

## HYDROLOGY REPORT

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Farrow Lake Stream Bridge carries Route 6 over Deadman Stream, in the town of Topsfield, Maine. Deadman Stream flows from Farrow Lake approximately 0.25 miles upstream of the bridge. The stream flows southeast from the bridge for an additional 2.5 miles, ending in the town of Talmadge.

The drainage basin characteristics for the Farrow Lake Stream Bridge are based on peak flow estimates provided by the MaineDOT Environmental Office. Peak flows are calculated using Peak flow regression equations. No other flow data is available.

### SUMMARY

|                        |       |                    |
|------------------------|-------|--------------------|
| Drainage Area          | 3.40  | mi <sup>2</sup>    |
| April Avg. Flow        | 13.50 | ft <sup>3</sup> /s |
| August Avg. Flow       | 0.60  | ft <sup>3</sup> /s |
| Ordinary High (Q1.1)   | 50.9  | ft <sup>3</sup> /s |
| 10-year Flood (Q10)    | 198.9 | ft <sup>3</sup> /s |
| 25-year Flood (Q25)    | 260.8 | ft <sup>3</sup> /s |
| Design Discharge (Q50) | 300.3 | ft <sup>3</sup> /s |
| Check Discharge (Q100) | 351.6 | ft <sup>3</sup> /s |
| Scour Discharge (Q500) | 467.6 | ft <sup>3</sup> /s |

Reported by: Bartlett, Benjamin J

Date: April 20, 2017

Note: All elevations based on North American Vertical Datum (NAVD) of 1988.

## HYDRAULIC REPORT

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### EXISTING STRUCTURE

The existing structure was analyzed as a concrete box culvert in the HY-8 program version 7.30. The structure was modeled as a 10' span by 6' rise box culvert with 1' of fill in the bottom, to reflect the natural streambed. No nearby structures exist to affect the tailwater, so the tailwater conditions were modeled as an irregular channel located just downstream from the outlet. Based on USGS topographic maps and survey, the stream slope was approximated as 0.0195 ft/ft or 1.95%.

The existing structure was analyzed using flows generated by the MaineDOT Environmental Office. This analysis resulted in the roadway overtopping at 384 cubic feet per second (cfs), which is between a Q100 and Q500 event. Since the existing structure was treated as a culvert, the headwater to depth ratio (Hw/D) was calculated for the Q50 and Q100 flows. The Hw/D values for Q50 and Q100 were calculated as 1.05 and 1.17 respectively. These values are larger than the 0.9 value that is required in the Bridge Design Guide (BDG). Outlet velocities were also calculated as part of the hydraulic analysis, with a maximum outlet velocity of 10.99 feet per second at Q500. At Q100, the freeboard from the edge of the road to the water surface is 0.35 feet or just over 4 inches, which is far below the 1' required in the BDG.

### PROPOSED 15' BOX CULVERT

Bankfull width for this stream was determined to be 15', so the first proposed structure that was analyzed was a 15' span by 6' rise box culvert. This structure was also analyzed in HY-8, using a very similar tailwater condition. The irregular channel from the existing analysis was used, but was slightly modified to reflect the proposed streambed. This analysis also resulted in the road being overtopped, but at 398 cfs, which is below the Q500 flow. The Hw/D ratios were calculated for the Q50 and Q100 flows, and were 1.04 and 1.17. These values are very similar to that of the existing structure, and still above the BDG requirement. The maximum outlet velocity at Q500 was reduced to 9.7 ft/s. As discussed previously, the proposed highway vertical alignment is being raised 1.75 feet at the bridge. The proposed models and conditions assumes this raise in alignment. At Q100, the freeboard from the edge of roadway to the water surface is 2.53 feet, which is above the 1' required by the BDG. These results show that this proposed structure doesn't improve hydraulic capacity over the existing, and the freeboard from the edge of the road is due to the proposed raise in road profile.

### PROPOSED 16' BOX CULVERT

In the effort to improve the hydraulic capacity of the structure, a 16' span box culvert was analyzed. The same rise was used as the 15' span box, and the same irregular channel was also used. This analysis results in the road overtopping around 425 cfs, which is just under the Q500 flow. The Hw/D ratios for the Q50 and Q100 flows were 1.00 and 1.11 respectively. These

values are lower than that of the existing and the proposed 15' box, but are still higher than the BDG requirement. The maximum outlet velocity at Q500 was reduced to 9.65 ft/s. At Q100, the freeboard is 2.77 feet, which is greater than the 1' required by the BDG. These results show that the proposed 16' span by 6' rise box culvert would improve the hydraulic capacity over the existing structure.

### **PROPOSED 18' BOX CULVERT**

In addition to analyzing a bankfull width box, a 1.2 bankfull width box culvert was analyzed. Farrow Lake (Deadman) Stream is not inside the Atlantic Salmon DPS, so increasing the opening to 1.2 bankfull width is not required. Because the structure is 1.2 bankfull width, streambanks would be needed to create a 15' bankfull channel. It was found that increasing the span 3 feet significantly improved the hydraulic capacity, before adding the banks. After adding the streambanks, the hydraulic capacity was found to be marginally better than the other two proposed options. The same irregular channel was used from the 15' box and the 16' box to analyze the 18' span box. The analysis shows that the road overtops, but at 448.15 cfs, which is still just under the Q500 flow. The Hw/D ratios for Q50 and Q100 drop to 0.99 and 1.10 respectively, which is slightly lower than the ratios for the other proposed options. The Q50 value is still over the BDG requirement. The maximum outlet velocity at Q500 drops to 9.4 ft/s, which is 0.3 ft/s lower than the 15' box. These results show that all three proposed options have a very similar hydraulic capacity.

### **PROPOSED FRAME**

Since the proposed frame option would have the same span as the proposed box option, and the streambed would be at the same elevation for both the box and frame, it was assumed that the hydraulics for both would be the same. Therefore, a hydraulic analysis was not performed for a frame option.

### **SCOUR**

The proposed structure will have cast-in-place toe walls anchored to bedrock, which will prevent any of the material below the box from scouring. There will also be 10' long by 2' thick riprap aprons at both ends of the culvert to prevent scour. Due to these preventative measures, scour is not a concern.

### **CONCLUSION**

Based on the results for the three proposed structures, a 15' span by 6' rise box culvert is recommended. All three proposed options have very similar Hw/D ratios. The fact that streambanks need to be added to the 18' span box makes it a less attractive option. Since a 1.2 bankfull width structure is not required, it is not practicable to create more work to construct streambanks and receive a similar result to the bankfull width structure. The Hw/D values still don't meet the requirements of the BDG, but site restrictions prevent those values from being

met, without constructing a significantly oversized structure. The stream is small, and the surrounding area is very flat. The road crosses over the stream with little vertical clearance, and bedrock is just below the proposed box. This restricts the rise of the box culvert, and as it is, the roadway is being raised as much as 1.75 feet over the structure to achieve the 6' rise proposed. If the rise was increased any more, there would be significantly more approach work than there already is, and there would be significant impacts to the three driveways within the project limits.

### SUMMARY

|  |                 | Existing<br>Structure     | Recommended<br>Structure           | 18' Span by 6'      | 16' Span by 6'      |
|--|-----------------|---------------------------|------------------------------------|---------------------|---------------------|
|  |                 | 10' Span<br>Concrete Slab | 15' Span by 6'<br>Rise Box Culvert | Rise Box<br>Culvert | Rise Box<br>Culvert |
| Total Area of Waterway Opening         | ft <sup>2</sup> | 50                        | 60                                 | 68                  | 64                  |
| Headwater elevation @ Q <sub>1.1</sub> | ft              | 432.34                    | 432.78                             | 432.84              | 432.73              |
| Headwater elevation @ Q <sub>10</sub>  | ft              | 434.66                    | 434.65                             | 434.55              | 434.52              |
| Headwater elevation @ Q <sub>25</sub>  | ft              | 435.43                    | 435.28                             | 435.12              | 435.12              |
| Headwater elevation @ Q <sub>50</sub>  | ft              | 435.89                    | 435.66                             | 435.46              | 435.49              |
| Headwater elevation @ Q <sub>100</sub> | ft              | 436.46                    | 436.17                             | 435.88              | 435.93              |
| Headwater elevation @ Q <sub>500</sub> | ft              | 437.13                    | 437.26                             | 437.04              | 437.15              |
| Hw/D Ratio @ Q <sub>50</sub>           | ft              | 1.05                      | 1.04                               | 0.99                | 1.00                |
| Hw/D Ratio @ Q <sub>100</sub>          | ft              | 1.17                      | 1.17                               | 1.1                 | 1.11                |
| Flood Of Record                        |                 |                           |                                    |                     |                     |
| Outlet Velocity @ Q <sub>1.1</sub>     | ft/s            | 5.49                      | 3.65                               | 3.93                | 3.42                |
| Outlet Velocity @ Q <sub>10</sub>      | ft/s            | 8.60                      | 7.51                               | 7.07                | 7.32                |
| Outlet Velocity @ Q <sub>25</sub>      | ft/s            | 9.47                      | 8.27                               | 7.79                | 8.08                |
| Outlet Velocity @ Q <sub>50</sub>      | ft/s            | 9.91                      | 8.66                               | 8.15                | 8.50                |
| Outlet Velocity @ Q <sub>100</sub>     | ft/s            | 10.44                     | 9.13                               | 8.59                | 8.93                |
| Outlet Velocity @ Q <sub>500</sub>     | ft/s            | 10.99                     | 9.70                               | 9.39                | 9.65                |

Reported by: Bartlett, Benjamin J

Date: June 5, 2018

Note: All elevations based on North American Vertical Datum (NAVD) of 1988.

# Appendix D

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## Hydraulics Data

WIN: 21706.00  
 Town: Topsfield  
 Route No. ME 6  
 Asset ID: 5378  
 Lat: 45.4131 Long: -67.7593

Project Name: Topsfield Farrow Lk Outlet  
 Stream Name: Deadman Str (Farrow Lk Outlet)  
 Bridge Name: Farrow Lake Br  
 Analysis by: CSH  
 Date: 12/29/2016

## Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999 & Lombard/Hodgkins, 2015)

*Enter data in blue cells only!*

|                | km <sup>2</sup> | mi <sup>2</sup> | ac     |
|----------------|-----------------|-----------------|--------|
| A              | 8.81            | 3.40            | 2176.0 |
| W              | 1.30            | 0.5             | 322.0  |
| P <sub>c</sub> | 596714          | 5031829         |        |
| County         | Washington      |                 |        |
| pptA           | 44.2            |                 |        |
| SG             | 0.00            |                 |        |

*Enter data in [mi<sup>2</sup>]*

Watershed Area *DRNAREA*

Wetlands area (by NWI)

watershed centroid (E, N; UTM 19N; meters)

choose county from drop-down menu

mean annual precipitation (inches; by look-up)

sand & gravel aquifer as decimal fraction of watershed A

**Worksheet prepared by:**

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ver. 2016 Feb 05

|                      |       |          |      |
|----------------------|-------|----------|------|
| A (km <sup>2</sup> ) | 8.81  | Conf Lvl | 0.67 |
| W (%)                | 14.80 |          |      |

NWI Wetlands % *STORNWI*

### References:

Hodgkins, G.A., 1999.  
 Estimating the magnitude of peak flows for streams  
 in Maine for selected recurrence intervals  
*WRIR 99-4008*, USGS Augusta, ME

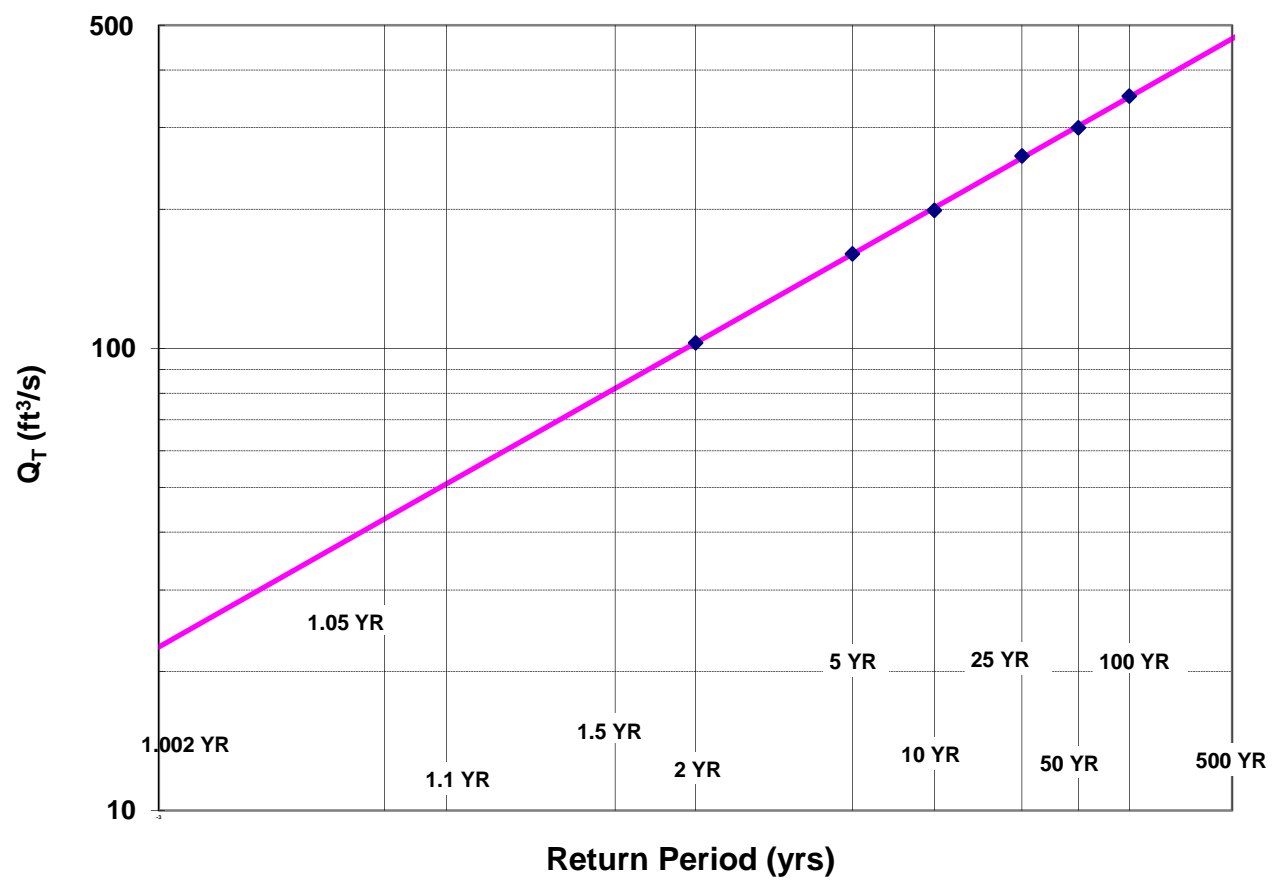
Lombard, P.J. & G.A. Hodgkins, 2015.  
 Peak flow regression equations for small, ungaged streams in  
 Maine - Comparing map-based to field-based variables  
*SIR 2015-4059*, USGS, Augusta, ME

$$Q_T = b \times A^a \times 10^{-ww}$$

| Ret Pd | Peak Flow Estimate |                                    |       |
|--------|--------------------|------------------------------------|-------|
| T (yr) | Lower              | Q <sub>T</sub> (m <sup>3</sup> /s) | Upper |
| 1.1    |                    | 1.44                               |       |
| 2      |                    | 2.91                               |       |
| 5      |                    | 4.53                               |       |
| 10     |                    | 5.63                               |       |
| 25     |                    | 7.39                               |       |
| 50     |                    | 8.50                               |       |
| 100    |                    | 9.96                               |       |
| 500    |                    | 13.24                              |       |

| Q <sub>T</sub> (ft <sup>3</sup> /s) |
|-------------------------------------|
| 50.9                                |
| 102.8                               |
| 160.1                               |
| 198.9                               |
| 260.8                               |
| 300.3                               |
| 351.6                               |
| 467.6                               |

## Log-Normal Probability Plot





WIN: 21706.00  
 Town: Topsfield  
 Route No. ME 6  
 Asset ID: 5378  
 Lat: 45.4131 Long: -67.7593

Project Name: Topsfield Farrow Lk Outlet  
 Stream Name: Deadman Str (Farrow Lk Outlet)  
 Bridge Name: Farrow Lake Br  
 Analysis by: CSH  
 Date: 12/29/2016

**DO NOT ENTER ANY DATA ON THIS PAGE; EVERYTHING IS CALCULATED**

**MAINE MONTHLY MEDIAN FLOWS and HYDRAULIC GEOMETRY BY USGS REGRESSION EQUATIONS (2004)**

| Value    | Variable | Explanation  |
|----------|----------|--|
| 3.40     | A        | Area (mi <sup>2</sup> )                                    |
| 596714.5 | $P_c$    | Watershed centroid (E,N; UTM; Zone 19; meters)             |
| 78.25    | DIST     | Distance from Coastal reference line (mi)                  |
| 44.2     | pptA     | Mean Annual Precipitation (inches)                         |
| 0.00     | SG       | Sand & Gravel Aquifer (decimal fraction of watershed area) |

| Month | $Q_{\text{median}}$<br>(ft <sup>3</sup> /s) | (m <sup>3</sup> /s) |
|-------|---|---------------------|
| Jan   | 2.65  | 0.0752              |
| Feb   | 2.62  | 0.0742              |
| Mar   | 4.29  | 0.1216              |
| Apr   | 13.50                                       | 0.3826              |
| May   | 7.24  | 0.2052              |
| Jun   | 2.74  | 0.0776              |
| Jul   | 0.86  | 0.0243              |
| Aug   | 0.60  | 0.0170              |
| Sep   | 0.64  | 0.0182              |
| Oct   | 1.14  | 0.0324              |
| Nov   | 4.18  | 0.1183              |
| Dec   | 4.36  | 0.1235              |

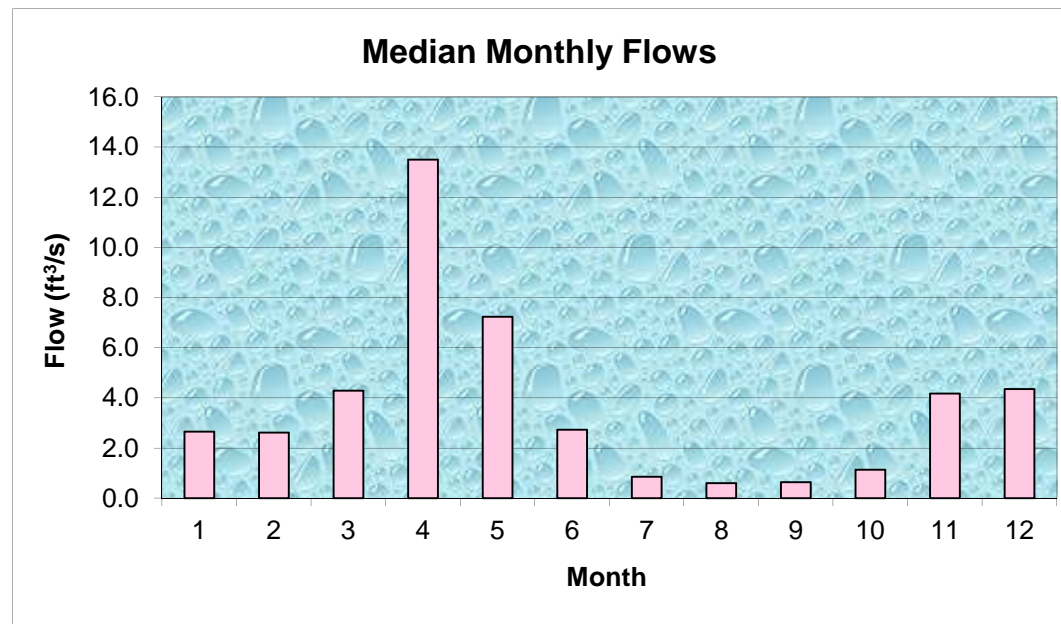
  

|                 |      |
|-----------------|------|
| $Q_{\text{bf}}$ | 18.8 |
| ann avg         | 6.9  |
| ann med         | 3.5  |
| $Q_{1.002}$     | 22.6 |
| $Q_{1.01}$      | 30.1 |
| $Q_{1.05}$      | 42.7 |
| $Q_{\text{bf}}$ | 52.2 |

assume v = 4ft/s

|                 |      |   |
|-----------------|------|---|
| $W_{\text{bf}}$ | 14.5 | estimated bankfull width (ft)                   |
| $d_{\text{bf}}$ | 0.9  | estimated bankfull depth (ft)                   |
| $A_{\text{bf}}$ | 13.0 | estimated bankfull flow area (ft <sup>2</sup> ) |



**References**

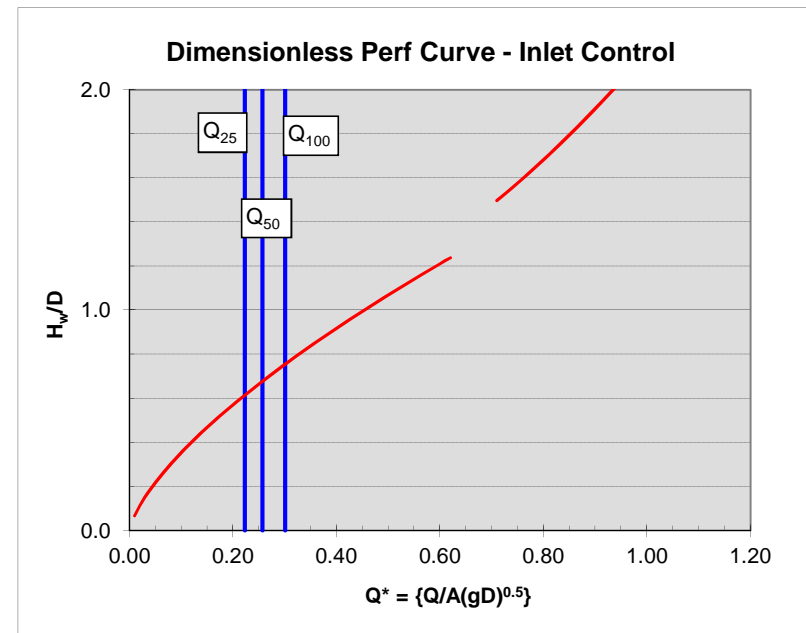
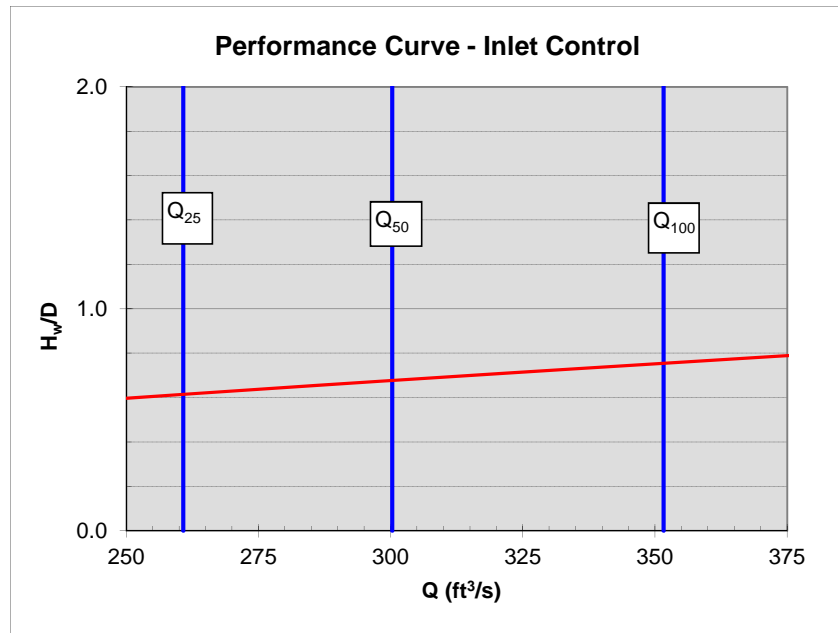
Dudley, R.W., 2004. Hydraulic Geometry Relations ..., SIR 2004-5042  
 Dudley, R.W., 2004. Estimating Monthly Streamflows ... , SIR 2004-5026

**NOTE:** This page is for preliminary sizing only.  
Final design should be done with HY8 or HDS-5

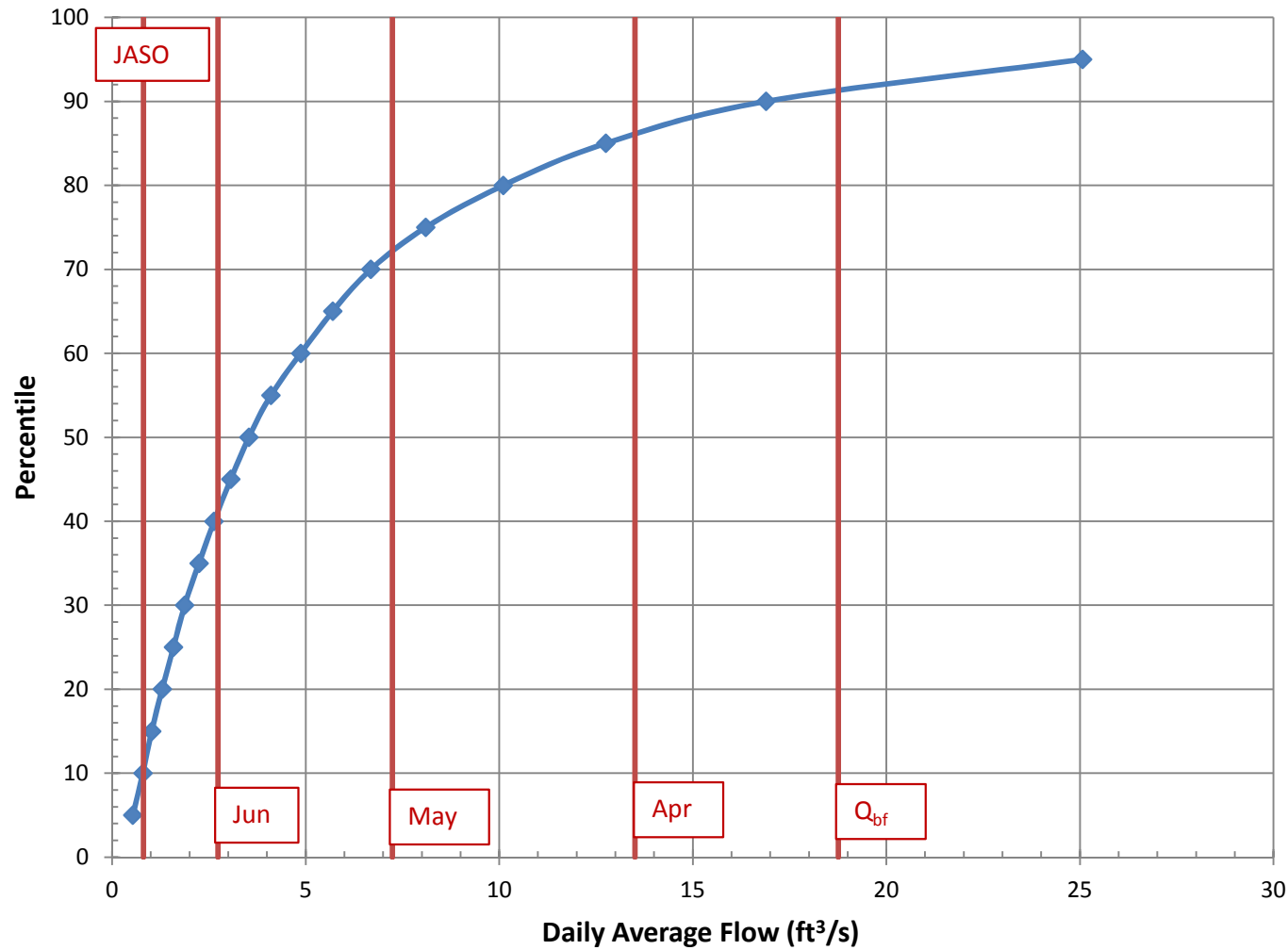
### Preliminary Culvert Sizing - Round & Box Culverts

|                        |              |           |       |  |
|------------------------|--------------|-----------|-------|--|
| Shape:                 | Box          |           |       |  |
| Type:                  | Box 0 ww     |           |       |  |
| D or R (ft)            | 6            | $Q_{25}$  | 260.8 | trial D / R = 8.1<br>trial w: BFW = 14.5 |
| w (ft)                 | 14 box width | $Q_{50}$  | 300.3 |  |
| Slope (ft/ft)          | 0.02         | $Q_{100}$ | 351.6 |  |
| A (ft <sup>2</sup> )   | 84.00        |           |       |  |
| g (ft/s <sup>2</sup> ) | 32.2         |           |       |  |

Note: culvert dimensions are for open flow area; adjust for lost capacity due to embedding / backfilling (min {2' / 25% rise} embedment)



## Daily Average Flow Distribution



### Daily Avg Flow Dist

$A_{ws} = (mi^2)$  3.4

Q (ft³/s)

| Pctl | Median | 84 <sup>th</sup> pctl |
|------|--------|-----------------------|
| 5    | 0.54   | 0.86                  |
| 10   | 0.79   | 1.20                  |
| 15   | 1.02   | 1.49                  |
| 20   | 1.29   | 1.81                  |
| 25   | 1.58   | 2.12                  |
| 30   | 1.87   | 2.42                  |
| 35   | 2.24   | 2.76                  |
| 40   | 2.63   | 3.18                  |
| 45   | 3.07   | 3.59                  |
| 50   | 3.53   | 4.24                  |
| 55   | 4.10   | 4.93                  |
| 60   | 4.87   | 5.79                  |
| 65   | 5.70   | 6.75                  |
| 70   | 6.68   | 7.87                  |
| 75   | 8.10   | 9.47                  |
| 80   | 10.11  | 11.30                 |
| 85   | 12.75  | 14.49                 |
| 90   | 16.89  | 19.45                 |
| 95   | 25.07  | 30.25                 |

Q<sub>bf</sub> 18.8

Q<sub>1.002</sub> 22.6

Q<sub>1.1</sub> 50.9

Q<sub>2</sub> 102.8



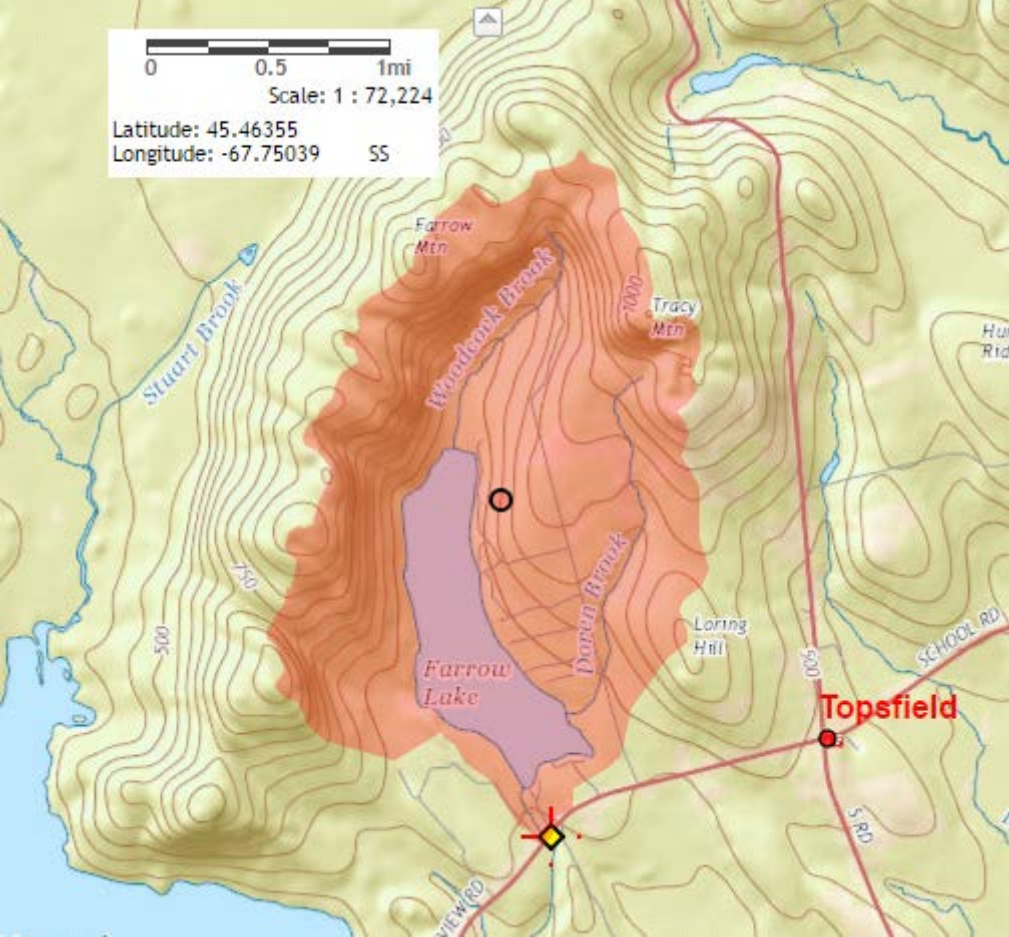


0 0.5 1mi

Scale: 1 : 72,224

Latitude: 45.46355

Longitude: -67.75039 SS



## **HY-8 Culvert Analysis Report**

## Site Data - Existing

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 429.63 ft

Outlet Station: 28.00 ft

Outlet Elevation: 429.63 ft

Number of Barrels: 1

## Culvert Data Summary - Existing

Barrel Shape: Concrete Box

Barrel Span: 10.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 12.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: NONE

```
*****
                                Straight Culvert
Inlet Elevation (invert): 430.63 ft,   Outlet Elevation (invert): 430.63 ft
                                Culvert Length: 28.00 ft,   Culvert Slope: 0.0000
*****
```

### Tailwater Channel Data - Existing

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0195

User Defined Channel Cross-Section:

| Coord No. | Station (ft) | Elevation (ft) | Manning's n |
|-----------|--------------|----------------|-------------|
| 1         | 0.00         | 446.00         | 0.0300      |
| 2         | 29.28        | 445.00         | 0.1000      |
| 3         | 41.79        | 444.00         | 0.1000      |
| 4         | 63.98        | 443.00         | 0.1000      |
| 5         | 78.22        | 442.00         | 0.1000      |
| 6         | 95.00        | 441.00         | 0.1000      |
| 7         | 112.15       | 440.00         | 0.1000      |
| 8         | 132.73       | 439.00         | 0.1000      |
| 9         | 150.70       | 438.00         | 0.1000      |
| 10        | 170.97       | 437.00         | 0.1000      |
| 11        | 201.53       | 436.00         | 0.1000      |
| 12        | 276.42       | 435.00         | 0.1000      |
| 13        | 317.39       | 434.00         | 0.1000      |
| 14        | 339.08       | 433.00         | 0.1000      |
| 15        | 377.73       | 432.00         | 0.1000      |
| 16        | 382.93       | 431.00         | 0.0450      |
| 17        | 385.80       | 430.00         | 0.0450      |
| 18        | 391.20       | 430.00         | 0.0450      |
| 19        | 393.35       | 431.00         | 0.0450      |
| 20        | 400.13       | 432.00         | 0.0300      |
| 21        | 427.75       | 433.00         | 0.0300      |
| 22        | 478.47       | 434.00         | 0.0300      |
| 23        | 538.20       | 435.00         | 0.0300      |



**Roadway Data for Crossing: Existing**

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

| Coord No. | Station (ft) | Elevation (ft) |
|-----------|--------------|----------------|
| 0         | 300.00       | 436.76         |
| 1         | 350.00       | 436.81         |
| 2         | 375.00       | 436.83         |
| 3         | 425.00       | 437.01         |
| 4         | 450.00       | 437.24         |
| 5         | 475.00       | 437.63         |
| 6         | 500.00       | 438.19         |

Roadway Surface: Paved

Roadway Top Width: 28.00 ft

**Table 1 - Summary of Culvert Flows at Crossing: Existing**

| Headwater Elevation (ft) | Discharge Names | Total Discharge (cfs) | Existing Discharge (cfs) | Roadway Discharge (cfs) | Iterations  |
|--------------------------|-----------------|-----------------------|--------------------------|-------------------------|-------------|
| 432.34                   | Q 1.1           | 50.90                 | 50.90                    | 0.00                    | 1           |
| 433.28                   | Q 2             | 102.80                | 102.80                   | 0.00                    | 1           |
| 434.14                   | Q 5             | 160.10                | 160.10                   | 0.00                    | 1           |
| 434.66                   | Q 10            | 198.90                | 198.90                   | 0.00                    | 1           |
| 435.43                   | Q 25            | 260.80                | 260.80                   | 0.00                    | 1           |
| 435.89                   | Q 50            | 300.30                | 300.30                   | 0.00                    | 1           |
| 436.46                   | Q 100           | 351.60                | 351.60                   | 0.00                    | 1           |
| 437.13                   | Q 500           | 467.60                | 409.50                   | 57.73                   | 6           |
| 436.81                   | Overtopping     | 384.00                | 384.00                   | 0.00                    | Overtopping |

**Table 2 - Culvert Summary Table: Existing**

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|-----------------|-----------------------|-------------------------|--------------------------|--------------------------|---------------------------|-----------|-------------------|---------------------|-------------------|----------------------|------------------------|---------------------------|
| Q 1.1           | 50.90                 | 50.90                   | 432.34                   | 1.460                    | 1.709                     | 8-H2c     | -1.000            | 0.927               | 0.927             | 1.337                | 5.488                  | 4.208                     |
| Q 2             | 102.80                | 102.80                  | 433.28                   | 2.332                    | 2.646                     | 8-H2c     | -1.000            | 1.491               | 1.491             | 1.876                | 6.895                  | 4.751                     |
| Q 5             | 160.10                | 160.10                  | 434.14                   | 3.125                    | 3.505                     | 8-H2c     | -1.000            | 2.002               | 2.002             | 2.241                | 7.998                  | 5.062                     |
| Q 10            | 198.90                | 198.90                  | 434.66                   | 3.652                    | 4.029                     | 8-H2c     | -1.000            | 2.313               | 2.313             | 2.414                | 8.600                  | 5.064                     |
| Q 25            | 260.80                | 260.80                  | 435.43                   | 4.368                    | 4.801                     | 8-H2c     | -1.000            | 2.754               | 2.754             | 2.633                | 9.468                  | 5.038                     |
| Q 50            | 300.30                | 300.30                  | 435.89                   | 4.833                    | 5.262                     | 8-H2c     | -1.000            | 3.031               | 3.031             | 2.748                | 9.908                  | 5.034                     |
| Q 100           | 351.60                | 351.60                  | 436.46                   | 5.607                    | 5.833                     | 8-H2c     | -1.000            | 3.368               | 3.368             | 2.880                | 10.440                 | 5.045                     |
| Q 500           | 467.60                | 409.50                  | 437.13                   | 6.499                    | 6.445                     | 8-H2t     | -1.000            | 3.725               | 3.725             | 3.130                | 10.994                 | 5.084                     |

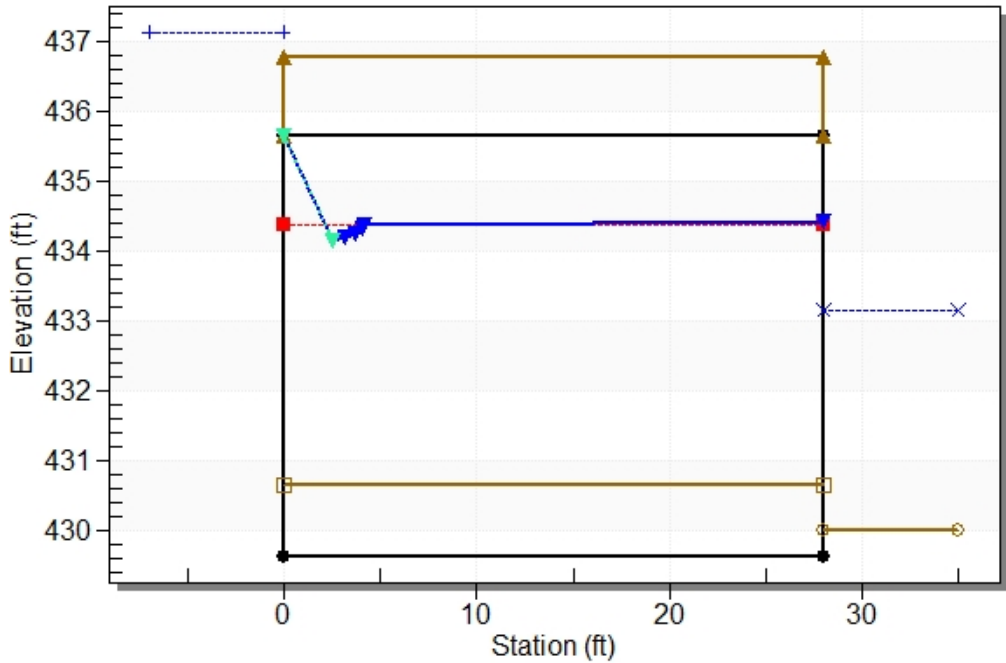
**Table 3 - Downstream Channel Rating Curve (Crossing: Existing)**

| Flow (cfs) | Water Surface Elev (ft) | Depth (ft) | Velocity (ft/s) | Shear (psf) | Froude Number |
|------------|-------------------------|------------|-----------------|-------------|---------------|
| 50.90      | 431.34                  | 1.34       | 4.21            | 1.63        | 0.81          |
| 102.80     | 431.88                  | 1.88       | 4.75            | 2.28        | 0.82          |
| 160.10     | 432.24                  | 2.24       | 5.06            | 2.73        | 0.98          |
| 198.90     | 432.41                  | 2.41       | 5.06            | 2.94        | 1.01          |
| 260.80     | 432.63                  | 2.63       | 5.04            | 3.20        | 0.99          |
| 300.30     | 432.75                  | 2.75       | 5.03            | 3.34        | 0.97          |
| 351.60     | 432.88                  | 2.88       | 5.05            | 3.50        | 0.96          |
| 467.60     | 433.13                  | 3.13       | 5.08            | 3.81        | 0.93          |

**Water Surface Profile Plot for Culvert: Existing**

Crossing - Existing, Design Discharge - 467.6 cfs

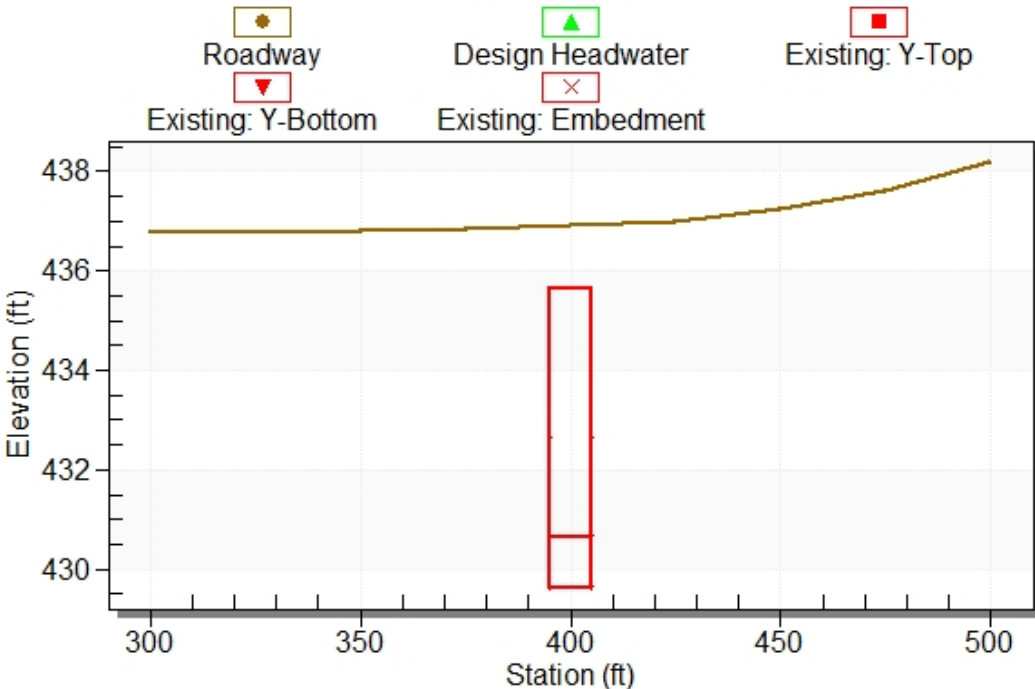
Culvert - Existing, Culvert Discharge - 409.5 cfs



**Crossing Front View (Roadway Profile): Existing**

Crossing Front View

(Not to scale)



### Site Data - Proposed 15' Box

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 429.50 ft

Outlet Station: 56.00 ft

Outlet Elevation: 429.00 ft

Number of Barrels: 1

### Culvert Data Summary - Proposed 15' Box

Barrel Shape: Concrete Box

Barrel Span: 15.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 24.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

\*\*\*\*\*  
Straight Culvert  
Inlet Elevation (invert): 431.50 ft,    Outlet Elevation (invert): 431.00 ft  
Culvert Length: 56.00 ft,    Culvert Slope: 0.0089  
\*\*\*\*\*

### **Tailwater Channel Data - Topsfield Farrow Lake Proposed**

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0195

User Defined Channel Cross-Section:

| Coord No. | Station (ft) | Elevation (ft) | Manning's n |
|-----------|--------------|----------------|-------------|
| 1         | 0.00         | 446.00         | 0.0300      |
| 2         | 29.28        | 445.00         | 0.1000      |
| 3         | 41.79        | 444.00         | 0.1000      |
| 4         | 63.98        | 443.00         | 0.1000      |
| 5         | 78.22        | 442.00         | 0.1000      |
| 6         | 95.00        | 441.00         | 0.1000      |
| 7         | 112.15       | 440.00         | 0.1000      |
| 8         | 132.73       | 439.00         | 0.1000      |
| 9         | 150.70       | 438.00         | 0.1000      |
| 10        | 170.97       | 437.00         | 0.1000      |
| 11        | 201.53       | 436.00         | 0.1000      |
| 12        | 276.42       | 435.00         | 0.1000      |
| 13        | 317.39       | 434.00         | 0.1000      |
| 14        | 339.08       | 433.00         | 0.1000      |
| 15        | 377.73       | 432.00         | 0.1000      |
| 16        | 382.93       | 431.00         | 0.0450      |
| 17        | 385.80       | 431.00         | 0.0450      |
| 18        | 391.20       | 431.00         | 0.0450      |
| 19        | 393.35       | 431.00         | 0.0450      |
| 20        | 400.13       | 432.00         | 0.0300      |
| 21        | 427.75       | 433.00         | 0.0300      |
| 22        | 478.47       | 434.00         | 0.0300      |
| 23        | 538.20       | 435.00         | 0.0300      |

### **Roadway Data for Crossing: Topsfield Farrow Lake Proposed**

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

| Coord No. | Station (ft) | Elevation (ft) |
|-----------|--------------|----------------|
| 0         | 200.00       | 436.97         |
| 1         | 225.00       | 436.91         |
| 2         | 250.00       | 436.89         |
| 3         | 275.00       | 437.02         |
| 4         | 300.00       | 437.30         |
| 5         | 325.00       | 437.74         |
| 6         | 350.00       | 438.18         |
| 7         | 375.00       | 438.50         |
| 8         | 400.00       | 438.70         |
| 9         | 425.00       | 438.76         |
| 10        | 450.00       | 438.76         |
| 11        | 475.00       | 438.76         |
| 12        | 500.00       | 438.86         |
| 13        | 525.00       | 439.15         |
| 14        | 550.00       | 439.63         |

Roadway Surface: Paved

Roadway Top Width: 32.00 ft

**Table 4 - Summary of Culvert Flows at Crossing: Proposed 15' Box**

| Headwater Elevation (ft) | Discharge Names | Total Discharge (cfs) | Proposed Box Discharge (cfs) | Roadway Discharge (cfs) | Iterations  |
|--------------------------|-----------------|-----------------------|------------------------------|-------------------------|-------------|
| 432.78                   | Q 1.1           | 50.90                 | 50.90                        | 0.00                    | 1           |
| 433.53                   | Q 2             | 102.80                | 102.80                       | 0.00                    | 1           |
| 434.23                   | Q 5             | 160.10                | 160.10                       | 0.00                    | 1           |
| 434.65                   | Q 10            | 198.90                | 198.90                       | 0.00                    | 1           |
| 435.28                   | Q 25            | 260.80                | 260.80                       | 0.00                    | 1           |
| 435.66                   | Q 50            | 300.30                | 300.30                       | 0.00                    | 1           |
| 436.17                   | Q 100           | 351.60                | 351.60                       | 0.00                    | 1           |
| 437.26                   | Q 500           | 467.60                | 422.39                       | 44.88                   | 7           |
| 436.89                   | Overtopping     | 398.37                | 398.37                       | 0.00                    | Overtopping |

**Table 5 - Culvert Summary Table: Proposed 15' Box**

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|-----------------|-----------------------|-------------------------|--------------------------|--------------------------|---------------------------|-----------|-------------------|---------------------|-------------------|----------------------|------------------------|---------------------------|
| Q 1.1           | 50.90                 | 50.90                   | 432.78                   | 1.215                    | 1.278                     | 3-M1t     | 0.909             | 0.704               | 0.930             | 0.930                | 3.648                  | 3.422                     |
| Q 2             | 102.80                | 102.80                  | 433.53                   | 1.934                    | 2.032                     | 3-M2t     | 1.387             | 1.141               | 1.307             | 1.307                | 5.245                  | 3.895                     |
| Q 5             | 160.10                | 160.10                  | 434.23                   | 2.546                    | 2.729                     | 3-M2t     | 1.813             | 1.532               | 1.564             | 1.564                | 6.823                  | 4.043                     |
| Q 10            | 198.90                | 198.90                  | 434.65                   | 2.953                    | 3.155                     | 2-M2c     | 2.061             | 1.767               | 1.767             | 1.699                | 7.505                  | 4.124                     |
| Q 25            | 260.80                | 260.80                  | 435.28                   | 3.586                    | 3.783                     | 2-M2c     | 2.427             | 2.102               | 2.102             | 1.876                | 8.271                  | 4.244                     |
| Q 50            | 300.30                | 300.30                  | 435.66                   | 3.986                    | 4.161                     | 7-M2c     | 2.647             | 2.311               | 2.311             | 1.973                | 8.663                  | 4.318                     |
| Q 100           | 351.60                | 351.60                  | 436.17                   | 4.671                    | 4.627                     | 7-M2c     | 2.905             | 2.567               | 2.567             | 2.089                | 9.130                  | 4.389                     |
| Q 500           | 467.60                | 422.39                  | 437.26                   | 5.759                    | 5.238                     | 7-M2c     | 3.245             | 2.902               | 2.902             | 2.307                | 9.702                  | 4.560                     |

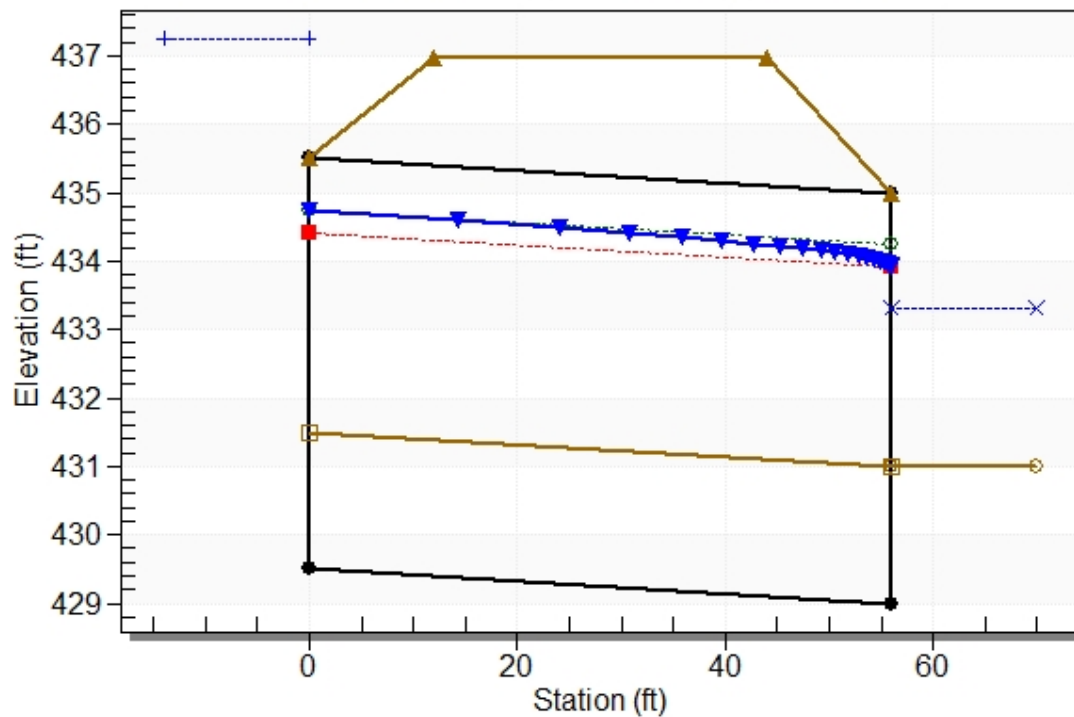
**Table 6 - Downstream Channel Rating Curve (Crossing: Farrow Lake Proposed 15')**

| Flow (cfs) | Water Surface Elev (ft) | Depth (ft) | Velocity (ft/s) | Shear (psf) | Froude Number |
|------------|-------------------------|------------|-----------------|-------------|---------------|
| 50.90      | 431.93                  | 0.93       | 3.42            | 1.13        | 0.73          |
| 102.80     | 432.31                  | 1.31       | 3.90            | 1.59        | 0.87          |
| 160.10     | 432.56                  | 1.56       | 4.04            | 1.90        | 0.88          |
| 198.90     | 432.70                  | 1.70       | 4.12            | 2.07        | 0.87          |
| 260.80     | 432.88                  | 1.88       | 4.24            | 2.28        | 0.86          |
| 300.30     | 432.97                  | 1.97       | 4.32            | 2.40        | 0.85          |
| 351.60     | 433.09                  | 2.09       | 4.39            | 2.54        | 0.84          |
| 467.60     | 433.31                  | 2.31       | 4.56            | 2.81        | 0.84          |

**Water Surface Profile Plot for Culvert: Proposed 15' Box**

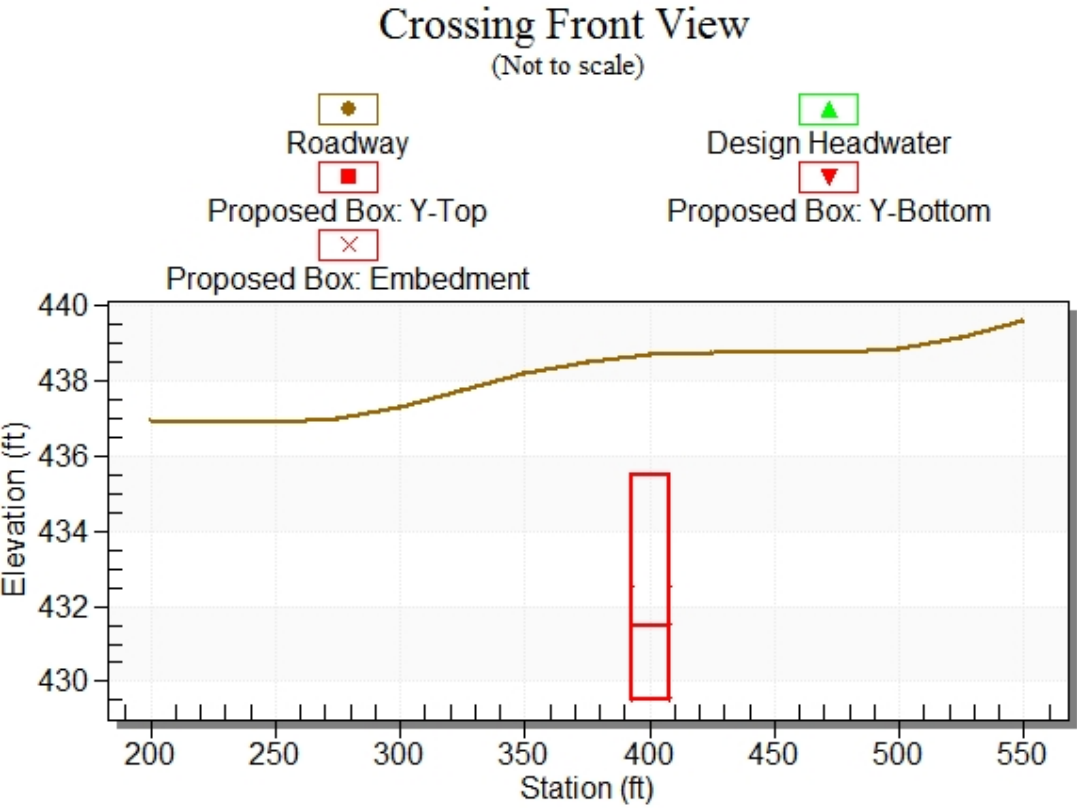
Crossing - Topsfield Farrow Lake, Design Discharge - 467.6 cfs

Culvert - Proposed Box, Culvert Discharge - 422.4 cfs





Crossing Front View (Roadway Profile): Proposed 15' Box



### Site Data - Proposed 16' Box

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 429.50 ft

Outlet Station: 56.00 ft

Outlet Elevation: 429.00 ft

Number of Barrels: 1

### Culvert Data Summary - Proposed 16' Box

Barrel Shape: Concrete Box

Barrel Span: 16.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 24.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

\*\*\*\*\*  
Straight Culvert  
Inlet Elevation (invert): 431.50 ft,    Outlet Elevation (invert): 431.00 ft  
Culvert Length: 56.00 ft,    Culvert Slope: 0.0089  
\*\*\*\*\*

## Tailwater Channel Data - Topsfield Farrow Lake Proposed

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0195

User Defined Channel Cross-Section:

| Coord No. | Station (ft) | Elevation (ft) | Manning's n |
|-----------|--------------|----------------|-------------|
| 1         | 0.00         | 446.00         | 0.0300      |
| 2         | 29.28        | 445.00         | 0.1000      |
| 3         | 41.79        | 444.00         | 0.1000      |
| 4         | 63.98        | 443.00         | 0.1000      |
| 5         | 78.22        | 442.00         | 0.1000      |
| 6         | 95.00        | 441.00         | 0.1000      |
| 7         | 112.15       | 440.00         | 0.1000      |
| 8         | 132.73       | 439.00         | 0.1000      |
| 9         | 150.70       | 438.00         | 0.1000      |
| 10        | 170.97       | 437.00         | 0.1000      |
| 11        | 201.53       | 436.00         | 0.1000      |
| 12        | 276.42       | 435.00         | 0.1000      |
| 13        | 317.39       | 434.00         | 0.1000      |
| 14        | 339.08       | 433.00         | 0.1000      |
| 15        | 377.73       | 432.00         | 0.1000      |
| 16        | 382.93       | 431.00         | 0.0450      |
| 17        | 385.80       | 431.00         | 0.0450      |
| 18        | 391.20       | 431.00         | 0.0450      |
| 19        | 393.35       | 431.00         | 0.0450      |
| 20        | 400.13       | 432.00         | 0.0300      |
| 21        | 427.75       | 433.00         | 0.0300      |
| 22        | 478.47       | 434.00         | 0.0300      |
| 23        | 538.20       | 435.00         | 0.0300      |

## Roadway Data for Crossing: Topsfield Farrow Lake Proposed

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

| Coord No. | Station (ft) | Elevation (ft) |
|-----------|--------------|----------------|
| 0         | 200.00       | 436.97         |
| 1         | 225.00       | 436.91         |
| 2         | 250.00       | 436.89         |
| 3         | 275.00       | 437.02         |
| 4         | 300.00       | 437.30         |
| 5         | 325.00       | 437.74         |
| 6         | 350.00       | 438.18         |
| 7         | 375.00       | 438.50         |
| 8         | 400.00       | 438.70         |
| 9         | 425.00       | 438.76         |
| 10        | 450.00       | 438.76         |
| 11        | 475.00       | 438.76         |
| 12        | 500.00       | 438.86         |
| 13        | 525.00       | 439.15         |
| 14        | 550.00       | 439.63         |

Roadway Surface: Paved

Roadway Top Width: 32.00 ft

**Table 7 - Summary of Culvert Flows at Crossing: Proposed 16' Box**

| Headwater Elevation (ft) | Discharge Names | Total Discharge (cfs) | Proposed Box Discharge (cfs) | Roadway Discharge (cfs) | Iterations  |
|--------------------------|-----------------|-----------------------|------------------------------|-------------------------|-------------|
| 432.73                   | Q 1.1           | 50.90                 | 50.90                        | 0.00                    | 1           |
| 433.45                   | Q 2             | 102.80                | 102.80                       | 0.00                    | 1           |
| 434.11                   | Q 5             | 160.10                | 160.10                       | 0.00                    | 1           |
| 434.52                   | Q 10            | 198.90                | 198.90                       | 0.00                    | 1           |
| 435.12                   | Q 25            | 260.80                | 260.80                       | 0.00                    | 1           |
| 435.49                   | Q 50            | 300.30                | 300.30                       | 0.00                    | 1           |
| 435.93                   | Q 100           | 351.60                | 351.60                       | 0.00                    | 1           |
| 437.15                   | Q 500           | 467.60                | 443.28                       | 24.13                   | 9           |
| 436.89                   | Overtopping     | 424.93                | 424.93                       | 0.00                    | Overtopping |

**Table 8 - Culvert Summary Table: Proposed 16' Box**

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|-----------------|-----------------------|-------------------------|--------------------------|--------------------------|---------------------------|-----------|-------------------|---------------------|-------------------|----------------------|------------------------|---------------------------|
| Q 1.1           | 50.90                 | 50.90                   | 432.73                   | 1.165                    | 1.225                     | 3-M1t     | 0.874             | 0.671               | 0.930             | 0.930                | 3.420                  | 3.422                     |
| Q 2             | 102.80                | 102.80                  | 433.45                   | 1.853                    | 1.947                     | 3-M2t     | 1.338             | 1.093               | 1.307             | 1.307                | 4.918                  | 3.895                     |
| Q 5             | 160.10                | 160.10                  | 434.11                   | 2.441                    | 2.614                     | 3-M2t     | 1.743             | 1.469               | 1.564             | 1.564                | 6.397                  | 4.043                     |
| Q 10            | 198.90                | 198.90                  | 434.52                   | 2.823                    | 3.021                     | 3-M2t     | 1.980             | 1.694               | 1.699             | 1.699                | 7.318                  | 4.124                     |
| Q 25            | 260.80                | 260.80                  | 435.12                   | 3.421                    | 3.623                     | 2-M2c     | 2.334             | 2.018               | 2.018             | 1.876                | 8.077                  | 4.244                     |
| Q 50            | 300.30                | 300.30                  | 435.49                   | 3.796                    | 3.985                     | 2-M2c     | 2.541             | 2.212               | 2.212             | 1.973                | 8.486                  | 4.318                     |
| Q 100           | 351.60                | 351.60                  | 435.93                   | 4.333                    | 4.430                     | 7-M2c     | 2.794             | 2.461               | 2.461             | 2.089                | 8.930                  | 4.389                     |
| Q 500           | 467.60                | 443.28                  | 437.15                   | 5.654                    | 5.181                     | 7-M2c     | 3.212             | 2.871               | 2.871             | 2.307                | 9.648                  | 4.560                     |

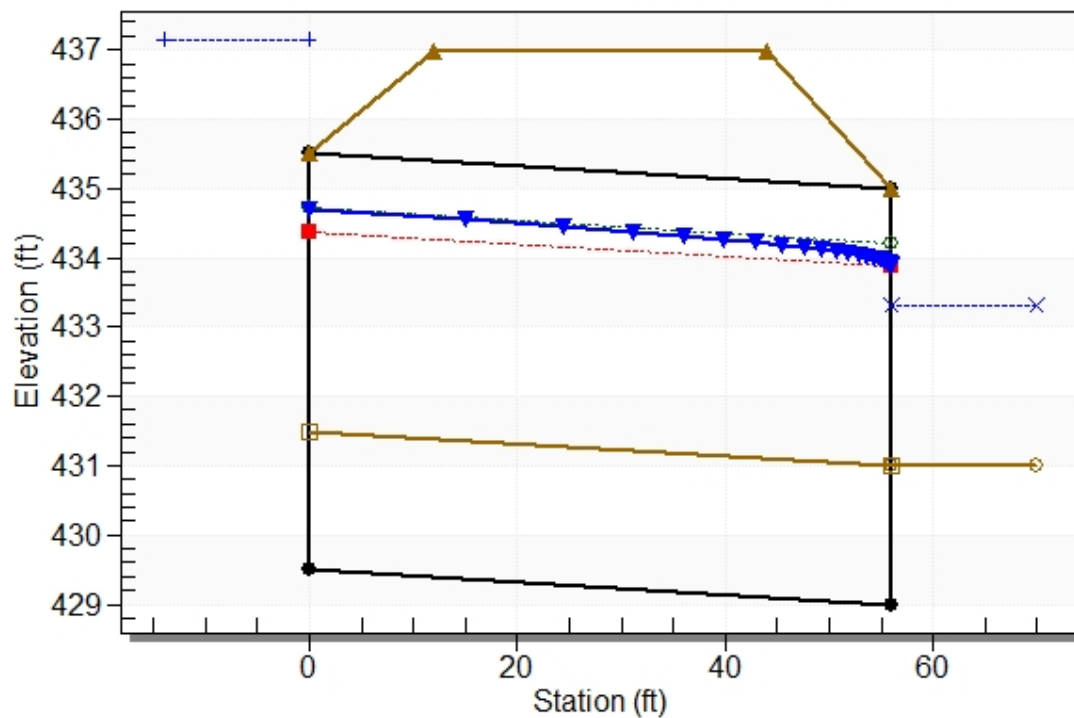
**Table 9 - Downstream Channel Rating Curve (Crossing: Farrow Lake Proposed 16')**

| Flow (cfs) | Water Surface Elev (ft) | Depth (ft) | Velocity (ft/s) | Shear (psf) | Froude Number |
|------------|-------------------------|------------|-----------------|-------------|---------------|
| 50.90      | 431.93                  | 0.93       | 3.42            | 1.13        | 0.73          |
| 102.80     | 432.31                  | 1.31       | 3.90            | 1.59        | 0.87          |
| 160.10     | 432.56                  | 1.56       | 4.04            | 1.90        | 0.88          |
| 198.90     | 432.70                  | 1.70       | 4.12            | 2.07        | 0.87          |
| 260.80     | 432.88                  | 1.88       | 4.24            | 2.28        | 0.86          |
| 300.30     | 432.97                  | 1.97       | 4.32            | 2.40        | 0.85          |
| 351.60     | 433.09                  | 2.09       | 4.39            | 2.54        | 0.84          |
| 467.60     | 433.31                  | 2.31       | 4.56            | 2.81        | 0.84          |

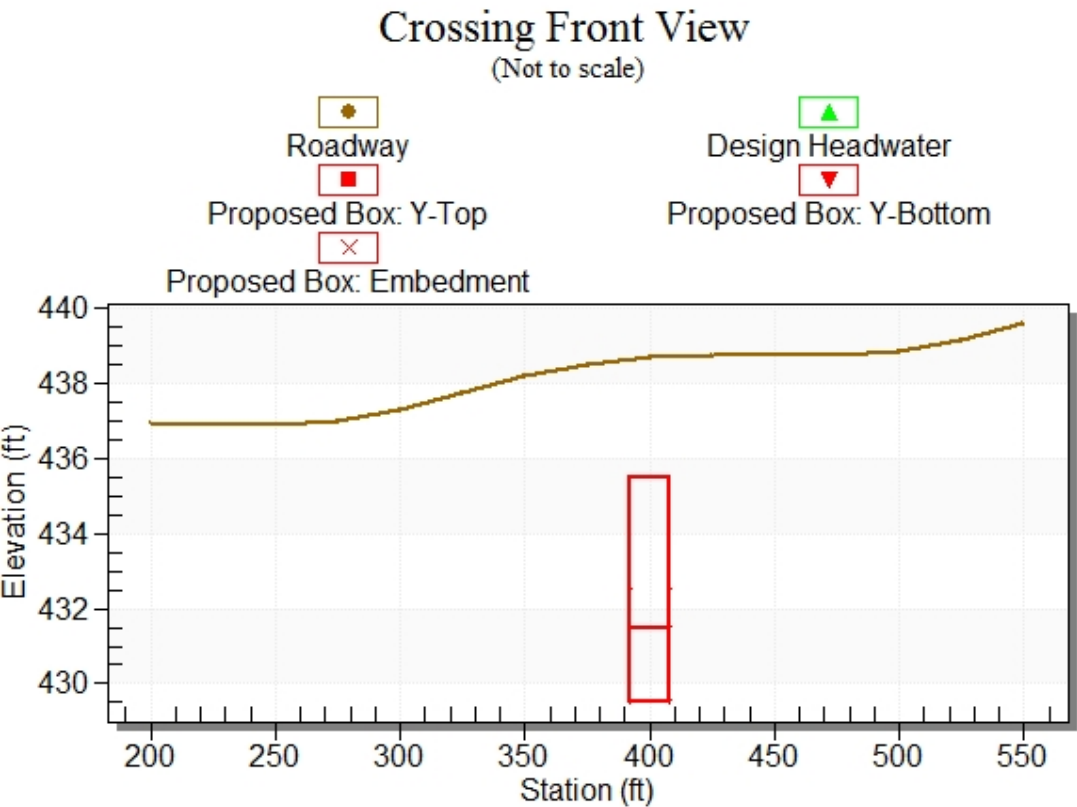
**Water Surface Profile Plot for Culvert: Proposed 16' Box**

Crossing - Topsfield Farrow Lake, Design Discharge - 467.6 cfs

Culvert - Proposed Box, Culvert Discharge - 443.3 cfs



Crossing Front View (Roadway Profile): Proposed 16' Box



### Site Data - Proposed 18' Box

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 429.50 ft

Outlet Station: 56.00 ft

Outlet Elevation: 429.00 ft

Number of Barrels: 1

### Culvert Data Summary - Proposed 18' Box

Barrel Shape: Concrete Box

Barrel Span: 18.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 24.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

\*\*\*\*\*  
Straight Culvert  
Inlet Elevation (invert): 431.50 ft,    Outlet Elevation (invert): 431.00 ft  
Culvert Length: 56.00 ft,    Culvert Slope: 0.0089  
\*\*\*\*\*



## Tailwater Channel Data - Topsfield Farrow Lake

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0195

User Defined Channel Cross-Section:

| Coord No. | Station (ft) | Elevation (ft) | Manning's n |
|-----------|--------------|----------------|-------------|
| 1         | 0.00         | 446.00         | 0.0300      |
| 2         | 29.28        | 445.00         | 0.1000      |
| 3         | 41.79        | 444.00         | 0.1000      |
| 4         | 63.98        | 443.00         | 0.1000      |
| 5         | 78.22        | 442.00         | 0.1000      |
| 6         | 95.00        | 441.00         | 0.1000      |
| 7         | 112.15       | 440.00         | 0.1000      |
| 8         | 132.73       | 439.00         | 0.1000      |
| 9         | 150.70       | 438.00         | 0.1000      |
| 10        | 170.97       | 437.00         | 0.1000      |
| 11        | 201.53       | 436.00         | 0.1000      |
| 12        | 276.42       | 435.00         | 0.1000      |
| 13        | 317.39       | 434.00         | 0.1000      |
| 14        | 339.08       | 433.00         | 0.1000      |
| 15        | 377.73       | 432.00         | 0.1000      |
| 16        | 382.93       | 431.00         | 0.0450      |
| 17        | 385.80       | 431.00         | 0.0450      |
| 18        | 391.20       | 431.00         | 0.0450      |
| 19        | 393.35       | 431.00         | 0.0450      |
| 20        | 400.13       | 432.00         | 0.0300      |
| 21        | 427.75       | 433.00         | 0.0300      |
| 22        | 478.47       | 434.00         | 0.0300      |
| 23        | 538.20       | 435.00         | 0.0300      |

## Roadway Data for Crossing: Topsfield Farrow Lake

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

| Coord No. | Station (ft) | Elevation (ft) |
|-----------|--------------|----------------|
| 0         | 200.00       | 436.97         |
| 1         | 225.00       | 436.91         |
| 2         | 250.00       | 436.89         |
| 3         | 275.00       | 437.02         |
| 4         | 300.00       | 437.30         |
| 5         | 325.00       | 437.74         |
| 6         | 350.00       | 438.18         |
| 7         | 375.00       | 438.50         |
| 8         | 400.00       | 438.70         |
| 9         | 425.00       | 438.76         |
| 10        | 450.00       | 438.76         |
| 11        | 475.00       | 438.76         |
| 12        | 500.00       | 438.86         |
| 13        | 525.00       | 439.15         |
| 14        | 550.00       | 439.63         |

Roadway Surface: Paved

Roadway Top Width: 32.00 ft

**Table 10 - Summary of Culvert Flows at Crossing: Proposed 18' Box**

| Headwater Elevation (ft) | Discharge Names | Total Discharge (cfs) | Proposed Box Discharge (cfs) | Roadway Discharge (cfs) | Iterations  |
|--------------------------|-----------------|-----------------------|------------------------------|-------------------------|-------------|
| 432.84                   | Q 1.1           | 50.90                 | 50.90                        | 0.00                    | 1           |
| 433.53                   | Q 2             | 102.80                | 102.80                       | 0.00                    | 1           |
| 434.16                   | Q 5             | 160.10                | 160.10                       | 0.00                    | 1           |
| 434.55                   | Q 10            | 198.90                | 198.90                       | 0.00                    | 1           |
| 435.12                   | Q 25            | 260.80                | 260.80                       | 0.00                    | 1           |
| 435.46                   | Q 50            | 300.30                | 300.30                       | 0.00                    | 1           |
| 435.88                   | Q 100           | 351.60                | 351.60                       | 0.00                    | 1           |
| 437.04                   | Q 500           | 467.60                | 459.22                       | 8.13                    | 10          |
| 436.89                   | Overtopping     | 448.15                | 448.15                       | 0.00                    | Overtopping |

**Table 11 - Culvert Summary Table: Proposed 18' Box**

| Discharge Names | Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|-----------------|-----------------------|-------------------------|--------------------------|--------------------------|---------------------------|-----------|-------------------|---------------------|-------------------|----------------------|------------------------|---------------------------|
| Q 1.1           | 50.90                 | 50.90                   | 432.84                   | 1.185                    | 1.337                     | 3-M1t     | 0.923             | 0.756               | 0.930             | 0.930                | 3.928                  | 3.422                     |
| Q 2             | 102.80                | 102.80                  | 433.53                   | 1.806                    | 2.028                     | 3-M2t     | 1.347             | 1.221               | 1.307             | 1.307                | 5.267                  | 3.895                     |
| Q 5             | 160.10                | 160.10                  | 434.16                   | 2.359                    | 2.660                     | 2-M2c     | 1.690             | 1.575               | 1.575             | 1.564                | 6.574                  | 4.043                     |
| Q 10            | 198.90                | 198.90                  | 434.55                   | 2.721                    | 3.046                     | 2-M2c     | 1.899             | 1.786               | 1.786             | 1.699                | 7.068                  | 4.124                     |
| Q 25            | 260.80                | 260.80                  | 435.12                   | 3.292                    | 3.616                     | 2-M2c     | 2.209             | 2.083               | 2.083             | 1.876                | 7.785                  | 4.244                     |
| Q 50            | 300.30                | 300.30                  | 435.46                   | 3.648                    | 3.958                     | 2-M2c     | 2.384             | 2.269               | 2.269             | 1.973                | 8.151                  | 4.318                     |
| Q 100           | 351.60                | 351.60                  | 435.88                   | 4.110                    | 4.379                     | 7-M2c     | 2.608             | 2.496               | 2.496             | 2.089                | 8.591                  | 4.389                     |
| Q 500           | 467.60                | 459.22                  | 437.04                   | 5.541                    | 5.208                     | 7-M2c     | 3.036             | 2.938               | 2.938             | 2.307                | 9.393                  | 4.560                     |

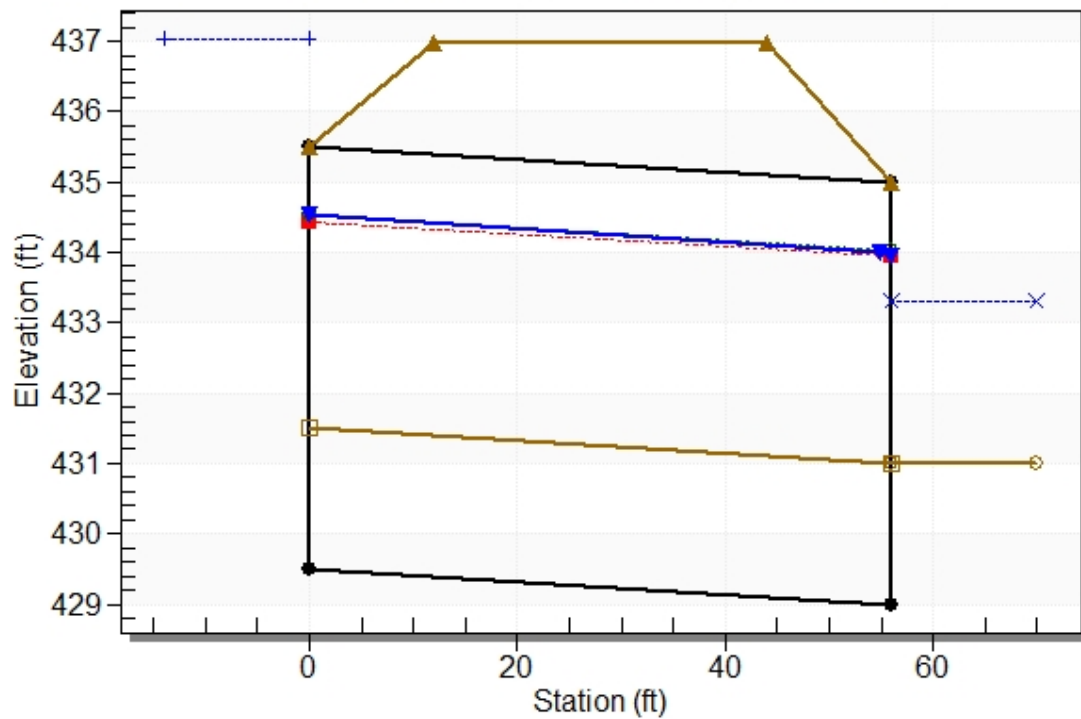
**Table 12 - Downstream Channel Rating Curve (Crossing: Farrow Lake Proposed 18')**

| Flow (cfs) | Water Surface Elev (ft) | Depth (ft) | Velocity (ft/s) | Shear (psf) | Froude Number |
|------------|-------------------------|------------|-----------------|-------------|---------------|
| 50.90      | 431.93                  | 0.93       | 3.42            | 1.13        | 0.73          |
| 102.80     | 432.31                  | 1.31       | 3.90            | 1.59        | 0.87          |
| 160.10     | 432.56                  | 1.56       | 4.04            | 1.90        | 0.88          |
| 198.90     | 432.70                  | 1.70       | 4.12            | 2.07        | 0.87          |
| 260.80     | 432.88                  | 1.88       | 4.24            | 2.28        | 0.86          |
| 300.30     | 432.97                  | 1.97       | 4.32            | 2.40        | 0.85          |
| 351.60     | 433.09                  | 2.09       | 4.39            | 2.54        | 0.84          |
| 467.60     | 433.31                  | 2.31       | 4.56            | 2.81        | 0.84          |

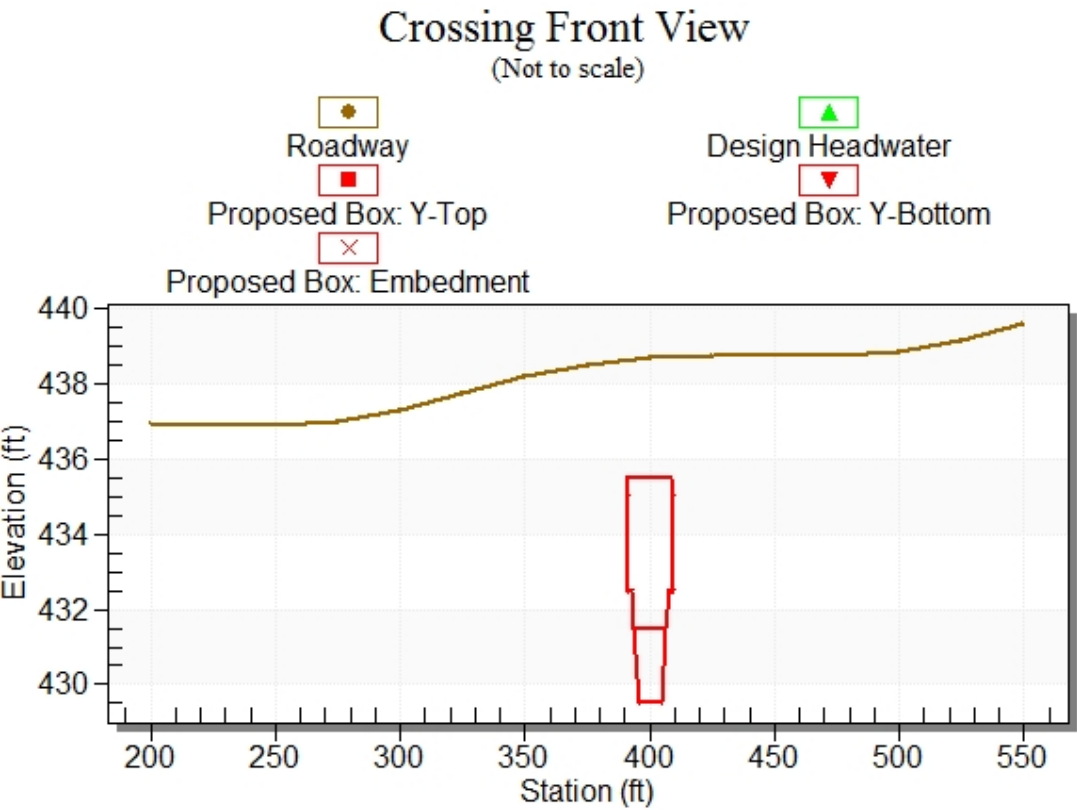
**Water Surface Profile Plot for Culvert: Proposed 18' Box**

Crossing - Topsfield Farrow Lake, Design Discharge - 467.6 cfs

Culvert - Proposed Box, Culvert Discharge - 459.2 cfs



Crossing Front View (Roadway Profile): Proposed 18' Box



| <b>Culvert</b> | <b>Invert<br/>Elevation (ft)</b> | <b>Q50 Elevation<br/>(ft)</b> | <b>Water Depth<br/>(ft)</b> | <b>Culvert<br/>Depth (ft)</b> | <b>Hw/D</b> | <b>Q100<br/>Elevation (ft)</b> | <b>Hw/D</b> | <b>Increase over<br/>Existing (ft)</b> |
|----------------|----------------------------------|-------------------------------|-----------------------------|-------------------------------|-------------|--------------------------------|-------------|--|
| Existing       | 430.63                           | 435.89                        | 5.26                        | 5.00                          | 1.05        | 436.46                         | 1.17        | 0.00                                   |
| Box 15' x 6'   | 431.50                           | 435.66                        | 4.16                        | 4.00                          | 1.04        | 436.17                         | 1.17        | -0.29                                  |
| Box 16' x 6'   | 431.50                           | 435.49                        | 3.99                        | 4.00                          | 1.00        | 435.93                         | 1.11        | -0.53                                  |
| Box 18' x 6'   | 431.50                           | 435.46                        | 3.96                        | 4.00                          | 0.99        | 435.88                         | 1.10        | -0.58                                  |