similar situations around the state.

Disadvantages

- Not as aesthetically pleasing as other alternatives.
- Maintenance would require working from an elevated platform, also over water. Fall protection would be recommended while performing maintenance.

**Figure 1 – Fence-Type Barrier**

## Alternative 2 – Rotating Drum Screens with Maintenance Walkway and Security Fence

In Alternative 2, the fish barrier is constructed of a series of rotating drum screens. The screens are to be constructed to continually rotate at the top of the spillway when water level is any amount above spillway elevation. The rotating drum screens are "self-cleaning" of debris, to reduce maintenance. Similar to Alternative 1, this alternative includes a maintenance walkway and security fence. This alternative has advantages and disadvantages as listed below. An example of a rotating drum screen can be seen below in Figure 2.

Advantages

- Maintenance could be performed as needed, but not expected very often.
- Drum Screen openings are relatively small and would be very effective in preventing fish from escaping.
- Drums are "self-cleaning" minimizing maintenance.
- Downstream barrier not necessary with this alternative.

Disadvantages

- Not as aesthetically pleasing as other alternatives.
- Maintenance would require working from an elevated platform, also over water. Fall protection would be recommended while performing maintenance.
- Drum screens are custom products and would require custom fabrication, which is less cost-effective.

**Figure 2 – Rotating Drum Screen**

## Alternative 3 – Electric Strip Barrier

In this alternative, an electric strip will be placed on the spillway and could prevent fish approaching the spillway to a desired radius. This alternative requires supplied power to the electric strips. In this alternative, walkway and security fence is not necessary, but could be included in design. This alternative has advantages and disadvantages shown below. An example of an electric strip barrier can be seen below in Figure 3.

Advantages

- Aesthetically pleasing with flow cascading over the top of the spillway.
- Very efficient in preventing fish from escaping over the spillway.
- Debris is not expected to accumulate on electric strip, minimizing maintenance.
- Downstream barrier not necessary with this alternative.

Disadvantages

- Barrier requires supplied power.
- Electric Strip would require routine inspection.
- Potentially harmful to fish or other aquatic life.
- Electric Strip is a custom product and would require custom fabrication, which is less cost-effective.
- Electric Strips would require eventual replacement.

**Figure 3 – Electric Strip Barrier**

# Final Design Details

## Selection of Alternative

In selecting an alternative, feasibility, practicality, and maintenance requirements were considered. Feasibility was considered pertaining to the functionality of the barrier. Practicality was assessed considering the projected cost of the project. Consideration of maintenance requirements is also important considering the staff limitations and labor hours associated with general maintenance. Table 1 below displays these considerations for selection of the alternative.

**Table 1 – Selection of Alternative**

| Alternative | Feasible | Practical | Maintenance Requirements |
|---|---|---|---|
| Fence-Type Barrier | Yes | Yes | Moderate |
| Rotating Drum Screens | Yes | No | Moderate |
| Electric Strip Barrier | Yes | No | Low |

Alternative 1 – Fence-Type Barrier with Maintenance Walkway, Lower Spillway Barrier and Security Fence is recommended as the most cost-effective solution. Though maintenance will be required periodically, this alternative includes a walkway to aid the performance of maintenance as maintenance is not expected to be needed more than once per season (or less). Alternative 1 also is the most cost effective, thus most practical solution for Boone County. All three alternatives are considered as feasible considering the constructability and functionality of the barrier. Alternative 2 and Alternative 3 were evaluated as not practical considering custom fabrication, replacement of moving parts with the drum screens and replacement and power requirement for the electric strip barrier are generally expensive. All three alternatives have some maintenance required, however Alternative 3 was considered as having the lowest maintenance of the three alternatives.

## Design of Alternative

Design considerations for this alternative were governed by a design storm event for projected water height above the spillway structure. The fish barrier must function during low and high-water events, therefor the spacing of horizontal members were designed to provide cross-sectional area large enough to allow flow during a design storm event. For design of the fence members, hydraulic force was analyzed to design rigid upright members and force on horizontal members. Horizontal member connections were designed to fail under total blockage, allowing the debris (causing the blockage) to pass through. The maintenance walkway was designed considering two load scenarios, one during high water and one without water but with the weight of four workers. Finally, the lower barrier was designed to carry the same load the as the maintenance walkway, though maintenance is not expected often on the lower barrier.

## Design Storm Event

In analyzing the hydrology of the watershed as it pertains to the spillway structure and design of the fish barrier, the volume of water approaching the spillway at various event return frequencies were evaluated using United States Geological Service (USGS) Streamstats tool (https://streamstats.usgs.gov/). The barrier is recommended to be constructed to function during a 100-year event (return frequency probability of 1%) to match the design storm event specified in the as-built plans for the existing spillway given to the Bonne County Conservation Board. Comparing the information found using Streamstats with the information from the as-built plan set, the volume of water over the spillway during a 100-year event was found to be 6,700 cubic feet per second (cfs). This information is consistent with the as-built plans for the spillway. With this information, in conjunction with the as-built plans, the estimated height of water over the spillway during a 100-year event is 5.45 ft. For this reason, the barrier is recommended to be constructed at a design height of 6 ft. USGS Streamstats results are included in Appendix A: Calculations.

## Design of Fence-Type Barrier

Hydraulic analysis was performed for the design of this barrier to ensure the barrier could withstand a design storm event. The 100-year event estimate of 6,700 cfs of flow and 5.45 ft of water over the spillway has been considered for force on fence members. Horizontal fence members were designed as having tube geometry as opposed to square or angle geometry. The tube geometry offers structural integrity while having lower resistance to the flow of water. Horizontal members were designed to withstand hydraulic force during a 100-year event with some blockage from debris. For this reason, horizontal members will be made of 2-inch galvanized tubing, fastened to vertical members over a span of 8 feet. Horizontal members will be fastened with bolts designed to fail when the force on horizontal members becomes too great as result of blockage during high flow events. In these scenarios, the fastener will fail, the horizontal member will drop down to allow the debris to pass. When working conditions are safe, workers could lift the existing member back into place and fasten with a new bolt without the need to recover fence sections or members from the bottom of the spillway. Vertical members are designed to be constructed of W6 x 12 uprights, welded to a base plate that will be mounted to the peak of the spillway crest. Vertical members are designed with the assumption of a 100-year event with total blockage. This ensures the members are built to withstand a design event without failure. Hydraulic calculations are included in Appendix A: Calculations.

Horizontal members will have 2” vertical spacing to allow minimal water resistance while maintaining a spacing small enough to retain 1.5” to 2” sized fish. Typical fence section is displayed below in Figure 4.

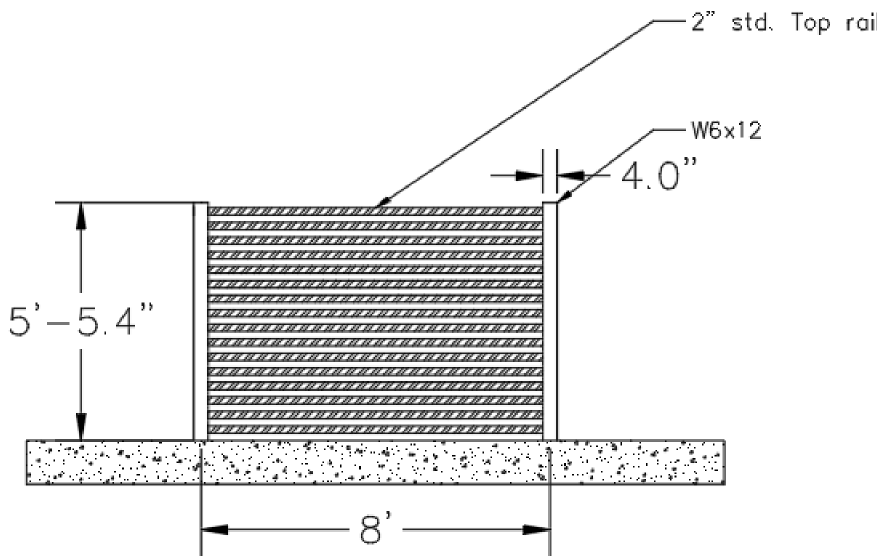


**Figure 4 Typical Fence Section**

## Design of Shear Pins

Shear pin fasteners will be used for connecting horizontal members to the rigid upright members. During a scenario in which a barrier section is completely blocked, the fastener is designed to fail in tension, allowing the debris to pass. The shear pin is a typical ¼ inch stainless steel bolt with a notch cut into it by the manufacturer. The notch reduces the tension strength of the bolt to facilitate failure when blockage occurs. Once the shear pin fails, the horizontal member can fall on one side and allow the debris to pass. This design yields less maintenance, where a worker would simply access the structure, pick up one side of the horizontal member, and replace the bolt, without the need to retrieve the member from the bottom of the spillway or downstream in Bluff Creek. Typical shear pin detail can be seen below in Figure 5.

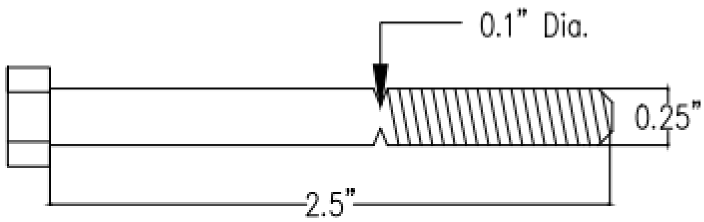


**Figure 5 – Shear Pin Detail**

## Design of Maintenance Walkway

Though maintenance is not expected often, structural analysis is imperative to the design of this project, for building a resilient and robust structure that will last decades to come, and most importantly the safety of the maintenance workers responsible for keeping the barrier clear of debris, or other maintenance work. The primary purpose of the maintenance walkway is to clear debris from the barrier as needed. For structural analysis of the maintenance walkway, two load scenarios were considered. The first scenario was without high water and with the weight of four workers on top of the barrier. The second scenario is during a high-water event, but without the weight of workers. The second scenario governed the design of the maintenance walkway structure. Force calculations for design of the maintenance walkway can be found in Appendix A. The gallery of the maintenance walkway will be constructed of L3 x 3 x 0.5 angle. The structure will be mounted with two bracing members welded to a base plate and fastened into the side of the existing spillway with stainless steel wedge anchors. The maintenance walkway grading is 1” galvanized serrated grading. Maintenance walkway detail is displayed below in Figure 6.

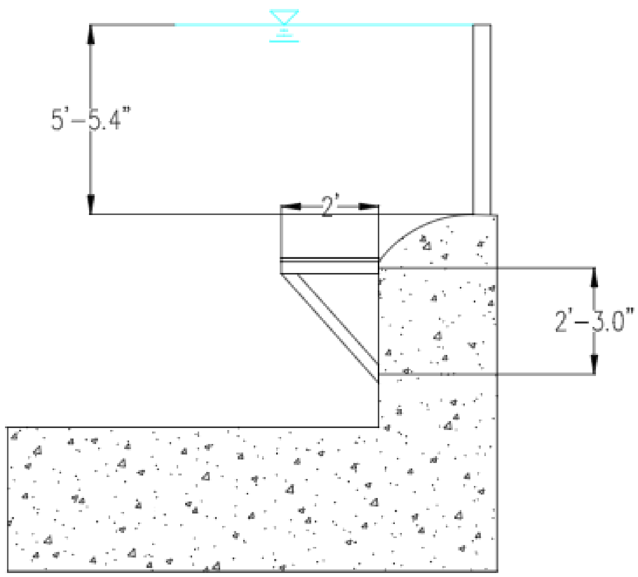


**Figure 6 Typical Maintenance Walkway Detail**

## Design of Lower Spillway Barrier

To prevent the invasion of gizzard shad, a lower barrier is designed to be mounted on the face of the spillway. Similar to the upper barrier, the lower barrier is designed for a 100-year event. On the downstream side of the spillway, the 100-year event flood elevation is estimated at 1,062 ft elevation. This event elevation was estimated using a FEMA Floodplain map is provided in Appendix B.

Design of the lower barrier used the same load scenarios as the primary barrier maintenance walkway. The lower barrier gallery will be constructed of 3” steel angle, braced and mounted to the face of the spillway at design elevation. The barrier will consist of 1” galvanized serrated grading, similar to the maintenance walkway for the fence-type barrier. Lower barrier detail can be seen below in Figure 7.

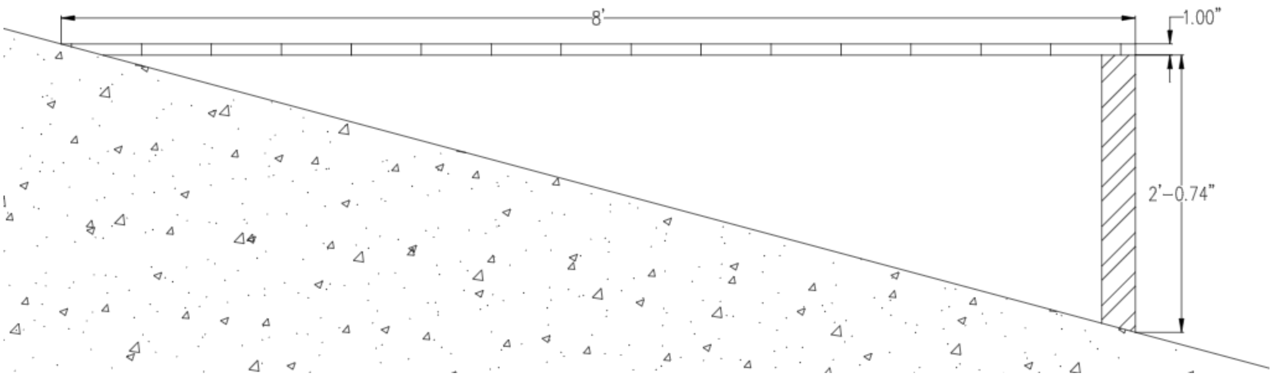


**Figure 7 Lower Barrier Detail**

## Security Fence

To prevent unauthorized individuals from accessing the maintenance walkway and fish barrier, the County requests a security fence to be included in this project. Just west of the spillway, an existing security fence surrounds a control outlet. The security fence will be similar height and appearance as the fence surrounding the control outlet, approximately 8 ft high, chain-link fencing. Security fence will run on both sides of the spillway beginning near the crest of the spillway, following the wingwall into the lake.

## Financial Impact

Iowa DNR and Boone County invest in stocking fish to Don Williams Lake annually to accommodate recreational fishing. Ben Dodd (personal communication, 9/17/2018), Iowa DNR Fisheries Biologist, suggests approximately 50% of stocked fish escape the lake over the spillway. Iowa DNR is currently studying the efficiency of a fence-type barrier at another location in Iowa; however, Ben Dodd claims the barrier has been effective and has noticed an increase in retaining stocked fish. Iowa DNR and Boone County stocked 5,215 fish in 2017 with an estimated cost of $8,344. With a modest estimate of 50% efficiency, the Don Williams Spillway Fish Barrier Project would save Iowa DNR and Boone County $2,085 last year and likely more in lost revenue. These savings could be used for improvements elsewhere, rebuilding, maintaining, and upgrading Don Williams Lake and many other sites across Iowa.

## Engineer’s Cost Estimate

Estimated costs for this project include material costs and total project cost. Material costs are estimated using common prices for materials, including necessary fabrication or alterations. For the primary barrier, walkway, and secondary barrier, the cost was determined using RSMeans construction costs book from 2016. The cost for the “shear” pins are from Fastenal. The cost for the security fence was found using the Iowa DOT’s website from past bid tabs for eight foot security fence. The total project cost includes material cost, labor costs, a 20% contingency, and extra 10% for engineering administration. Detailed cost estimate for Alternative 1 is included in Appendix C: Cost Estimates.

**Table 2 – Cost Estimate Table**

| Item | Cost |
|---|---|
| Primary Fish Barrier | $14,900 |
| Walkway Structure | $20,600 |
| Secondary Fish Barrier | $11,000 |
| Security Fence | $11,000 |
| **Total Project Cost** | **$75,000** |

AISC steel Construction Manuel 14th edition

RS Means Commercial Renovations Cost Data 36th annual Edition 2015

# Appendix A

## Calculations

## A.) Hydraulic force of water

At 100-year frequency storm event, conservative discharge

design elevation of waterlevel is 1065.0'
Peak Stage if flooding at 1070.45' (100-year frequency storm)

Flowrate = $Q := 6700 \frac{ft^3}{s}$

Length of Spillway = $L := 125.5\ ft$

Height of water = $y := 5.45\ ft$

$A := 41.373\ ft^2$

Area of fence = $A_f := y \cdot 8\ ft$

Area of spillway = $A_s := L \cdot y = 683.975\ ft^2$

velocity of water = $v := \frac{Q}{A_s} = 9.796\ \frac{ft}{s}$

specific weight water $\gamma_w := 62.43\ \frac{lbf}{ft^3}$

$$Vy := \frac{\left(\frac{Q}{L \cdot y}\right)^2}{2} = 47.978\ \frac{ft^2}{s^2}$$

Force of water on fence

$$F_{x\_water} := \frac{\gamma_w \cdot Vy \cdot A_f}{g} = 4.059\ kip$$

Force of water acting on the barrier as if it was a solid barrier

**B.) Load Calculations on Walkway**

Load combinations for walkway under 2 different conditions

Case 1: People, low water level

Force from water

$\rho_{water} := 1 \frac{gm}{cm^3}$ $g := 32.2 \frac{ft}{s^2}$ $h_{w.1} := 4\ in$ $A_{grate} := 2\ ft \cdot 8\ ft$

$P_{w.1} := \rho_{water} \cdot g \cdot h_{w.1} = 0.145\ psi$

$F_{water.1} := A_{grate} \cdot P_{w.1} = 0.333\ kip$ assuming gate section is one piece due to debris

Force of grate: 1" x 3/16" serrated

$P_{grate} := 7.4 \frac{lbf}{ft^2}$ $F_{grate} := P_{grate} \cdot A_{grate} = 0.118\ kip$

Beam: L3X3X 1/2

$W := 9.4 \frac{lbf}{ft}$ $L := 2\ ft$ $F_{beam} := W \cdot L = 0.019\ kip$

force of 4 people - 1200lbf

$F_{people} := 1200\ lbf$

Load Calculation

$Pu_1 := 1.2 \cdot (F_{beam} + F_{grate}) + 1.6 \cdot (F_{people} + F_{water.1}) = 2.618\ kip$

Case 2

$\rho_{water} := 1 \frac{gm}{cm^3}$ $g := 32.2 \frac{ft}{s^2}$ $h_{w.2} := 5.45\ ft$ $A_{grate} := 2\ ft \cdot 8\ ft$

$P_{w.2} := \rho_{water} \cdot g \cdot h_{w.2} = 2.365\ psi$

$F_{water.2} := A_{grate} \cdot P_{w.2} = 5.448\ kip$

Beam and grates stay same

$Pu_2 := 1.2 \cdot (F_{beam} + F_{grate}) + 1.6 \cdot (F_{water.2}) = 8.882\ kip$ case 2 would govern

$Pu := 8.89\ kip$

$Mu := Pu \cdot \frac{L}{4} = 4.445\ kip \cdot ft$ required bending strength

**C.) Allowable Strength of Walkway Members**

Strength of the memeber L4x4x1/2 — A36 steel

$Ag := 3.75\ in^2$ $d := 4.0\ in$ $b := 4.0\ in$ $t := 0.5\ in$ $Fu := 58\ ksi$

$x := 1.18\ in$ $y := 1.18\ in$ $U := 1$ $Z_x := 3.50\ in^3$ $Fy := 36\ ksi$

$Z_y := 3.50\ in^3$

Tensile strength:

$\phi Pn := 0.9 \cdot Fy \cdot Ag = 121.5\ kip$

$\phi Pn := U \cdot b \cdot t \cdot Fu = 116\ kip$

Plastic Bending moments

$M_{px} := Fy \cdot Z_x = 10.5\ kip \cdot ft$

$M_{py} := Fy \cdot Z_y = 10.5\ kip \cdot ft$ Look for a smaller section

Strength of the memeber L3x3x1/2

$Ag := 2.76\ in^2$ $d := 3.0\ in$ $b := 3.0\ in$ $t := 0.5\ in$ $Z_x := 1.91\ in^3$

$x := 1.18\ in$ $y := 1.18\ in$

$Z_y := 1.91\ in^3$

Tensile strength:

$\phi Pn := 0.9 \cdot Fy \cdot Ag = 89.424\ kip$

$\phi Pn := U \cdot b \cdot t \cdot Fu = 87\ kip$

Plastic Bending moments

$M_{px} := Fy \cdot Z_x = 5.73\ kip \cdot ft$ Strength is adequite Use **L3x3x1/2** member

$M_{py} := Fy \cdot Z_y = 5.73\ kip \cdot ft$

Forces at the connections to the crest of the spillway:

Moment:

$Mu = 4.445\ kip \cdot ft$

Reaction Forces

$$R_{Uy} := \frac{Pu}{2} = 4.445\ kip$$

Forces in memebers:

$$F2 := \frac{-R_{Uy}}{\sin(48.366\ deg)} = -5.947\ kip$$

$F1 := -F2 \cdot \cos(48.366\ deg) = 3.951\ kip$ at the connection to the wall, base plate subjected to 3.951 kip force

**D.) Strength of Existing Concrete and Anchor Bolts**

Strength existing concrete and baseplate connections

$fc' := 3500\ psi$ 7x7 plate $Ru := Pu$

$N := 7\ in$ $B := 7\ in$ $e := .75\ in$

$A_1 := B \cdot N$ $A_2 := (N + 2 \cdot e) \cdot (B + 2 \cdot e)$

$$\phi_c P_P := 0.65 \cdot 0.85 \cdot fc' \cdot A_1 \cdot min\left(2, \sqrt{\frac{A_2}{A_1}}\right) = 115.058\ kip$$

$l := 2\ in + 0.25\ in$ $Fy := 36\ ksi$

$$l := \max\left(\frac{N-d}{2}, \frac{B-b}{2}, \frac{b}{4}\right) = 2\ in$$

$$t_p := l \cdot \sqrt{\frac{2 \cdot F_{x\_water}}{0.9 \cdot B \cdot N \cdot Fy}} = 0.143\ in$$

use 3/16in plate (0.1875")

Strength of anchor bolts

$Fu_{bolt} := 58\ ksi$

$db := 0.5\ in$

$dbh := 0.5\ in + 0.175\ in$

$$\phi Rn := 0.75 \cdot 0.75 \cdot Fu_{bolt} \cdot \left(\frac{\pi \cdot db^2}{4}\right) \cdot 4 = 25.624\ kip$$

## E.) Strength of Bolts and Welds

Connection strength based on bolt shear

$d_b := .5 \cdot in$ $Fu_b := 58\ ksi$

$Ab := .25 \cdot \pi \cdot d_b^{\ 2} = 0.196\ in^2$

$Fnt := .75 \cdot Fu_b = 43.5\ ksi$

$\phi Rn := (0.75 \cdot Fnt \cdot Ab) \cdot 4 = 25.624\ kip$

Strength of weld

$b := 3\ in$ $d := 3\ in$

$L := (b + d) \cdot 2 = 12\ in$

A36

$Fu := 58\ ksi$

$Fy := 36\ ksi$

$w := \frac{1}{8}\ in$ 1/8" minimum fillet weld size for 3/16 in plate min.

$Fexx := 70\ ksi$

$Rw1 := 0.6 \cdot Fexx$

$Rwt := 0.6 \cdot Fexx$

$Fw := 0.6 \cdot Fexx \cdot (1 + .5 \cdot 1^{1.5})$

Based on the base metal yielding and fracture along the weld base

$\phi Rn := min(1.0 \cdot 0.68\ Fy \cdot w \cdot L, 0.75 \cdot 0.6 \cdot Fu \cdot w \cdot L) = 36.72\ kip$ OK

Based on weld fracture along effective throat dimension taken as 0.707 w.

$\phi Rn := 0.75 \cdot (0.707 \cdot w)\ L \cdot Fw = 50.109\ kip$ OK

## F.) Strength of Barrier Uprights Members

$Fy := 36\ ksi$ A36 Steel

Hydro-Static Force on Barrier

$b_{fence} := 8\ ft$ $\gamma_{water} := 62.4\ \frac{lbf}{ft^3}$

$h_{water} := 5.45\ ft$ $A_{fence} := h_{water} \cdot b_{fence} = 43.6\ ft^2$

$P_{water} := \gamma_{water} \cdot h_{water} = 2.362\ psi$ pressure at the bottom

$w_{water} := .5 \cdot P_{water} \cdot h_{water} = 0.927\ \frac{kip}{ft}$

$F_{water} := w_{water} \cdot b_{fence} = 7.414\ kip$

$M_{water} := \left(\frac{h_{water}}{3} \cdot F_{water}\right) \cdot 1.6 = 21.549\ kip \cdot ft$ live load factored moment acting with respect to the base of vertical uprights

Strength of steel tubes 2"std. pipe

$D_O := 2.375\ in$ $D_I := 2.07\ in$ .143in wall thickness

$Sx := 0.528\ in^3$ $Zx := 0.713\ in^3$

$f := \frac{M_{water}}{Sx} = 489.756\ ksi$ maximum stress

$My := Fy \cdot Sx = 1.584\ kip \cdot ft$ bening moment at the maximum stress

$Mp := Fy \cdot Zx = 2.139\ kip \cdot ft$ plastic moment capacity of pipe

$\phi Mp := 0.9 \cdot Mp = 1.925\ kip \cdot ft$ strength does not satisfy.

Strength of steel tubes 2" XS. pipe

$D_O := 2.375\ in$ $D_I := 1.94\ in$ $t := 0.204\ in$ 0.204in wall thickness

$Sx := 0.696\ in^3$ $Zx := 0.964\ in^3$

$f := \frac{M_{water}}{Sx} = 371.539\ ksi$ maximum stress

$My := Fy \cdot Sx = 2.088\ kip \cdot ft$ bening moment at the maximum stress

$Mp := Fy \cdot Zx = 2.892\ kip \cdot ft$ plastic moment capacity of pipe

$\phi Mp := 0.9 \cdot Mp = 2.603\ kip \cdot ft$ strength does not satisfy.

$Zx := \frac{M_{water}}{0.9\ Fy} = 7.981\ in^3$ finding required Zx for the factored moment

HSS 4.5x4.5x0.375 section $E := 29000\ ksi$

$H := 4.5\ in$ $h := 3.45\ in$ $B := 4.5\ in$ $b := 3.45\ in$ $t_{des} := 0.349\ in$

$Z := 8.36\ in^3$ $S := 6.79$

$\lambda_{pw} := 2.42 \cdot \sqrt{\frac{E}{Fy}} = 68.685$ $\lambda_{rw} := 5.70 \cdot \sqrt{\frac{E}{Fy}} = 161.779$

$\lambda_w := \frac{h}{t_{des}} = 9.885$

$Mp := Fy \cdot Z = 25.08\ kip \cdot ft$

$\phi Mn := 0.9 \cdot (Mp) = 22.572\ kip \cdot ft$

$M_{water} < \phi Mn = 1$ this shows that the factored moment due to the water is lower than the strength of the member.

$Ru := F_{water}$

W 6x12 section $E := 29000\ ksi$

$d := 6.03\ in$ $b_f := 4.00\ in$ $t_f := 0.28\ in$ $t_w := 0.23\ in$ $Z_X := 8.30\ in^3$

$\lambda_{pw} := 2.42 \cdot \sqrt{\frac{E}{Fy}} = 68.685$ $\lambda_{rw} := 5.70 \cdot \sqrt{\frac{E}{Fy}} = 161.779$

$\lambda_w := \frac{h}{t_{des}} = 9.885$

$Mp := Fy \cdot Z_X = 24.9\ kip \cdot ft$

$\phi Mn := 0.9 \cdot (Mp) = 22.41\ kip \cdot ft$

$M_{water} < \phi Mn = 1$ This shows that the factored moment due to the water is lower than the strength of the member.

$Ru := F_{water}$

Thickness of barrier baseplate

$N := 7.5\ in$ $B := 7.5\ in$ dimension of bearing plate $Fy := 36\ ksi$

$l := \max\left(\frac{N - (0.95 \cdot d)}{2}, \frac{B - (0.8 \cdot b_f)}{2}, \frac{1}{4} \cdot \sqrt{d \cdot b_f}\right) = 2.15\ in$

$t_p := l \cdot \sqrt{\frac{2 \cdot F_{water}}{0.9 \cdot B \cdot N \cdot Fy}} = 0.1939\ in$ use 1/4 in plate (0.25")

$n := \frac{B - (0.8 \cdot b_f)}{2} = 2.15\ in$ $m := \frac{N - (0.95 \cdot d)}{2} = 0.886\ in$ spacing on either side of W memeber

Checking bolt shear for 2 bolts in tension

$d_b := 0.5\ in$ $Fu_b := 58\ ksi$

$Ab := .25 \cdot \pi \cdot d_b^{\ 2} = 0.196\ in^2$

$Fnt := .75 \cdot Fu_b = 43.5\ ksi$

$\phi Rn := (0.75 \cdot Fnt \cdot Ab) \cdot 2 = 12.812\ kip$ >Fwater

Strength of weld for barrier upright

$b_f := 4\ in$ $d := 6.03\ in$ $L := 27.6\ in$ A36 $Fy := 36\ ksi$ $Fu := 58\ ksi$

$w := \frac{1}{8}\ in$ 1/8" minimum fillet weld size $Fexx := 70\ ksi$

$Rw1 := 0.6 \cdot Fexx$ $Rwt := 0.6 \cdot Fexx$ $Fw := 0.6 \cdot Fexx \cdot (1 + .5 \cdot 1^{1.5})$

Based on the base metal yielding and fracture along the weld base

$\phi Rn := min(1.0 \cdot 0.68\ Fy \cdot w \cdot L, 0.75 \cdot 0.6 \cdot Fu \cdot w \cdot L) = 84.456\ kip$ OK

Based on weld fracture along effective throat dimension taken as 0.707 w.

$\phi Rn := 0.75 \cdot (0.707 \cdot w)\ L \cdot Fw = 115.25\ kip$ OK

# Appendix B

## FEMA Floodplain Map

# National Flood Hazard Layer FIRMette

FEMA

42°6'52.58"N

94°1'25.54"W


94°0'48.09"W

42°6'25.89"N

Feet

0 250 500 1,000 1,500 2,000

1:6,000

## Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

**SPECIAL FLOOD HAZARD AREAS**
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

**OTHER AREAS OF FLOOD HAZARD**
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

**OTHER AREAS**
- NO SCREEN — Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

**GENERAL STRUCTURES**
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

**OTHER FEATURES**
- 20.2 / 17.5 — Cross Sections with 1% Annual Chance Water Surface Elevation
- 8 — Coastal Transect
- 513 — Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

**MAP PANELS**
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 10/29/2018 at 1:09:22 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

# Appendix C

## Cost Estimate

Fish Barrier

| ITEM | Material | Units | Quantity | Price | Cost ($) | | |
|---|---|---|---|---|---|---|---|
| 1 | Steel Barrier Uprights | LS | 18 | $ 575.00 | $ 10,350.00 | | |
| 2 | 8' long 2"dia bars | EA | 256 | $ 13.00 | $ 3,328.00 | | RSmeans |
| 3 | Shear pins and fasteners | EA | 512 | $ 2.25 | $ 1,152.00 | | |
| 4 | Steel structure | LS | 18 | $ 860.00 | $ 15,480.00 | | |
| 5 | Walkway grating 1"x3/16" 2'x8' section | EA | 18 | $ 284.00 | $ 5,112.00 | | **RSMeans** |
| 6 | 8' security fence | LF | 550 | $ 20.00 | $ 11,000.00 | | https://www.metalsdepot.com/steel-products/steel-bar-grating |
| 7 | Secondary barrier | SF | 1 | $ 11,000.00 | $ 11,000.00 | | IDOT |
| | | | | **Material Cost** | **$ 57,422.00** | | |
| | | | | 10% Contingency | $ 5,742.20 | | |
| | | | | )% Engineering and Administratic | $ 11,484.40 | | |
| | | | | **Total Project Cost** | **$ 74,648.60** | | |

| | |
|---|---|
| Construction Subtotal | $ 57,422.00 |
| 10% contingencies | $ 5,742.20 |
| 20% Engineering and Administartion | $ 11,484.40 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Steel substructure | | | | | | |
| drilling holes 1/2 in 2 in deep (EA) | 4 holes | 8 | 32.2 | 257.6 | | |
| welding 3/16in (lf) | 2 plates 24in | 2 | 13.15 | 26.3 | | |
| 3x3x.5 (LB) | 9.4 | 47 | 10.25 | 481.75 | | |
| 2plate(SF) | 0.68 | | 14.85 | 10.098 | | |
| Bolts (EA) | 4 | 8 | 10.51 | 84.08 | | |
| | | | Sum unit price | 859.828 | $860 | RS means |
| Barrier posts | | | | | | |
| W6x12 (EA) | | | | 120 | | |
| plate (sf) | 0.391 | 1 | 14.85 | 5.80635 | | |
| drilling holes 1/2 in 2 in deep (EA) | | 4 | 32.2 | 128.8 | | |
| welding 3/16in (lf) | | 1.5 | 13.15 | 19.725 | | |
| Bolts (EA) | 4 | | 10.51 | 42.04 | | |
| 2 holes/ shear pin | 16bars | 32 | 8.05 | 257.6 | | |
| | | | | 573.97135 | $575 | RS means |
| | | | | | | |
| Secondary barrier | Lf/quantity | | | | | |
| steel member | 60ft wide | | 15 | 900 | | |
| Plates | 2 | 0.391 | 14.85 | 11.6127 | | |
| drilling holes 1/2 in 2 in deep (EA) | 8 | | 32.2 | 257.6 | | |
| welding 3/16in (lf) | 5 | | 13.15 | 65.75 | | |
| Bolts (EA) | 8 | | 10.51 | 84.08 | | |
| Walkway grating | 480 SF | | 20 | 9600 | | |
| | | | | 10919.0427 | 11000 | |