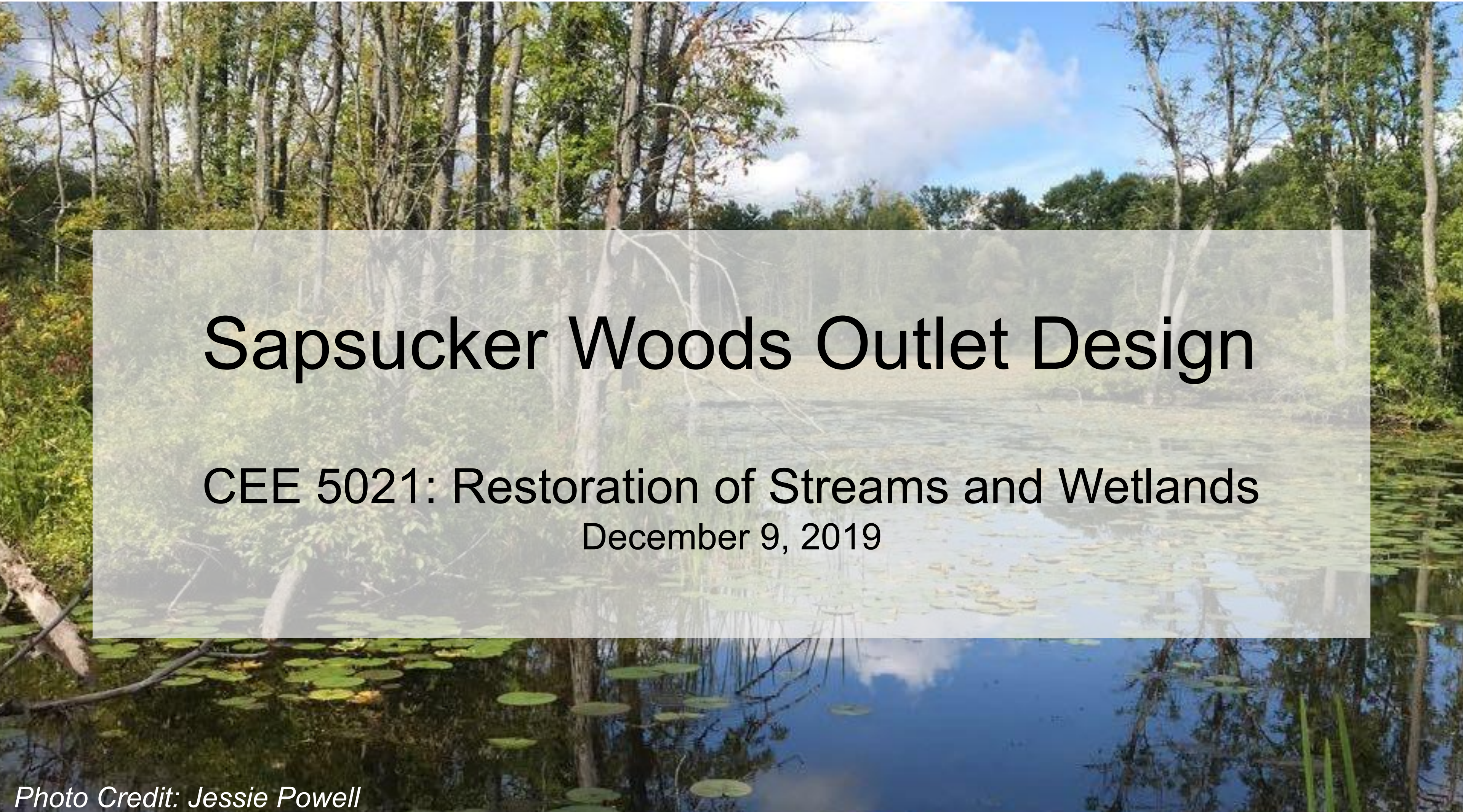


Sapsucker Woods Outlet Design

CEE 5021: Restoration of Streams and Wetlands

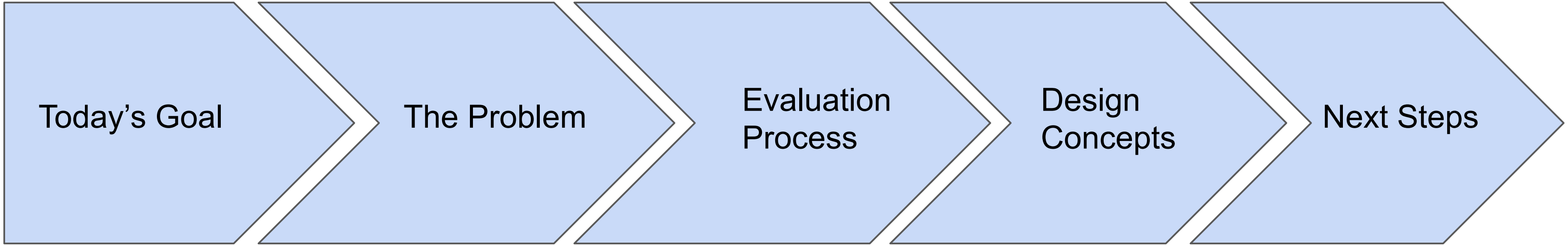
December 9, 2019

Photo Credit: Jessie Powell

CEE 5021/6025 Team

- Eirini Sarri - Project Manager
- Nick Gill
- Haowen Jin
- Mary McGuinn
- Wenduo Nie
- Jessie Powell
- Hannah Si
- Ari Wetzel
- Ke Xu

Outline


Today’s Goal
The Problem
Evaluation Process
Design Concepts
Next Steps

Today's goal is to describe:

- The problem
- Evaluation process
- Concept plans considered

➔ **Gain your input to refine our proposed concept and go to final design next semester**

The Problem

- Beaver population recovering
- Beaver plugged current outlet system
  - Localized flooding
  - Dam safety
    - Bank Den tunneling
    - Reduced freeboard in storm events - overtopping failure
  - Increased tree mortality
  - Increased maintenance demands

The American Beaver

Photo credit: Castro 2017

Maintenance

- Increased frequency of debris removal
- Staff time and cost
- Corrugated metal pipe (CMP) at end of design life

Outlet Structure

CMP at Sapsucker Woods

Photo credit: CEE 5021/6025 Fall 2019

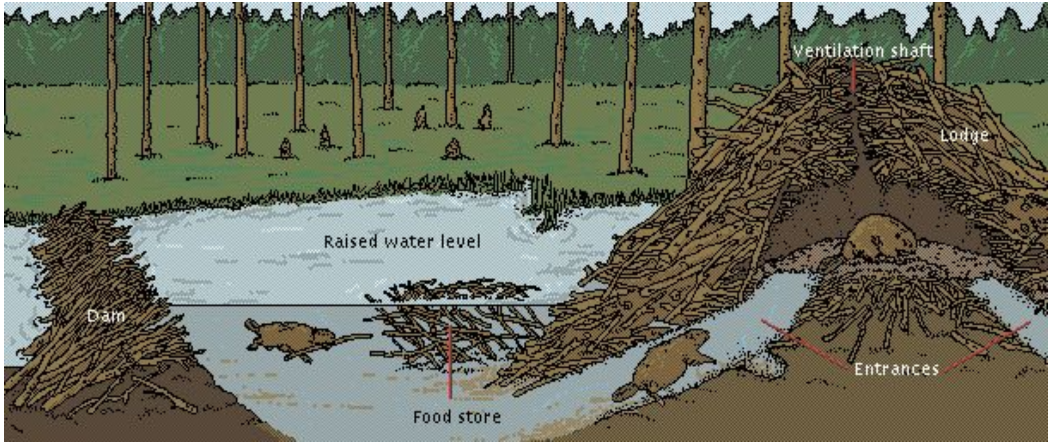
Client Needs

- Lab of Ornithology - conservation organization
- Coexist peacefully with beavers

Photo credit: Cornell University and WCS

Beaver Needs

- Safe shelter
  - Deep water - protection from predators
- Food source
- Beaver motivation
  - Stop the noise of running water

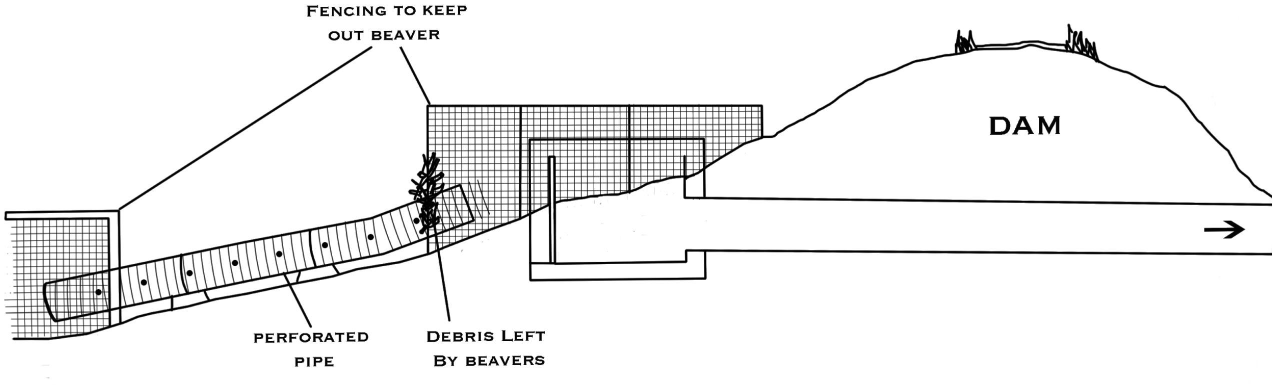


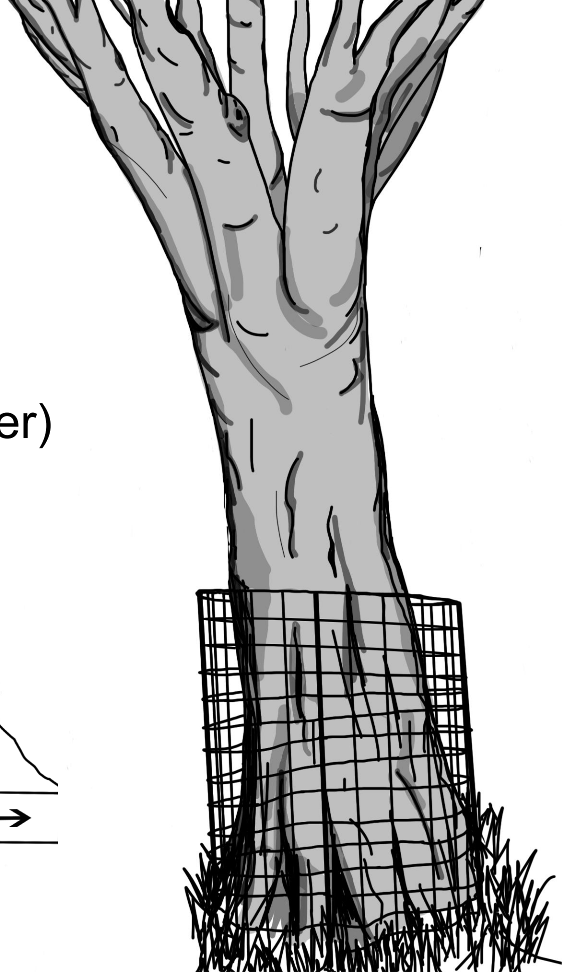
Construction of beaver dam and lodge

Photo credit: Strong 1997

Beaver Impact Minimization

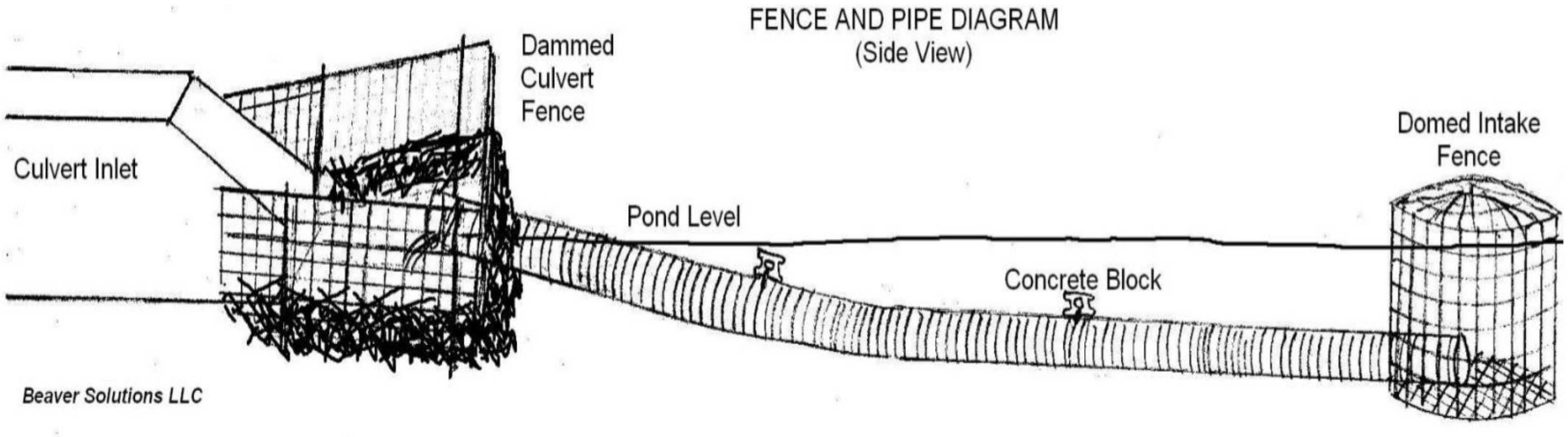
- Sound reduction
- Barriers around food source
- Increasing difficulty of damming (bigger, longer, deeper)





Drawing credit: Nick Gill

Previous Control Attempt



Beaver Solutions™ Flexible Pond Leveler™ installed 4 years ago

Source: Jeff Payne

Facility Manager's Perspective

Regarding previous design, "we were planning to rebuild the outlet system due to the main drain pipe deterioration and the beaver completely burying the outlet system we installed 4 years ago [...], I was skeptical of the design when we installed it and suggested that we run 80 feet of pipe along the water's edge to a secondary cage at the edge of the water so we could maintain the outlet".

Jeff Payne

Email on September 18, 2019

Temporary Solution

Floating high density polyethylene (HDPE) perforated pipe.

Regular maintenance of beaver debris removal around weir structure.

Current Status

- Temporary HDPE is being held down by tree trunks
- There is still beaver activity in the outlet but the system is working

Site History

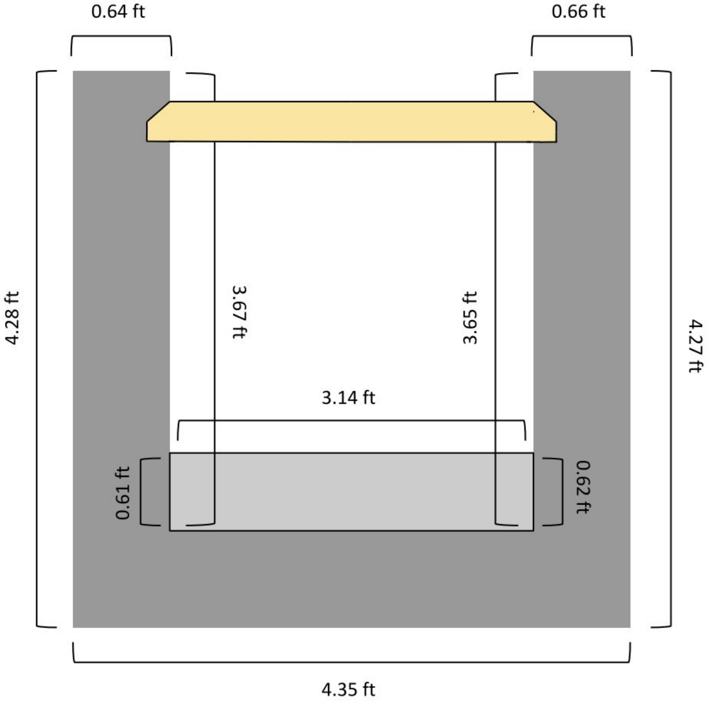
Aerial photographs from 1938 and 1965.

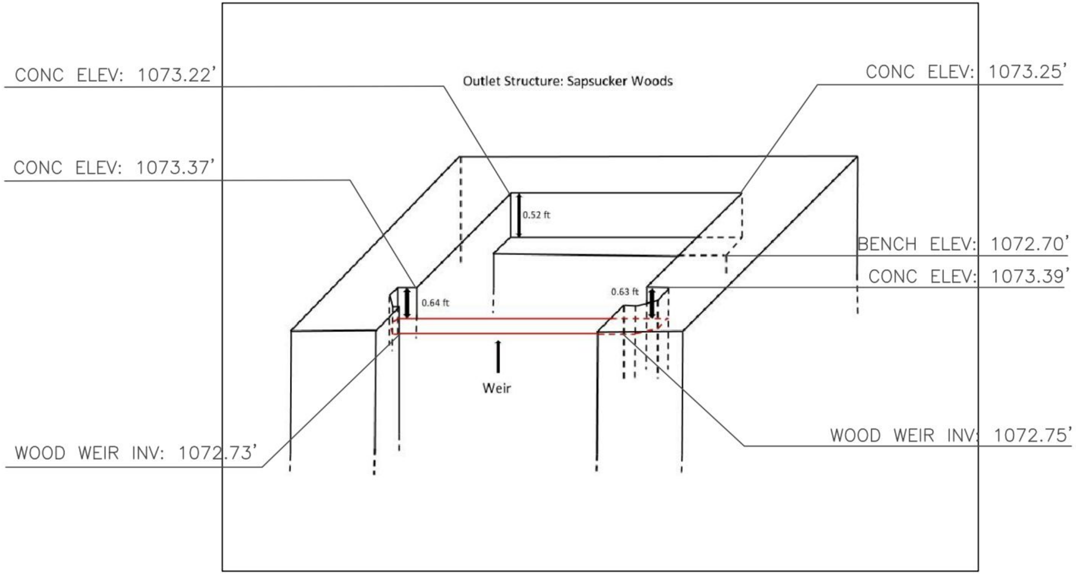
Source: Cornell University Library

Recent Aerial Photograph

Source: Tompkins County GIS

Existing Outlet





Credit: CEE 5021/6025 Fall 2019

BREACH OF BEAVER DAM 1068.8

EXIST. REMNANTS OF BEAVER DAM TOP OF BEV DAM

SURVEY NOTES:

1. Tax Map Parcel # 45.1-1-55.4

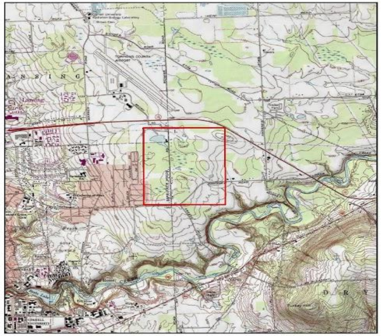
2. This map has been oriented to The New York Coordinate System of 1983, Central Zone, and vertically to The North American Vertical Datum of 1988 (NAVD 88), using RTN GPS. All horizontal and vertical information is expressed in U.S. Survey Feet.

3. Topographic/Bathymetric data, and the monumentation shown were located in the field using RTN GPS and conventional survey methods. Field locations were completed on November 1, 2019.

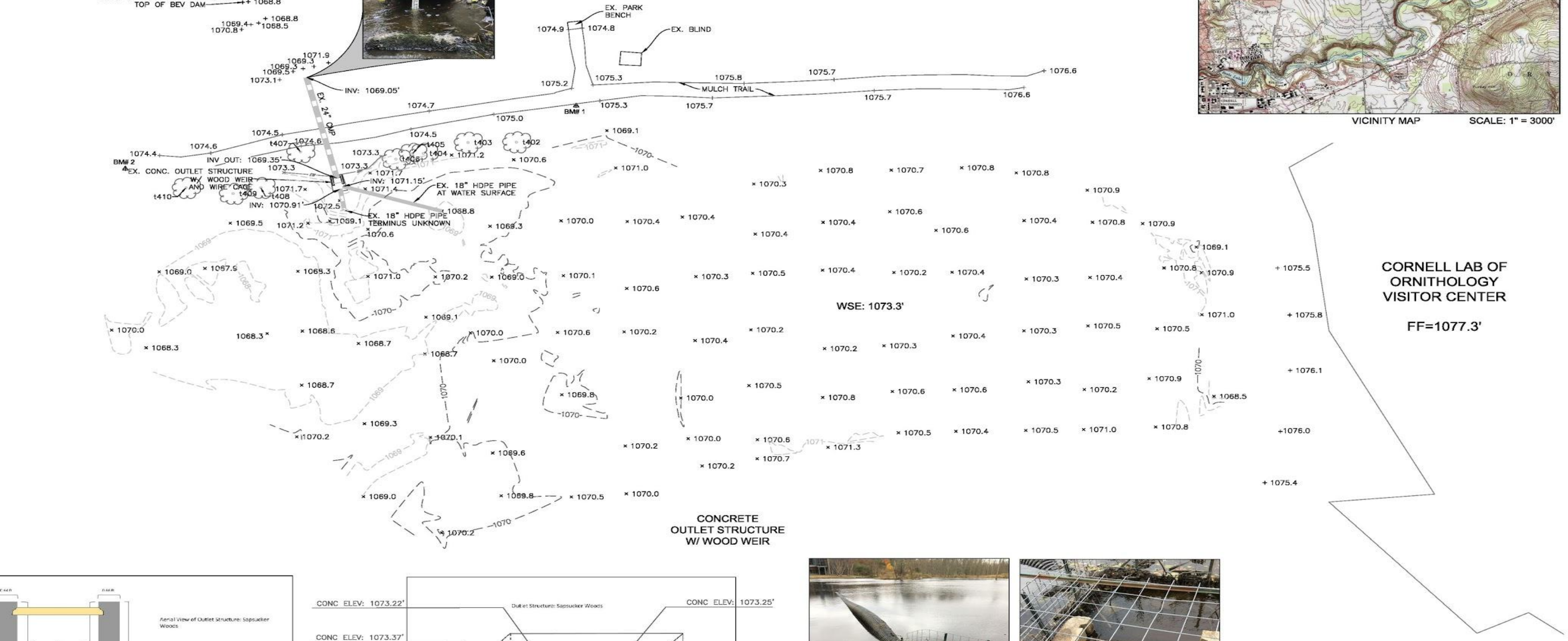
4. The boundary line information shown hereon is for information purposes only and does not constitute a boundary survey by WSSI. Monumentation, including traverse stations, fly points and concrete monuments, shown on this drawing should be used to orient topographic information and wetland locations to any future boundary, topographic, or location survey.

5. WSSI Contour Interval = 0.5'

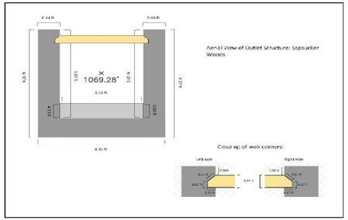
6. Laboratory of Ornithology Cornell University Grading plans dated 04/06/01 provided by the Cornell University Facilities Engineering Department display elevations that are +/- 0.7' higher than those surveyed and displayed by WSSI here on. We believe that this is a combination of datum difference and benchmark discrepancies. We believe that the original site plans may have used the National Geodetic Vertical Datum of 1929 which explains a difference of 0.5' with the remaining 0.2' likely to be a BM difference. While establishing onsite control WSSI RTN GPS indicated a vertical accuracy of +/-0.1'. We have maintained the use of NAVD 88 datum because the topo being used for the watershed analysis uses the 88 datum.

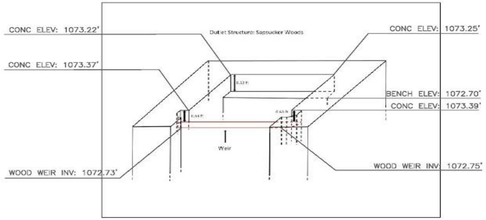


VICINITY MAP SCALE: 1" = 3000'



CONCRETE OUTLET STRUCTURE W/ WOOD WEIR

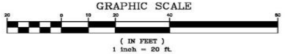




Benchmark in NAVD 1988

WSSI 1 REBAR and CAP: Elevation = 1075.20'

WSSI 2 REBAR and CAP: Elevation = 1074.27'



Wetland Studies and Solutions, Inc. a DAVEY company
5300 Wellington Branch Drive • Suite 100
Gainesville, Virginia 20155
Phone: 703-679-5600 • Fax: 703-679-5601
www.wetlands.com

TOPOGRAPHIC/BATHYMETRIC EXHIBIT

Prepared For: WSSI

Sapsucker Woods Pond

Tompkins County, Virginia

REVISIONS

No.	Date	Description	Rev. By	App. By

DATE: November 12, 2019 SCALE: 1" = 20' C.I.: 0.5'

Horizontal Datum: NY CENT NAD 83

Vertical Datum: NAVD 1988

Boundary and Topo Source: Tompkins County Digital Data

Design	Draft	Approved
PFS	CJL	CJL

Sheet #

1 of 1

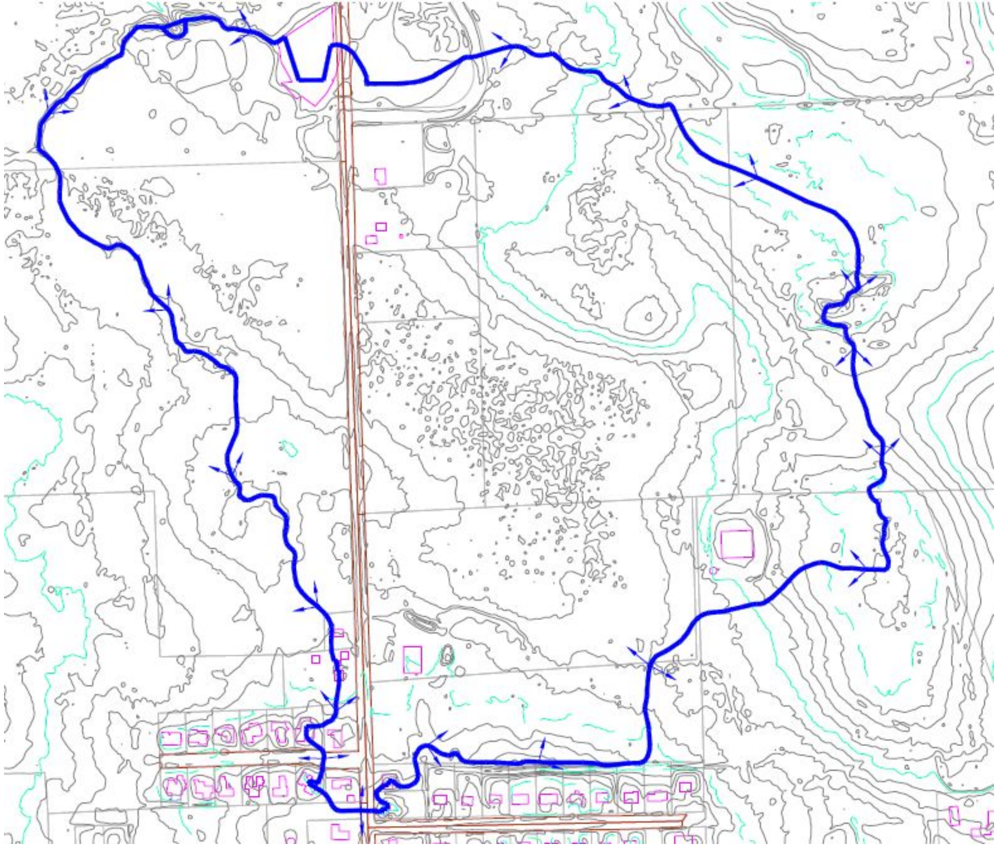
Computer File Name:

Survey pictures

Watershed

Area: 128 acres

- Flat
- Indistinct drainage divides in some locations
  - Detailed survey watershed cost ~ $40,000 (not worth it)
  - Roof and parking lot area delineated with design plans

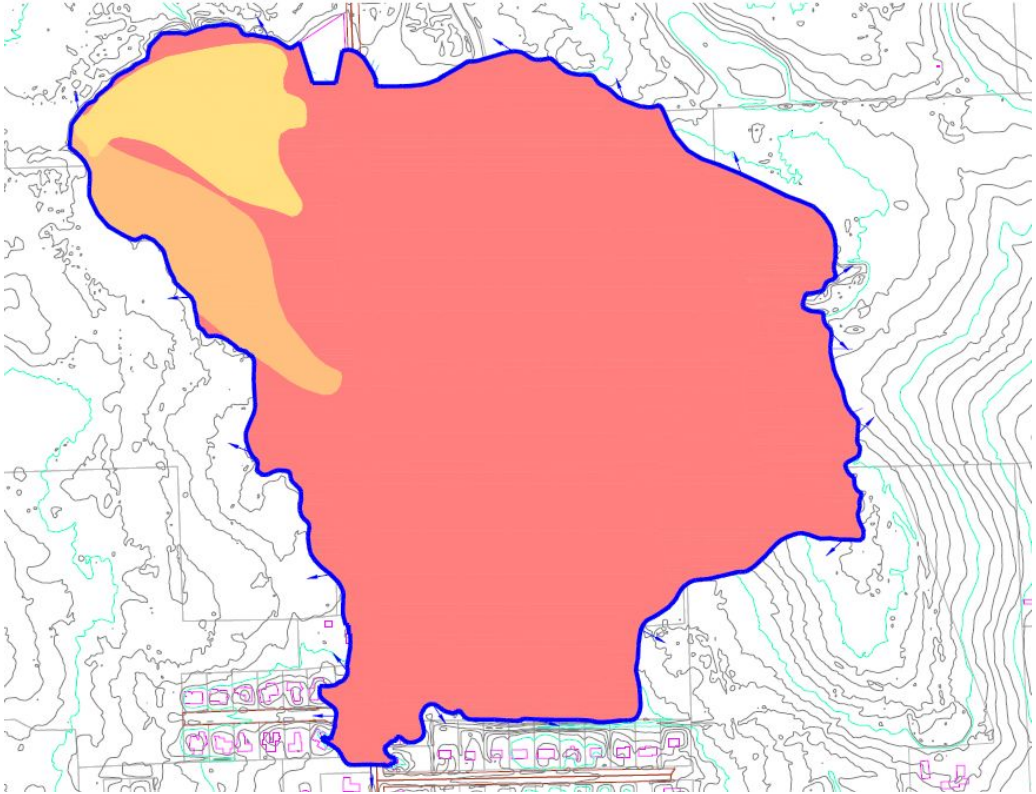


CN - Hydrologic Soil Group (HSG)

Pond

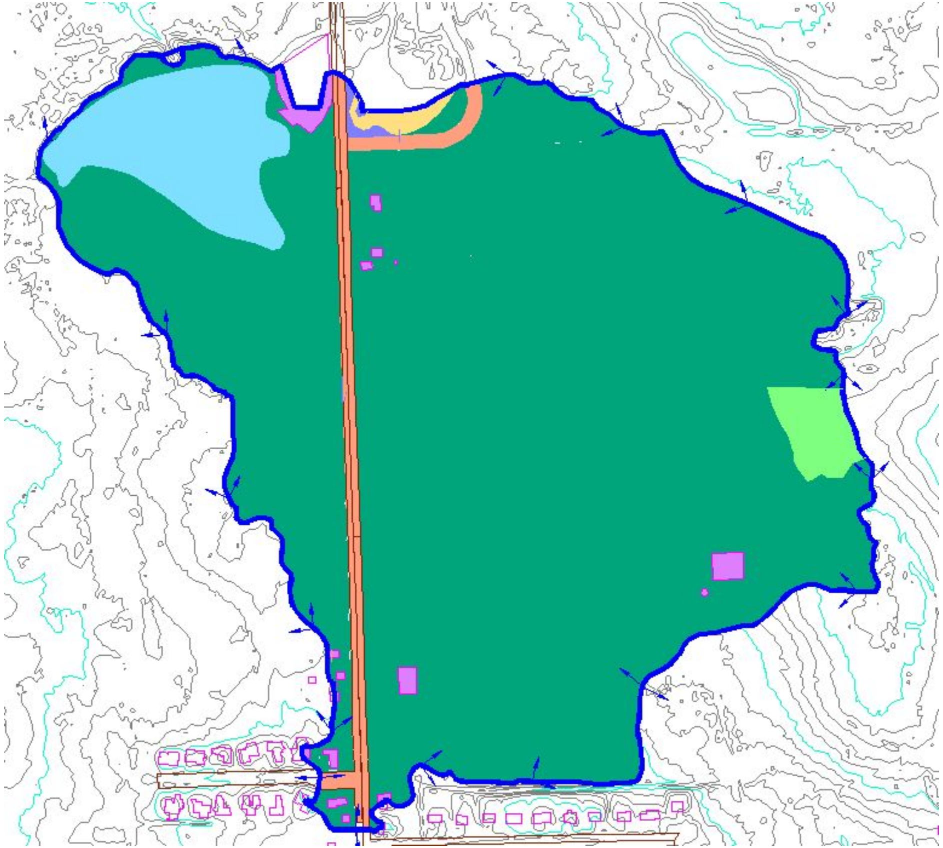
Hydrologic Group C

Hydrologic Group D



CN-Land Cover

Parking Lot	
Road	
Buildings	
Herbaceous	
Water	
Grass	
Woods	



CN - Sample calculation

Soil series	Associated area (acres)	Cover type	Hydrologic condition	Hydrologic soil group	Associated CN	Fraction of total area	Associated CN * Fraction of area
ErA	77.3	Woods	Good	D	77	0.61	46.66
ErA	3.5	Road	-	D	98	0.03	2.72
ErA	0.5	Buildings	-	D	98	0.00	0.40
ErA	0.6	Parking lot	-	D	98	0.00	0.44
ErA	0.3	Herbaceous	Good	D	85	0.00	0.18
BgC	8.2	Woods	Good	C	70	0.06	4.52

⋮

Total watershed area (acres)	128	Total watershed curve number	79

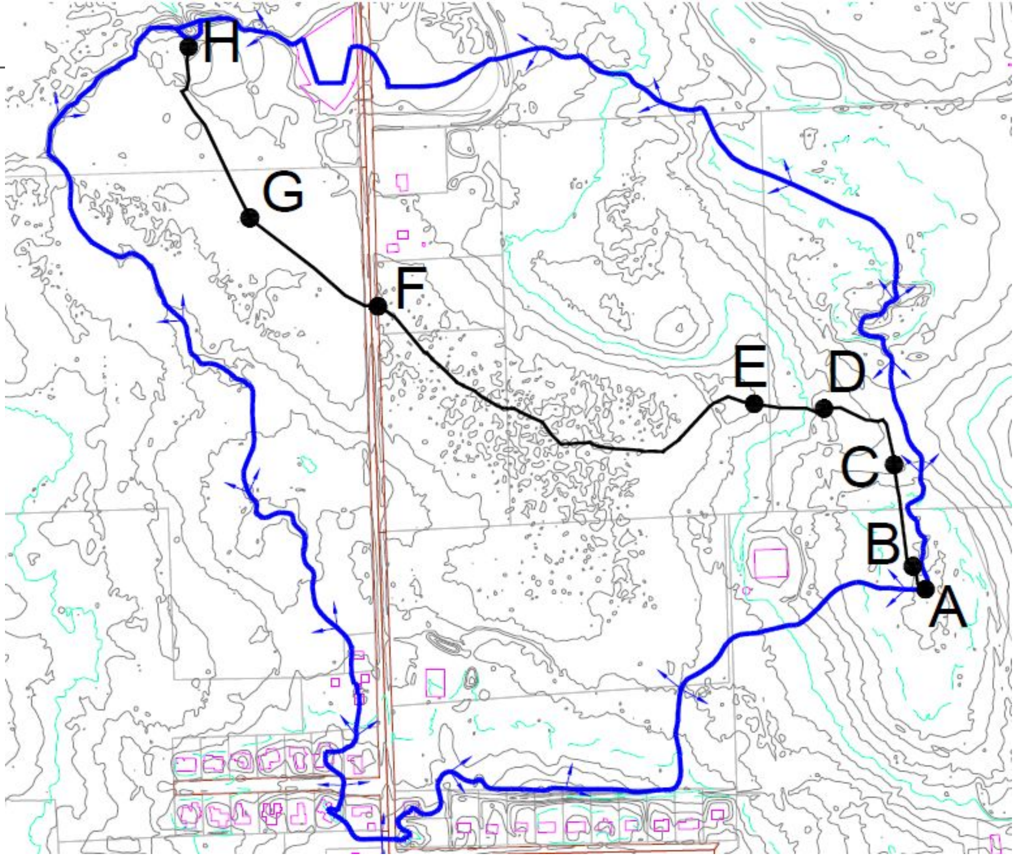
Tc: Sheet flow (A → B)

NRCS National Engineering Handbook:
Part 630 Hydrology (eq. 15-8):

$$T_t = \frac{0.007(n\ell)^{0.8}}{(P_2)^{0.5} S^{0.4}}$$

T_t = sheet flow travel time, hr
n = Manning's roughness coefficient
l = sheet flow length, ft*
P_2 = 2-year, 24-hour rainfall, in
S = slope of land surface, ft/ft

* NYS Stormwater Management Design Manual:
Up to 250 ft for S < 1% or 100 ft otherwise

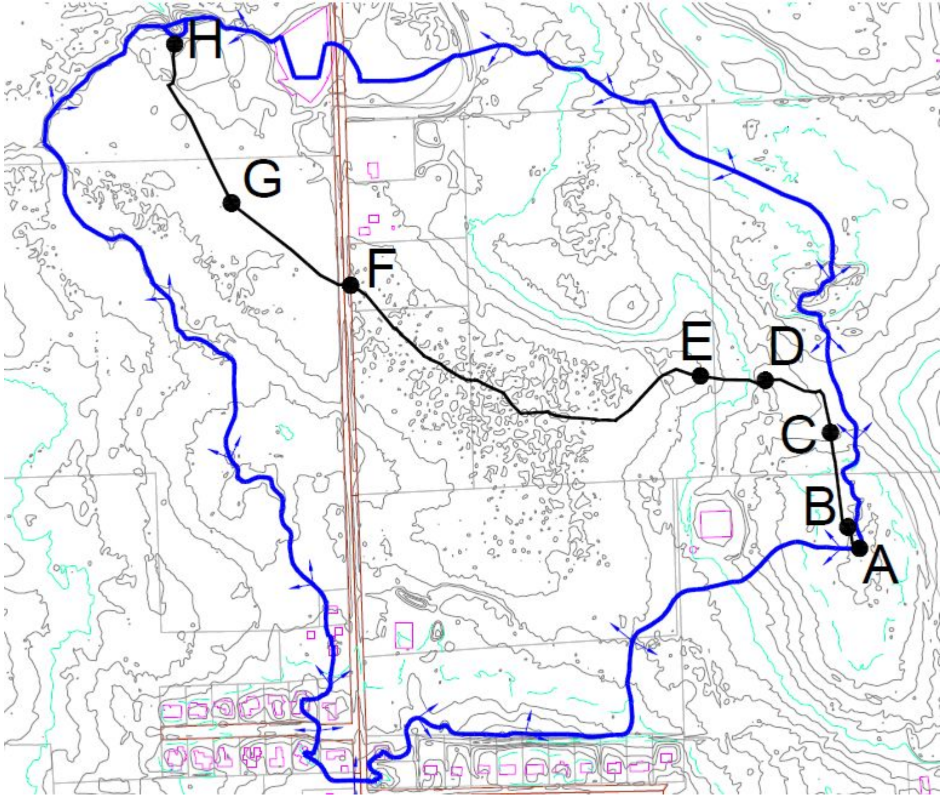


Tc: Shallow concentration (B → F)

NRCS National Engineering Handbook:
Part 630 Hydrology (eq. 15-1):

$$T_t = \frac{\ell}{3{,}600V}$$

T_t = travel time, hr
l = distance between B and C, ft
V = average velocity of flow, ft/s

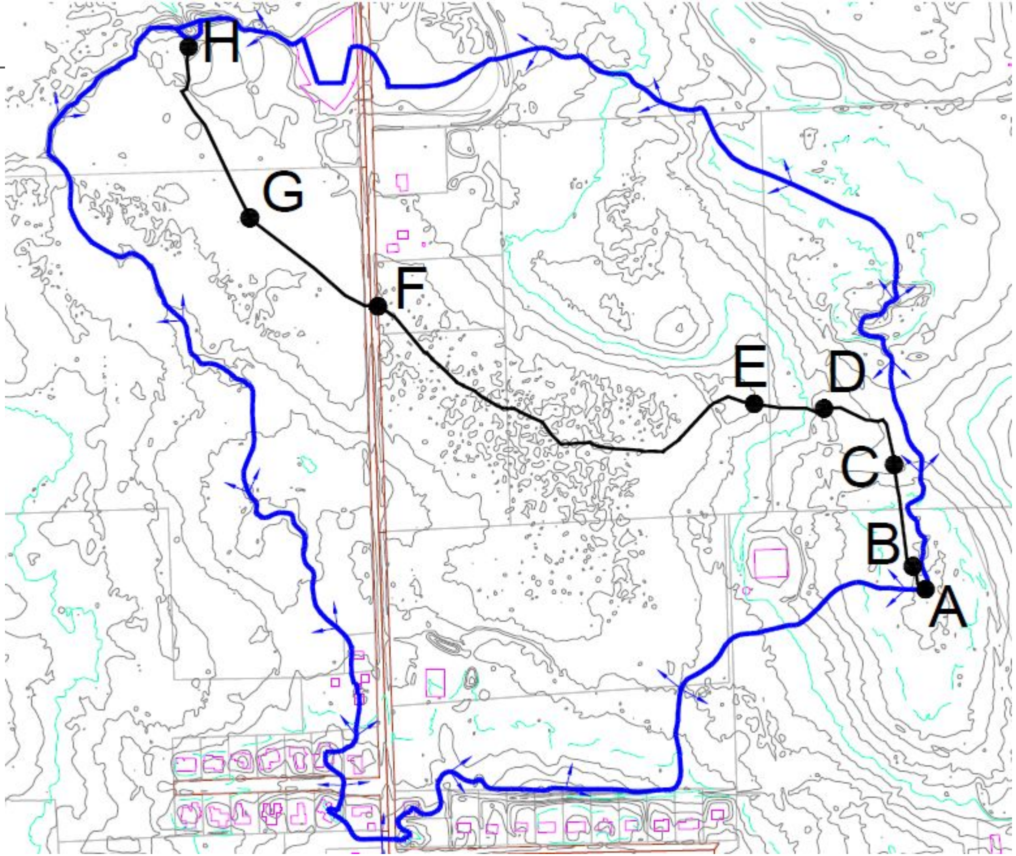


Tc: Channel Flow (F → G)

NRCS National Engineering Handbook:
Part 630 Hydrology (eq. 15-1, 15-10):

$$T_t = \frac{\ell}{3,600V} \qquad V = \frac{1.49r^{\frac{2}{3}}s^{\frac{1}{2}}}{n}$$

T_t = time of travel, hr
l = length of channel from F to G, ft
V = velocity, ft/s
r = hydraulic radius, ft
s = channel slope, ft/ft
n =Manning's n

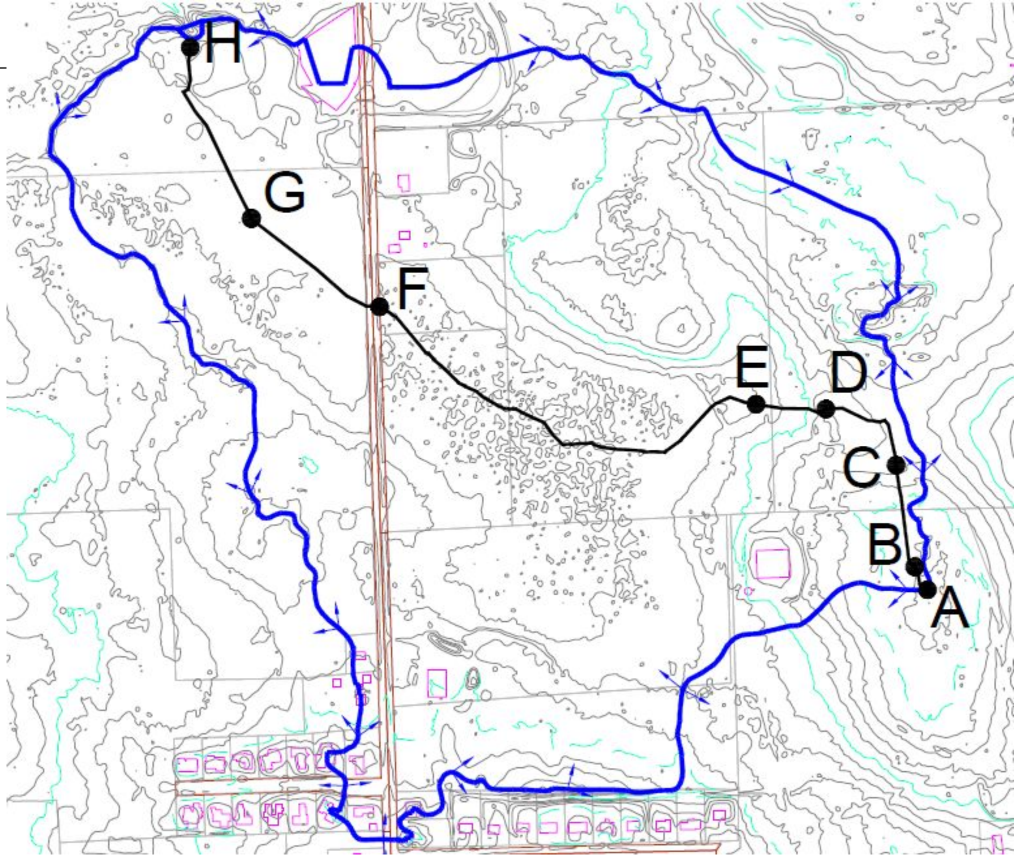


Tc: Pond Flow (G → H)

NRCS National Engineering Handbook:
Part 630 Hydrology (eq. 15-1, 15-11):

$$T_t = \frac{\ell}{3{,}600V} \qquad V_w = \sqrt{gD_m}$$

T_t = time of travel, hr
l = length of channel from G to H, ft
V = velocity, ft/s
g = gravity constant (32.2 ft/s^2)
D_m = mean depth of pond



Time of Concentration

Path	Land Cover	Flow Type	Length (ft)	Time (mins)
A-B	Woods	Sheet flow	250	84.6
B-C	Woods	Shallow Concentrated Flow	226	12.4
C-D	Grass	Shallow Concentrated Flow	388	9.8
D-E	Woods	Shallow Concentrated Flow	257	10.7
E-F	Forested Wetland	Shallow Concentrated Flow	1616	304
F-G	Woods	Channel Flow	565	14.1
G-H	Pond	Pond Travel	683	1.2
Total	**-**	**-**	**3985**	**437 (7.3 hr)**

Small Storm (<1 year) Precipitation

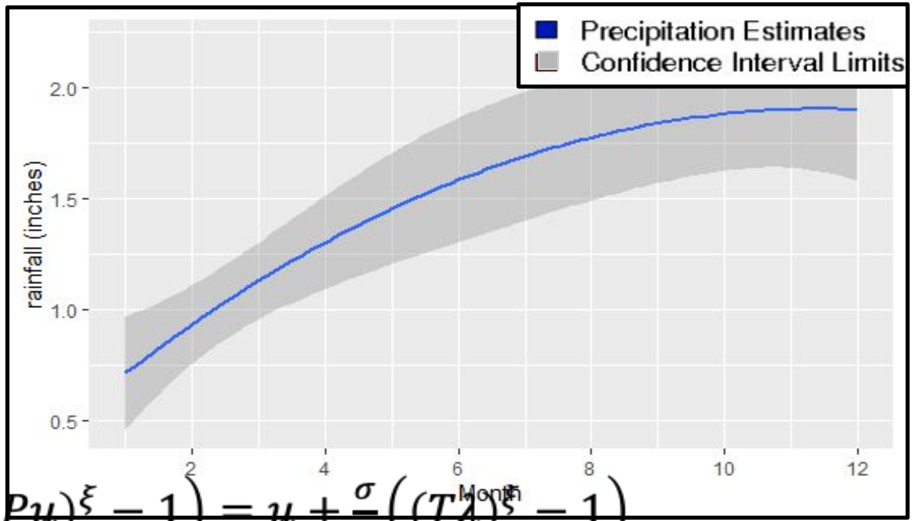
*data collected from the NRCC/NRCS center for Sapsucker Woods - Ithaca, NY

Generalized Pareto Distribution (GPD)

(2019, Steinschneider)

Statistically driven approach incorporating threshold (*u*), scale (σ), shape (ξ), and average number of exceedance (λ) per time (*T*)

GPD: Rainfall [in] vs. Month



$$PRCP(in) = u + \frac{\sigma}{\xi}\left((m(1 - Pu)^{\xi} - 1\right) = u + \frac{\sigma}{\xi}\left((T\lambda)^{\xi} - 1\right)$$

$$s.t. P(x \leq u)$$

Small Storm (<1 year) Precipitation

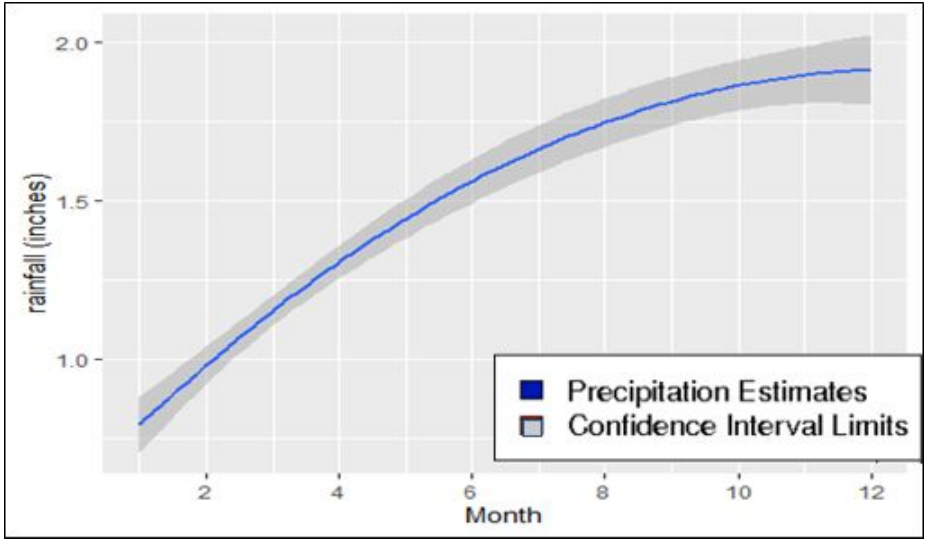
*data collected from the NRCC/NRCS center for Sapsucker Woods - Ithaca, NY

Ranking Method (Wetland Studies and Solutions, Inc.)

- 30 years of historic data ranked in descending order
- Rank calculated by recurrence interval

$$\#\,Events = \frac{\#\,Years\ on\ Record}{Recurrence\ Interval}$$

Ranking Method: Rainfall [in] vs. Month



Small Storm Source Comparison

Return Period	Ranking PRCP [in]	GPD PRCP [in]
1 mo	**0.75**	**0.65**
2 mo	**1.01**	**0.98**
3 mo	**1.18**	**1.18**
4 mo	**1.32**	**1.33**
5 mo	**1.46**	**1.44**
6 mo	**1.51**	**1.54**
1 yr	**(1.92)**	**(1.91)**

Large Storm (>1 year) Precipitation

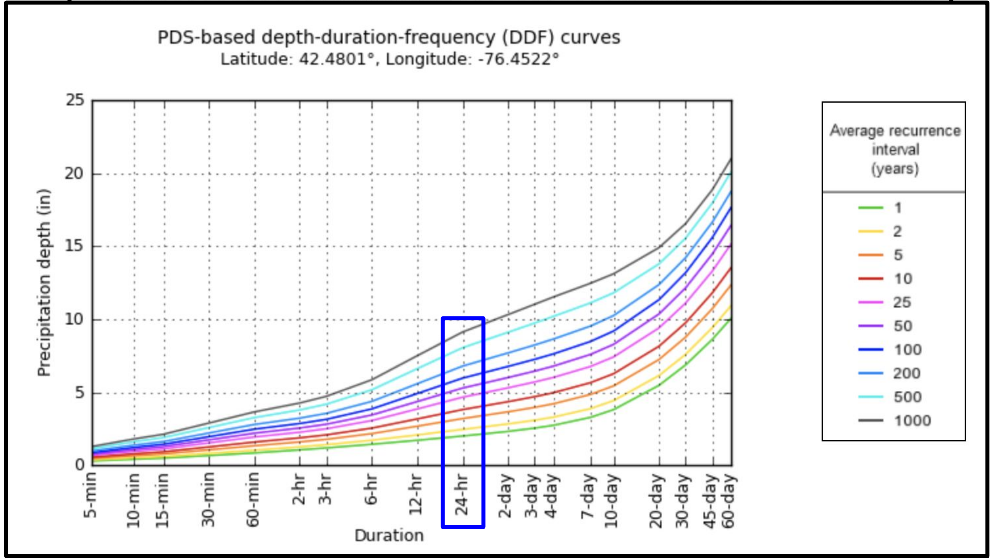
NRCC/NRCS

- NRCC/NRCS center for Sapsucker Woods - Ithaca NY
- Each return period found separately
- Use extreme precipitation estimate

NOAA 14-point Precipitation Analysis

- Estimates for Sapsucker Woods - Ithaca, NY

Time (hours)	Estimate (inches)	Lower Limit (inches)	Upper Limit (inches)
21*	1.91	1.79	2.03
22*	1.94	1.82	2.06
23*	1.97	1.86	2.09
24	2.01	1.89	2.12



Large Storm Source Comparison

Return Period	NOAA Atlas PRCP [in]	NRCS/NRCC PRCP [in]
1 yr	**2.01**	**2.01**
2 yr	**2.46**	**2.34**
10 yr	**3.82**	**3.43**
100 yr	**5.98**	**5.92**

Design Storm Flow Rate (TR-55)

- USDA *"Urban Hydrology for Small Watershed" (1986)*
- Estimate the runoff for each return period

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

- Estimate the peak discharge for each return period

$$q_p = \frac{2Q}{1.1t_c + 1.1 * 1.67t_c}$$

When:
CN = 79
t_c = 437 min
S = 2.66 in

Results

Return Period	PRCP [in]	q [cfs]
1 mo	0.75	**0.20**
2 mo	1.01	**0.88**
3 mo	1.18	**1.53**
4 mo	1.32	**2.18**
5 mo	1.46	**2.90**
6 mo	1.51	**3.18**
1 yr	2.01	**6.38**
2 yr	2.34	**9.78**
10 yr	3.43	**21.94**
100 yr	5.92	**44.19**

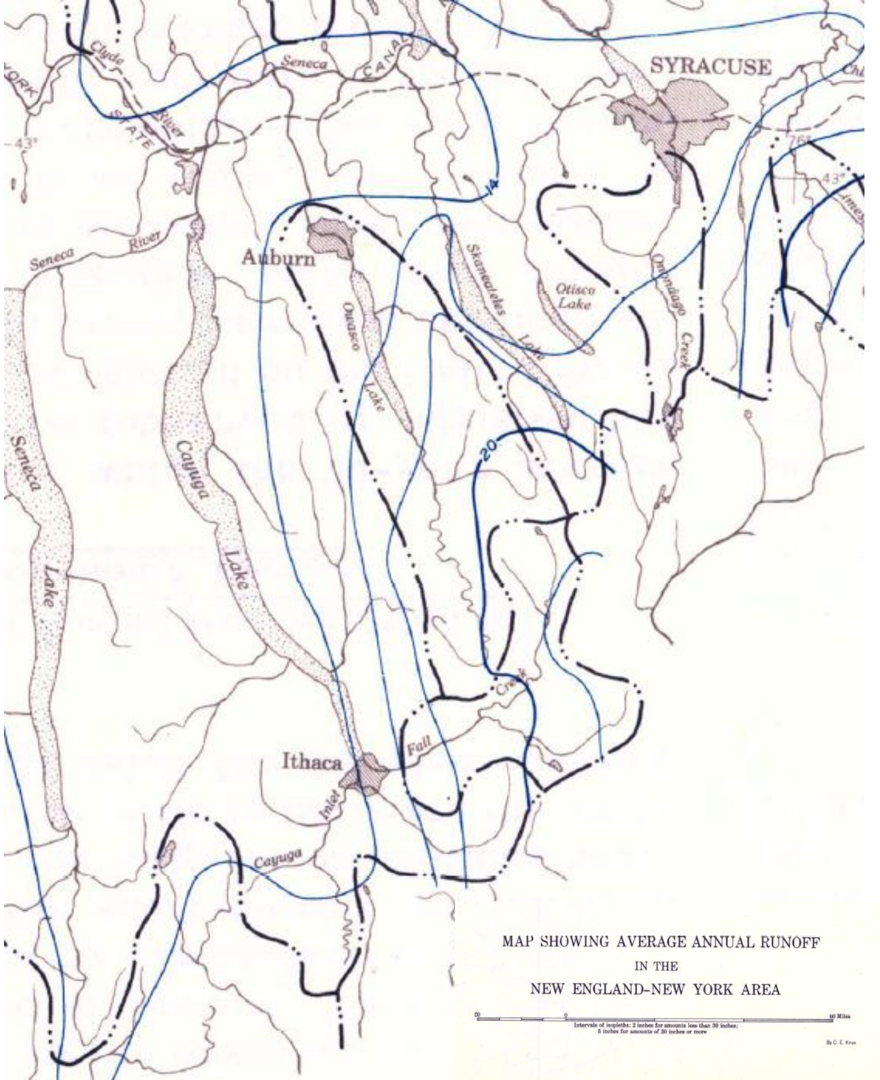
When:

t_c = 437 min

A = 128 ac

Baseflow

- While it is unconservative to not include baseflow, we also were conservative by excluding the flow reduction benefit of stage-storage in the pond
- We determined that the baseflow was relatively small - because the average flow rate is approximately 14 in/year or 1 cfs / sq.mile - or 0.2 cfs for this outlet



Design Constraints/Assumptions

- Limit work so it is considered “maintenance”
  - Total outlet structure replacement can trigger dam safety standards
    - Free board requirements
    - No trees on dam or toe area
      - Ecological impact
  - Risk is low because:
    - Low height: less than 6 feet
    - Overland relief around building and to northwest
    - No habitable structures immediately downstream
- Match existing wood outlet capacity and elevation
  - Consistent with “maintenance”
  - Minimize change in user experience

Options Considered

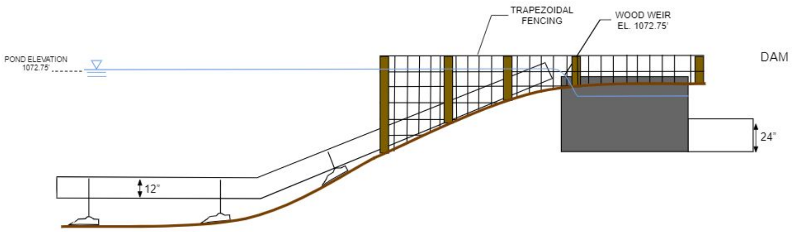
- Lengthened and Cleaned Flexible Pond Leveler
  - Deeper location
- Clemson Water Leveler
  - Straight pipe or stand pipe
  - Through concrete structure, wood weir, or through dam
  - Various pipe sizes
- Beaver Deceiver around outlet structure
  - Different shapes and distances from structure to limit sound
- Gate Valve or Agri Drain Inline Water Level Control Structure™
- Tree protection

Option Plans

Clemson Water Leveler

Flexible Pond Leveler

(1)



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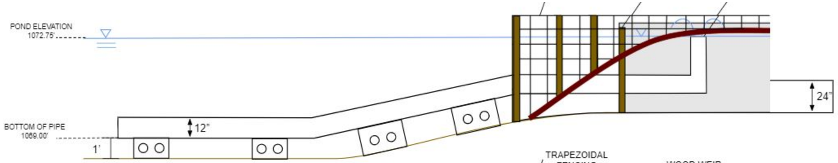

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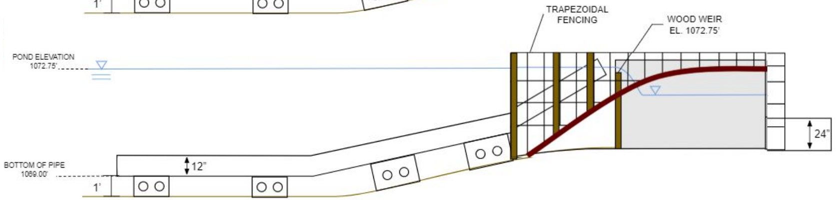
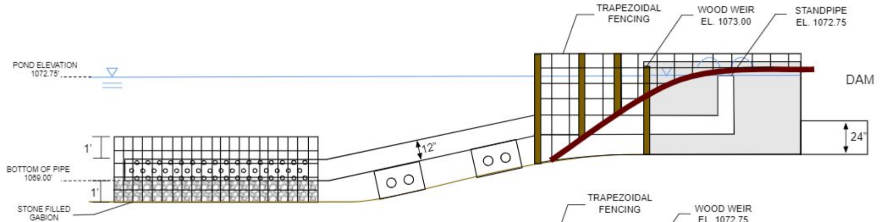


(1) Weighted, straight; (2) Lifted, elbowed; (3) Lifted, straight.

(4)



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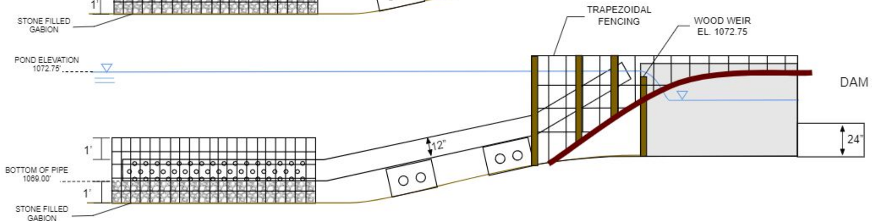
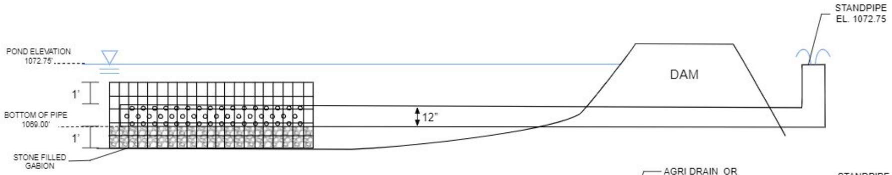


(6)



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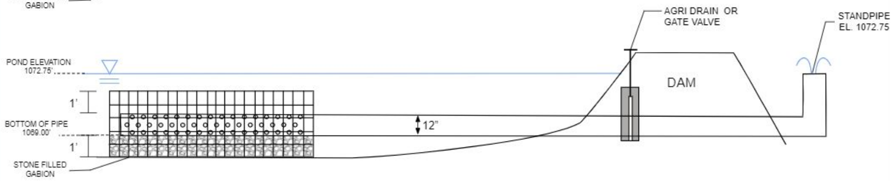
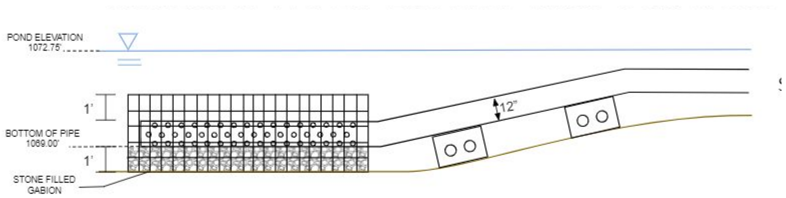


(4) Lifted, elbowed, with structure; (5) Lifted, straight, with structure; (6) Through dam, elbowed; (7) Through dam, elbowed, Agri Drain device

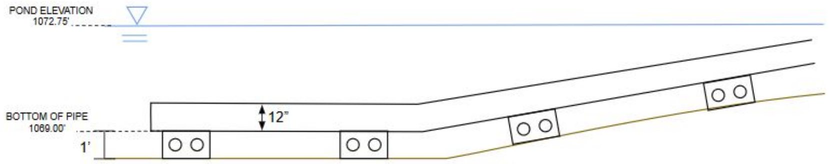
Design credit: CEE 5021/6025 Fall 2019

Option Plans

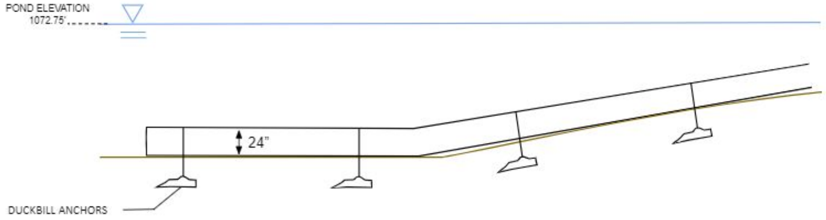
(1)



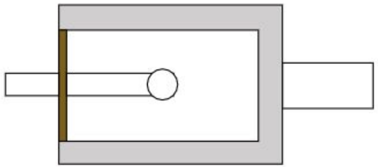
(2)



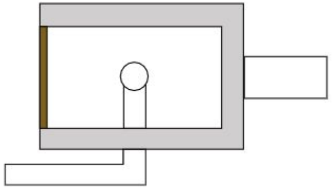
(3)



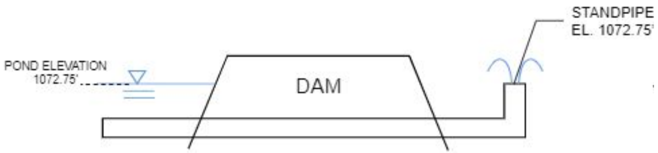
Clemson Water Leveler (1) or Flexible Pond Leveler (2) (Lifted) and (3) (Anchored)



(4)



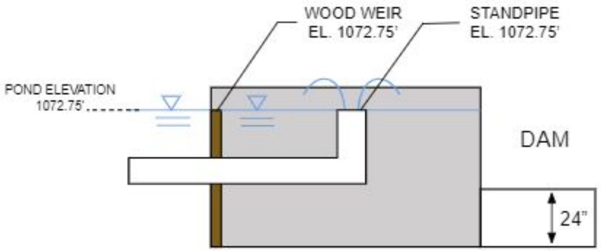
(5)



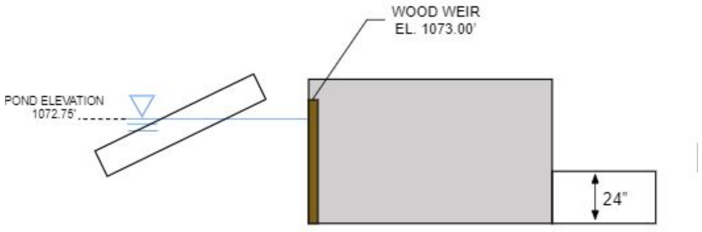
(6)

Through weir (4), concrete (5), or dam (6)

Option Plans

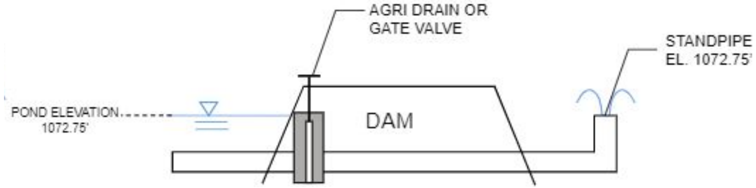


(7)

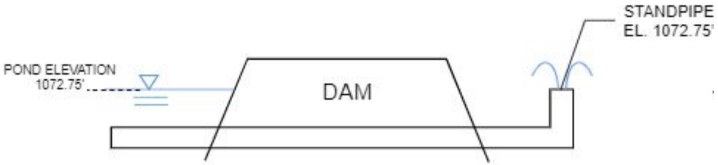


(8)

Elbowed (7) or straight (8)



(9)



(10)

With (9) or without (10) Agri Drain/gate valve device

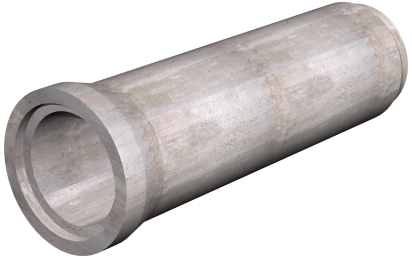
Outlet Pipe Replacement

- Replace with HDPE or concrete
  - HDPE: Cheaper, easier to install, installation deformation
  - Concrete: More expensive, longer life
- Add rodent guard

Current pipe

(Corrugated metal pipe)

HDPE pipe



Reinforced concrete pipe

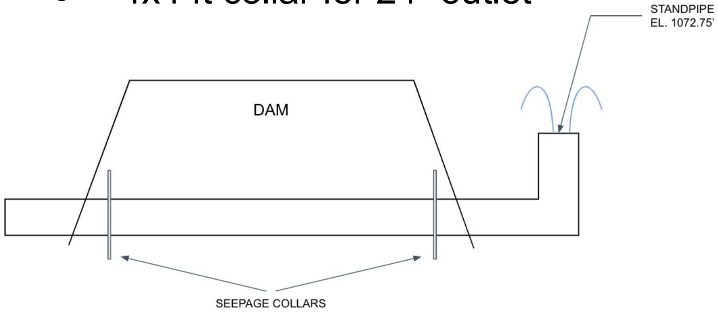
Rodent guard

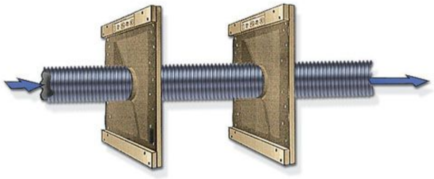
Sources: Wetland Studies and Solutions, Inc. 2019, Tractor Supply Co., Oldcastle Infrastructure, Agri Drain Corporation

Seepage Control - Outlet or Clemson

Seepage Collar

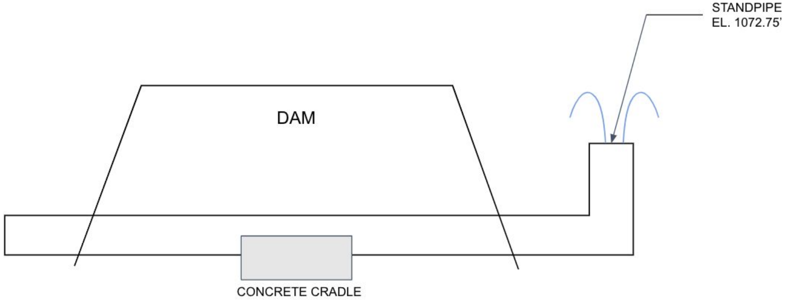
- 3x3 ft collar for 12” Clemson pipe
- 4x4 ft collar for 24” outlet

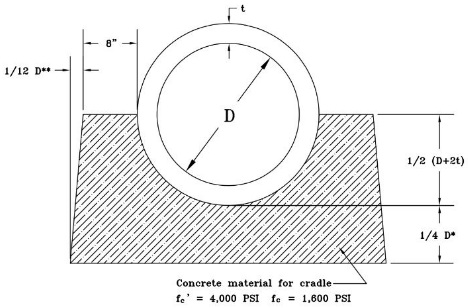




Concrete cradle

- Best for concrete pipe



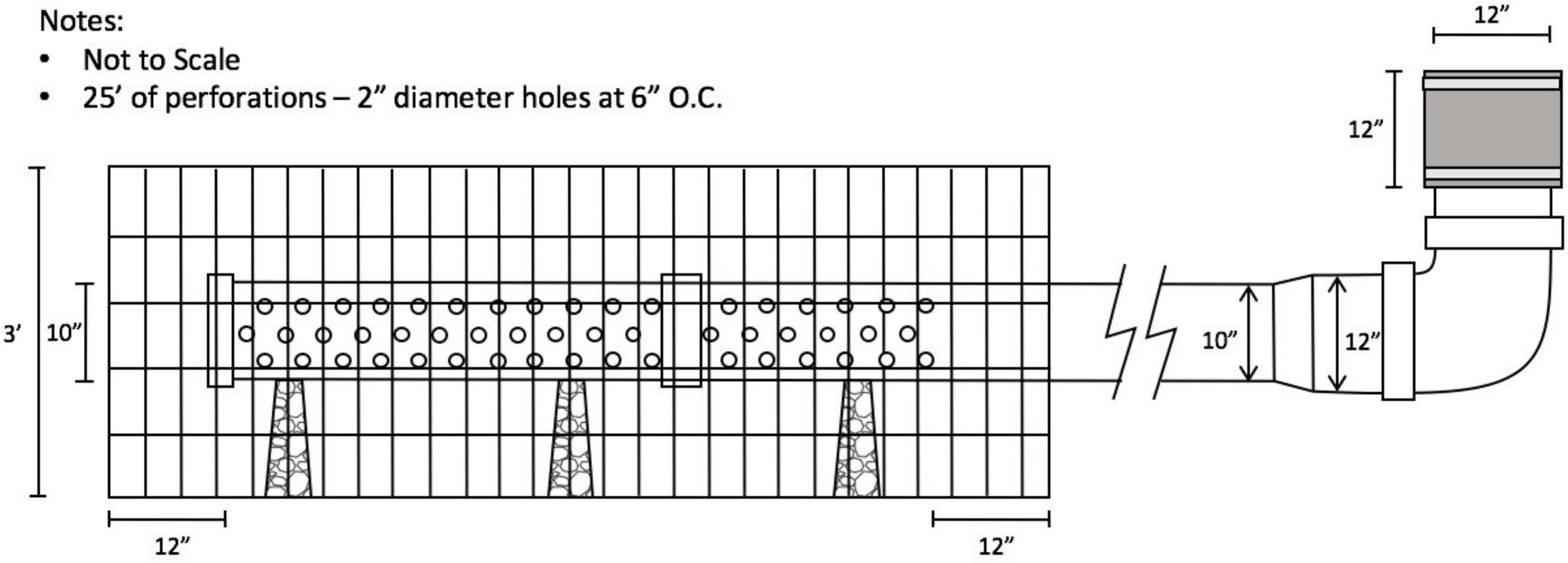


Source: Agri Drain and Fairfax County Public Facilities Manual

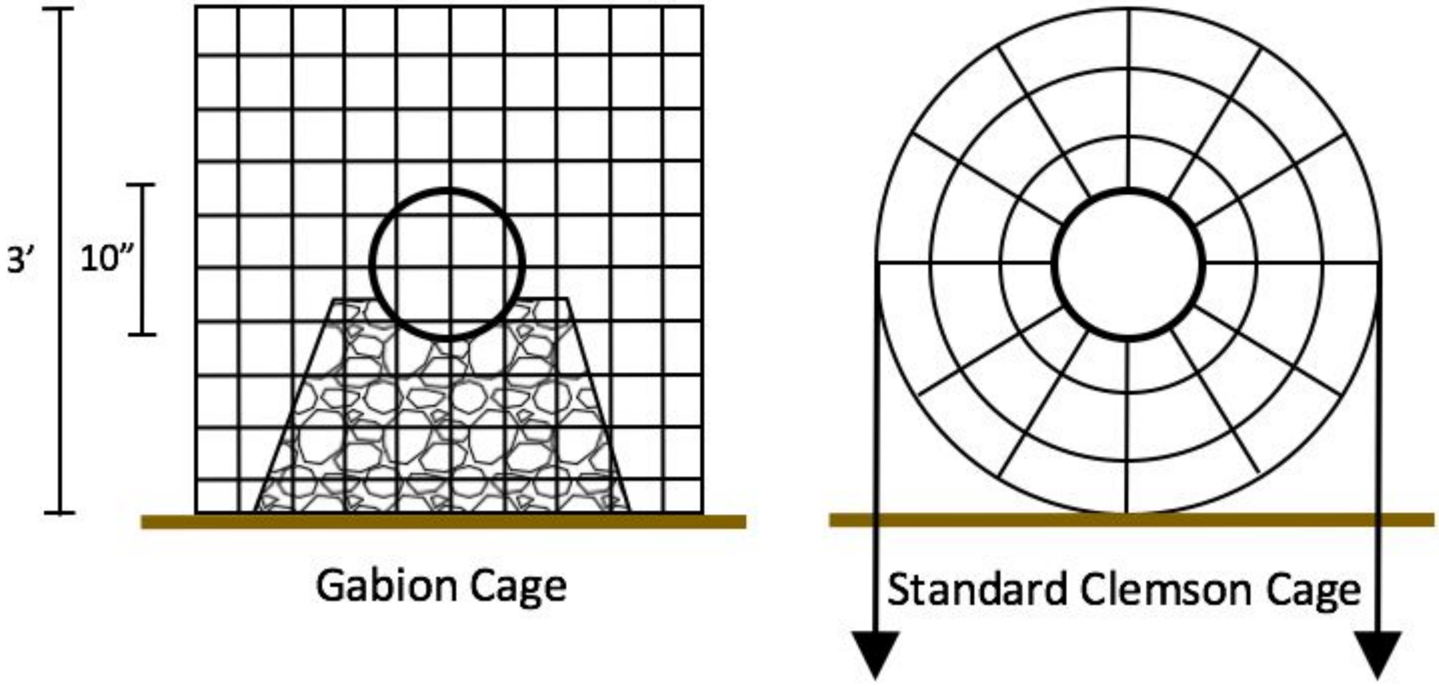
Recommended Clemson Water Leveler - Through Dam

Notes:

- Not to Scale
- 25’ of perforations – 2” diameter holes at 6” O.C.

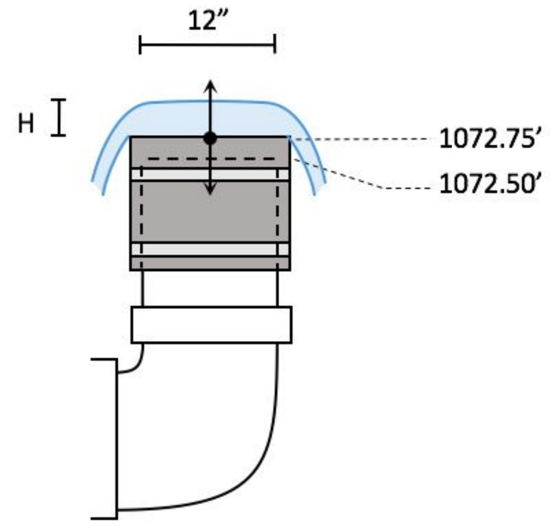


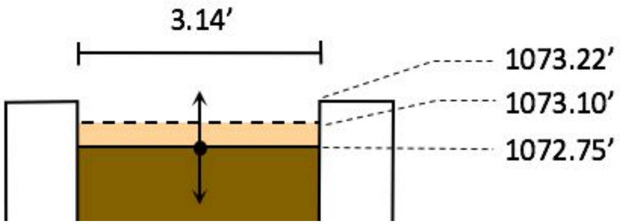
Clemson Water Leveler Cage Options



Flow Calculation Process

- Utilize CWL with elbow and standpipe
- Locate in deep water (el. 1068 (~5 ft)), 50 ft SW of structure
- Penetrate dam to outlet in stream +/- 90-100 ft from deep water
- Size standpipe to mimic existing wood weir elevation and weir length (12 in diameter)
- Flow rate capacity is the lesser of:
  - Standpipe flow
  - Pipe flow
  - Perforated pipe flow
- Standpipe H range: 0.25 to 0.47 ft
- Wooden weir raised at least 0.25 ft





Flow Calculations

1. Number of Holes: Clemson University recommends that the total area of the holes is equal to 10 times the cross sectional area of the pipe.

2. Orifice flow capacity checked (ideally 10x Qpipe):

$$Qinlet = Cd * Ainlet * (2 * g * h)^{(1/2)}$$

3. Pipe flow capacity calculated:

$$Qpipe = A * (2 * g * h)^{(1/2)} / (1 + Ke + KcL)^{(1/2)}$$

4. Standpipe flow capacity calculated (modeled as sharp-crested weir C = 2.6):

$$Qweir = C * L * H^{(3/2)}$$

Flow Calculation Results

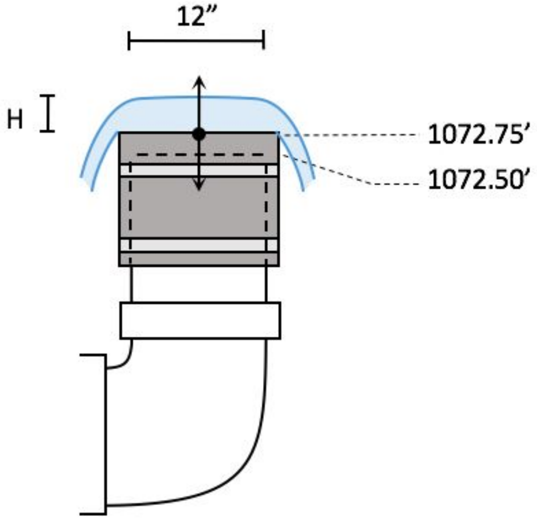
Determine governing flow rates - compare to peak flow / storm events

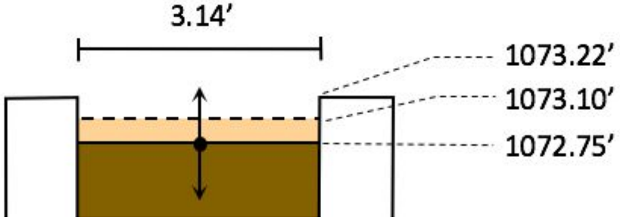
Pipe Diameter (in)	*Pipe Flow Rate (cfs)*			*Elbow Flow Rate (cfs)*		
H (ft)	*0.25*	*0.35*	*0.47*	*0.25*	*0.35*	*0.47*
12	1.11	1.32	1.53	1.02	1.69	2.63
14	1.52	1.79	2.08	N/A	N/A	N/A
16	1.98	2.34	2.71	N/A	N/A	N/A
18	2.50	2.96	3.43	N/A	N/A	N/A

Return Period	**q (cfs)**
1 mo	0.20
2 mo	0.88
3 mo	1.53
4 mo	2.18
5 mo	2.90
6 mo	3.18

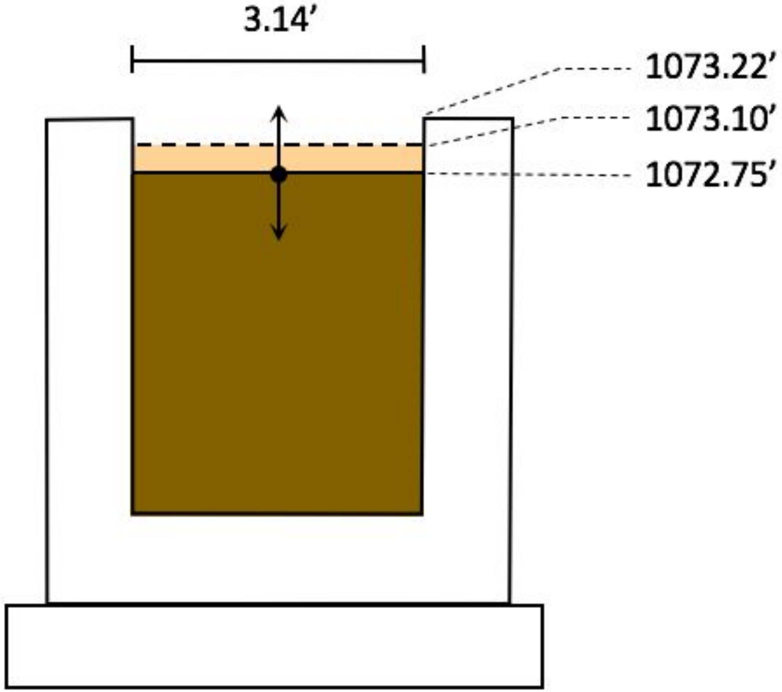
Operation Results

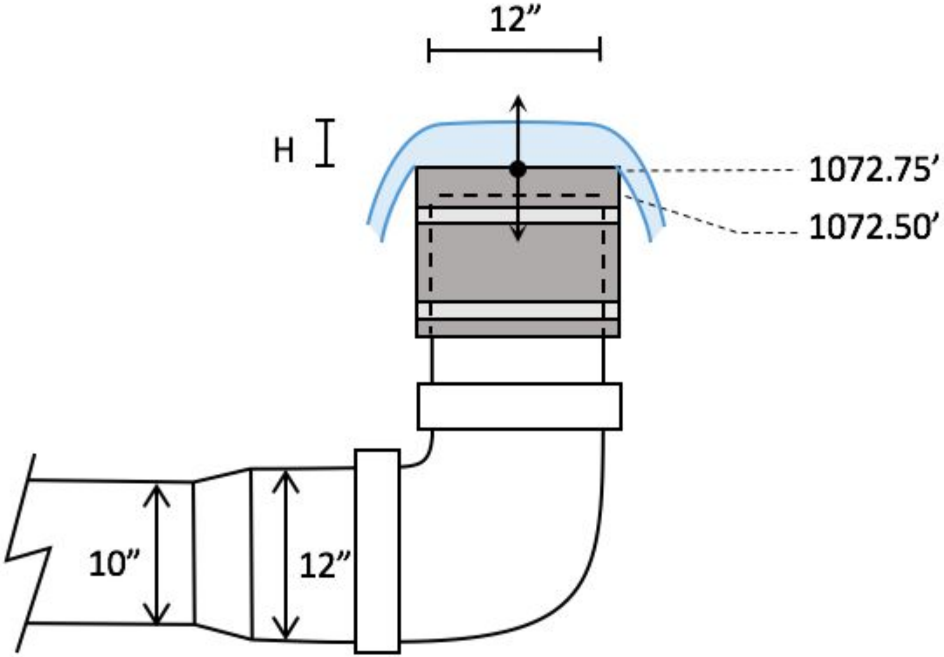
- The CWL can handle over the 4 mo. storm event
- The FM can modify the elevation of the wood weir and standpipe to determine when the water flow begins to split between the CWL and wood weir
    - Evaluate the maintenance requirements
- Initial operation suggestions
    - Standpipe elevation - 1072.75 (existing wood weir)
    - Raise wood weir to el. 1073.10





Preliminary Design of Outlet Pipe



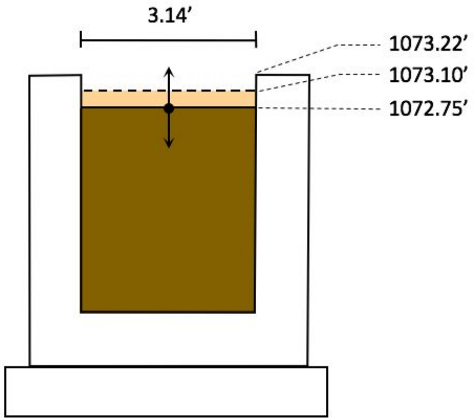


Note: Not to Scale

Adjustments

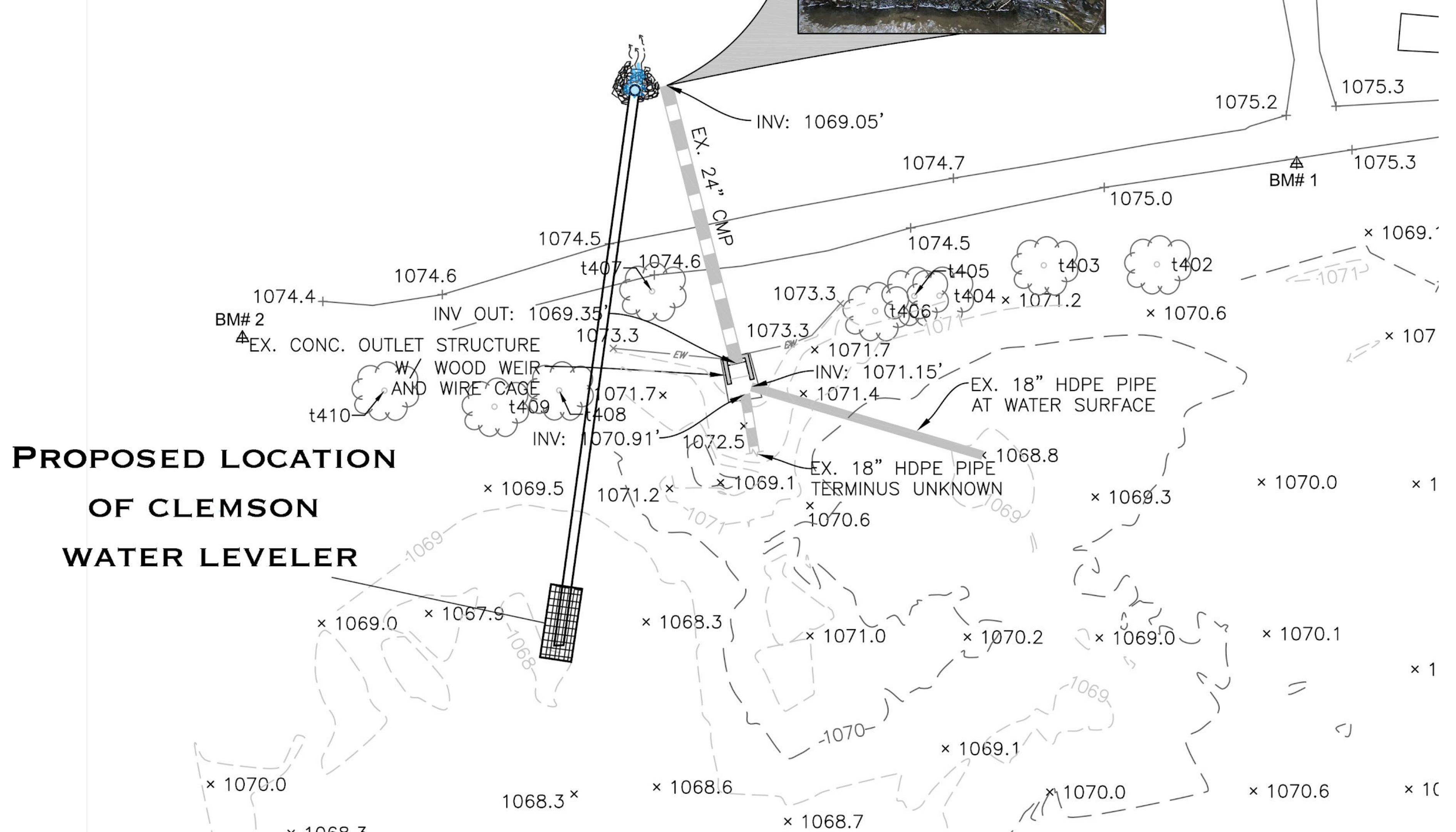
- Allow “fine tuning” by facilities manager
- Easy maintenance
  - Neoprene sleeve to adjust standpipe elevation
  - Wooden weir
  - Agri Drain inline control structure
    - Substitute for valve
    - Allows additional water elevation adjustment

Neoprene Sleeve



Agri Drain Inline Water Level Control Structures™

Source: Supply.com and Agri Drain Corporation

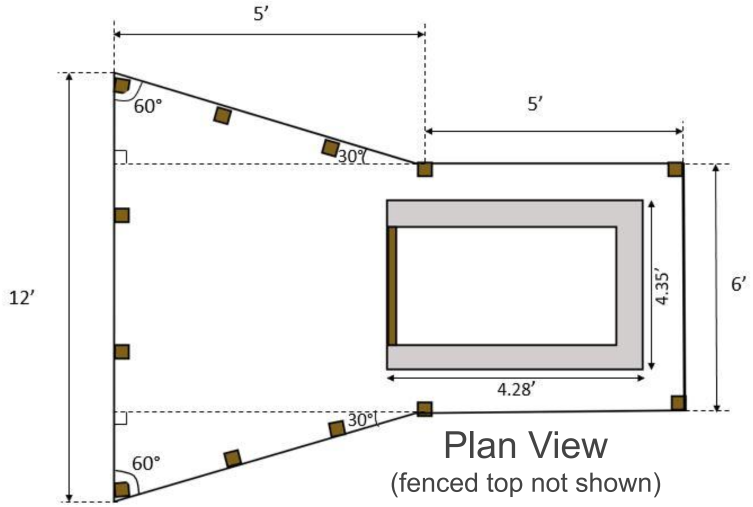


PROPOSED LOCATION OF CLEMSON WATER LEVELER
INV: 1069.05'
EX. 24" CMP
INV OUT: 1069.35'
EX. CONC. OUTLET STRUCTURE W/ WOOD WEIR AND WIRE CAGE
INV: 1071.15'
INV: 1070.91'
EX. 18" HDPE PIPE AT WATER SURFACE
EX. 18" HDPE PIPE TERMINUS UNKNOWN
BM# 1
BM# 2
t402
t403
t404
t405
t406
t407
t408
t409
t410
EW
1075.2
1075.3
1075.3
1074.7
1075.0
1074.5
1074.5
1074.6
1074.6
1074.4
1073.3
1073.3
1073.3
1071.2
1070.6
1071.7
1071.7
1071.4
1072.5
1068.8
1069.5
1071.2
1069.1
1070.6
1069.3
1070.0
1069.0
1067.9
1068.3
1071.0
1070.2
1069.0
1070.1
1069.1
1070.0
1068.3
1068.6
1070.0
1070.6
1068.7
1069
1068
1071
1070

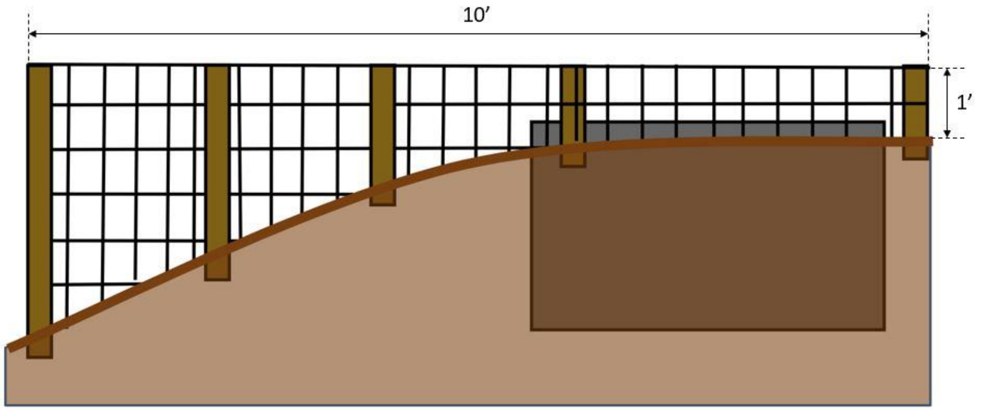
Beaver Deceiver Fencing - Backup

- When Clemson flow is exceeded or is blocked
- Trapezoidal design
  - Unnatural angle
  - Deeper
  - Sound separation
  - Longer dam

unattractive



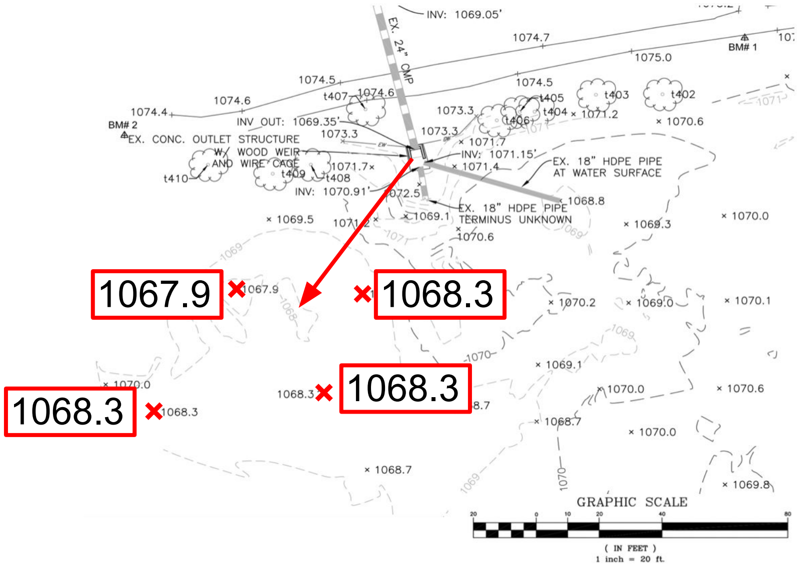
Plan View
(fenced top not shown)



Profile View

Reuse of Pond Leveler - as redundant feature

- Recovery of initial investment - if labor cost are not excessive
- Implement Jeff's suggestion
  - " ...run 80 feet of pipe along the water's edge to a secondary cage at the edge of the water so we could maintain the outlet but was assured that these systems have never failed by the installer."



Email on September 18, 2019

Constructability

- Pond water control
  - Trenching through the dam requires removal of pond water in the area of the work
  - Max of 6 inches water removal per day to prevent dam slope failure
  - Preferably summer

Photo credit: Ariana Wetzel

Constructability

1. Drain pond through weir
   a. Low cost but impacts all organisms living/using the ponded area
   b. Pump used for low spots
2. Pump water out through a filter bag
   a. Bag protects downstream areas from turbidity but more expensive than #1
   b. Can be combined with #1 for ponded areas
3. Temporary dam - CofferDam
   a. Set dam then drain by lowering the wood weirs and/or using a pump/bag system (can be used for low spots)
   b. Minimizes impacts to aquatic system
   c. More costly than #1 or #2.

PortaDam

AquaDam

Source: AquaDam, Portadam

Next Steps for 2020

- Concept selection
- Facility manager input - potential work session
- Cost estimation
- Final design/plan
- Contractor input?
- Permitting?
  - Wetland permits will likely be a non-reporting nationwide permit - class can meet local Army Corp representative
  - Local and Cornell permitting - discuss with facility manager

Thank you

Lab of Ornithology

- John Fitzpatrick
- Jeff Payne
- Ben Wheeler

Charissa King-O'Brien

WSSI Team

Photo credit: Mike Rolband

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Questions?