Lake Accotink Sustainability Plan

Fairfax County, Virginia

WSSI #22647.01

May 31, 2017

Prepared for:

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Fairfax, Virginia

Introduction

As part of the Master Planning effort for Lake Accotink Park, Wetland Studies and Solutions, Inc. (WSSI) has assessed the feasibility of six potential options for the long term management of the lake itself. The six options include:

A) "Do nothing".

B) The current plan of dredging on approximately a 15-year interval.

C) Construction of a sediment forebay (either just upstream or within the existing footprint of the lake).

D) Installation of "beaver dam" structures in line with Accotink Creek upstream of the lake.

E) Removing the existing dam and returning Accotink Creek to a single thread channel within the current lake footprint.

F) Removal of a portion of the existing dam to create a smaller lake along with a single thread channel.

Specifically, the goals of this assessment were to determine the pros and cons of each option in terms of several factors, including suitability for public use (and impacts), environmental benefits (primarily water quality), and cost effectiveness. The results of this analysis provide one piece of the puzzle as the stakeholders (County staff, citizens, regulatory agencies) make decisions regarding the future management of Lake Accotink.

The degree to which the proposed management options may provide water quality benefits is of particular importance as potential credit toward meeting the County's regulatory requirements may help offset implementation costs. Another consideration in the ultimate decision will be the requirements specified in the Accotink Creek TMDL that is currently under development. However, regardless of the outcome of the TMDL, the impact on the downstream receiving waters resulting from each potential management option will be a consideration.

This assessment utilized existing information contained in the numerous studies of Lake Accotink that have been conducted over a period of many years, bathymetric surveys conducted by others, and watershed information obtained from Fairfax County. No additional investigations were performed.

The remainder of this memo outlines the results of the assessment of each management option. As part of this project, WSSI also developed a presentation summarizing the history of the previous studies, along with the results of this analysis and presented it to DPWES and FCPA staff, the FCPA Board, and to the public. Portions of the overall presentation were modified depending on the particular audience. A copy of the most complete presentation provide to DPWES staff is provided in Appendix A. A more detailed discussion of the trapping efficiency of Lake Accotink is provided in Appendix B. Estimated costs to implement each of the options are provided in Appendix C.

<u>Option A – "Do Nothing"</u>

Lake Accotink has been dredged three times over the past 40 years, with the most recent completed in 2008. The frequency with which the sediment accumulates has reduced the interval between dredging operations to approximately 15 years in order to maintain reasonable usefulness of the lake. Previous studies have shown that the rate at which sediment accumulates is variable and is dependent upon the amount of rainfall. A study performed by HDR Engineering (HDR, 2002) developed a methodology for predicting sediment capture in the lake. The applicability of this trapping efficiency model to Lake Accotink was evaluated using bathymetric survey data from 2001, 2011, and again in 2015. Details of this trapping efficiency assessment is provided in Appendix B.

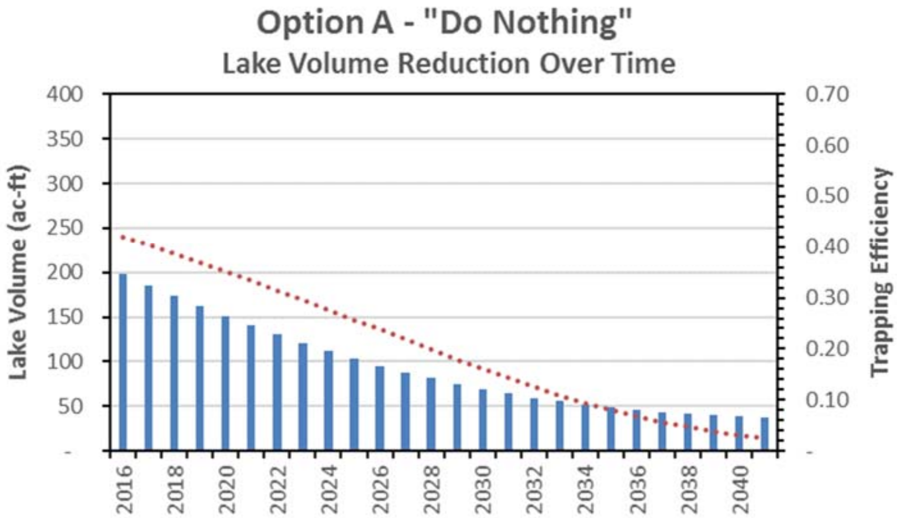
To summarize, the sediment model does provide a reasonable estimate of the sedimentation in Lake Accotink. Inserting the surveyed lake volume in 2001, then applying the rate of sedimentation based on the incoming flow rates (i.e. the sediment model) from 2001 until 2015 (also including the dredging event in 2008) results in predicted lake volumes within approximately 11% of the surveyed volumes in 2011 and 2015. If only the time frame from 2011 to 2015 is considered and the starting volume from the 2011 survey is inserted (252 ac-ft), the model predicts the lake volume in 2015 very well (Table 1, 197 ac-ft vs the surveyed volume of 196 ac-ft). The average trapping efficiency during this period of 47% is used throughout the remainder of this water quality analysis.

<u>Table 1</u>

Year	*Average Lake Inflow*		*Sediment Inflow to Lake*		*Lake Volume*	*Trapping Efficiency*	*Sediment Detained*
	cfs	*ac-ft*	*cy*	*ac-ft*	*ac-ft*	*%*	*ac-ft*
2011	59	42,794	57,951	36	252	44%	16
2012	39	28,142	36,375	23	236	53%	12
2013	42	30,644	40,058	25	224	50%	12
2014	59	42,615	57,688	36	212	40%	14
2015	41	29,840	38,874	24	197	47%	11

Assuming an average annual inflow rate of 48 cfs and a corresponding sediment delivery to the lake of approximately 46,000 cy (based on an average of the sediment influx for the previous 5 years, Table 1), along with the trapping efficiency curve and a starting lake volume of 197 ac-ft (based on the 2015 survey), the predicted sedimentation is provided below (trapping efficiency is noted by the dashed line):

Figure 1

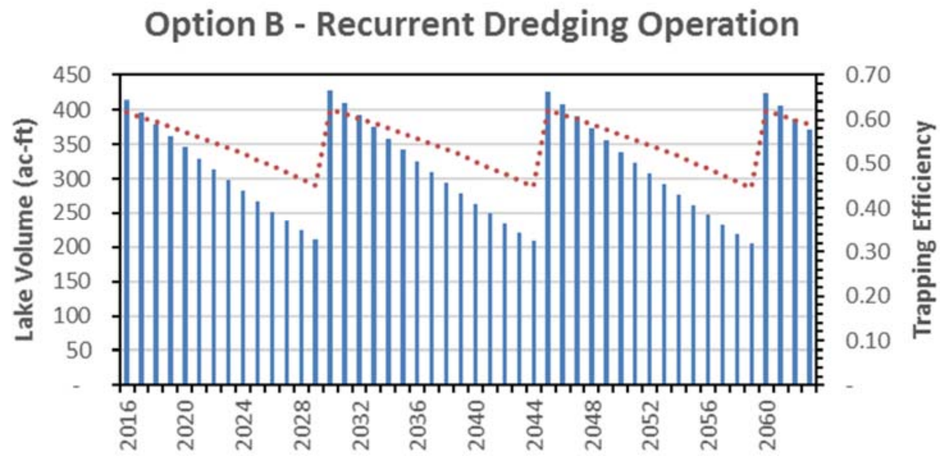


From the above, it is evident that the current volume of the lake is at the point where another dredging would be necessary to provide for reasonable usefulness. How this is defined is subjective, but for the purposes of this analysis it is defined as providing an average depth of 8 ft (approximately 400 ac-ft). Allowing the lake to continue to fill in will result in it developing into a wetland area with little opportunity to pursue the same types of open water activities currently enjoyed (boating, fishing, etc.). While this would represent a change in the use of the lake area, it would provide beneficial wetland habitat.

Option B – Continue with Current Dredging Plan

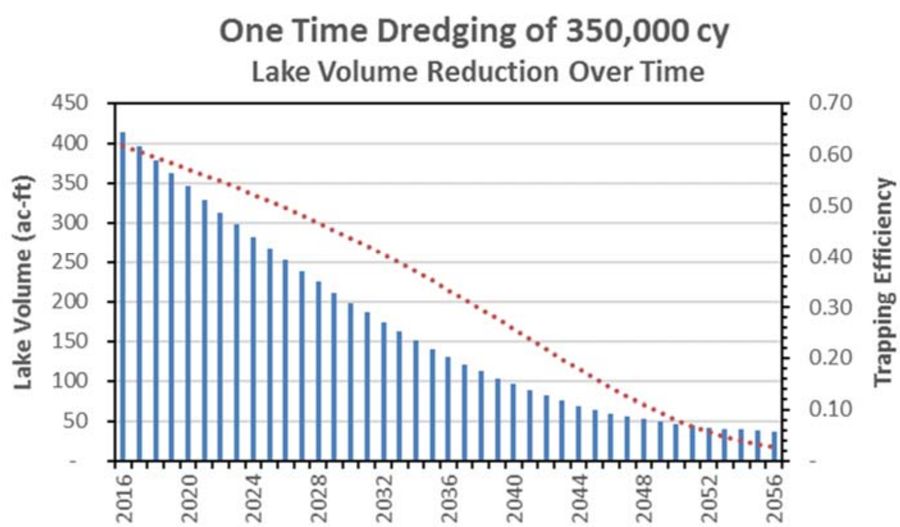
Option B would not provide the possibility for the County to receive pollutant removal credit as the current regulations are written as it does not represent an upgrade in the water quality performance of the lake (as provided by Option C, below). Option B assumes removal of 350,000 cy in order to provide for an average 8 ft depth within the lake. Assuming an average annual inflow rate of 48 cfs and a corresponding sediment delivery to the lake of approximately 46,000 cy (based on an average of the sediment influx for the previous 5 years, Table 1), along with the trapping efficiency curve, the predicted sedimentation is provided below (trapping efficiency is noted by the dashed line). Note that it is assumed dredging would take place when the lake volume is reduced to approximately 200 ac-ft:

Figure 2



As depicted above, a dredging operation to remove 350,000 cy (assuming a current volume of approximately 197 ac-ft) would have to be repeated approximately every 15 years in order to maintain a lake volume of greater than 200 ac-ft. If the lake were to be dredged now and no additional dredging were to take place, the lake volume would begin to stabilize after approximately 40 years with essentially no incoming sediment being captured (as depicted in Figure 3).

Figure 3



This Option would enable the lake to provide the similar function that it has for many years, but does require significant expense to continue with the dredging program. There is also the practical consideration of determining how and where to dispose of the dredge material. Additional information is provided in Appendix C.

Option C – Sediment Removal Plus Sediment Forebay

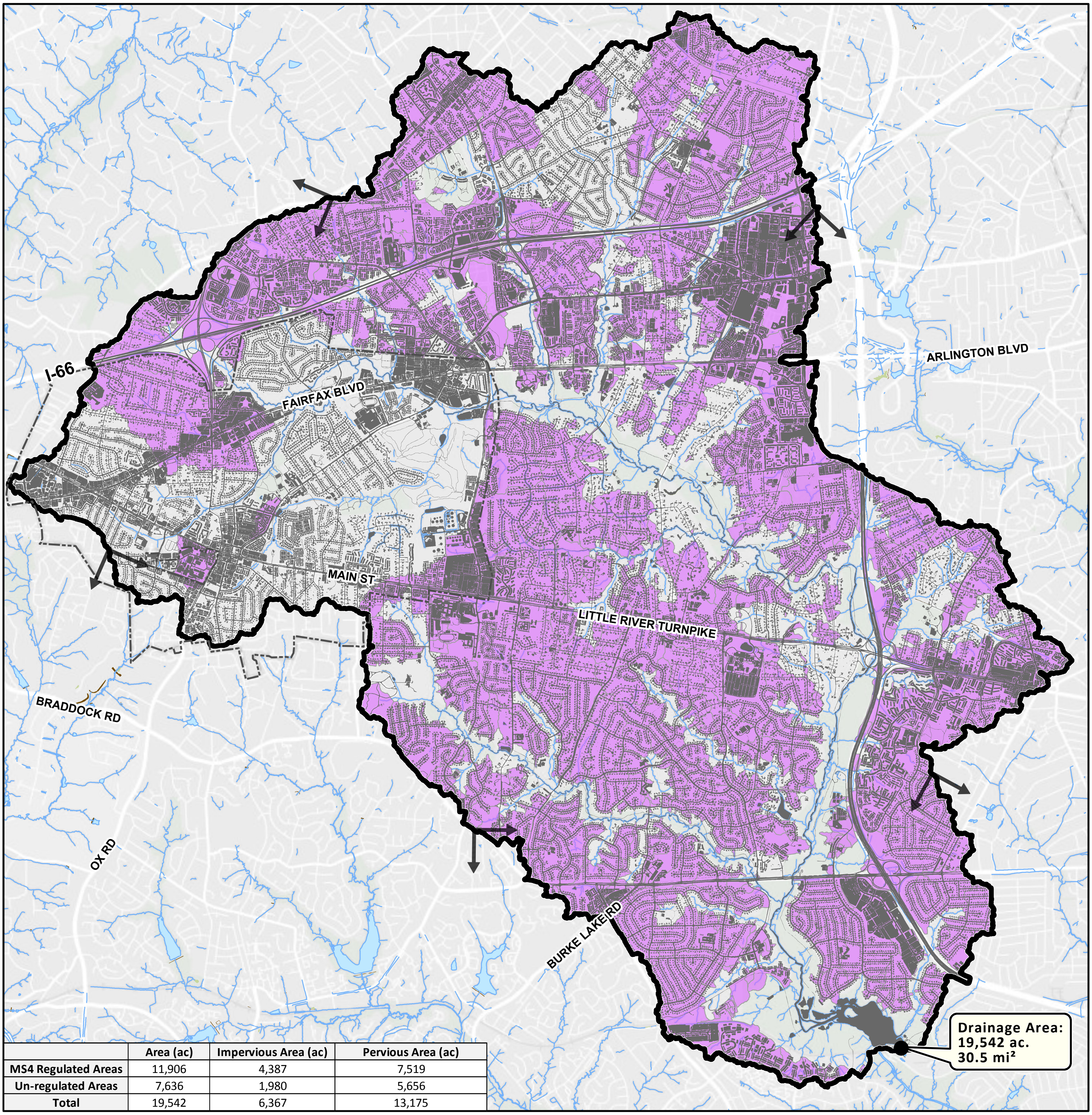
The methodology used to compute the potential phosphorus removal level that Option C may be able to achieve is contained in Guidance Memo No. 15-2005, Chesapeake Bay TMDL Action Plan Guidance, dated May 18, 2015 (Guidance Memo) developed by DEQ. This document provides information on how to compute the potential credit that can be achieved through implementation of retrofits to stormwater management facilities and/or through stream restoration. While it is recognized that Lake Accotink was not specifically constructed to serve in a stormwater management (SWM) capacity, it does provide that function, particularly in relation to the amount of sediment (and associated pollutants) it detains.

The contributing watershed to Lake Accotink is approximately 31 square miles, with roughly 1/3 comprised of impervious area. Another important aspect of the contributing watershed relates to the areas contained within the County's MS4 area (i.e. regulated areas)[1]. While the entire watershed drains to the lake, full credit can only be obtained for treatment of the regulated areas and a portion of the pollutant load generated by unregulated areas that exceeds the required baseline reduction. Note that the Guidance Memo does allow for credit for treating forested areas – however, Fairfax County does not currently take such credit. As such, all forested areas have been assumed to be pervious for the purposes of this analysis. A map depicting the applicable MS4 area (as well as impervious areas) is provided in Exhibit 1.

While the Guidance Memo is largely intended to provide instruction for how localities can calculate the amount of pollutant removal credit that can be claimed through the retrofit of smaller SWM/BMP facilities that were designed and built specifically to provide SWM, it also allows for the methodology to be applied to older facilities that were constructed for other reasons. There is also some precedent for a locality claiming credit for the retrofit of a large reservoir, as was done for an impoundment located in Chesterfield County, VA (Falling Creek Reservoir). In that instance, the locality worked with DEQ to develop a strategy whereby they received pollutant removal credit for dredging the reservoir, adding a sediment forebay, and development of a maintenance plan to ensure it continues to function as intended. Whether or not the plan has been fully implemented is uncertain. At this early stage of the investigation of potential Lake Accotink management options, determining the pollutant removal potential is the first step.

The primary goal of this Option would be to enhance the current pollutant removal capability of the lake in order to claim pollutant removal credit in accordance with the Guidance Memo. According to this document, impoundments constructed prior to 2009 for which enhancement and/or restoration are performed may be eligible to receive pollutant removal credit for any incremental increase in the level of treatment. The basic procedure is to compute the level of treatment the facility receives prior to any enhancement, then to compute the improved level after the facility retrofit. In this instance, the retrofit would include the addition of a sediment forebay, dredging of the main lake (removal of 350,000 cy), and development of an ongoing maintenance program to ensure the forebays are routinely dredged (annually is assumed for the

[1] *Credit may also be received for treatment of MS4 areas within other jurisdictions that drain to the County's MS4 system. The total MS4 area was obtained from Fairfax County and has been included in the analysis.*



	Area (ac)	Impervious Area (ac)	Pervious Area (ac)
MS4 Regulated Areas	11,906	4,387	7,519
Un-regulated Areas	7,636	1,980	5,656
Total	19,542	6,367	13,175

MS4 Service Areas & Impervious Surface
Lake Accotink Watershed
WSSI #23304.01
Original Scale: 1" = 1 mile

Lake Accotink Watershed
Impervious Surface Area
MS4 Service Areas

N
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Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

MS4 Service Areas received from Fairfax County

Wetland Studies and Solutions, Inc.
a DAVEY company

Exhibit 1

purpose of this analysis). In addition, a baseline, "existing" condition must be specified – for this analysis this condition is assumed to be the 2015 surveyed volume of approximately 197 ac-ft.

As previously presented, this analysis also assumes addition of a 94 ac-ft sediment forebay. The volume for this forebay was developed following DEQ guidance that states it can be sized to contain a minimum of 15% of the required treatment volume (TV) for the watershed. To compute the required TV, land use data (obtained from Fairfax County GIS) was plugged into the Virginia Runoff Reduction Methodology (VRRM) spreadsheet, resulting in a total TV of 630 ac-ft. Taking 15% of this value results in the 94 ac-ft sediment forebay that has been used in this analysis. While two locations have been considered for the forebay, the option where it is located upstream of the main lake was investigated for this analysis (i.e. this provides the largest volume overall and therefore represents the best case scenario).

The procedure to compute the incremental increase in pollutant removal involves computation of the runoff depth over the watershed that the impoundment is capable of treating through use of the following equation:

Equation 1

$$RD = \frac{RS\ x\ 12}{IA}$$

Where:

RD	=	Runoff Depth Treated (in)
RS	=	Runoff Storage (ac-ft)
IA	=	Impervious Area (acres)

Once the runoff depth has been computed, the Guidance Memo provides the option of computing the removal efficiency of the enhanced impoundment through the use of either efficiency curves or fifth-order polynomials. For this analysis, fifth-order polynomials lent themselves to spreadsheet computation and were therefore utilized.

Because sediment continually builds-up in the lake, the RS term is not static over time. Using the modeling discussed above, the available storage in the lake (RS) was recomputed for each year following dredging to account for the sedimentation and subsequent reduction in trapping efficiency.

Once the treatment efficiency of the enhanced impoundment has been determined, any treatment provided by upstream BMP's must be subtracted. This value was determined through a review of GIS information obtained from the County that revealed that there are several hundred upstream BMP's that provide treatment for approximately 645 ac. Assuming average removal efficiencies for each pollutant of concern (POC) resulted in approximately a 1.5% reduction in the total load achieved by the upstream BMP's. The results of the efficiency computations are summarized in Tables 2-4 below for each POC.

Table 2

Phosphorus

Year	Existing Condition			Enhanced Condition			Credit Achieved
	RS	RD	Removal	RS	RD	Removal	
2015	197	0.39	35%	508	1.00	55%	18%
2016	197	0.39	35%	494	0.97	54%	18%
2017	197	0.39	35%	480	0.94	54%	17%
2018	197	0.39	35%	466	0.92	54%	17%
2019	197	0.39	35%	452	0.89	53%	16%
2020	197	0.39	35%	439	0.86	52%	16%
2021	197	0.39	35%	425	0.84	52%	15%
2022	197	0.39	35%	412	0.81	51%	15%
2023	197	0.39	35%	399	0.78	51%	14%
2024	197	0.39	35%	386	0.76	50%	13%

Table 3

Nitrogen

Year	Existing Condition			Enhanced Condition			Credit Achieved
	RS	RD	Removal	RS	RD	Removal	
2015	197	0.39	22%	508	1.00	35%	11%
2016	197	0.39	22%	494	0.97	35%	11%
2017	197	0.39	22%	480	0.94	34%	11%
2018	197	0.39	22%	466	0.92	34%	10%
2019	197	0.39	22%	452	0.89	34%	10%
2020	197	0.39	22%	439	0.86	33%	10%
2021	197	0.39	22%	425	0.84	33%	9%
2022	197	0.39	22%	412	0.81	33%	9%
2023	197	0.39	22%	399	0.78	32%	8%
2024	197	0.39	22%	386	0.76	32%	8%

Table 4

Sediment

Year	Existing Condition			Enhanced Condition			Credit Achieved
	RS	RD	Removal	RS	RD	Removal	
2015	197	0.39	22%	508	1.00	70%	46%
2016	197	0.39	22%	494	0.97	69%	45%
2017	197	0.39	22%	480	0.94	69%	45%
2018	197	0.39	22%	466	0.92	68%	44%
2019	197	0.39	22%	452	0.89	67%	44%
2020	197	0.39	22%	439	0.86	67%	43%
2021	197	0.39	22%	425	0.84	66%	42%
2022	197	0.39	22%	412	0.81	65%	41%
2023	197	0.39	22%	399	0.78	65%	41%
2024	197	0.39	22%	386	0.76	64%	40%

With the removal rate of the enhanced lake determined, the next step was to compute the pollutant load delivered to the lake from the contributing watershed. In performing this analysis, it was necessary to recognize that not all of the contributing watershed is actually within either the County's MS4 area or portions of other jurisdiction's MS4 areas for which the County is responsible (Exhibit 1). Since one of the goals of this analysis was to determine the potential credit that may be achieved toward meeting the County's regulatory requirements under the MS4 program, proper crediting of the treatment of non-regulated areas (i.e. areas outside the applicable MS4 area) had to be performed. The procedure outlined in the Guidance Memo was utilized, as defined by the following basic steps:

1) Compute the removal efficiency of the enhanced lake (as described above).

2) Determine the breakdown of the contributing watershed in terms of regulated vs non-regulated areas, further broken down by pervious and impervious area (Table 5):

Table 5

Land Use Area (ac)

Category	Urban Impervious	Urban Pervious	Total Urban
Regulated Land	4,387	7,520	11,907
Unregulated Land	1,980	5,656	7,636
Totals	6,367	13,176	19,543

3) Compute the ratio of land type category (regulated and unregulated) compared to the total land area:

Regulated Land/Total Acres =	0.61
Unregulated Land/Total Acres =	0.39
	1.00

4) Compute the loading for each POC (TP, TN, and TSS). This was accomplished using the loading rates contained in the MS4 permit:

Table 6

Annual POC Loads

Category	TN		TP		TSS	
	Rate (lbs/ac)	Load (lbs)	Rate (lbs/ac)	Load (lbs)	Rate (lbs/ac)	Load (lbs)
Impervious	16.86	107,348	1.62	10,315	1171	7,457,794
Pervious	10.07	132,682	0.41	5,402	176	2,316,341
TOTAL		240,030		15,717		9,774,135

5) Determine the amount of credit that can be claimed – full credit can be claimed for treatment of all regulated lands, but credit for unregulated lands can only be achieved for amounts removed beyond required baseline reductions. The baseline reductions for each POC were computed by first determining the total required removal rate for the life of the permit (specified rate for the first 5% reduction for the first permit term x 20) and multiplying that by the total number of unregulated acres (both pervious and impervious). The results are summarized below in Table 7.

Table 7

Required Unregulated Baseline Reductions

Category	TN			TP			TSS		
	5% lbs/ac/yr	Permit Life lbs/ac/yr	Total Load lbs/yr	5% lbs/ac/yr	Permit Life lbs/ac/yr	Total Load lbs/yr	5% lbs/ac/yr	Permit Life lbs/ac/yr	Total Load lbs/yr
Impervious	0.07587	1.5174	3,004	0.01296	0.2592	513	11.7132	234.264	463,843
Pervious	0.03021	0.6042	3,417	0.001486	0.029725	168	0.769125	15.3825	87,003
TOTAL			6,422			681			550,846

6) Compute the amount of credit that can be claimed by the enhanced Lake Accotink for each land category (regulated and unregulated). This value is defined as:

$$POC\ Removal = \sum Pollutant\ Load\ x\ Removal\ Rate\ x\ Land\ Ratio$$

Where:

POC Removal	=	Total TN, TP, and TSS Removed (lbs)
Pollutant Load	=	Pollutants Delivered to Lake (Table 6, lbs)
Removal Rate	=	Computed Lake Removal Efficiency (%)
Land Ratio	=	Weighted Land Use Category (Regulated, Unregulated, Forest)

Note: The portion of the total *POC Removal* term for the unregulated land must be reduced by the value of the required baseline reductions (Table 7). If the required baseline reduction is greater than the value of the *POC Removal* term, then no credit for unregulated land may be taken. In this case, some credit may be taken for each POC.

A summary of the potential pollutant removal credit that may be claimed by the enhancement of Lake Accotink is summarized in Tables 8-10 for each of the POC's.

Table 8

Phosphorus (lbs/yr)

Year	*Removed*	*Per Land Category*		*Allowable*
		Regulated	*Unregulated*	
2015	2,871	1,749	440	2,189
2016	2,802	1,707	413	2,120
2017	2,730	1,663	385	2,048
2018	2,654	1,617	356	1,973
2019	2,574	1,569	325	1,893
2020	2,491	1,518	292	1,810
2021	2,404	1,464	258	1,722
2022	2,312	1,409	222	1,631
2023	2,216	1,350	185	1,535
2024	2,116	1,289	145	1,434

Table 9

Nitrogen (lbs/yr)

Year	*Removed*	*Per Land Category*		*Allowable*
		Regulated	*Unregulated*	
2015	26,578	16,193	3,963	20,156
2016	25,910	15,786	3,702	19,488
2017	25,208	15,359	3,428	18,786
2018	24,472	14,910	3,140	18,050
2019	23,699	14,439	2,838	17,277
2020	22,888	13,945	2,521	16,466
2021	22,038	13,427	2,189	15,616
2022	21,147	12,885	1,841	14,726
2023	20,215	12,317	1,477	13,794
2024	19,240	11,723	1,096	12,819

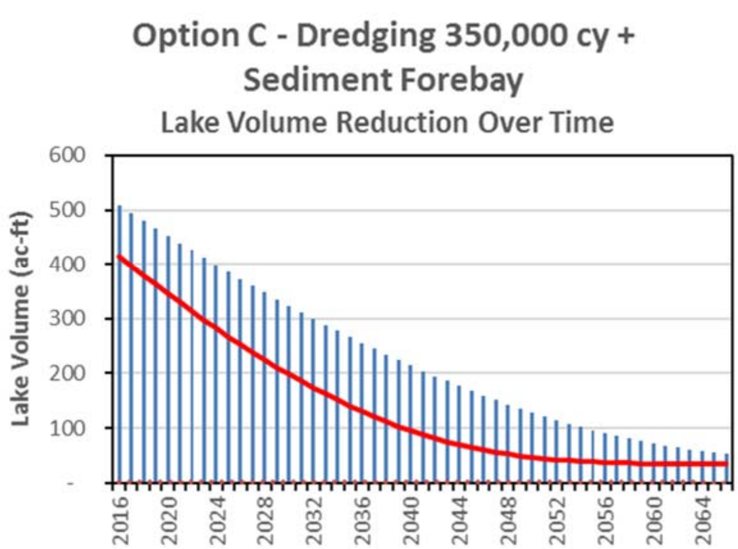
Table 10

Sediment (lbs/yr)

Year	*Removed*	*Per Land Category*		*Allowable*
		Regulated	*Unregulated*	
2015	4,497,540	2,740,225	1,206,469	3,946,694
2016	4,443,168	2,707,097	1,185,225	3,892,322
2017	4,386,068	2,672,308	1,162,914	3,835,222
2018	4,326,121	2,635,784	1,139,491	3,775,275
2019	4,263,209	2,597,454	1,114,910	3,712,363
2020	4,197,217	2,557,246	1,089,124	3,646,370
2021	4,128,032	2,515,094	1,062,092	3,577,186
2022	4,055,550	2,470,932	1,033,771	3,504,704
2023	3,979,672	2,424,702	1,004,124	3,428,826
2024	3,900,309	2,376,349	973,114	3,349,463

The tables represent a 10-year period following the enhancement and depicts that the volume of the lake, along with the associated credit, drops each year. This can be attributed to the fact that the forebay only traps approximately 26% of the incoming sediment load, even with an annual dredging program (assuming the average inflow and sediment influx over the past 5-years, as discussed for Option B). The remainder of the sediment continues into the larger lake where a portion settles out. A prediction of the sedimentation under this scenario is provided below:

Figure 4



The red line depicts the predicted sedimentation of the main lake for the scenario where the main lake is dredged but without the forebay in place. It is evident that the rate of sedimentation in the main lake is reduced, however it remains significant. The difference is the potential pollutant removal credit that can potentially be claimed, which this analysis indicates may be substantial. The financial benefit of the pollutant removal is presented in Appendix C.

As with the 2 previous options, Option C would allow for the continued use of the lake as it currently stands (as open water recreation). The construction of the forebay would require impacts to upstream wetlands, but would provide a modest increase in the time between required dredging operations in the main lake area. Locating suitable disposal areas would also be an issue for this option. Unlike the previous two options, Option C also requires an annual maintenance dredging of the sediment forebay with temporary, on-site disposal options (ideally). More information on the potential on-site areas is provided in the presentation in Appendix A, as well as in the cost analysis (Appendix C).

Option D – Installation of "Beaver Dam" Structures

This options includes the installation of low, sheet pile walls installed perpendicular to the mainstem upstream of the lake to trap sediment. The assumption for this analysis is that four of these "dams" would be installed, with it estimated that each may trap up to 12,000 cy of sediment. How long this process may take is uncertain and once full, their usefulness in terms of sediment removal will have been exhausted. In addition, there is no plan for performing sediment removal as their locations will make permanent access difficult that would result in more disruption than it would be worth.

Based on the estimated sediment influx over the past five years, these four structures would only remove approximately 1 years' worth of incoming sediment at their maximum storage capacity (approximately 29 ac-ft in total). The cost of these structures will only be a fraction of that to implement the other options (Appendix C). However, they do not appear to represent a viable, long term management strategy as their benefit to the lake would be minimal.

Option E – Single Thread Channel, Full or Partial Dam Removal

As currently proposed, this option would not provide verifiable water quality treatment for which credit could be claimed. While it would detain some sediment, as does any stream during periods of overbank flows, it is uncertain how this can be quantified and claimed. There are potential adverse impacts posed by this option as sediment that is currently detained is passed downstream. The additional sediment could result in reduced stream health and could also potentially impact downstream infrastructure (culverts, etc.).

As has been discussed, another potential implication relates to the Accotink Creek TMDL that is currently in the development process. While the requirements of this new regulation are not yet determined, what is certain is that the modeling that is being utilized to develop the TMDL assumes that Lake Accotink does trap sediment. With the proposition of removing the lake all together, it seems the elimination of sediment trapping will require consultation with DEQ. The future Accotink TMDL is not the focus of this assessment, but the potential significance warranted mentioning.

As presented above, if Option A ("do nothing") is implemented such that no further dredging is conducted and the average inflow and sediment influx experienced over the past 5 years is propagated forward, trapping efficiency will drop to essentially zero after approximately 25 years. Even for Option C (dredging of main lake and addition of a sediment forebay), the trapping efficiency will be reduced to a negligible amount after approximately 35 years. With the current estimated volume of 197 ac-ft, the estimated trapping efficiency is only about 43% (assuming the 5-yr average inflow/sediment influx). It is uncertain what DEQ assumes for the TMDL being developed in terms of trapping efficiency. However, it is clear the only way it can be maintained is through continued dredging of the main lake, even if forebays are installed. Hopefully this fact can be used to the County's advantage as the long term management strategies are developed.

The benefit of this option is the elimination of future dredging requirements. However, the current, open-water recreational opportunities would be lost.

Option F – Single Thread Channel with Smaller Lake

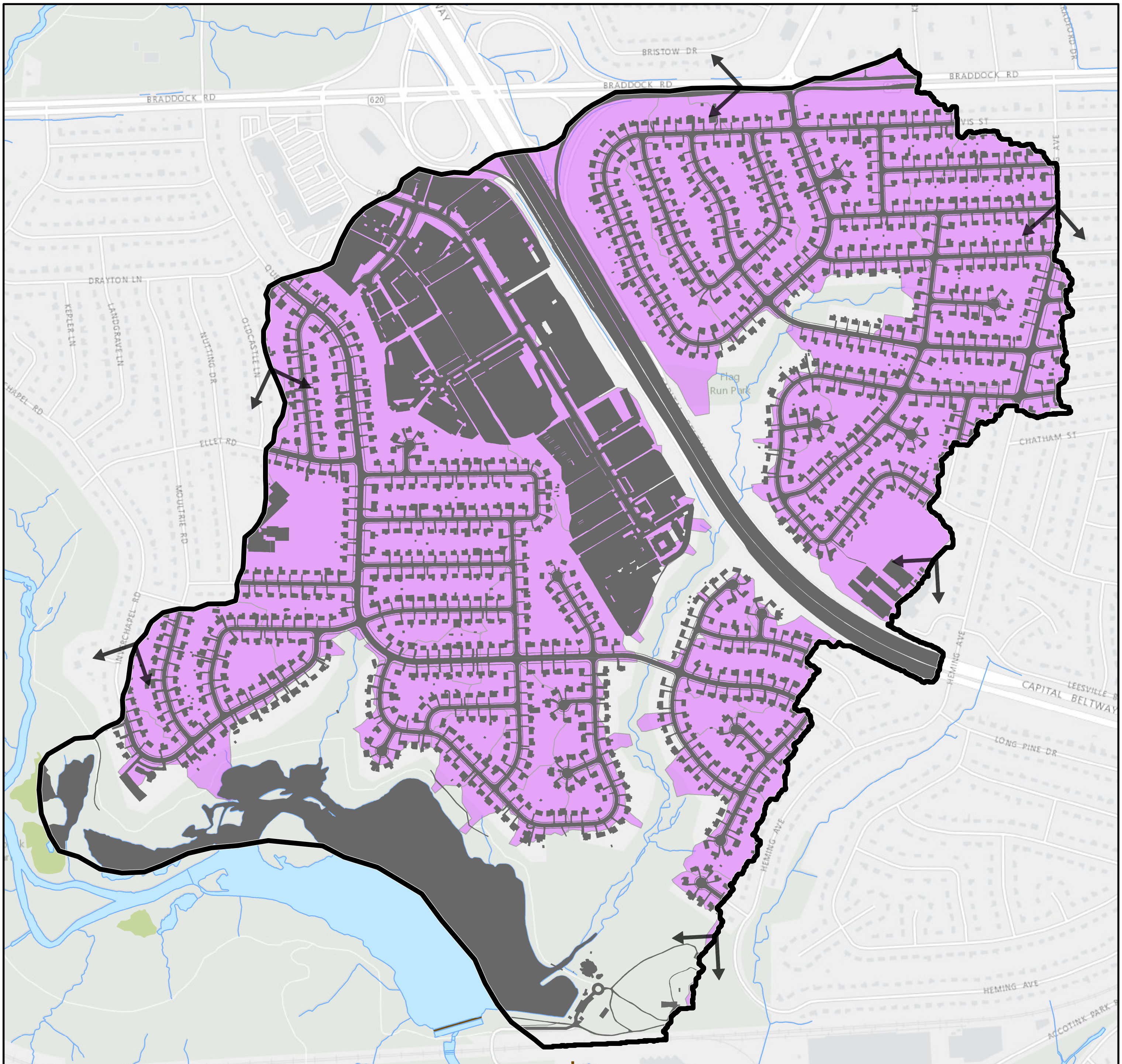
As with Option E, most of the sediment load will also be passed downstream under this scenario. A difference is the smaller sub-shed that will drain directly into the smaller lake. As shown in Exhibit 2 on the following page, the drainage area totals approximately 662 ac, or about 3% of the entire watershed. There are two primary inflows into the area that would encompass this smaller lake, one of which is currently proposed for restoration. It is recommended that the other channel also be restored in order to limit the sediment influx into this lake.

Computing the POC load to the smaller lake, along with assumed removal rates (given that this impoundment has yet to be designed, it is not unrealistic to assume these efficiencies could be achieved) results in the following removal potential:

Table 11

POC	*Total Load (lbs)*	*Removal Rate (%)*	*Removal Credit (lbs)*
TP	580	75	411
TN	8,388	40	3,167
TSS	370,061	50	165,366

Note this analysis does include a reduction for unregulated areas – however, most of the contributing drainage area is either within the County's MS4. A more detailed analysis can provide a more exact level of removal once the smaller lake is designed.



	Area (ac)	Impervious Area (ac)	Pervious Area (ac)
MS4 Regulated Areas	464	185	279
Un-regulated Areas	198	70	128
Total	662	255	407

MS4 Service Areas & Impervious Surface
Design Sub-shed
WSSI #23304.01
Original Scale: 1" = 1,000'

Design Subshed

Impervious Surface Area

MS4 Service Areas

N
W E
S

0 1,000
Feet

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MS4 Service Areas received from Fairfax County

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Exhibit 2

The primary benefit of this option is that it allows for open-water recreational opportunities to continue, while also eliminating the need to perform dredging on such a large scale.

Summary

This analysis was performed to determine the pros and cons of each of the six Lake Accotink management options in terms of several factors, including suitability for public use (and impacts), environmental benefits (primarily water quality), and cost effectiveness. This includes not only adverse impacts resulting from the potential export of pollutants downstream should those options that remove the dam be adopted, but also the potential for the County to receive credit for the pollutant removal functions that the lake provides. Another significant factor is the cost to implement each of the options, which is provided in Appendix C.

The current lake volume is estimated at approximately 200 ac-ft. This analysis assumes that reasonable usefulness is achieved with an average depth of 8 ft, which equates to a volume of approximately 400 ac-ft. As a result, the lake is currently in an impaired condition and will continue to worsen without another major dredging operation.

Maintaining the current plan of dredging the lake on approximately a 15-year cycle would continue to provide sediment trapping benefits and open-water recreational opportunities for the community. However, no credit toward the County's pollutant removal goals can currently be claimed. If the dredging program were to cease after one more operation (removing 350,000 cy), it is estimated the lake would fill to the point where very little additional sediment is trapped in approximately 40 years, at which time use of the lake as it currently exists would cease.

Installation of a sediment forebay, along with some sediment removal from the main lake and development of a long term maintenance plan, may enable the County to obtain significant pollutant removal credit. The potential cost-benefit of the nutrient removal is provided in Appendix C. Even with the installation and maintenance of sediment forebays, however, the trapping efficiency of the lake will be reduced to a negligible level after approximately 50 years without additional dredging of the main lake.

The option to install beaver dam structures would detain sediment, but only until their capacity has been exhausted. It is estimated that the maximum sediment volume would only detain approximately one years' supply. Benefits to the lake would therefore be minimal.

The options that propose to return the lake to a single thread channel (E and F) would enable the existing sediment influx to pass through to downstream receiving waters. This would likely have impacts in the main stem of Accotink Creek in terms of stream health, potentially in relation to downstream infrastructure (culvert crossings, etc.), and possibly in relation to the Accotink Creek TMDL. The option with the smaller lake does present the opportunity to receive pollutant removal credit for the smaller sub-shed, provided the lake is designed with the necessary design elements to achieve a Level 2 design. This option also provides for open-water recreational opportunities to continue.

References

1) HDR Engineering, Inc., "Final, Lake Accotink Dredge Study (with Appendices)", February, 2002.

2) Brune, Gunnar M., "Trap Efficiencies of Reservoirs", Transactions, American Geophysical Union, Volume 34, Number 3, June, 1953.

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Lake Accotink Sustainability Plan
Summary of Potential Alternatives

Presented by:
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April 27, 2016

Presentation Agenda

1) Brief History of Lake Accotink
2) Review of Previous Studies
3) Sustainability Alternatives
4) Pollutant Removal Credit??
5) Summary

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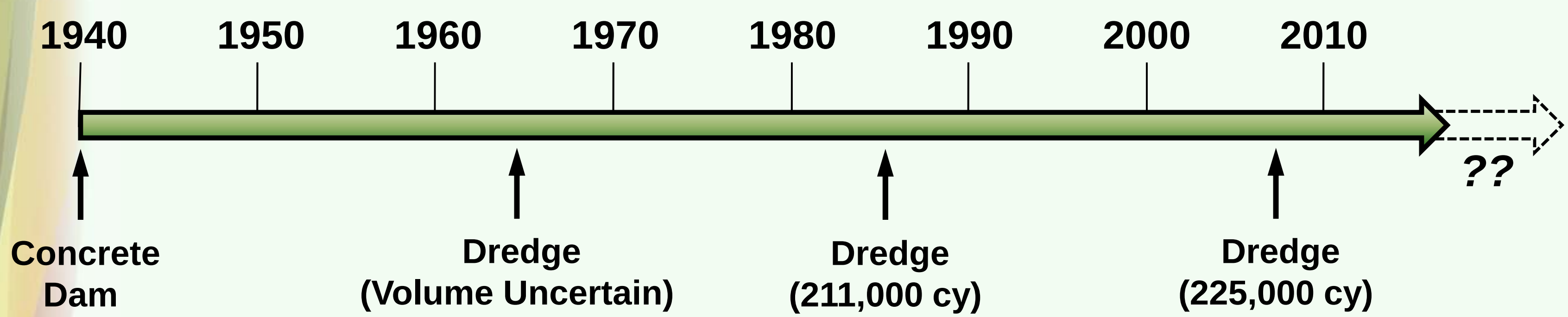
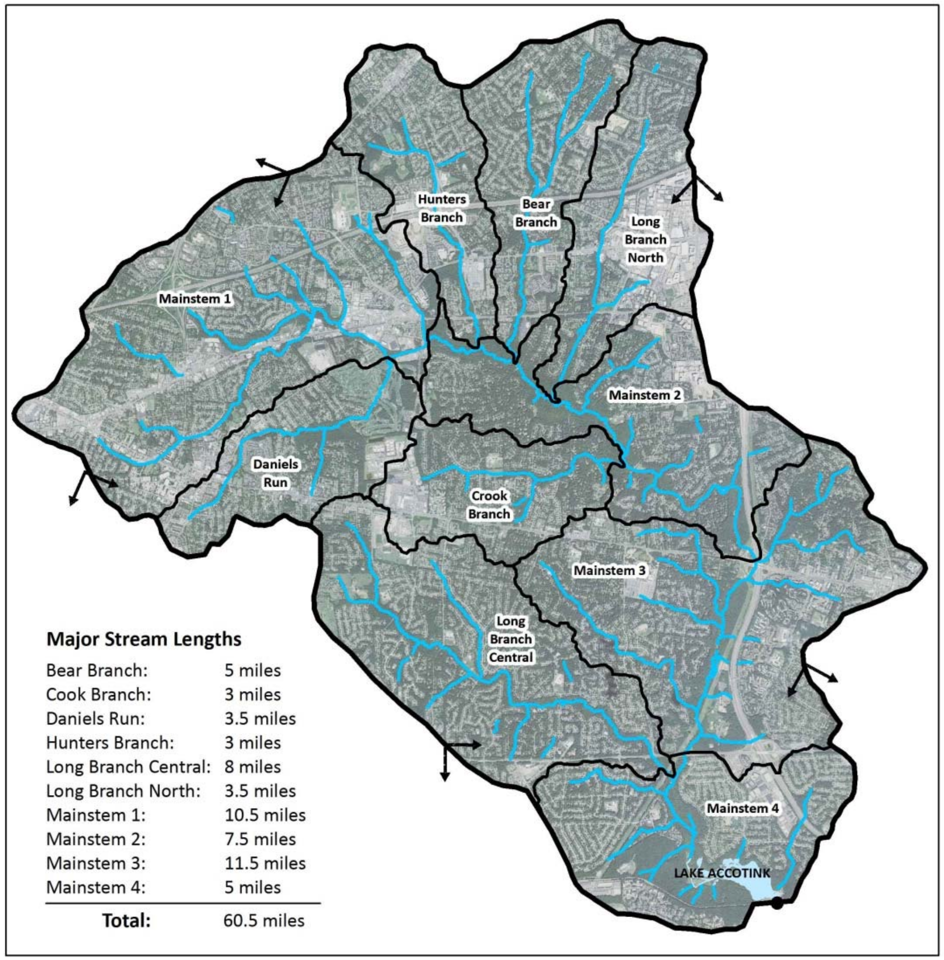
Brief History of Lake Accotink

- Original “Springfield Dam” built in 1918 (removed 1922)
- Current concrete spillway and dam constructed in 1940 for Ft Belvoir
- Acquired by FCPA 1967
- Drainage Area = 31 mi^2
- 30% Impervious Cover



Brief History of Lake Accotink



Lake Accotink
Watershed, Subwatersheds, & Major Streams
WSSI #22647.01
Original Scale: 1" = 1 mile

Aerial Source: NAIP. Summer 2014.

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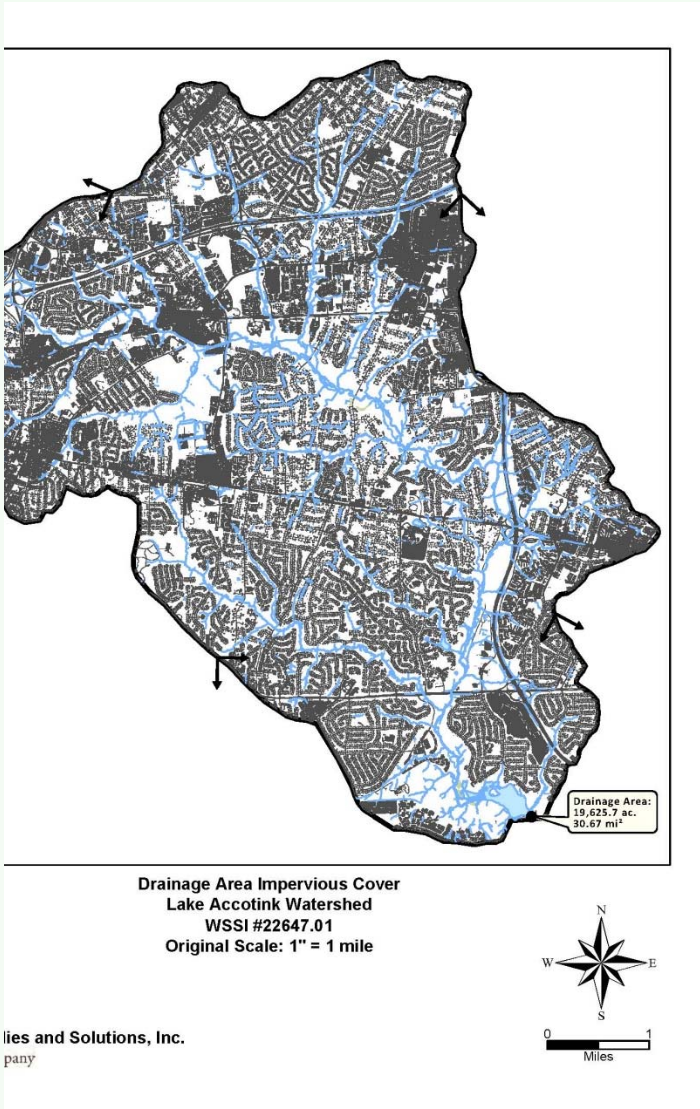
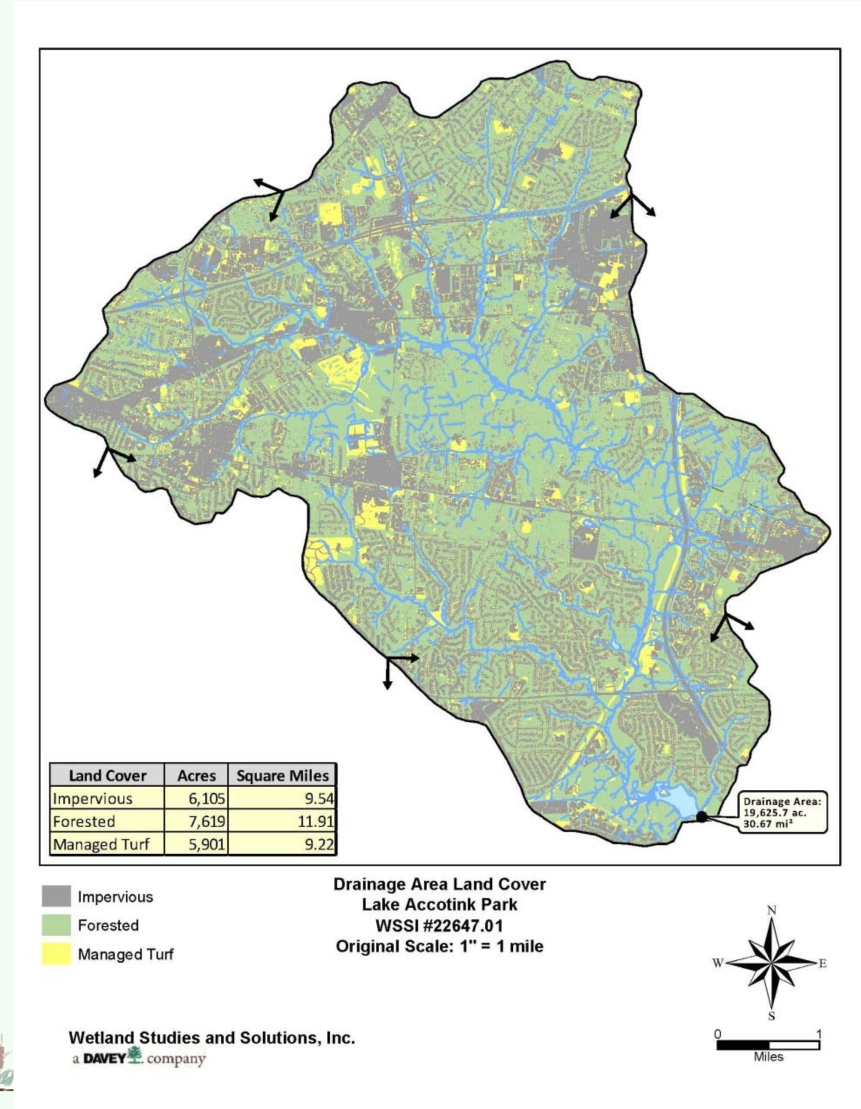
N W E S

0 1 Miles

Brief History of Lake Accotink





Land Cover	Acres	Square Miles
Impervious	6,105	9.54
Forested	7,619	11.91
Managed Turf	5,901	9.22

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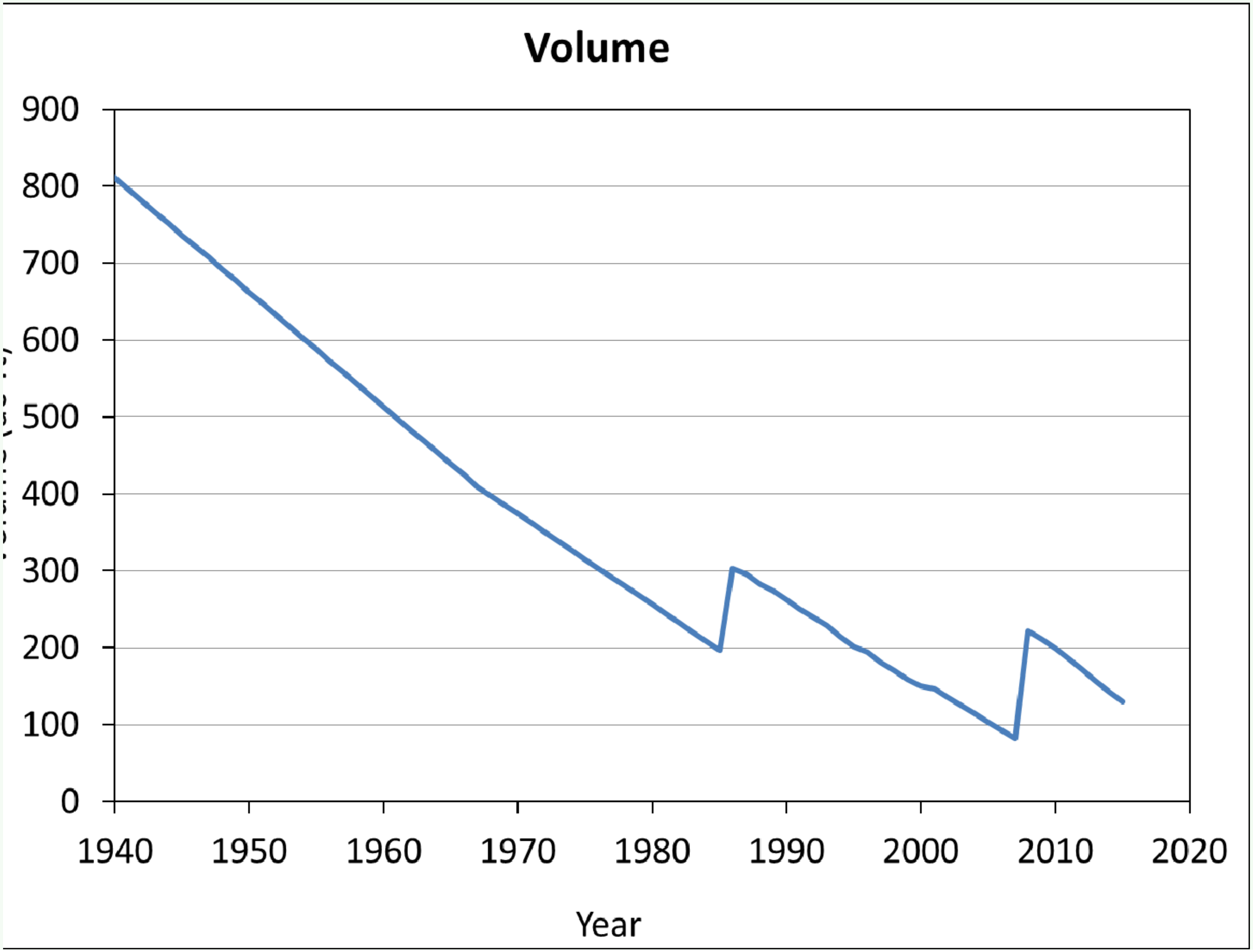
Brief History of Lake Accotink



Brief History of Lake Accotink

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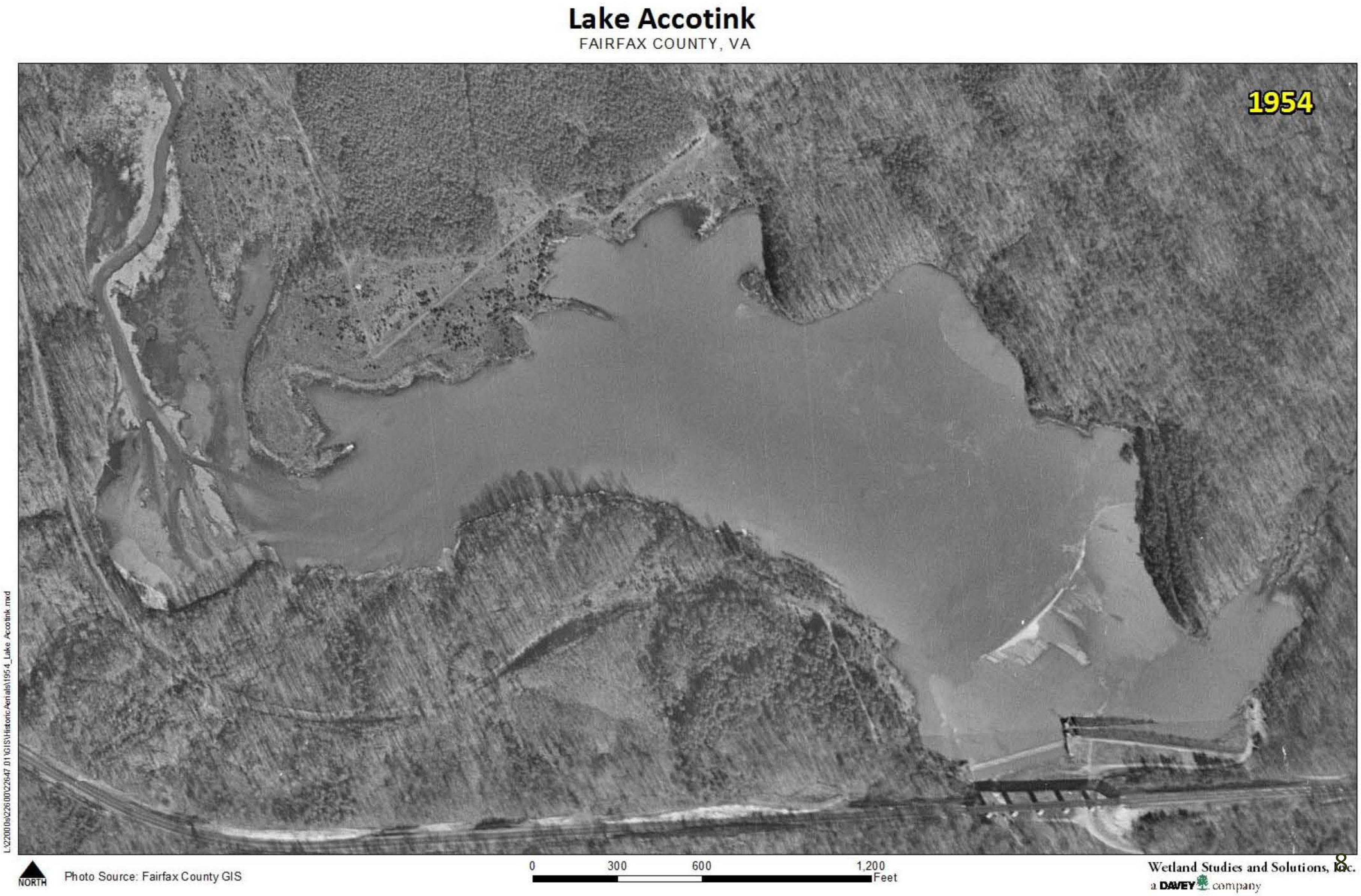

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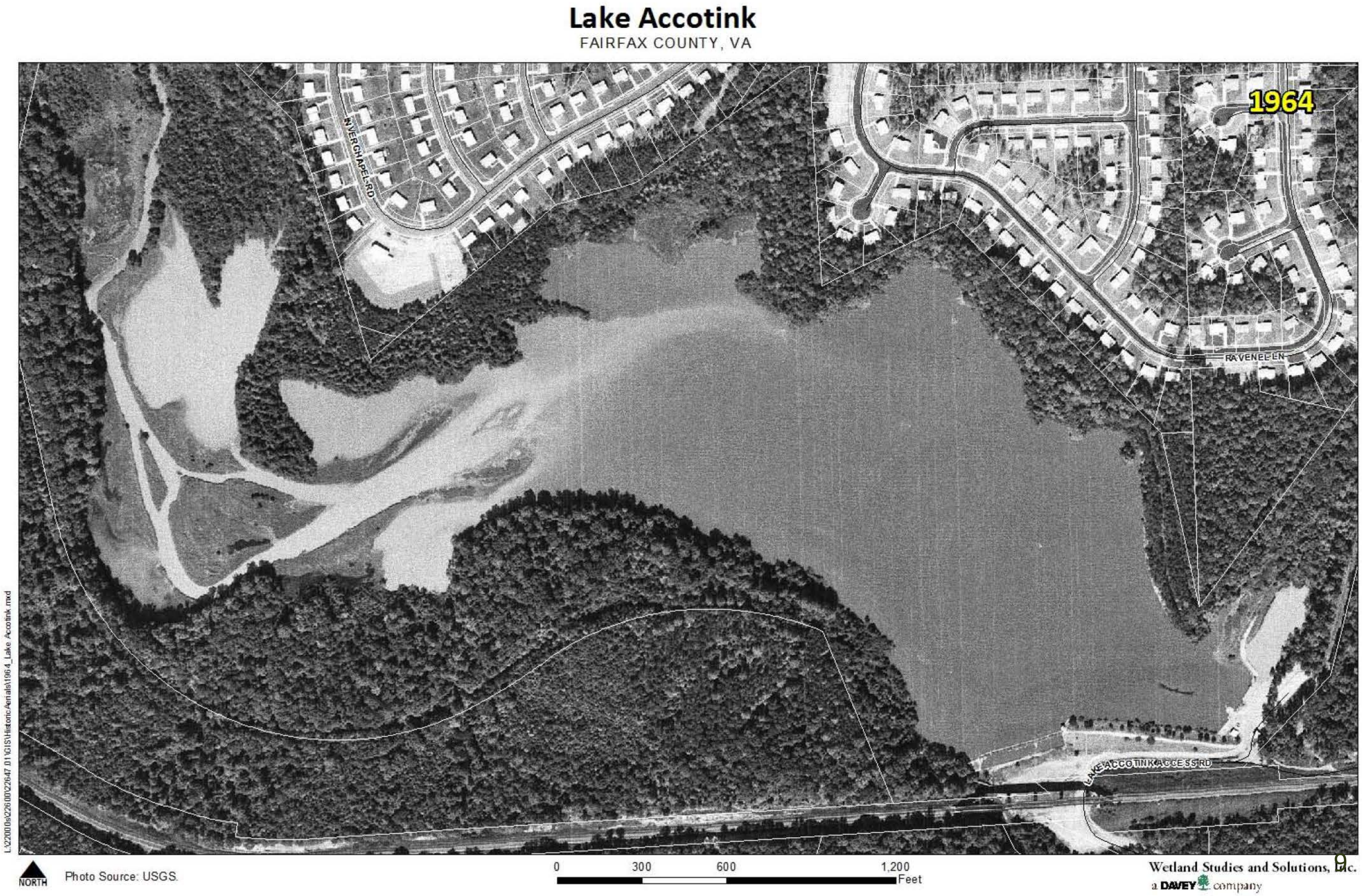

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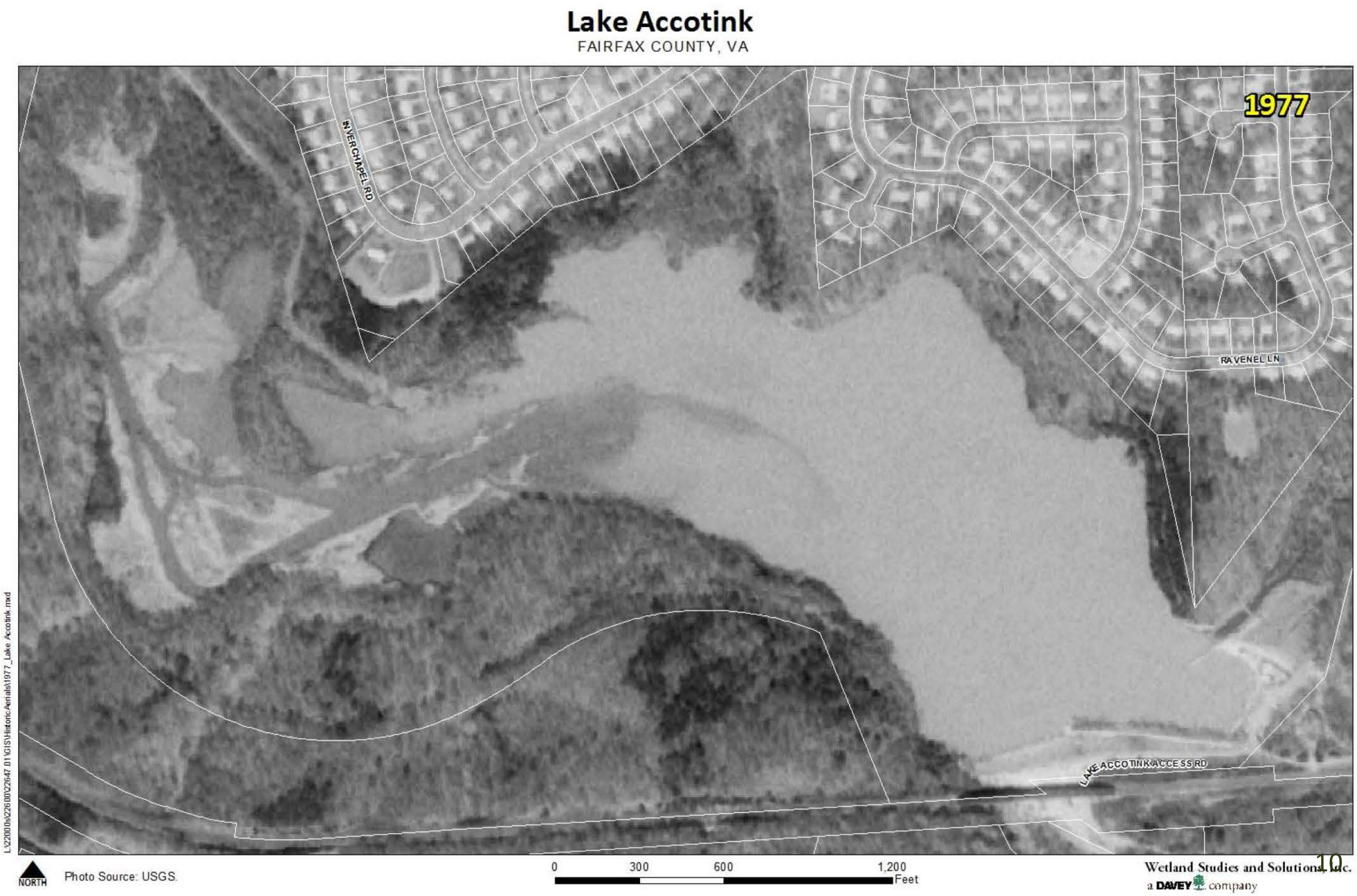

Brief History of Lake Accotink

Brief History of Lake Accotink

Brief History of Lake Accotink

Lake Accotink
FAIRFAX COUNTY, VA

NORTH

Photo Source: Aerials Express

0 300 600 1,200 Feet

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Brief History of Lake Accotink

Brief History of Lake Accotink

Lake Accotink
FAIRFAX COUNTY, VA

NORTH Photo Source: Aerials Express

0 300 600 1,200 Feet

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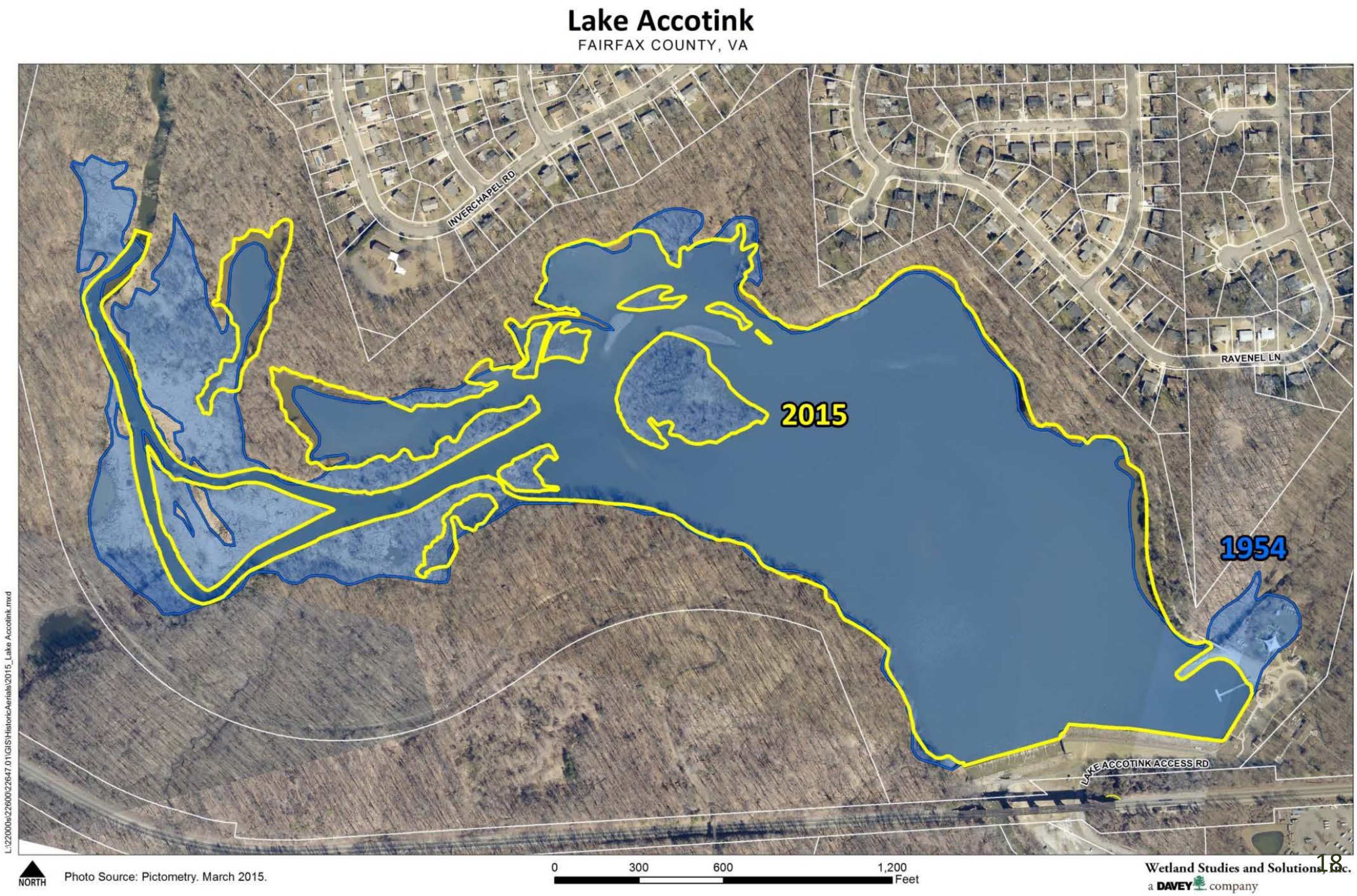
Brief History of Lake Accotink

Brief History of Lake Accotink

Brief History of Lake Accotink



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Diagnostic and Feasibility Study for the Restoration of Lake Accotink

(NUSAC Incorporated, 1982)

eport Highlights

1940: Vol = 811 ac-ft
1967: Vol = 408 ac-ft
1982: Vol = 230 ac-ft

Avg. Sedimentation Rate = **24,000** cy/yr

Avg. Sedimentation Rate = **19,000** cy/yr

*By 1982, capture rate estimated at **<u>17,500</u>** <u>cy/yr</u>*

<u>Note:</u> *Capture rate decreases as the lake volume decreases. Estimated to have reduced from 70% to 40% during this period*

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Diagnostic and Feasibility Study for the Restoration of Lake Accotink

(NUSAC Incorporated, 1982)

Considered Alternative

1) Dredge to remove 111,175 cy (5-ft avg depth, 50 ac pool)
   - Drain and excavate
   - Drag line
   - Hydraulic → ***Cost effective and feasible***

2) Inflow Sediment Basin
   - Too large (7-11 times existing lake based on requirements at the time!)

3) Bypass Flows through Lake
   - Pipe (98" would only handle 2-yr storm)
   - Earthen Berm (concerned about erosion)
   - Sheet Pile Wall → ***Deemed feasible – more study***

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F.X. Browne Sedimentation Studies 1983-1988
(Associated with 1985 Dredge Event)

tudy Highlights

- By 1985: 44 ac, Average Depth = 4 ft
- Resulting from development 1960's – 1970's
- Total Sediment Load = 10,200 tons/year (16,800 cy/yr)
  - *Half other rates* (based on a sediment rating curve)
  - Estimated 30-40 years to refill with sediment after 1985 dredging event.
- 99% of sediment load is from storm events.
- Sedimentation rate dropping since watershed is nearly built out.
- Upstream forebay investigated – 27 acres, Vol = 82 ac-ft ⟶ ***Deemed infeasible***

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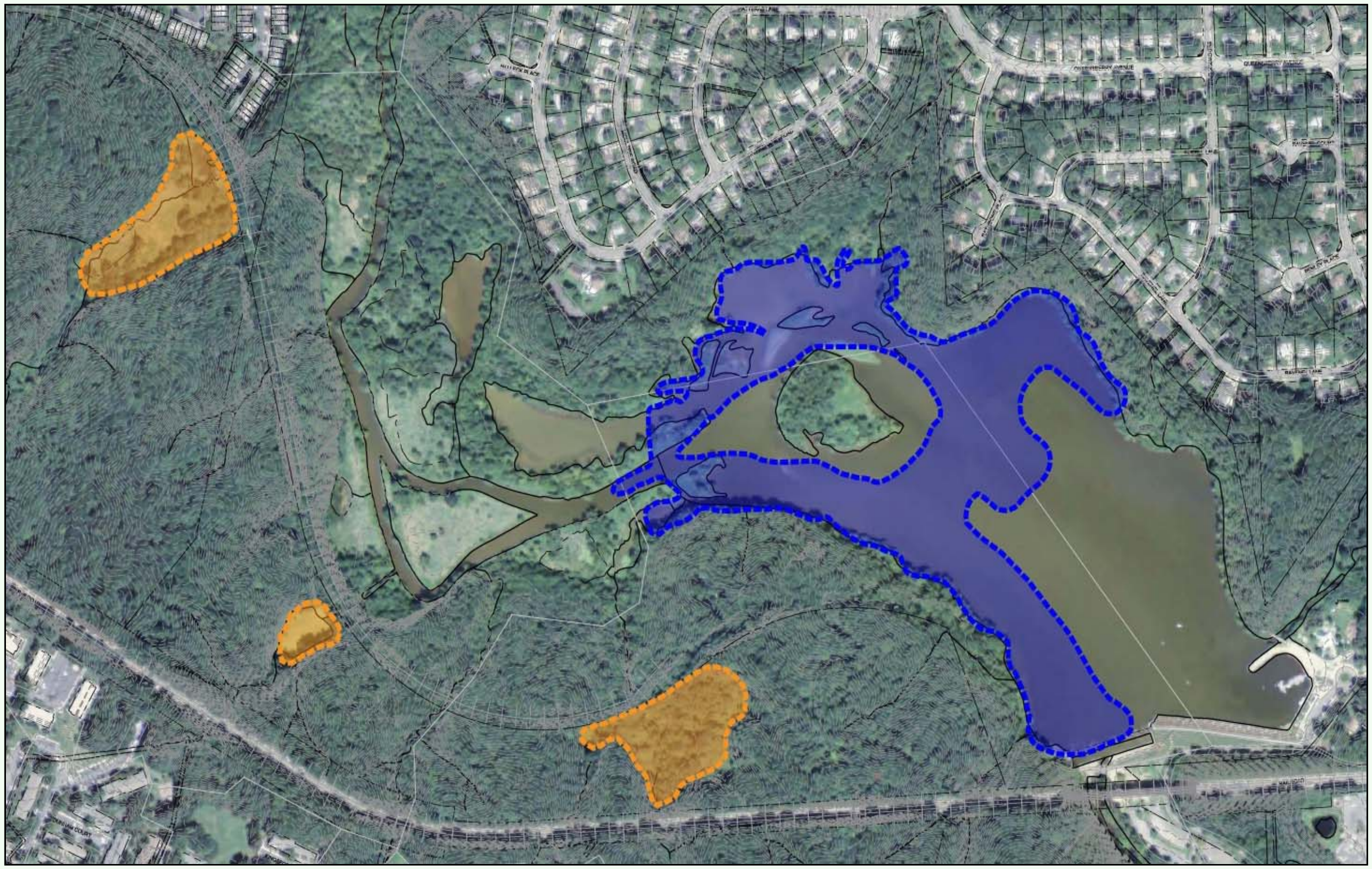
F.X. Browne Sedimentation Studies 1983-1988

(Associated with 1985 Dredge Event)

985 Dredge Summary

211,000 cy removed by hydraulic method

3 onsite sedimentation basins (dams built across upland swales with underdrains)



Lake Accotink – Sediment Management Program Study

(HDR Engineering, Inc., January 2002)

urpose:

To evaluate potential structural and non-structural methods to control sediment, and to identify different maintenance programs to manage sediment deposition in Lake Accotink.

Why??

Because the estimated 30-40 year lifespan of the 1985 dredge event only lasted <u>13 years</u>!

oals:

- Maximize the lifespan of the 2008 dredging event.
- Minimize the scale of future events.
- Maintain the lake quality as a recreational and environmental resource.
- Provide recommendations on how to handle sediment inflow.

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Lake Accotink – Sediment Management Program Study

(HDR Engineering, Inc., January 2002)

Computed sedimentation rates based on 2 methods:

1) Comparison of bathymetric data (1985 post dredge and 2000)
2) Stormwater analysis (suspended concentrations, gage flow rates, modeling)[1].

Conclusions (from 1986-2001):

- Average Sediment Inflow → ***20,600 tons/yr***
- Estimated Capture Efficiency → ***54%***
- Average Sediment Retained → ***17,411 cy/yr***
- Sources:
  - Bank Erosion – 80%
  - Surface Erosion – 20%

- Proposed Dredge Volume of 225,000 cy will be filled in within 13 years.

[1] *Highly dependent on runoff volumes – more runoff results in more sedimentation.*

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Lake Accotink – Sediment Management Program Study

(HDR Engineering, Inc., January 2002)

ternatives to Extend Dredge Timeline:

lternatives to Extend Dredge Timeline:

A Trap sediment before it reaches Lake Accotink

1) Forebay Immediately Upstream
2) In-Lake Forebay
3) Use Existing Upstream Ponds
4) Regional Pond Below Braddock Road
5) Regional Pond for Middle Branch

B Streambank Stabilization

Lake Accotink – Sediment Management Program Study

(HDR Engineering, Inc., January 2002)

asible Alternatives:

1) Forebays – either upstream or in-lake
    - Necessity to make either cost-effective → *On-site disposal*
    - Two new potential sites identified:

2) Stream Restoration – Expensive (60 miles of upstream channels!)

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Final - Lake Accotink Dredge Study

(HDR Engineering, Inc., February 2002)

(Companion to Previous HDR Study – Specifically for Planned Dredging Event)

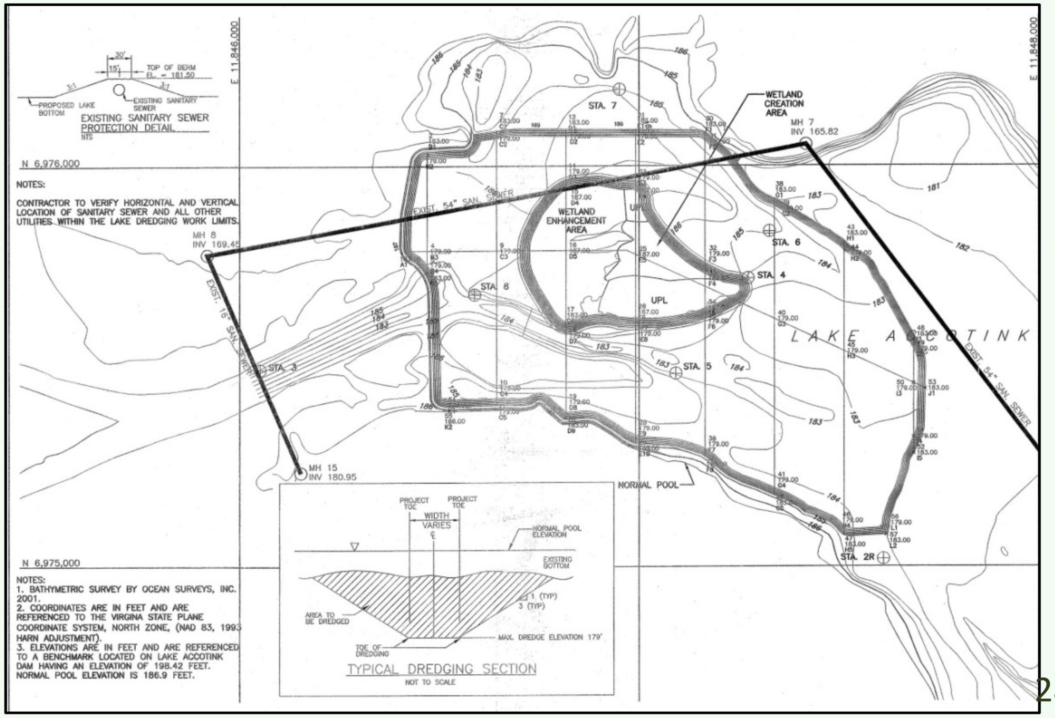
pose:

To restore the lake to an average depth of 5 to 8 ft for recreational boating.

ort Highlights:

1) Remove 225,000 cy, primarliy from the “delta” area

Dredge footprint from design plans



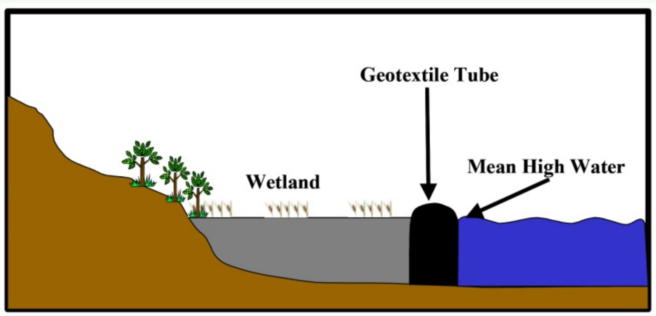
Final - Lake Accotink Dredge Study

(HDR Engineering, Inc., February 2002)

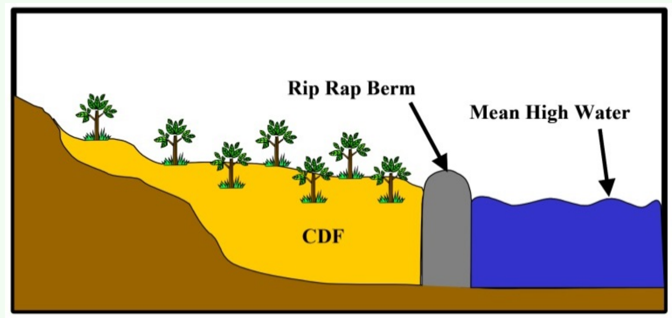
ɔort Highlights:

2) Considered Disposal Alternatives Included:

- In-lake (either wetland or upland creation)
- On-site “upland” areas (previously used basins 1,3, and 4)
- Various off-site disposal areas



Wetland Creation Cross-Section



Upland Creation Cross-Section

3) Settled on off-site at Virginia Concrete site
4) Sediment is largely comprised of sand and low plasticity silts and clays (excellent for hydraulic dredging!)

Presentation Agenda

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2016 Lake Sustainability Study

Where are we now??

<u>Continuing problem of sedimentation and associated loss of lake function:</u>

- Since 2011, **90,895 c**y have been deposited, mostly in the upper region.
- Sedimentation rate = **22,750 cy/yr**.
- Based on the source (primarily streambank erosion), this will continue until the streams have stabilized – could be decades!

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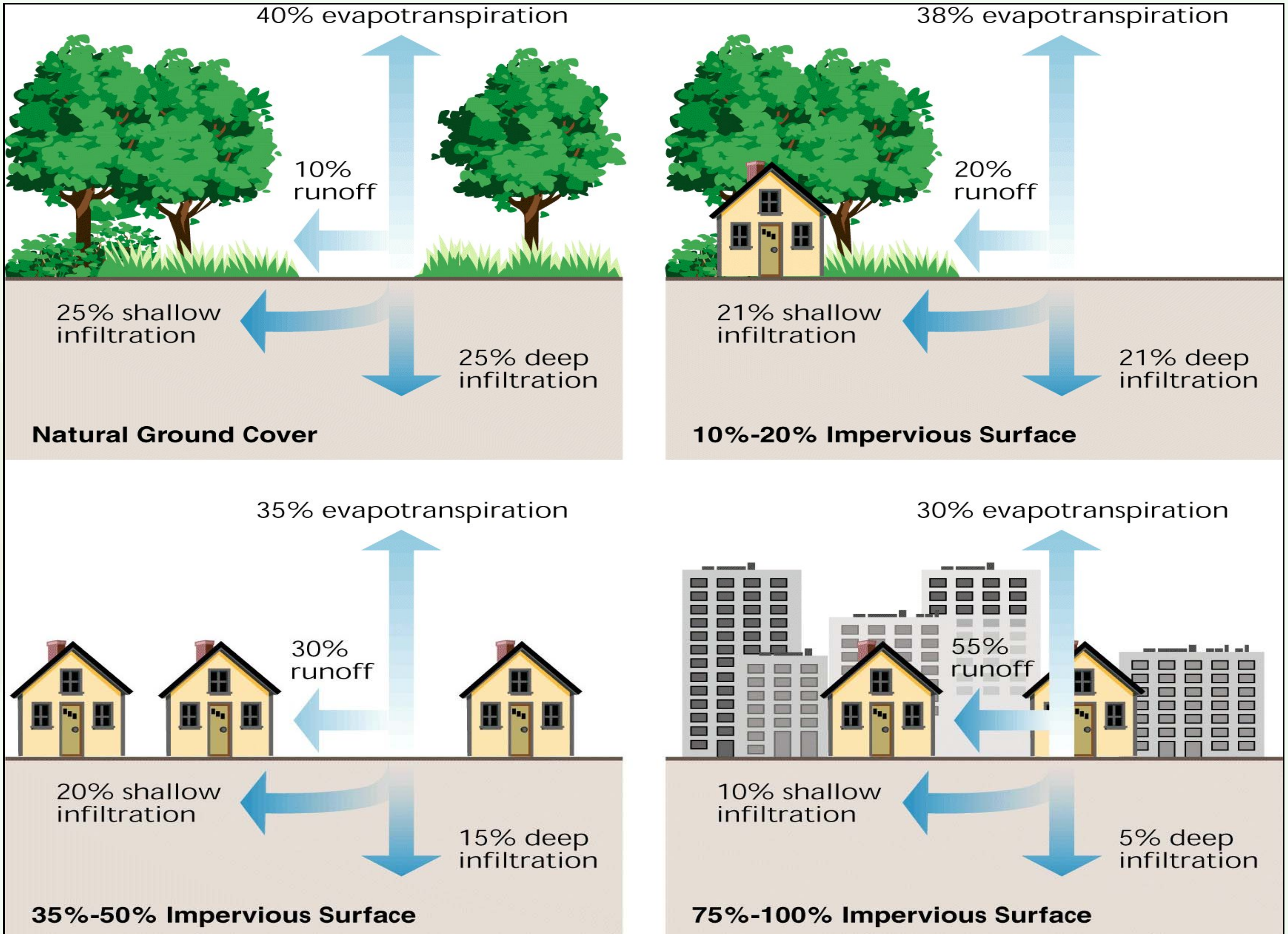
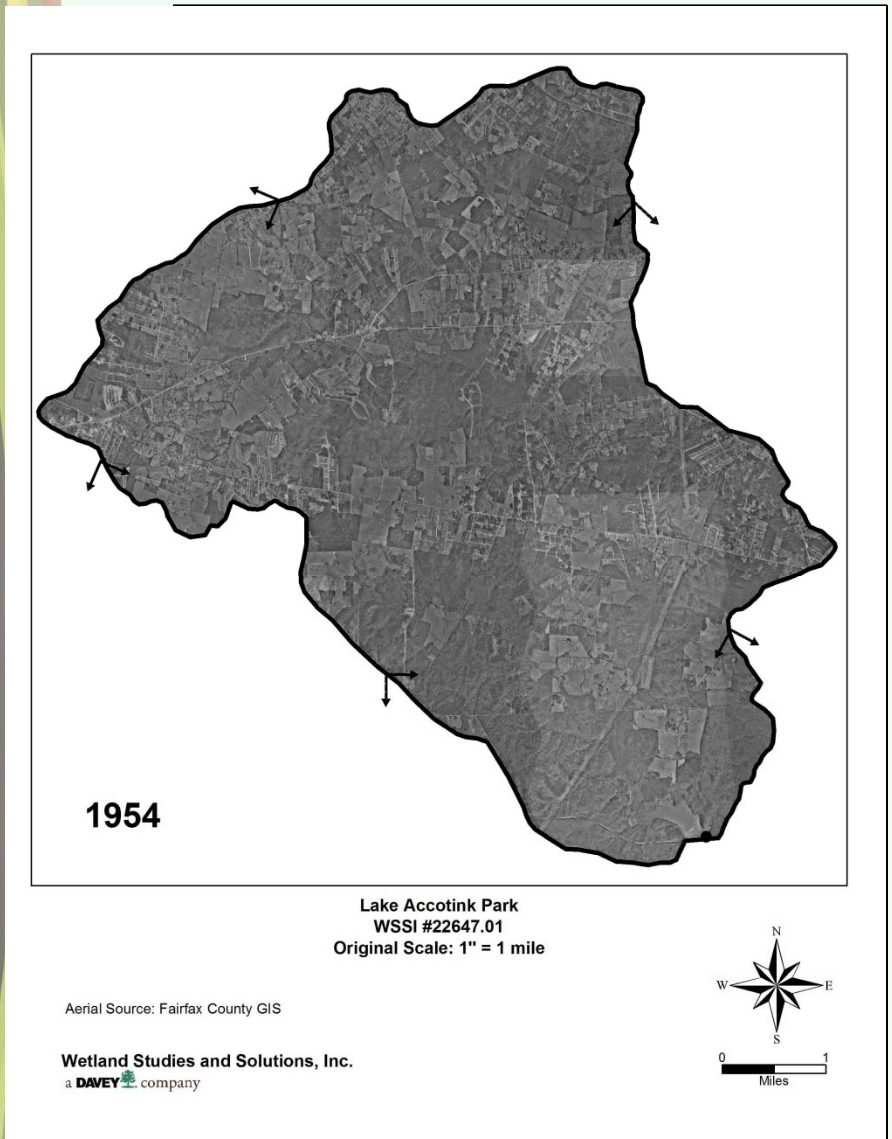
2016 Lake Sustainability Study

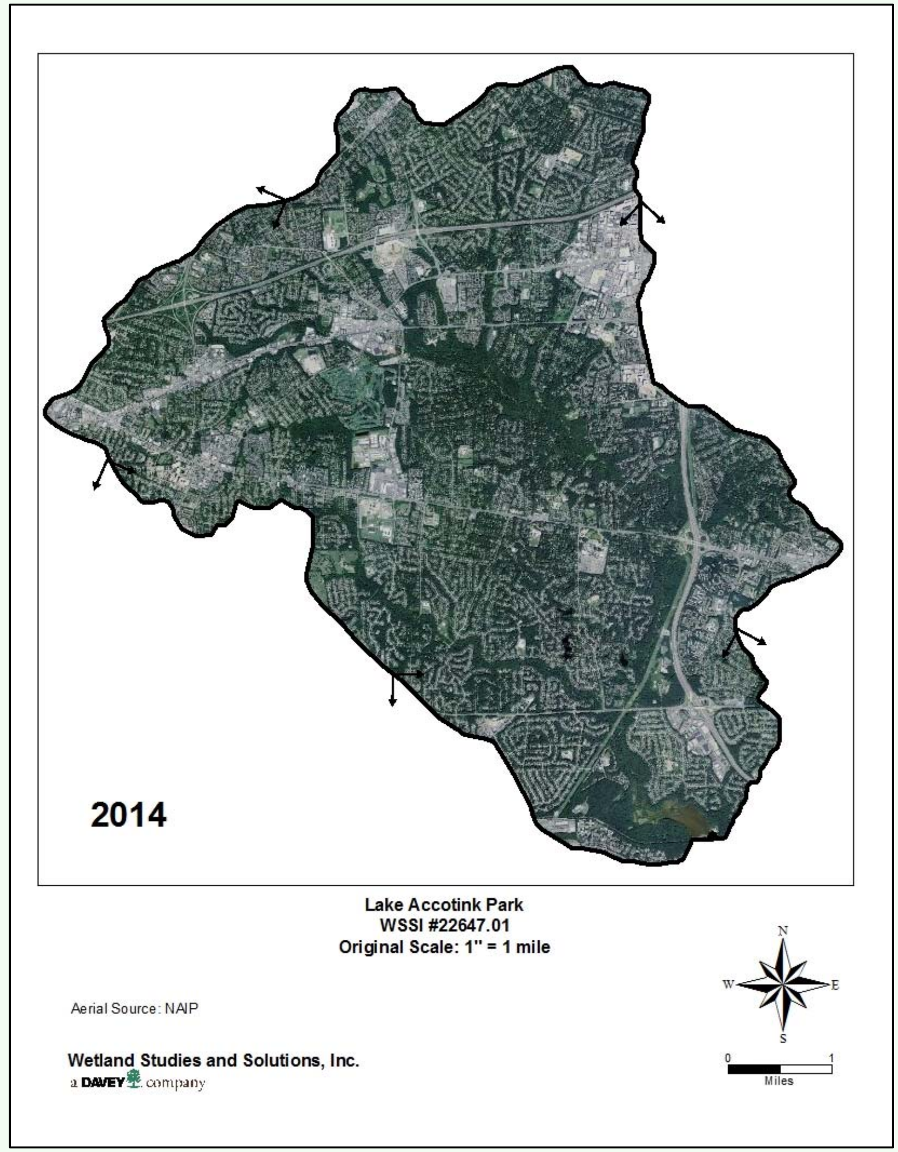
Why are streams eroding??

Source: The Federal Interagency Stream Restoration Working Group



2016 Lake Sustainability Study





2016 Lake Sustainability Study

Typical urban streams? Yes. But these tributaries also drain <u>directly</u> into Lake Accotink.

2016 Lake Sustainability Study

Study Goal

To investigate alternatives for the management of Lake Accotink, taking into account the sediment influx.

Alternatives

A) Construct a sediment forebay within the upper lake.

B) Construct a sediment forebay immediately above the lake.

C) Alteration of the dam to return the lake to a single thread channel, with smaller "off-line" ponds.

D) Same as alternative C but with no ponds (land is reclaimed - reforested, wetland creation, or open space).

E) Construction of smaller "beaver dam" type structures upstream of the lake in line with the stream.

F) Continue with current operation (major dredge every 15-20 years).

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2016 Lake Sustainability Study
In-Lake Forebay

Location

- Around “island” – essentially the 2008 dredge footprint

Configuration

- Surface Area – 13.3 ac
- Depth – 8 ft
- Volume – 94 ac-ft
- Sized for 15% of Tv

Maintenance Dredging

- Average Trap Efficiency ~ 20%. Can be increased with larger volume.
- Requires on-site disposal site to be viable

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2016 Lake Sustainability Study
In-Lake Forebay

Pros

- Reduce sediment influx to main lake, increasing duration between larger dredging events
- Minor wetland impacts (mostly open water)

Cons

- Initial construction would require large, off-site disposal area
- Maintenance dredging would impact main lake
- May reduce BMP credit (reduced lake volume)
- Maintenance dredging requires on-site disposal option to be cost effective. Disposal/reuse of dry material necessary.

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2016 Lake Sustainability Study
Upstream Forebay

Location

- Just upstream of the main pool

Configuration

- Surface Area – 13.3 ac
- Depth – 8 ft
- Volume – 94 ac-ft
- Sized for 15% of Tv

Maintenance Dredging

- Average Trap Efficiency ~ 20% (can be increased with larger volume).
- Requires on-site disposal site to be viable.

2016 Lake Sustainability Study
Upstream Forebay

Pros

- Reduce sediment influx to main lake, increasing duration between larger dredging events
- Maintenance dredging would not impact main lake.

Cons

- Initial construction would require large, off-site disposal area.
- Maintenance dredging requires on-site disposal option to be cost effective. Disposal/reuse of dry material necessary.
- Wetland impacts (~ 5 ac).

2016 Lake Sustainability Study
Potential On-Site Disposal Options

Basin 4 with established wetland

Pros

- Reduced maintenance dredging cost.
- Basin 4 capacity can be increased to 50,000 cy (HDR, 2002)

Cons

- Basin 4 – Wetlands have been established, possibly requiring mitigation. Impacts to long haul road.
- Other sites are not on FCPA property, requiring easements. Capacity uncertain.

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2016 Lake Sustainability Study
Potential On-Site Disposal Options

Pros

- Reduced maintenance dredging cost
- Immediately adjacent to forebays
- Will provide open space meadow habitat

Cons

- Wetland impacts likely based on exact footprint – mitigation or creation may be required

2016 Lake Sustainability Study
On-Site Disposal Options for Forebays

2016 Lake Sustainability Study
On-Site Disposal Options for Forebays

2016 Lake Sustainability Study
Single Channel with Smaller Lake

Location

- Stream along southern shore, smaller “off-line” lake/wetlands along northern shore.

Configuration

- Lake Surface Area – 18.5 ac
- Depth – 8 ft
- Stream Length – 2,500 lf, 90 ft wide (bankfull), 6 ft deep, transports sediment

Maintenance Dredging

- Not necessary

2016 Lake Sustainability Study
Single Channel with Smaller Lake

Pros

- Eliminate sediment deposition and need for dredging
- “Off-line” lake water quality should be greatly enhanced as storm flows bypass
- Depicted grading “balances” (no offsite disposal)

Cons

- Significant earth moving operation with “wet” sediments – additional study necessary
- Will no longer trap sediments/pollutants – regulatory implications?
- Expensive implementation cost
- Likely a multi-year project

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2016 Lake Sustainability Study
Single Channel with Smaller Lake

2016 Lake Sustainability Study
Single Channel with Smaller Lake

2016 Lake Sustainability Study
Single Channel with Smaller Lake

2016 Lake Sustainability Study
Single Channel with Smaller Lake

2016 Lake Sustainability Study
Single Channel with Smaller Lake

2016 Lake Sustainability Study
Single Channel with Smaller Lake

2016 Lake Sustainability Study
Single Channel with Reclaimed Land

Location

- Stream along southern shore, reclaimed remaining footprint (reforest, wetlands, open space)

Configuration

- Stream Creation Length – 3,300 lf

Maintenance Dredging

- Not necessary

2016 Lake Sustainability Study
Single Channel with Reclaimed Land

Pros

- Eliminate sediment deposition and need for dredging
- No significant excavation

Cons

- Channel creation in "wet" sediments – additional study necessary for best method
- Will no longer trap sediments/pollutants – regulatory implications?
- No open water

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2016 Lake Sustainability Study
In-line "Beaver Dams"

Location

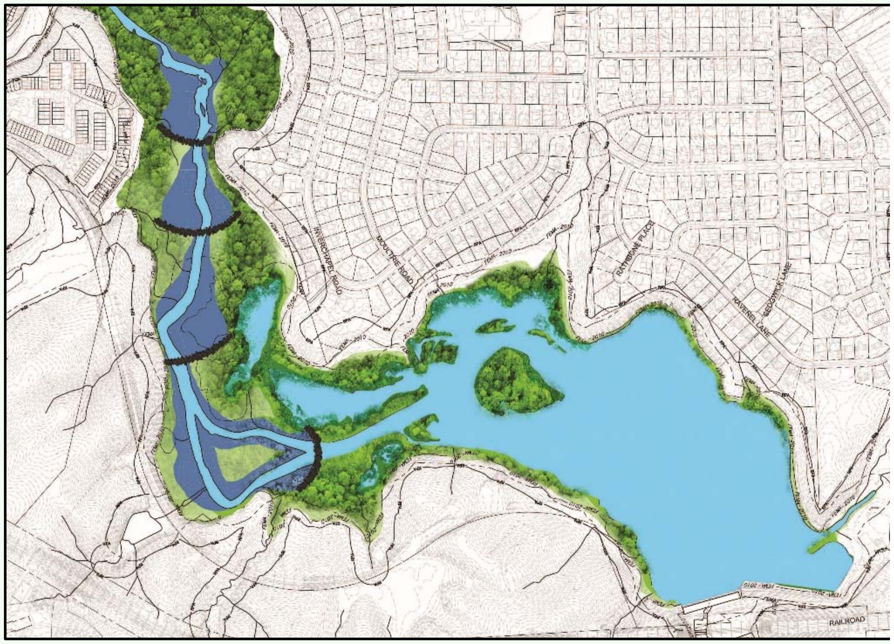
- Upstream and within Accotink Creek

Configuration

- Sheet pile "walls" within the channel to encourage sediment deposition. Rough capacity estimate of up to12,000 cy per structure over time (variable)

Maintenance Dredging

- Reduced frequency in main lake



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2016 Lake Sustainability Study
In-line "Beaver Dams"

Pros

- Sediments trapped upstream
- Inexpensive to install
- Can install more or less as desired within the Accotink main channel throughout the County

Cons

- Will convert existing forested wetland areas to "beaver swamps" over time
- Limited capacity – but will also reduce erosion in vicinity of the structure

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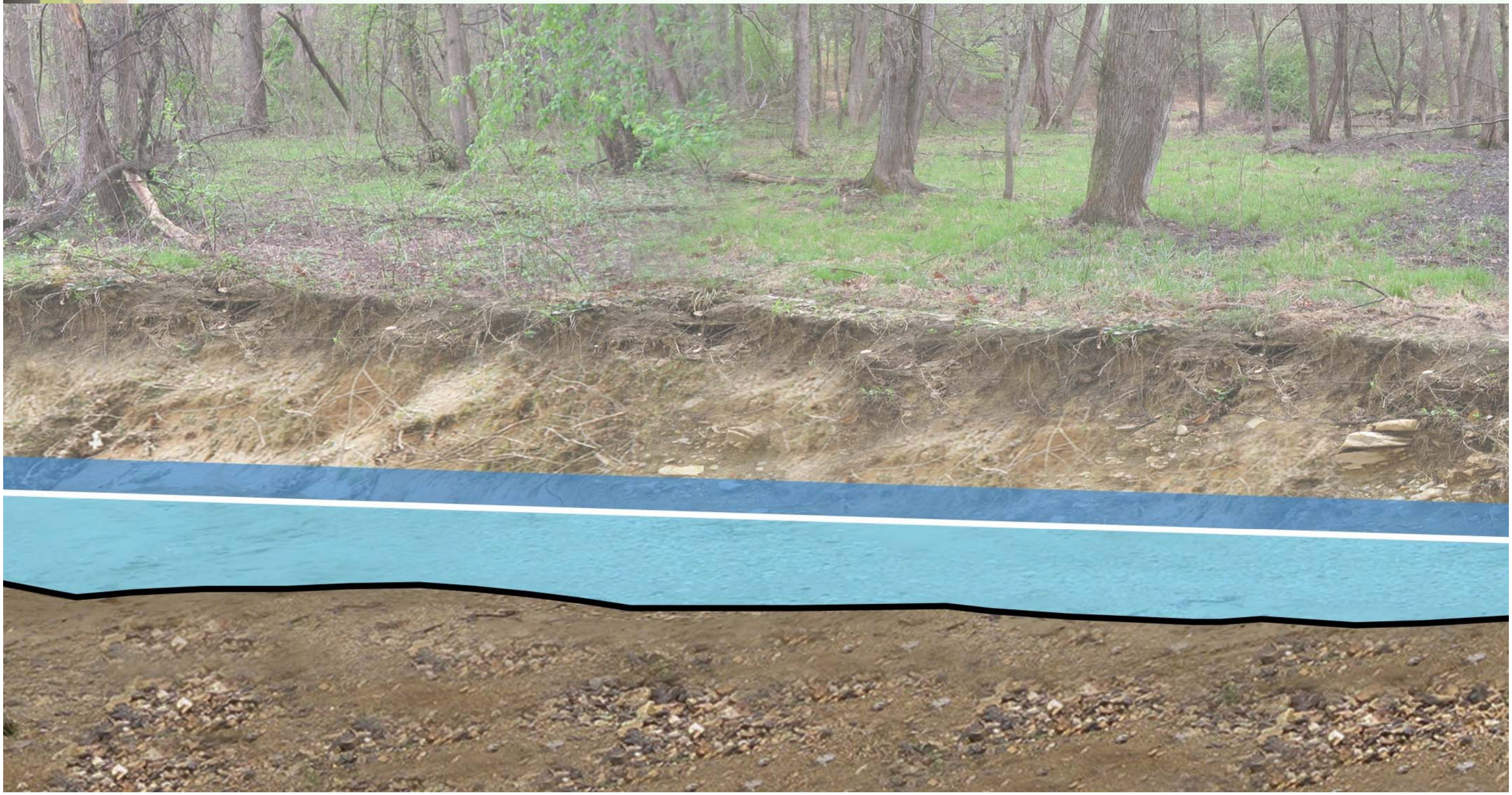
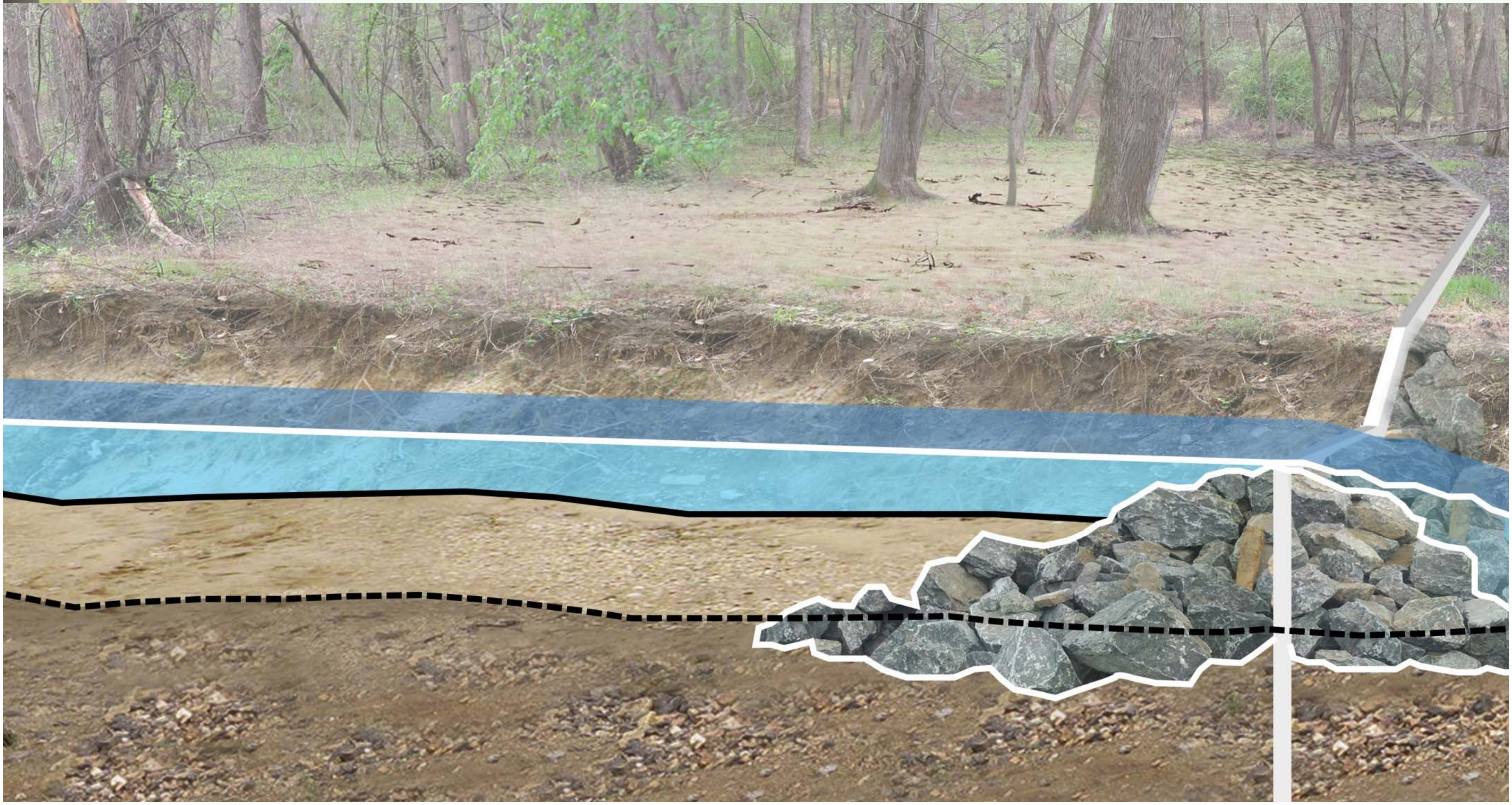
2016 Lake Sustainability Study
In-line "Beaver Dams"



2016 Lake Sustainability Study
In-line "Beaver Dams"



2016 Lake Sustainability Study
No Action

Continue with dredging on ~ 15-20 year cycle

Pros

- Only requires action every 15 years

Cons

- Lake water quality/usefulness reduced for longer periods
- Need offsite disposal area

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ginia Stormwater BMP Clearinghouse

ecification No. 14: Wet Ponds

Stormwater Functions Summary

Table 14.1. Summary of Stormwater Functions Provided by Wet Ponds

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR) [1]	0%	0%
Total Phosphorus (TP) EMC Reduction[2] **by BMP Treatment Process**	50% (45%) [3]	75% (65%) [3]
Total Phosphorus (TP) Mass Load Removal	50% (45%) [3]	75% (65%) [3]
Total Nitrogen (TN) EMC Reduction[2] **by BMP Treatment Process**	30% (20%) [3]	40% (30%) [3]
Total Nitrogen (TN) Mass Load Removal	30% (20%) [3]	40% (30%) [3]
Channel Protection	Yes; detention storage can be provided above the permanent pool.	
Flood Mitigation	Yes; flood control storage can be provided above the permanent pool.	

[1] Runoff Reduction rates for ponds used for year round irrigation can be determined through a water budget computation.

[2] Change in event mean concentration (EMC) through the practice.

[3] Note that EMC removal rate is slightly lower in the coastal plain if the wet pond is influenced by groundwater. See **Section 6.2** of this design specification and CSN Technical Bulletin No. 2. (2009).

Sources: CWP and CSN (2008), CWP (2007)

Design Criteria

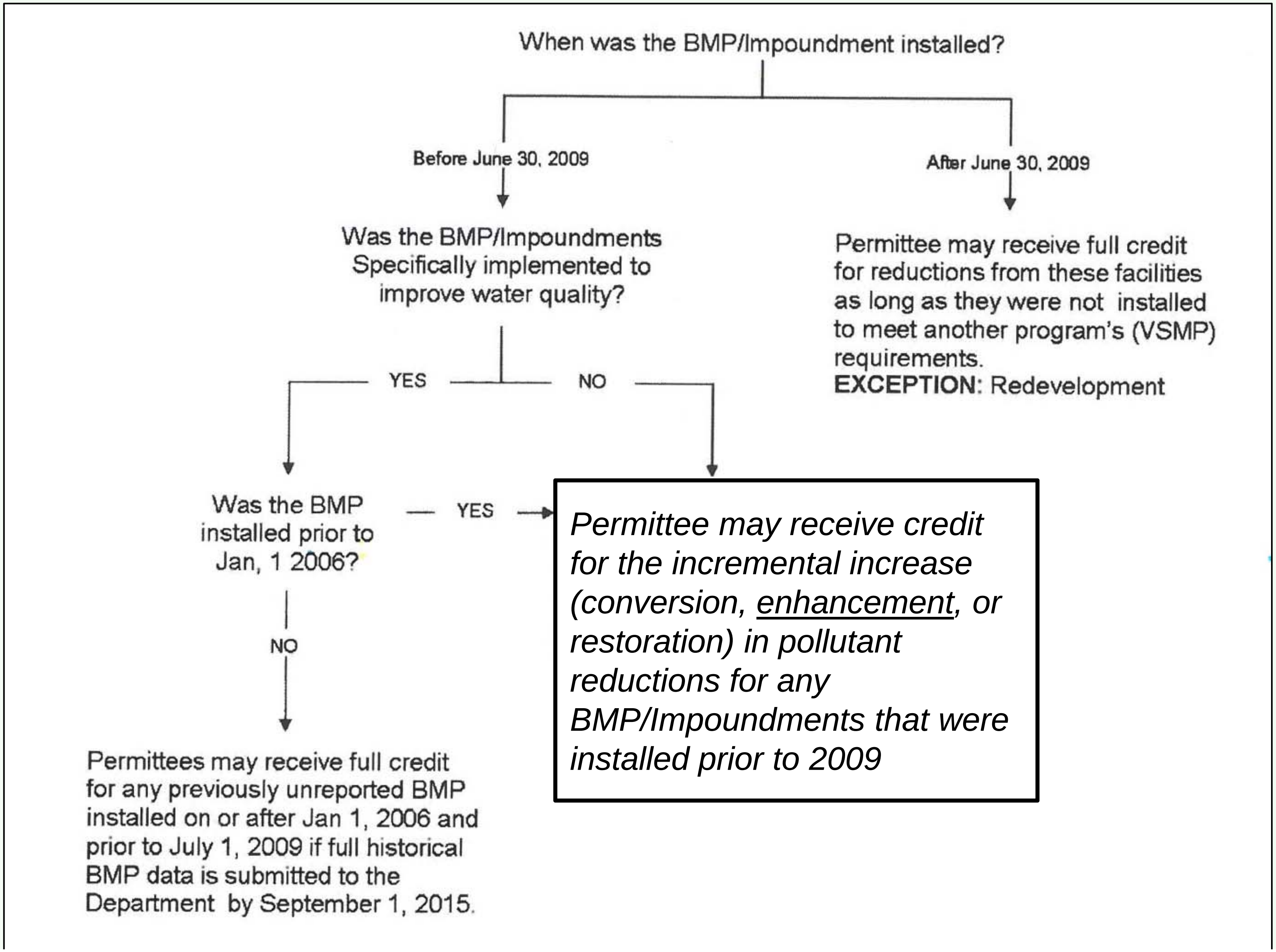
Table 14.2. Level 1 and 2 Wet Pond Design Guidance

Level 1 Design (RR:0 [1]; TP: 50 [5]; TN:30 [5])	Level 2 Design (RR:0 [1]; TP: 75 [5]; TN:40 [5])
Tv = [(1.0)(Rv)(A)/12] – volume reduced by upstream BMP	Tv = [1.5 (Rv) (A) /12] – volume reduced by upstream BMP
Single Pond Cell (with forebay)	Wet ED [2] (24 hr) and/or a Multiple Cell Design [3]
Length/Width ratio OR Flow path = 2:1 or more	Length/Width ratio OR Flow path = 3:1 or more
Length of shortest flow path / overall length [4] = 0.5 or more	Length of shortest flow path/overall length[4] = 0.8 or more
Standard aquatic benches	Wetlands more than 10% of pond area
Turf in pond buffers	Pond landscaping to discourage geese
No Internal Pond Mechanisms	Aeration (preferably bubblers that extend to or near the bottom or floating islands

[1] Runoff volume reduction can be computed for wet ponds designed for water reuse and upland irrigation.
[2] Extended Detention may be provided to meet a maximum of 50% of the Treatment Volume; Refer to Design Specification 15 for ED design
[3] At least three internal cells must be included, including the forebay
[4] In the case of multiple inflows, the flow path is measured from the dominant inflows (that comprise 80% or more of the total pond inflow)
[5] Due to groundwater influence, slightly lower TP and TN removal rates in coastal plain (**Section 7.2**) and CSN Technical Bulletin No. 2. (2009)

Sources: CSN (2009), CWP and CSN (2008), CWP (2007)

2016 Lake Sustainability Study
Pollutant Removal Credit



2016 Lake Sustainability Study
Pollutant Removal Credit

What is “Enhancement”???

Requires

1) Increase in storage above baseline storage

2) Installation of a sediment forebay
   - Level I requires 15% of Tv (570 ac-ft) = 86 ac-ft (VRRM)

3) Will require regular maintenance dredging

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2016 Lake Sustainability Study
Pollutant Removal Credit

Per April 2015 draft Revisions to DEQ Memo No. 14-2012,
"Guidance for Meeting Special Condition for Chesapeake Bay TMDL Requirements"

Procedure

Compute runoff depth treated for both **Existing** and **Enhanced** conditions:

$$\boldsymbol{RD = \frac{RS(12)}{IA}}$$

Where: *RD = Runoff Depth (in)*
RS = Runoff Storage (ac-ft)
IA = Impervious Area (acres)

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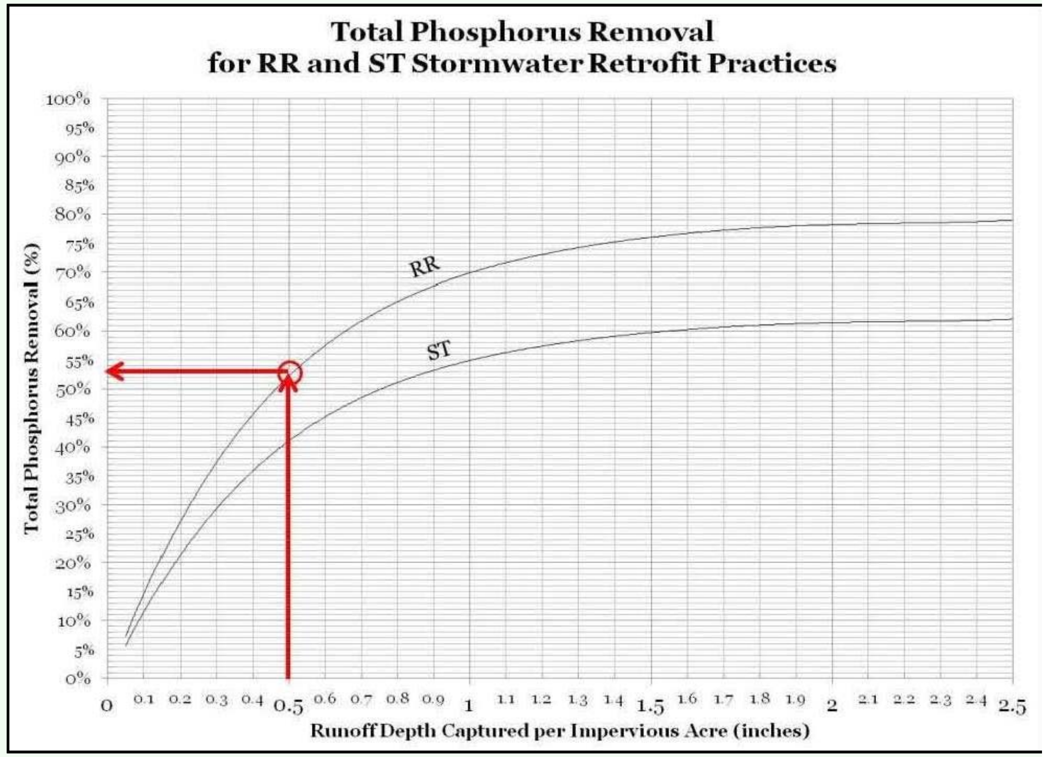
2016 Lake Sustainability Study
Pollutant Removal Credit

<u>Existing Conditions</u>

RS = 200 ac-ft (assumed)
RD = 0.39 in
TP Removal = <u>23%</u>

<u>Enhanced Conditions</u>

Remove 100,000 cy (Example)
RS = 262 ac-ft
RD = 0.51 in
TP Removal = <u>27%</u>



Note: IA = 6,105 ac (both scenarios)

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Pollutant Removal Credit

- Net Increase in TP Removal = 4% (27% - 23%)
- However, must reduce by upstream BMP treatment.

From *Accotink Creek Watershed Management Plan:*

- 500 ac treated
- Assume 40% removal = 154 lbs TP removed
  Total Accotink watershed loading = 15,500 lbs
- TP Removal by upstream BMP's = 1%
- Enhanced Lake Accotink Removal = **3%** or about 460 lbs TP/yr
  (for this example of removing 100,000 cy)

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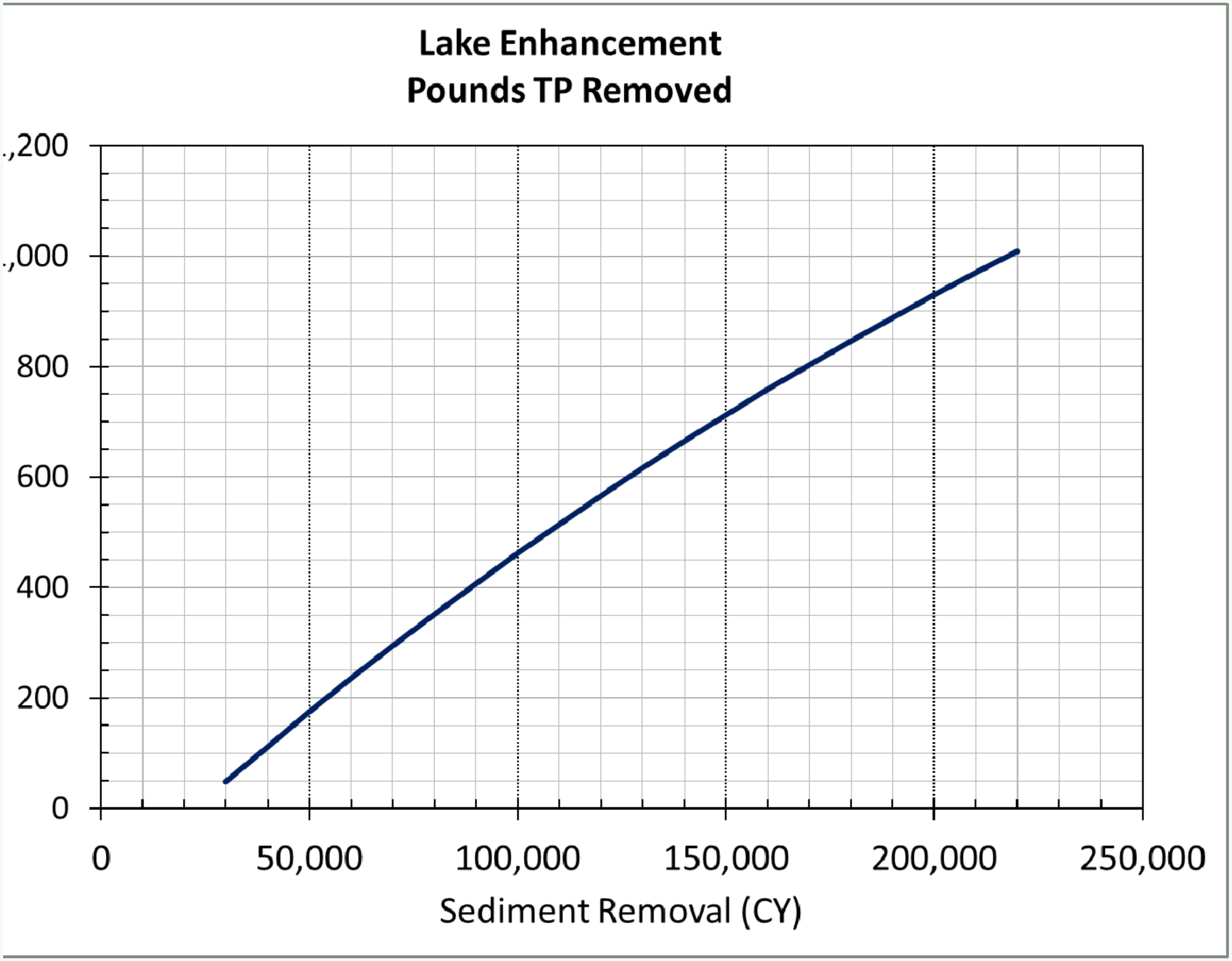
2016 Lake Sustainability Study
Pollutant Removal Credit



2016 Lake Sustainability Study
Pollutant Removal Credit

TP Removal Credit Summary

- Potential for TP removal credit to offset dredging expense

- Will likely require
  - dredging to obtain volume above “baseline” storage
  - Installation of a minimum 90 ac sediment forebay
  - Regular maintenance dredging

- Additional factor – new Accotink TMDL (requirements are uncertain)

Close coordination DEQ required!!

Wetland Studies and Solutions, Inc. a DAVEY company

Presentation Agenda

1) Brief History of Lake Accotink
2) Review of Previous Studies
3) Sustainability Alternatives
4) Pollutant Removal Credit??
5) Summary

Summary

1) Lake Accotink accumulates approximately 20,000 cy /year and will continue to do so for the foreseeable future.

2) The current dredging cycle is approximately 15-20 years based on this rate.

3) The primary sediment source is streambank erosion (approximately 80%).

4) Several lake sustainability options were examined:
   - Installing a sediment forebay within the current lake pool.
   - Installing a sediment forebay immediately upstream of the lake pool.
   - Removing a portion of the dam to provide a single thread channel and a smaller “off-line” lake.
   - Removing the dam to return the valley to a single thread channel and reclaim the current lake area (reforest, open space, and/or wetlands).
   - Install “beaver dam” type structures in Accotink Creek upstream of the lake to trap sediment.
   - Continue with the current dredging cycle.

Summary

5) Each option is quite different, but some common challenges/considerations:
   - Forebay alternatives require on-site disposal options. All dredging alternatives require ultimate off-site disposal.
   - Many alternatives involve wetland impacts – on-site mitigation may be possible. Coordination with regulators (DEQ, COE) important.
   - Dam removal alternatives may have regulatory implications regarding the pending Accotink TMDL, as well as the Chesapeake Bay TMDL.
   - Dam removal alternatives will require careful study to adequately handle accumulated sediments in development of the design.
6) Procedures for obtaining pollutant removal credit for "enhancing" the performance of the lake are available. Again, close coordination with DEQ/COE necessary.
7) **Stakeholder input is essential!!**

hesitate to ask this….but any questions??

Appendix B

Lake Accotink Sustainability Plan
Trapping Efficiency Estimation

Per the conference call on November 30, 2016, available data during the specified timeframe (1996 - 2015) was reviewed in order to compute an estimate of the sediment trapping efficiency of Lake Accotink during this period. The methodology that was employed was based on that described in the report *Final – Lake Accotink Dredge Study*, February, 2002 (developed by HDR). A description of the methodology and associated data is provided below.

Methodology

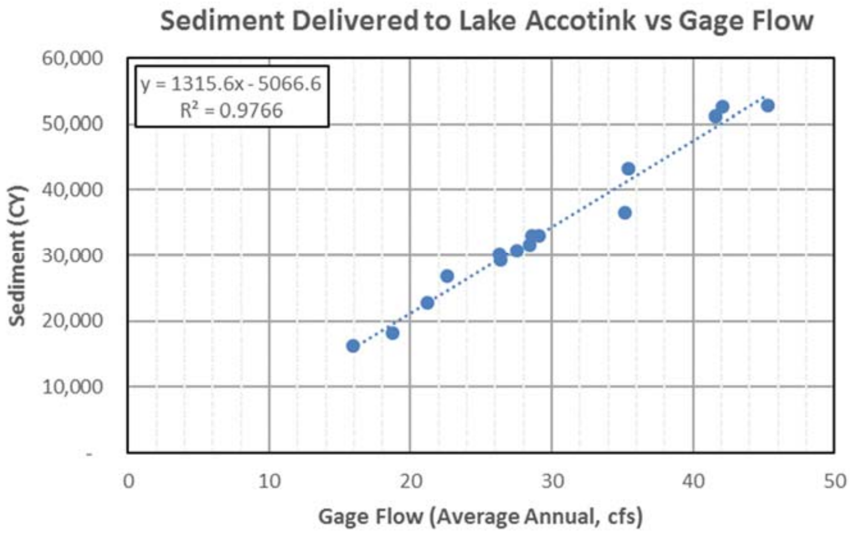
The methodology is based on a correlation of the sediment concentrations with stormwater flow rates. Data was obtained from USGS Gage 01654000 located approximately 800 ft upstream of Braddock Road. The gage data was adjusted to account for the difference in contributing drainage areas between the gage and Lake Accotink.

To determine an estimate of the sediment capture efficiency in Lake Accotink, a sedimentation curve developed by Brune (Brune, 1953) that computes the trapping efficiency for reservoirs based on the average annual inflow to the lake and the lake capacity. There are three curves associated with this methodology, with the upper curve deemed to be the most representative of Lake Accotink.

To test the applicability of their methodology, HDR compared the amount of sediment captured by the lake as predicted by the sediment modeling results to the volume measured through bathymetric surveys (conducted in 1986 and again in 2001). From this comparison, the computed sedimentation based on the model was deemed to be representative of the manner in which Lake Accotink captures sediment.

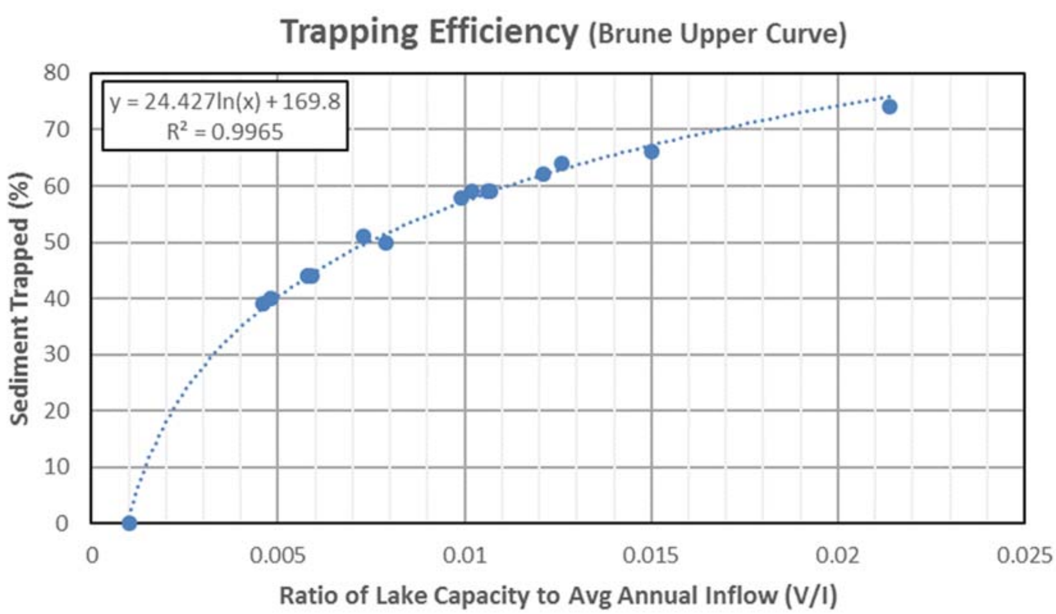
To facilitate the analysis to assess whether this model continues to provide a reasonable estimate of the capture efficiency in Lake Accotink for the more recent time period (1996 - 2015), the upstream gage data vs the corresponding sediment accumulation in Lake Accotink for the period from 1986 - 2001, as presented in the HDR study was plotted (Figure 1):

Figure 1



The upper Brune curve was also digitized to facilitate the analysis (Figure 2):

Figure 2



Results

Utilizing the available gage data for the period from 1996 - 2015, along with the sedimentation and trapping efficiency curves, results in the following estimation of the trapping efficiency during the period from 1996 - 2015 (note the dredging event in 2008 has been accounted for):

Table 1

A	B	C	D	E	F	G	H	I	J	K
Year	Inflow (I)			Lake Vol.	Sed. Inflow into lake			Trapping	Sediment (ac-ft)	
	Gage, cfs	Lake, cfs	Lake, ac-ft	(V) ac-ft	cy	ac-ft	V/I	Efficiency	Retained	Passed
1996	45	56	40,471	194	54,530	34	0.00480	0.39	13	20
1997	35	43	31,448	181	41,243	26	0.005757	0.44	11	14
1998	42	52	37,612	170	50,320	31	0.004515	0.38	12	19
1999	23	28	20,191	158	24,666	15	0.007826	0.51	8	7
2000	29	35	25,551	150	32,560	20	0.005877	0.44	9	11
2001	25	31	22,424	209	27,955	17	0.0093	0.56	10	8
2002	11	13	9,649	199	9,142	6	0.020616	0.75	4	1
2003	51	63	45,474	195	61,897	38	0.004281	0.37	14	24
2004	41	50	36,540	181	48,741	30	0.004943	0.40	12	18
2005	35	43	31,269	169	40,979	25	0.005389	0.42	11	15
2006	37	45	32,877	158	43,347	27	0.0048	0.39	11	16
2007	27	33	24,122	147	30,455	19	0.006103	0.45	9	10
2008	37	45	32,877	258	43,347	27	0.007857	0.51	14	13
2009	23	29	20,816	244	25,587	16	0.011745	0.61	10	6
2010	31	39	28,053	235	36,243	22	0.008369	0.53	12	11
2011	48	59	42,794	223	57,951	36	0.005208	0.41	15	21
2012	32	39	28,142	208	36,375	23	0.007392	0.50	11	11
2013	34	42	30,644	197	40,058	25	0.006421	0.46	12	13
2014	48	59	42,615	185	57,688	36	0.004346	0.37	13	23
2015	33	41	29,840	172	38,874	24	0.005764	0.44	11	14

An explanation for the derivation of some of the values in Table 1 follows. As stated above, the gage flow (column B) was obtained from the USGS gage above Braddock Road. This term was scaled up to account for the increased drainage area to Lake Accotink (a factor of 1.234), as described in the HDR study. The starting lake volume (Column E) was also obtained from the HDR analysis (194 ac-ft). The sediment inflow to the lake was computed using the curve in Figure 1. Note that this curve provides the volume of sediment delivered to the lake based on the recorded gage flow. This volume was computed assuming a density of 45 lbs/cf (as suggested in the HDR study) to reflect the uncompacted nature of the sediments deposited in the lake. This is the same procedure followed in the HDR study. Comparison of the results of this computation for the overlapping years compares favorably with those provided in Appendix A of the HDR study.

The flow rate term for the Brune curve (V/I, Column H) was derived by dividing the lake volume (Column E) by the average annual inflow (Column D). The Trapping Efficiency (Column I) was then computed using the Brune curve (Figure 2), followed by the computation of the amount of sediment retained by the lake (Column J). The lake volume for the subsequent year was then computed by reducing by the volume of captured sediment and the process repeated.

Moving through the computations up to year 2001, the above procedure was followed without adjustment. However, it appears from the HDR study that the analysis they performed comparing data from 1986 - 2001 included bathymetric data from only the upper ¾ of the lake. While the entire lake was surveyed in 2001, that was not the case in 1986. The assumption was made that the majority of the sediment would have been deposited in this upper region. Based on that analysis, the conclusion was reached that the sediment model provided a reasonable way to quantify sedimentation in Lake Accotink.

However, since a full lake survey was conducted in 2001 and those performed in 2011 and 2015 were also of the entire lake, the sedimentation analysis from 2001 - 2015 was performed using the entire lake volume (from the HDR report) as a starting point. As depicted in Table 1, the sediment model predicts the lake volume within approximately 11% of the surveyed lake volumes in 2011 and 2015 (252 and 196 ac-ft, respectively). Further, if the surveyed lake volume of 252 ac-ft from 2011 is inserted to replace the predicted lake volume, the model accurately estimates the surveyed lake volume of 196 ac-ft in 2015 (within 1 ac-ft). As a result, it was determined that the sediment model does continue to provide a reasonable estimate of the trapping efficiency in Lake Accotink.

With the suitability of the model confirmed, the focus of this analysis can be determined – the estimated capture efficiency in Lake Accotink over the past 20 years compared to the more recent estimation over the past 4 years. From Table 1, the longer term, average capture efficiency is estimated at 47% for the period from 1996 - 2015. For the period from 2011 - 2015, the average efficiency as predicted by the model (with the surveyed volume in 2001 inserted) is 43%. However, if the actual lake volume in 2011 of 252 ac-ft is inserted, the average capture efficiency from 2011 - 2015 is also 47%.

To provide additional information for consideration, the long term annual inflow rates and sediment capture values for the period of analysis (1996 - 2015) were plotted and are provided below. Figure 3 indicates the stream flow has an upward trend. The two prominent spikes in sediment capture (Figure 4) can be attributed to a very dry year (2002) and to the dredging event of 2008 that increased the lake capacity.

Figure 3

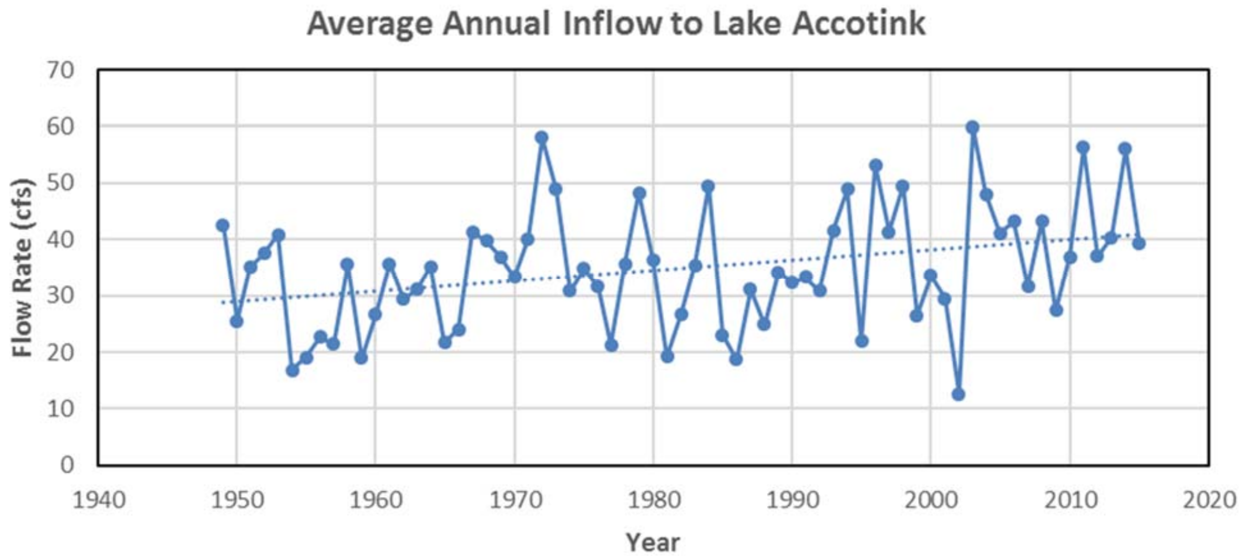
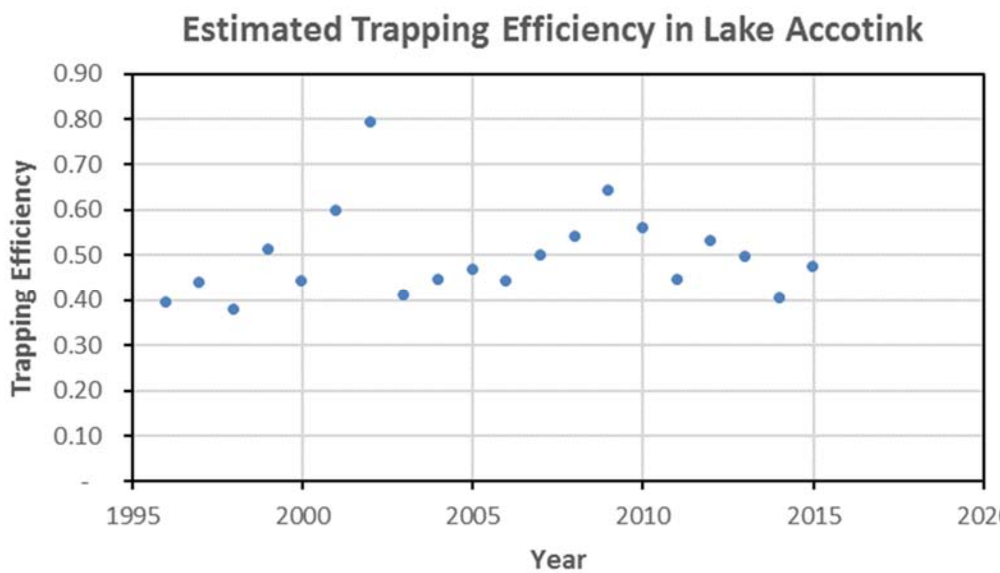


Figure 4



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Appendix C

Lake Accotink Sustainability Plan
Cost Estimates

As part of the review of the potential long term management options for Lake Accotink, Wetland Studies and Solutions, Inc. (WSSI) has developed ballpark cost estimates for each of the six potential management options under consideration:

A) The "do nothing" option.
B) The current plan of dredging on approximately a 15-year interval.
C) Construction of a sediment forebay (either just upstream or within the existing footprint of the lake).
D) Installation of "beaver dam" structures in line with Accotink Creek upstream of the lake.
E) Removing the existing dam and returning Accotink Creek to a single thread channel within the current lake footprint.
F) Removal of a portion of the existing dam to create a smaller lake along with a single thread channel.

Note that no design work has been performed, thus the estimated costs include a 30% contingency. While some of the tasks are more easily estimated than others, major unknowns (e.g. available disposal sites, sediment analyses, potential archeological/permitting issues, etc.) warrant inclusion of a significant contingency. In addition, it is assumed that dredging will be performed hydraulically and that a suitable disposal/dewatering area will be located in sufficient proximity to the lake. Costs associated with the dredging options also assume the material will be removed from the dewatering site and disposed of at a suitable location once they have sufficiently dewatered. The conservative assumption (higher cost) is that it may be easier to find a temporary, nearby location for dewatering only. If a beneficial use for the material can be found, or if the dewatering area also serves as the final disposal area, significant savings could potentially be realized. This was not considered in this analysis.

A brief discussion of the assumptions and total costs for each of the management options is provided in the following sections, followed by a summary that provides annualized costs to enable a direct comparison between the options. Note that more detail on the estimated costs for each option is provided in this Appendix.

Option A – "Do Nothing"

As the name suggests, this option is the least expensive as costs would be limited to annual maintenance of the existing dam. However, this option would also require upgrade and/or more significant maintenance of the dam at some point in order to keep it in compliance with dam safety regulations. Based on discussions with our sub-consultant AECOM, it is reasonable to assume that a similar type of repair that was performed in 2005 would be required on an estimated 30-year cycle.

Estimated Annual Maintenance Cost: ***$13,000***

Estimated Repair Cost (30 yr Cycle): ***$4,700,000***

<u>Option B – Continue with Current Dredging Method</u>

As mentioned above, this option assumes hydraulic dredging to an as yet undetermined disposal/dewatering area, followed by removal for final disposal once the sediments have dewatered. This is viewed as the most practical method of removal given the significant quantities. Removal of the sediments from the dewatering area would require approximately 35,000 truck-trips (assuming 10 cy/truck). Previous studies have identified several possible locations that would have to be explored further. This option would also require dam repairs and annual maintenance, as discussed for Option A.
Total Estimated Dredge Cost: ***$29,275,459*** *(removal of 350,000 cy @ approximately* ***$84/cy)***

Estimated Annual Maintenance Cost: ***$13,000***

Estimated Repair Cost (30 Yr Cycle): ***$4,700,000***

<u>Option C – Install In-lake Forebay</u>

This option is similar to the Option B, with the addition of the sediment forebay to be used for an annual sediment removal program. The initial volume of material to be dredged for this option is 500,000 cy (150,000 cy of which is attributable to the installation of a sediment forebay). As with the previous option, hydraulic dredging is assumed with the initial volume deposited at an offsite area for ultimate removal after dewatering (for this case, 50,000 truck trips would be required for final disposal).

This option also includes costs associated with establishing an on-site disposal area to accommodate the annual removal of sediment from the sediment forebay (12,000 cy). As with the initial dredging operation of the entire lake, the plan is to allow the material from the forebay to dewater (on-site), then truck it off for final disposal. This would require approximately 1,200 truck-trips, which would impact the park and/or immediately adjacent neighborhoods. Costs for establishing an on-site disposal area are considered (either previously used basin 4 located south of the lake or a newly a newly established basin north of the lake). The cost to fortify the existing trail to Rolling Road (assuming the previously utilized basin is selected as the on-site disposal area) is also included in this analysis. Annual dam maintenance and periodic repair costs are also necessary for this Option (same as Options A and B).

This is the only option that also represents the possibility of obtaining credit for the significant sediment (and associated nutrient) removal represented by the lake. This potential benefit is quantified in more detail in the Summary section.

Total Estimated Dredge Cost: ***$45,043,460*** *(removal of 500,000 cy @ approximately* ***$90/cy****)*

Estimated Annual Dredging Cost: ***$776,472*** *(removal of 12,000 cy @ approximately* ***$65/cy****)*

Estimated Annual Maintenance Cost: ***$13,000***
Estimated Repair Cost (30 yr Cycle): ***$4,700,000***

Option D – Install of "Beaver Dam" Structures

The installation of the beaver dams provides limited overall relief from the sedimentation of Lake Accotink, as discussed in the *Water Quality Analysis*. For the purposes of this costing exercise, the installation of four structures was assumed. This option would involve wetland impacts, which have been included. Maintenance includes nominal costs to inspect and perform minor repairs if necessary, which would diminish over time.

Total Cost: ***$932,874***

Estimated Annual Maintenance Cost: ***$19,500***

Option E – Single Channel With Reclaimed Land (Remove Dam)

Creation of a single thread channel with removal of the dam assumes all material will be utilized on site, eliminating the major expense of offsite disposal. However, there is an uncertainty in the manipulation of the "wet" sediments to create the single thread channel at this conceptual stage of the project. As such, a premium for handling the wet material was added to the cost. There is also additional investigative work necessary for determining the best dam removal option. This analysis considered several options and includes the cost for the currently suggested option, based on the limited information available at this time. Details on the estimated dam removal costs and options are attached (developed by AECOM). It is assumed any wetland impacts would be self-mitigating.

Also provided are the annual maintenance costs that might be expected for the first five years after the completion of construction, primarily to ensure the vegetation has been adequately established. This short term cost was assumed as part of the initial construction for the purpose of computing the annualized cost (presented in the Summary section). While the intent is for the new channel to be stable and self-maintaining after this initial establishment period, costs for routine annual maintenance have also been included. As the channel becomes more established, this cost should diminish over time.

While there is no pollutant removal credit that can be realized with this option, there is the considerable long-term cost benefit of the one-time construction cost with no further dredging.

Total Cost: ***$11,176,815***

Estimated Annual Maintenance Cost: ***$26,000***

Option F – Single Channel with Smaller Lake (Modification of Existing Dam)

The cost for this option is very similar to that for the previous option. The primary difference is for the excavation of the smaller lake. Sediments for this option would also remain within the current lake footprint. This Option also assumes any wetland impacts would be self-mitigating.

Total Cost: ***$12,932,706***

Estimated Annual Maintenance Cost: ***$26,000***

Summary

To provide a means of comparison between each of the options, above costs are summarized below in Table 1. Estimated annualized costs are also provided.

Table 1 – Cost Summary

Option	Construction	30% Contingency	Total Estimated Cost[2]	$/cy w/o Contingency	$/cy with Contingency	Estimated Annual Maintenance[2]	Assumed Lifespan (yrs)	Estimated Annualized Cost[3]
A[1]	$7,346,000	$2,204,000	$9,550,000	-	-	$13,000	30	$237,000
B[1]	$22,520,000	$6,756,000	$29,276,000	$64	$84	$13,000	15	$2,691,000
C[1]	$34,649,000	$10,395,000	$45,044,000	$69	$90	$776,000	30	$4,695,000
D	$718,000	$215,000	$933,000	-	-	$19,500	60	$291,000
E	$8,818,000	$2,645,000	$11,463,000	-	-	$26,000	60	$440,000
F	$10,168,000	$3,050,000	$13,218,000	-	-	$26,000	60	$503,000

[1] Assumes resurfacing/repair in 30 years and again in 60 years. Cost for last repair/resurfacing used as the basis ($4.7M, obtained from DCR report ("Costs, Funding, and Prioritization of Virginia Dams to Meet Minimum Public Safety Stanfards", 12/12/11)

[2] Assumes 30% contingency

[3] Assumes 3% interst rate

From the above, it is clear that the options that include continued dredging operations are significantly more expensive than the other, non-dredging options. Should further study locate a more cost effective means of disposal than assumed in this analysis, these costs could be reduced. Regardless, the dredging options will likely remain the more expensive of the potential management options under consideration.

Another factor to be considered for the option that proposes to enhance the current function of the lake through installation of a sediment forebay and adoption of a regular maintenance dredging operation (Option C) is the pollutant removal credit that could potentially be achieved. To assess this credit in terms of $/lb of phosphorus removal, it is necessary to compute the "net present value" (NPV) of implementing Option C (note that costs were included for two dredging cycles, at 30 and 60 yrs):

P	Intial Cost	$45,043,460	Forebay (150,000 cy) + Main Lake 350,000 cy)
A	Annual Dredging	$776,472	12,000 cy
F1	Dredge Main Lake	$45,759,891	350,000 cy, 30 yrs
F2	Main Lake	$71,526,381	350,000 cy, 60 yrs
F3	Repair/Resurface	$7,346,477	30 yrs
F4	Repair/Resurface	$11,483,133	60 yrs

NPV = P + A(P/A,3%,30) + F1(P/F,3%,30) +F2(P/F,3%,60)+F3(P/F,3%,30)+F4(P/F,3%,60)
= **$100,048,310**

Note the "Repair/Resurface" cost was derived using the most recent repair cost of $4,700,000, scaled up assuming a 1.5% inflation rate for the specified durations (30 or 60 years). The next step is to compute the average total phosphorus (TP) removal (lbs) during the approximate 30-yr dredge cycle. Using the methodology presented in the *Water Quality Analysis* and extrapolating the TP removal presented in Table 8 for 30 years results in an average removal of approximately 900 lbs/yr (ranging from approximately 2,200 lbs/yr right after the dredging operation takes place to effectively zero after approximately 20 years).

Dividing the computed NPV by the average TP removal results in a cost of approximately $111,000/lb of TP removed. While this average unit cost for TP removal over the 30-yr dredge cycle is not cost effective compared to other BMP's, obtaining credit for the removal of 900 lbs of TP/yr can help offset a portion of the dredging costs should the decision be made to continue the dredging program for other reasons.

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ALTERNATIVE B: CONTINUE WITH CURRENT DREDGING METHOD

PHASE	ITEM	UNIT	COST	QUANTITY	TOTAL
ENVIRONMENTAL STUDIES	WETLAND DELINEATION	LS	$12,500	1	$12,500
	JURISDICTIONAL DETERMINATION	LS	$1,000	1	$1,000
	EXISTING VEGETATION MAP	LS	$2,000	1	$2,000
ENGINEERING STUDIES	VOLUME ANALYSIS	LS	$15,000	1	$15,000
	DISPOSAL SITE STUDY/ASSESSMENT	LS	$25,000	1	$25,000
CULTURAL STUDIES	PHASE I	LS	$8,500	1	$8,500
SURVEY	DELINEATION SURVEY	LS	$11,000	1	$11,000
	BATHYMETRIC SURVEY	AC	$2,194	50	$109,707
	AS-BUILT/BATHYMETRIC SURVEY	AC	$2,194	50	$109,707
	CONTRACTED UTILITY DESIGNATION	LS	$15,000	1	$15,000
	UTILITY SURVEY (VISIBLE, EX. SEWER)	LS	$10,000	1	$10,000
	CONSTRUCTION STAKE-OUT	EA	$10,000	1	$10,000
CONCEPT DESIGN PHASE	CONCEPTUAL DESIGN PLANS	LS	$35,000	1	$35,000
	PUBLIC MEETINGS	EA	$5,000	1	$5,000
	PROJECT TEAM MEETINGS	EA	$2,500	3	$7,500
	COST ESTIMATE	LS	$2,500	1	$2,500
DESIGN DEVELOPMENT PHASE	DESIGN PLANS	LS	$20,000	1	$20,000
	PUBLIC MEETINGS	EA	$10,000	1	$10,000
	COST ESTIMATE	LS	$2,500	1	$2,500
CONSTRUCTION DOCUMENTS PHASE	FINAL DESIGN PLANS	LS	$25,000	1	$25,000
	COST ESTIMATE	LS	$5,000	1	$5,000
	VALUE ENGINEERING STUDY	LS	$32,000	1	$32,000
PERMITTING	CORPS PERMIT (INCLUDES VMRC)	LS	$20,000	1	$20,000
	DEQ PERMIT	LS	$5,000	1	$5,000
	VSMP/SWPPP	LS	$5,000	1	$5,000
	USACE PERMIT MONITORING	LS	$5,000	1	$5,000
	MEETINGS	LS	$10,000	1	$10,000
BIDDING	BID PACKAGE	LS	$10,000	1	$10,000
	BIDDING ADMINISTRATION	LS	$7,500	1	$7,500
	PRE-BID MEETINGS	EA	$10,000	1	$10,000
CONSTRUCTION	MOBILIZATION	LS	10%	1	$351,686
	PRE-CONSTRUCTION MEETINGS	LS	$5,000	1	$5,000
	CONSTRUCTION ADMINISTRATION	WK	$1,000	52	$52,000
	DREDGING/PUMPING TO DEWATERING AREA	CY	$7.00	350000	$2,450,000
	DISPOSAL SITE DELINEATION	LS	$12,500	1	$12,500
	DISPOSAL SITE JD	LS	$1,000	1	$1,000
	DISPOSAL SITE DELINEATION SURVEY	LS	$8,500	1	$8,500
	DISPOSAL SITE USM	LS	$2,000	1	$2,000
	DISPOSAL SITE GRADING - ROUGH	SY	$1	242000	$200,860
	DISPOSAL SITE SURVEY	AC	$2,800	50	$140,000
	CONSTRUCTION INSPECTION	WK	$5,000	52	$260,000
	RESTORATION SEEDING	SY	$1.50	250000	$375,000
	3 YEAR PERFORMANCE WARRANTY	LS	$10,000	1	$10,000
				SUBTOTAL:	$4,414,959

OPTION	ITEMS	UNIT	COST	QUANTITY	TOTAL
TRUCKING	LOAD & HAUL (from offsite disposal area)	CY	$25	262500	$6,583,500
	DUMP CHARGE	CY	$44	262500	$11,521,125
				SUBTOTAL:	$18,104,625

TOTAL: $22,519,584 $64 /cy

CONTINGENCY	30% Conceptual Level	LS	$6,755,875	1	$6,755,875

TOTAL w CONTINGENCY: $29,275,459 $84 /CY

ANNUAL MAINTENANCE	DAM INSPECTION/MAINTENANCE	LS	$10,000	1	$10,000

CONTINGENCY	30% Conceptual Level	LS	$3,000	1	$3,000

TOTAL w CONTINGENCY: $13,000

ALTERNATIVE C: INSTALL IN-LAKE FOREBAY

PHASE	ITEM	UNIT	COST	QUANTITY	TOTAL
ENVIRONMENTAL STUDIES	WETLAND DELINEATION	LS	$12,500	1	$12,500
	JURISDICTIONAL DETERMINATION	LS	$1,000	1	$1,000
	ENDANGERED SPECIES SURVEY	LS	$5,000	1	$5,000
	WETLAND IMPACT ASSESSMENT	LS	$1,000	1	$1,000
	MITIGATION ANALYSIS	LS	$1,000	1	$1,000
	EXISTING VEGETATION MAP	LS	$2,000	1	$2,000
ENGINEERING STUDIES	VOLUME ANALYSIS	LS	$15,000	1	$15,000
	DISPOSAL SITE STUDY/ASSESSMENT	LS	$25,000	1	$25,000
	HYDROLOGY AND HYDRAULICS	LS	$15,000	1	$15,000
	FLOODPLAIN MODELING/ANALYSIS	LS	$15,000	1	$15,000
	SEDIMENT TRANSPORT STUDY	LS	$20,000	1	$20,000
CULTURAL STUDIES	PHASE I AND II	LS	$67,000	1	$67,000
SURVEY	DELINEATION SURVEY	LS	$11,000	1	$11,000
	BATHYMETRIC SURVEY	AC	$2,194	50	$109,707
	DEWATERING AREA/ACCESS ROAD SURVEY/STAKEOUT	LF	$2.50	8700	$21,750
	AS-BUILT/BATHYMETRIC SURVEY	AC	$2,194	50	$109,707
	TREE SURVEY (12" OR GREATER)	AC	$800	10	$8,000
	CONTRACTED UTILITY DESIGNATION	LS	$15,000	1	$15,000
	UTILITY SURVEY (VISIBLE, EX. SEWER)	LS	$10,000	1	$10,000
	CONSTRUCTION STAKE-OUT	AC	$2,500	5	$12,500
	AS-BUILT (FOREBAY)	AC	$2,800	10	$28,000
CONCEPT DESIGN PHASE	CONCEPTUAL DESIGN PLANS	LS	$50,000	1	$50,000
	PUBLIC MEETINGS	EA	$5,000	3	$15,000
	PROJECT TEAM MEETINGS	EA	$2,500	3	$7,500
	COST ESTIMATE	LS	$7,500	1	$7,500
DESIGN DEVELOPMENT PHASE	DESIGN PLANS	LS	$35,000	1	$35,000
	PUBLIC MEETINGS	EA	$5,000	1	$5,000
	PROJECT TEAM MEETINGS	EA	$2,500	3	$7,500
	COST ESTIMATE	LS	$5,000	1	$5,000
CONSTRUCTION DOCUMENTS PHASE	FINAL DESIGN PLANS	LS	$25,000	1	$25,000
	PUBLIC MEETINGS	EA	$5,000	1	$5,000
	COST ESTIMATE	LS	$5,000	1	$5,000
	VALUE ENGINEERING STUDY	LS	$32,000	1	$32,000
PERMITTING	CORP PERMIT	LS	$30,000	1	$30,000
	DEQ PERMIT	LS	$5,000	1	$5,000
	VSMP/SWPPP	LS	$10,000	1	$10,000
	USACE PERMIT MONITORING	LS	$10,000	1	$10,000
	MEETINGS	LS	$20,000	1	$20,000
BIDDING	BID PACKAGE	LS	$10,000	1	$10,000
	BIDDING ADMINISTRATION	LS	$7,500	1	$7,500
	PRE-BID MEETING	EA	$10,000	1	$10,000
CONSTRUCTION	MOBILIZATION	LS	10%	1	$625,782
	PRE-CONSTRUCTION MEETINGS	LS	$10,000	1	$10,000
	ACCESS ROAD (DECK MATS)	LF	$22	4000	$88,000
	FILTER FABRIC (BENEATH DECK MATS)	SY	$5	8000	$40,000
	CONSTRUCTION ADMINISTRATION	WK	$1,000	52	$52,000
	FOREBAY DREDGING	CY	$10	150000	$1,500,000
	DREDGING/PUMPING TO DEWATERING AREA	CY	$10	350000	$3,500,000
	DISPOSAL SITE DELINEATION	LS	$12,500	1	$12,500
	DISPOSAL SITE JD	LS	$1,000	1	$1,000
	DISPOSAL SITE DELINEATION SURVEY	LS	$8,500	1	$8,500
	DISPOSAL SITE USM	LS	$2,000	1	$2,000
	DISPOSAL SITE GRADING - ROUGH	SY	$1	242000	$200,860
	DISPOSAL SITE SURVEY	AC	$2,800	50	$140,000
	TRAIL REPAIR	SY	$58	500	$28,835
	CONSTRUCTION INSPECTION	WK	$5,000	52	$260,000
	PUBLIC MEETINGS	EA	$10,000	1	$10,000
	RESTORATION PLANTING	EA	$10	750	$7,125
	RESTORATION SEEDING	SY	$1.50	258000	$387,000
	3 YEAR PERFORMANCE WARRANTY	LS	$10,000	1	$10,000
MITIGATION	CREDITS	AC	$85,000	10	$850,000
				SUBTOTAL:	$7,690,765

OPTION	ITEMS	UNIT	COST	QUANTITY	TOTAL
TRUCKING	LOAD & HAUL (from offsite disposal area)	CY	$25	375000	$9,405,000
	DUMP CHARGE	CY	$44	375000	$16,458,750
				SUBTOTAL:	$25,863,750

ONSITE DISPOSAL AREA	ADDITIONAL DELINEATION	LS	$9,500	1	$9,500
	ADDITIONAL JD	LS	$1,000	1	$1,000
	ADDITIONAL DELINEATION SURVEY	LS	$8,500	1	$8,500
	USM	LS	$2,000	1	$2,000
	SITE GRADING - ROUGH	SY	$1	17000	$14,110
	SEDIMENT HAUL/LOADING	CY	$25	12000	$300,960
	DUMP CHARGE	CY	$44	12000	$526,680
	SURVEY DEWATERING BASIN	AC	$2,800	3.5	$9,800
	HAUL ROAD/BASIN DESIGN PLANS (LDS SUBMISSION)	LS	$25,000	1	$25,000
	STABILIZE HAUL ROAD	LS	$130,000	1	$130,000
HAUL TO ROLLING ROAD	SURVEY RAILROAD BED	LF	$2.50	8700	$21,750
	GEOTECH (BORING, STABILITY, CULVERT)	LS	$15,000	1	$15,000
HAUL THROUGH COMMUNITY	SURVEY ACCESS AND STAGING	LS	$20,000	1	$20,000
	ENTRANCE PLANS (LDS AND VDOT)	LS	$10,000	1	$10,000
				SUBTOTAL:	$1,094,300

TOTAL: $34,648,815 $69 /cy

CONTINGENCY	30% Conceptual Level	LS	$10,394,645	1	$10,394,645

TOTAL w CONTINGENCY: $45,043,460 $90 /cy

ANNUAL MAINTENANCE	MOBILIZATION	LS	5%	1	$27,966
	ANNUAL SEDIMENT REMOVAL/DREDGING	CY	$10	12000	$120,000
	SEDIMENT HAUL/LOADING	CY	$25	6000	$150,480
	DUMP CHARGE	CY	$44	6000	$263,340
	SEEDING	SY	$1.50	17000	$25,500
	DAM INSPECTION/MAINTENANCE	LS	$10,000	1	$10,000

SUBTOTAL: $597,286

ALTERNATIVE D: INSTALL BEAVER DAM STRUCTURES					
PHASE	**ITEM**	**UNIT**	**COST**	**QUANTITY**	**TOTAL**
ENVIRONMENTAL STUDIES	WETLAND DELINEATION	LS	$12,500	1	$12,500
	JURISDICTIONAL DETERMINATION	LS	$1,000	1	$1,000
	ENDANGERED SPECIES SURVEY	LS	$5,000	1	$5,000
	WETLAND IMPACT ASSESSMENT	LS	$1,000	1	$1,000
	MITIGATION ANALYSIS	LS	$500	1	$500
	EXISTING VEGETATION MAP	LS	$2,500	1	$2,500
ENGINEERING STUDIES	HYDROLOGY AND HYDRAULICS	LS	$7,500	1	$7,500
	FLOODPLAIN MODELING/ANALYSIS	LS	$15,000	1	$15,000
	SEDIMENT TRANSPORT STUDY	LS	$20,000	1	$20,000
CULTURAL STUDIES	PHASE I AND II	LS	$67,000	1	$67,000
SURVEY	DELINEATION SURVEY	LS	$16,000	1	$16,000
	TREE SURVEY (12" OR GREATER)	AC	$800	25	$20,000
	CONTRACTED UTILITY DESIGNATION	LS	$15,000	1	$15,000
	UTILITY SURVEY (VISIBLE, EX. SEWER)	LS	$10,000	1	$10,000
	CONSTRUCTION STAKE-OUT	AC	$2,500	25	$62,500
	AS-BUILT	AC	$2,800	25	$70,000
CONCEPT DESIGN PHASE	CONCEPTUAL DESIGN PLANS	LS	$15,000	1	$15,000
	PUBLIC MEETINGS	EA	$5,000	3	$15,000
	PROJECT TEAM MEETINGS	EA	$2,500	3	$7,500
	COST ESTIMATE	LS	$5,000	1	$5,000
DESIGN DEVELOPMENT PHASE	DESIGN PLANS	LS	$20,000	1	$20,000
	PUBLIC MEETINGS	EA	$5,000	1	$5,000
	COST ESTIMATE	LS	$5,000	1	$5,000
CONSTRUCTION DOCUMENTS PHASE	FINAL DESIGN PLANS	LS	$15,000	1	$15,000
	PUBLIC MEETINGS	EA	$5,000	1	$5,000
	COST ESTIMATE	LS	$5,000	1	$5,000
PERMITTING	CORPS PERMIT (INCLUDES VMRC)	LS	$20,000	1	$20,000
	DEQ PERMIT	LS	$5,000	1	$5,000
	VSMP/SWPPP	LS	$5,000	1	$5,000
	USACE PERMIT MONITORING	LS	$10,000	1	$10,000
	MEETINGS	LS	$20,000	1	$20,000
BIDDING	BID PACKAGE	LS	$10,000	1	$10,000
	BIDDING ADMINISTRATION	LS	$7,500	1	$7,500
	PRE-BID MEETINGS	LS	$10,000	1	$10,000
CONSTRUCTION	MOBILIZATION	LS	5%	1	$35,880
	PRE-CONSTRUCTION MEETINGS	LS	$20,000	1	$20,000
	ACCESS ROAD (DECK MATS)	LF	$22	3000	$66,000
	FILTER FABRIC (BENEATH DECK MATS)	SY	$5.00	6000	$30,000
	CONSTRUCTION ADMINISTRATION	LS	$1,000	12	$12,000
	EXCAVATION (USED AS FILL ON SITE)	CY	$25	2000	$50,160
	SITE GRADING - ROUGH	SY	$0.83	2000	$1,660
	SITE GRADING - FINE	SY	$0.62	2000	$1,240
	VINYL PILING INSTALLATION	VLF	$13	20000	$250,000
	SHEET PILE CAP INSTALLATION	20 LF	$710	100	$71,000
	REINFORCED BED MIX (BOTH SIDES OF PILE)	CY	$95	1000	$95,000
	TRAIL REPAIR	SY	$58	500	$28,835
	CONSTRUCTION INSPECTION	WK	$5,000	12	$60,000
	PUBLIC MEETINGS	EA	$10,000	1	$10,000
	RESTORATION PLANTING	EA	$10	600	$5,700
	RESTORATION SEEDING	SY	$1.50	4000	$6,000
	3 YEAR PERFORMANCE WARRANTY	LS	$10,000	1	$10,000
MITIGATION	CREDITS	AC	$85,000	5	$425,000
				TOTAL:	$717,595
CONTINGENCY	30% Conceptual Level	LS	$215,279	1	$215,279
				TOTAL w CONTINGENCY:	$932,874
ANNUAL MAINTENANCE	STABILIZATION (MISC. REPAIRS)	LS	$5,000	1	$5,000
	DAM INSPECTION/MAINTENANCE	LS	$10,000	1	$10,000
				SUBTOTAL:	$15,000
CONTINGENCY	30% Conceptual Level	LS	$4,500	1	$4,500
				TOTAL w CONTINGENCY:	$19,500

ALTERNATIVE E: SINGLE CHANNEL WITH RECLAIMED LAND (REMOVE DAM)					
PHASE	ITEM	UNIT	COST	QUANTITY	TOTAL
ENVIRONMENTAL STUDIES	WETLAND DELINEATION	LS	$32,500	1	$32,500
	JURISDICTIONAL DETERMINATION	LS	$1,500	1	$1,500
	ENDANGERED SPECIES SURVEY	LS	$10,000	1	$10,000
	WETLAND IMPACT ASSESSMENT	LS	$1,000	1	$1,000
	MITIGATION ANALYSIS	LS	$5,000	1	$5,000
	EXISTING VEGETATION MAP	LS	$3,500	1	$3,500
	USM	LS	$2,500	1	$2,500
ENGINEERING STUDIES	SEDIMENT ANALYSIS	LS	$30,000	1	$30,000
	HYDROLOGY AND HYDRAULICS	LS	$20,000	1	$20,000
	FLOODPLAIN MODELING/ANALYSIS	LS	$15,000	1	$15,000
	DAM/STRUCTURAL ANALYSIS	LS	$25,000	1	$25,000
	SEDIMENT TRANSPORT STUDY (UPSTREAM & DOWN)	LS	$30,000	1	$30,000
CULTURAL STUDIES	PHASE I, II, AND III ARCH INVESTIGATIONS (DAM)	LS	$117,000	1	$117,000
SURVEY	DELINEATION SURVEY	LS	$30,000	1	$30,000
	DAM SURVEY	LS	$15,000	1	$15,000
	ASBESTOS TESTING IN OGEE SPILLWAY	LS	$10,000	1	$10,000
	CONTRACTED UTILITY DESIGNATION	LS	$15,000	1	$15,000
	UTILITY SURVEY (VISIBLE, EX. SEWER)	LS	$10,000	1	$10,000
	CONSTRUCTION STAKE-OUT (STREAM)	LF	$20	3300	$66,000
	CONSTRUCTION STAKE-OUT (UPLAND, WETLAND)	AC	$2,500	40	$100,000
	AS-BUILT (STREAM)	LF	$20	3300	$66,000
	AS-BUILT (UPLAND, WETLAND)	AC	$2,800	40	$112,000
CONCEPT DESIGN PHASE	CONCEPTUAL DESIGN PLANS	LS	$75,000	1	$75,000
	PUBLIC MEETINGS	EA	$5,000	3	$15,000
	PROJECT TEAM MEETINGS	EA	$2,500	10	$25,000
	COST ESTIMATE	LS	$10,000	1	$10,000
DESIGN DEVELOPMENT PHASE	DESIGN PLANS	LS	$50,000	1	$50,000
	PUBLIC MEETINGS	EA	$10,000	2	$20,000
	PROJECT TEAM MEETINGS	EA	$2,500	3	$7,500
	COST ESTIMATE	LS	$5,000	1	$5,000
CONSTRUCTION DOCUMENTS PHASE	FINAL DESIGN PLANS	LS	$30,000	1	$30,000
	PUBLIC MEETINGS	EA	$10,000	1	$10,000
	PROJECT TEAM MEETINGS	EA	$2,500	3	$7,500
	COST ESTIMATE	LS	$5,000	1	$5,000
	VALUE ENGINEERING STUDY	LS	$32,000	1	$32,000
PERMITTING	CORP PERMIT (INCLUDES VMRC)	LS	$20,000	1	$20,000
	DEQ PERMIT	LS	$5,000	1	$5,000
	DCR DAM DECOMISSION/STRUCTURAL PERMITS	LS	$15,000	1	$15,000
	VSMP/SWPPP	LS	$10,000	1	$10,000
	USACE PERMIT MONITORING	LS	$10,000	1	$10,000
	MEETINGS	EA	$20,000	1	$20,000
BIDDING	BID PACKAGE	LS	$10,000	1	$10,000
	BIDDING ADMINISTRATION	LS	$7,500	1	$7,500
	PRE-BID MEETING	LS	$10,000	1	$10,000
CONSTRUCTION	MOBILIZATION	LS	5%	1	$355,050
	PRE-CONSTRUCTION MEETINGS	EA	$10,000	1	$10,000
	ACCESS ROAD (DECK MATS)	LF	$22	3000	$66,000
	FILTER FABRIC (BENEATH DECK MATS)	SY	$5.00	6000	$30,000
	CONSTRUCTION ADMINISTRATION	WK	$3,000	52	$156,000
	DAM DECOMMISSION/REMOVAL	LS	$556,000	1	$556,000
	EXCAVATION (USED AS FILL ON SITE)	CY	$25	100000	$2,508,000
	WET MATERIAL PREMIUM	CY	$5	100000	$500,000
	SITE GRADING - ROUGH	SY	$0.83	300000	$249,000
	SITE GRADING - FINE	SY	$0.62	300000	$186,000
	REINFORCED BED MIX (18")	CY	$95	16000	$1,520,000
	STREAM STRUCTURES	EA	$20,000	10	$200,000
	RESTORATION PLANTING	EA	$10	45000	$427,500
	RESTORATION SEEDING	SY	$1.50	275000	$412,500
	3 YEAR PERFORMANCE WARRANTY	LS	$10,000	1	$10,000
	CONSTRUCTION INSPECTION	WK	$5,000	52	$260,000
	PUBLIC MEETINGS	EA	$10,000	1	$10,000
MITIGATION	MITIGATION MONITORING	LS	$25,000	1	$25,000
				TOTAL:	$8,597,550
CONTINGENCY	30% Conceptual Level	LS	$2,579,265	1	$2,579,265
				TOTAL w CONTINGENCY:	$11,176,815

MAINTENANCE	STREAM CHANNEL STABILIZATION (5 yrs)	EA	$25,000	5	$125,000
	VEGETATION ESTABLISHMENT (5 yrs)	EA	$10,000	5	$50,000
	MONITORING (5 yrs)	EA	$5,000	5	$25,000
	LONG TERM ANNUAL	LS	$20,000	1	$20,000
				SUBTOTAL:	$220,000
CONTINGENCY	30% Conceptual Level	LS	$66,000	1	$66,000
				TOTAL w CONTINGENCY:	$286,000

ALTERNATIVE F: SINGLE CHANNEL WITH SMALLER LAKE (MODIFICATION OF EXISTING DAM)					
PHASE	**ITEM**	**UNIT**	**COST**	**QUANTITY**	**TOTAL**
ENVIRONMENTAL STUDIES	WETLAND DELINEATION	LS	$32,500	1	$32,500
	JURISDICTIONAL DETERMINATION	LS	$1,500	1	$1,500
	ENDANGERED SPECIES SURVEY	LS	$10,000	1	$10,000
	WETLAND IMPACT ASSESSMENT	LS	$1,000	1	$1,000
	MITIGATION ANALYSIS	LS	$5,000	1	$5,000
	EXISTING VEGETATION MAP	LS	$3,500	1	$3,500
	USM	LS	$2,500	1	$2,500
ENGINEERING STUDIES	SEDIMENT ANALYSIS	LS	$30,000	1	$30,000
	HYDROLOGY AND HYDRAULICS	LS	$25,000	1	$25,000
	FLOODPLAIN MODELING/ANALYSIS	LS	$30,000	1	$30,000
	DAM/STRUCTURAL ANALYSIS	LS	$25,000	1	$25,000
	SEDIMENT TRANSPORT STUDY (UPSTREAM & DOWN)	LS	$50,000	1	$50,000
CULTURAL STUDIES	PHASE I, II, AND III ARCH INVESTIGATIONS (DAM)	LS	$117,000	1	$117,000
SURVEY	DELINEATION SURVEY	LS	$30,000	1	$30,000
	DAM SURVEY	LS	$15,000	1	$15,000
	ASBESTOS TESTING IN OGEE SPILLWAY	LS	$10,000	1	$10,000
	CONTRACTED UTILITY DESIGNATION	LS	$15,000	1	$15,000
	UTILITY SURVEY (VISIBLE, EX. SEWER)	LS	$10,000	1	$10,000
	CONSTRUCTION STAKE-OUT (STREAM)	LF	$20	2500	$50,000
	CONSTRUCTION STAKE-OUT (UPLAND, WETLAND)	AC	$2,500	40	$100,000
	AS-BUILT (STREAM)	LF	$20	2500	$50,000
	AS-BUILT (UPLAND, WETLAND)	AC	$2,800	40	$112,000
	AS-BUILT (SMALLER POND)	AC	$2,800	18	$50,400
CONCEPT DESIGN PHASE	CONCEPTUAL DESIGN PLANS	LS	$75,000	1	$75,000
	PUBLIC MEETINGS	EA	$10,000	3	$30,000
	PROJECT TEAM MEETINGS	EA	$2,500	10	$25,000
	COST ESTIMATE	LS	$10,000	1	$10,000
DESIGN DEVELOPMENT PHASE	DESIGN PLANS	LS	$50,000	1	$50,000
	PUBLIC MEETINGS	EA	$10,000	2	$20,000
	PROJECT TEAM MEETINGS	EA	$2,500	3	$7,500
	COST ESTIMATE	LS	$5,000	1	$5,000
CONSTRUCTION DOCUMENTS PHASE	FINAL DESIGN PLANS	LS	$30,000	1	$30,000
	PUBLIC MEETINGS	EA	$10,000	1	$10,000
	PROJECT TEAM MEETINGS	EA	$2,500	3	$7,500
	COST ESTIMATE	LS	$10,000	1	$10,000
	VALUE ENGINEERING STUDY	LS	$32,000	1	$32,000
PERMITTING	CORP PERMIT (INCLUDES VMRC)	LS	$20,000	1	$20,000
	DEQ PERMIT	LS	$5,000	1	$5,000
	DCR DAM DECOMISSION/STRUCTURAL PERMITS	LS	$15,000	1	$15,000
	VSMP/SWPPP	LS	$10,000	1	$10,000
	USACE PERMIT MONITORING	LS	$10,000	1	$10,000
	MEETINGS	EA	$10,000	2	$20,000
BIDDING	BID PACKAGE	LS	$10,000	1	$10,000
	BIDDING ADMINISTRATION	LS	$7,500	1	$7,500
	PRE-BID MEETINGS	LS	$10,000	1	$10,000
CONSTRUCTION	MOBILIZATION	LS	5%	1	$415,635
	PRE-CONSTRUCTION MEETINGS	LS	$10,000	1	$10,000
	ACCESS ROAD (DECK MATS)	LF	$22	3000	$66,000
	FILTER FABRIC (BENEATH DECK MATS)	SY	$5.00	6000	$30,000
	CONSTRUCTION ADMINISTRATION	WK	$3,000	52	$156,000
	DAM DECOMMISSION/REMOVAL	LS	$556,000	1	$556,000
	EXCAVATION (USED AS FILL ON SITE)	CY	$25	165000	$4,138,200
	WET MATERIAL PREMIUM	CY	$5	165000	$825,000
	SITE GRADING - ROUGH	SY	$1	300000	$249,000
	SITE GRADING - FINE	SY	$1	300000	$186,000
	REINFORCED BED MIX (18")	CY	$95	11000	$1,045,000
	STREAM STRUCTURES	EA	$20,000	12	$240,000
	RESTORATION PLANTING	EA	$10	25000	$237,500
	RESTORATION SEEDING	SY	$1.50	196000	$294,000
	3 YEAR PERFORMANCE WARRANTY	LS	$10,000	1	$10,000
	CONSTRUCTION INSPECTION	WK	$5,000	52	$260,000
	PUBLIC MEETINGS	EA	$10,000	1	$10,000
MITIGATION	MITIGATION MONITORING	LS	$25,000	1	$25,000
				TOTAL:	$9,948,235

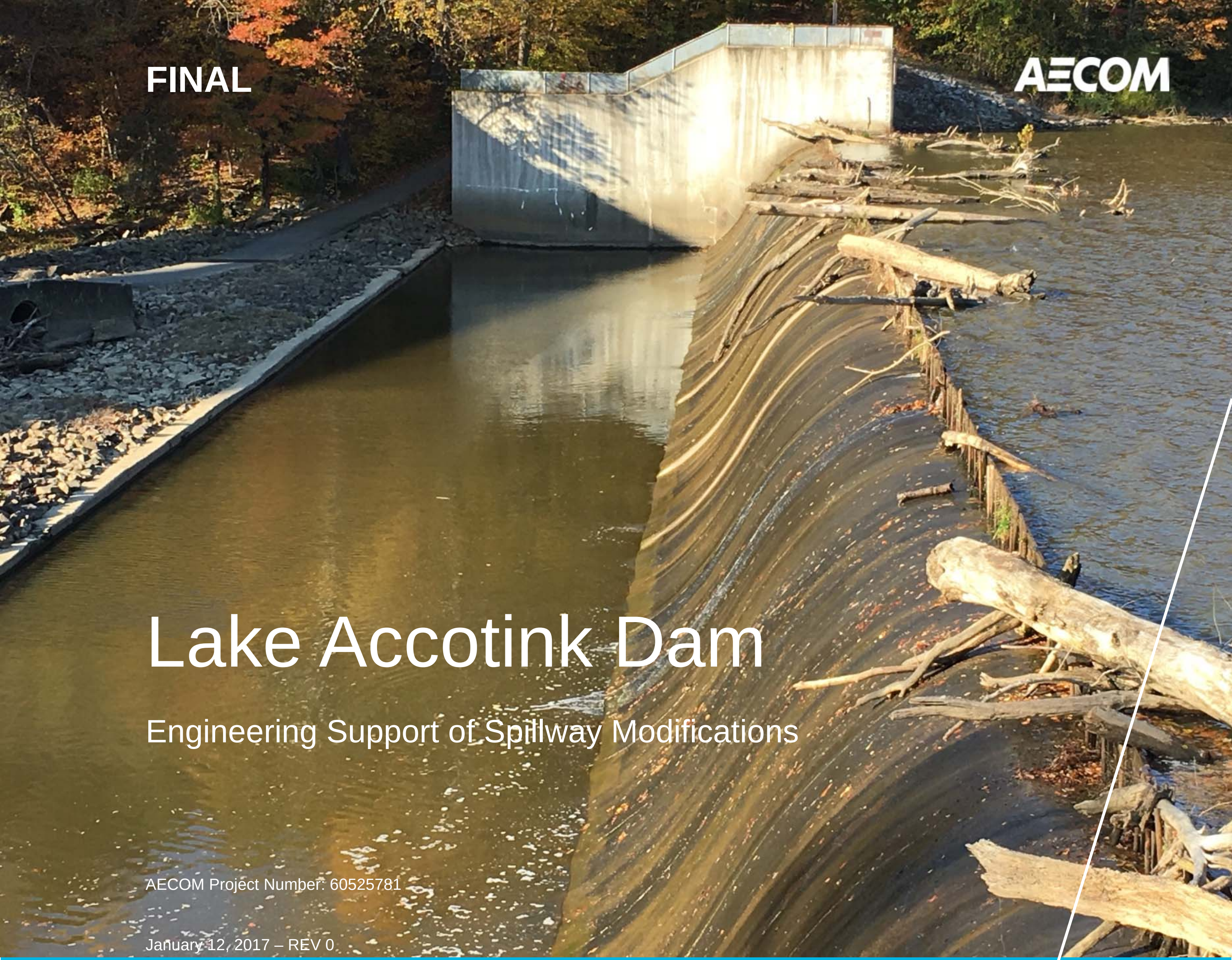
CONTINGENCY	30% Conceptual Level	LS	$2,984,471	1	$2,984,471

TOTAL w CONTINGENCY: $12,932,706

MAINTENANCE	STREAM CHANNEL STABILIZATION	EA	$25,000	5	$125,000
	VEGETATION ESTABLISHMENT	EA	$10,000	5	$50,000
	MONITORING	EA	$5,000	5	$25,000
	LONG TERM ANNUAL	LS	$20,000	1	$20,000
				SUBTOTAL:	$220,000

CONTINGENCY	30% Conceptual Level	LS	$66,000	1	$66,000

TOTAL w CONTINGENCY: $286,000



FINAL

AECOM

Lake Accotink Dam

Engineering Support of Spillway Modifications

AECOM Project Number: 60525781

January 12, 2017 – REV 0

COMMERCIAL IN CONFIDENCE

Quality information

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COST ESTIMATE Robert Pinciotti, P.E.	Ryan P. Gee, P.E.	Robert Pinciotti, P.E.

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Revision	Revision date	Details	Authorized	Name	Position
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REV 0	01/12/2017	Final Submission With Cost Estimate			

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Table of Contents

Attachments

1. Introduction

1.1 Background

Lake Accotink Dam is located in Fairfax County, Virginia on Accotink Creek. The 55 acre lake is currently operated by the Fairfax County Park Authority (FCPA) and used solely for recreation. The dam is approximately 100 years old and is classified as a high hazard dam per Virginia Department of Conservation and Recreation (DCR) dam safety regulations.

The dam is a composite structure, consisting of an earthen embankment section and concrete spillway section. The embankment section has maximum height of 28 feet with a crest length of approximately 700 feet. The concrete ogee spillway is located along the right abutment (looking downstream) and is aligned with Accotink Creek. It has a crest length of approximately 360 feet with a height of approximately 15 feet from the downstream channel invert (approximately elevation (El.) 170 ft) at the toe of the dam to the crest of the spillway. The spillway crest is at El. 185 ft and wooden flashboards are used to raise the normal pool to El. 186.5 ft. A 4 foot by 4 foot cast iron sluice gate at El. 168.5 ft is located adjacent to the east abutment and, according to the July 2013 annual Inspection Report, is "fully operational and operated on a weekly basis by the Park Authority staff".

The concrete spillway section is comprised of inclined concrete slabs with buttress walls (Ambursen dam) and an 8 foot wide and 10 foot high gallery that spans the entire length of the spillway. The gallery or interior of the spillway is divided into 30 chambers formed by two buttress walls, an upstream inclined concrete slab, a downstream inclined concrete spillway slab and a spillway based slab (or bedrock). The spillway discharges into a stilling basin that extends along the entire length of the spillway which is believed to have a concrete bottom at El. 165.4. Topography of the ground surface immediately downstream of the stilling basin is considerably higher than the stilling basin bottom. The stilling basin discharges into the stream channel which is aligned with the right side of the spillway. There is a paved access road which crosses the creek that has a notched channel from the stilling basin that carries low flows to the downstream channel via a culvert beneath the access road. There is also a low area just downstream of the stilling basin to the left of the stream channel where three pipes with concrete headwalls and endwalls can pass additional flows under the access road. The elevations of the three pipes are unknown but are higher than the elevation of the channel leading to the stream. For higher spillway discharges, water from the stilling basin will exceed the capacity of the notched channel between the stilling basin and stream channel and will overtop the access road. There is also a sewer manhole exposed along the access road in the area of the stream channel.

The original design information for Lake Accotink Dam is not available, however, there are historical project documents dated between 1986 and 2016 that have been found in the Fairfax County and DCR files, which are listed in Section 4 of this report. Repairs were made to the dam and spillway with record drawings from this work dated 2008. Annual dam inspections have been performed and documented that the dam is in "good condition".

Lake Accotink has a drainage area of approximately 30 square miles. Currently Accotink Dam has a conditional Virginia Dam Safety Operation and Maintenance (O&M) Certificate since the spillway can only pass 0.6 times the Probable Maximum Flood (PMF), well below the 0.9 PMF spillway design flood (SDF) requirement for a high hazard dam. We understand that Fairfax County is updating the hydrologic and hydraulic modeling and dam breach mapping in order to evaluate if the hazard potential classification can be reduced in order to require a lower SDF that would be sufficient for the issuance of a standard (non-conditional) O&M Certificate.

Accotink Creek is subject to significant sediment loads and Lake Accotink to sedimentation. Since constructed in circa 1918, the lake water surface area is reduced to approximately 50% of the initial area and the depth of water in the reservoir is greatly reduced, to approximately 4 feet of open water at the dam face. The sediment trap rate since prior dredging has been estimated at 15,000 cubic feet per year or greater. The Total Daily Maximum Load (TMDL) for Accotink Creek is for benthic impairment with Lake Accotink providing sediment storage capacity.

The FCPA with the assistance of Wetland Studies & Solutions (WSSI) is performing a master planning study for Lake Accotink and evaluating various alternatives to the current lake. We understand that one of the primary objectives of this study is to eliminate the need for future dredging. One alternative under consideration, and the reason for this study, is the removal of a portion of the ogee spillway to prevent impounding water (and sediment) during normal flows and either eliminate or greatly reduce the size of the lake. Another potential benefit of this concept would be the potential for declassifying the structure as an "impounding structure" and eliminate the need for an O&M Permit.

1.2 Scope of Work

The objective of AECOM's task order is to provide support to WSSI to further evaluate the feasibility of a removal of a portion of the Lake Accotink ogee spillway. Specifically, the following work items were established for this task:

- Based on existing available reports and data provided by Fairfax County, AECOM is to identify the steps and associated costs for designing and constructing a partial removal of the ogee spillway removal. AECOM is to identify data needs for designing the ogee spillway removal.
- AECOM is to perform an engineer's opinion of construction cost for the ogee spillway removal including assumptions and uncertainties.

1.3 Site Reconnaissance

AECOM visited the project site on Friday, November 4, 2016 and were met by representatives of WSSI. WSSI explained the Master Plan concepts which involve several options of site grading upstream of the dam and the primary concept (AECOM Option 1) for creating a notch in the dam.

No spill was occurring over the spillway during the site visit and we were able to observe that the overall condition of the spillway was good, free of significant spalling, delamination or cracking. Similarly, the earthen embankment was well maintained and did not contain noticeable sloughing, depressions or seepage.

Of particular interest during the site reconnaissance:

- We noted that water ponds within the stilling basin during a non-spill condition, which will need to be considered both for demolition activities and long-term post-demolition conditions. It is possible that by demolishing the primary spillway, the downstream wall of the stilling basin could then be considered a dam if it creates a significant backwater restriction during a flood event. Consideration will also need to be made whether the Stilling Basin should remain after spillway demolition to prevent downstream shoreline erosion and whether the basin is needed to slow the velocity of water.
- We observed that the vehicular roadway is lower in some areas than the crest of the embankment dam at the eastern end of the dam. This indicates that prior to overtopping, it is possible that water will flow down the roadway and act as an unintentional "emergency spillway".
- The downstream access path will be beneficial for construction activities, as it provides easy access to the full length of the spillway. We noticed the accessway is used by recreational hikers to connect to trails on either side of the dam. Further consideration will need to be made on how to safely keep the public away from demolition activities,

It is important to note that AECOM conducted a brief site reconnaissance in order to become familiar with the facility and site but did not perform a complete dam safety inspection or access the interior of the spillway. Photographs of AECOM's site reconnaissance are provided in Attachment No. 3.

2. Partial Spillway Removal Options

AECOM investigated three alternatives for removing a portion of the spillway, which are described in the subsections below. Option 1 is derived from the WSSI concept in the Master Plan. Options 2 and 3 were developed as alternatives that provide larger and deeper notches. Dredging of the sediment in the vicinity of the spillway will be required as part of each of the options. For all of the alternatives, we have assumed that the sediment would be removed adjacent to the upstream face of the spillway to the bottom of the notch. The overall evaluation of the need for removal of sediment from within the limits of the lake and the environmental and permitting uses related to the sediment is beyond the scope of this task.

Each of the options in this draft report shows the removal or demolition of the central portion of the spillway, as is shown in the 2016 Sustainability Study. However, we recommend that consideration also be given to shifting the breach to the right (west) so as to better align the new opening with the existing downstream channel.

We have assumed for each alternative that the existing sluice gate will be used to dewater the upstream side of the dam prior to demolition, and during concrete demolition diesel powered pumps would be used to control the water near the demolition area. The concrete slabs and buttresses would be demolished via hoe-ram, and then wire saw cut to the final elevation to create a clean demolition line.

It is important to note that no hydraulic analysis for the alternatives have been conducted at this point to understand how much water would be impounded behind the remaining section of the spillway/dam and what the downstream impacts would be. Therefore, it is unknown if the alternatives would restrict impounding water behind the remaining portions of the spillway/dam to the extent that the structure could be “de-classified” as an impounding structure (dam) and therefore, not subject the DCR impounding structure regulations. Given that the dam currently has a conditional certificate, it is our opinion that the de-classification of the structure should be an important criteria for selecting the desired concept.

2.1 Option 1 – WSSI Concept

The concept presented by WSSI in their April 26, 2016 presentation to Fairfax County titled “Lake Accotink Sustainability Plan Summary of Potential Alternatives”, shows the spillway being demolished at two elevations. In the center of the spillway, the bays between Buttresses No. 12 and 17 would be demolished to El. 170.0 ft and the remaining spillway bays would be demolished to EL. 176.5 ft. Based on the assumed cross-section of the concrete spillway section, this option would leave a concrete section about 5.4 feet high above the bottom of the stilling basin (El 165.4) and unless modifications were made downstream, water would still stand in the stilling basin. A hydraulic analysis would need to be conducted along with discussions with the DCR Dam Safety officials to determine if this option would still be considered a dam and subject to the DCR Impounding Structures regulations.

To accomplish the demolition and long-term stability, it is anticipated that the interior of the slab and buttress dam would need to be in-filled with concrete.

AECOM considered an Option 1A which places concrete inside the dam before demolition of the existing slabs and buttresses. The infill prior to demolition significantly reduces the risk of a dam breach should a significant flood event occur during demolition, but would require the demolished concrete be disposed away from the dam (off-site). We also considered an Option 1B which calls for the demolition of the slabs and buttresses and places the concrete spoils of demolition within the buttress bays, and then the concrete rubble is backfilled with concrete. Option 1B significantly reduces the amount of concrete required, and allows for the demolished material to remain on-site. Specifications would need to be provided for limiting the size and shape of the debris so as to limit the number and size of voids, although some voids would be inevitable. Further, the concrete mix design would need to be carefully considered to ensure the voids are grouted to the most reasonable extent possible. Option 1B could be appropriate if the structure no longer acts as a dam, but in our opinion is not appropriate otherwise.

To place the concrete on the interior of the spillway in Option 1A, a series of core drilled holes would need to be placed along the crest of the dam and along the downstream face of the dam. The holes in the crest of the dam would be used for concrete placement via concrete pump truck, and the holes in the downstream face would allow the standing water within the chambers to displace to the exterior during concrete placement operations.

2.2 Option 2 – Deep Notch at Center of Spillway

This option investigates widening the deep notch presented in Option No 1B, and omits the shallow notch across the remainder of the spillway crest. We believe that this concept will be much more efficient in passing flood flows, limiting the impounding water behind the remaining spillway/dam sections, and present a higher likelihood that the structure can be de-classified as a dam. The deep notch under this option was anticipated as being approximately 120 feet wide and located between Buttresses No. 10 through 20. We have maintained the crest elevation of El. 170 ft. to be consistent with the deep notch in Option No. 1.

Similar to Option 1B, we assumed that the demolition debris is placed between the remaining portions of the spillway buttresses walls, and is then backfilled with concrete. Again, encapsulation of the demolition debris in the backfill concrete would be applicable if the structure can be de-classified as a dam.

2.3 Option 3 – Full Height Spillway Removal at Center of Spillway

Similar to Option 2, this option would investigate the full height demolition of the spillway for a width of 120ft between Buttresses No. 10 and 20. Rather than maintain a crest elevation of 170 ft, the spillway would be entirely demolished down to the existing concrete foundation at approximately El 165. Under this option, the concrete in-fill would no longer be required and the amount of wire-saw cutting would be significantly reduced. All of the demolished concrete will need to be disposed off site.

This alternative would present the highest likelihood of de-classifying the structure as a dam, but consideration would need to be given to treatment of the stilling basin and higher riprap berm that carries the access road across the stream channel. In high flow situations, the berm would likely act as a dam and impound some water. Treatment of the downstream area would need to be considered for the hydraulic analysis.

3. Preferred Option & Cost Estimate

It is AECOM's opinion that Option No. 3 is the preferred concept due to the complete removal of the spillway down to the foundation, which is the option most likely to satisfy regulators that the facility will not function as a dam. Further, the full height removal does not involve creating a new sill elevation (at the bottom of the notch), and does not involve in-filling the remaining slab and buttresses with concrete at the bottom of the notch. The elimination of the need to create a new sill makes Option No. 3 the lowest cost option. It is possible that the VA DCR Regulators will require that a soft bottom channel be constructed in the existing concrete slab.

In our preparation of the Engineer's Opinion of Construction Cost (EOCC) for Option No. 3 included in Attachment No. 2, AECOM considered the unit rates provided by six contractor bids for recent local dam modification projects, as well as unit rates provided in RS Means Heavy Construction. Each line item in our EOCC provides the source of the unit rate. We believe that the EOCC accurately reflects what we would expect the cost to be for this work given our experience with similar types of concrete dam demolition work.

The EOCC is intended to capture the scope of work specific to the removal of the concrete spillway structure. The costs associated with construction water management, sediment removal and erosion controls are costs to be identified and captured by WSSI as part of the overall silt removal and re-grading work upstream of the dam, which is an integral part of the overall dam removal concept.

We have assumed that the concrete demolition debris from the spillway removal will be permanently disposed of on-site, upstream of the dam in a location within the footprint of the sediment re-grading earthwork.

4. Recommendations

AECOM has identified several additional studies that should be conducted to further refine and confirm the feasibility of the options presented in this report.

4.1 Hydrologic and Hydraulic Analysis

A hydrologic and hydraulic (H&H) analysis will need to be conducted in order to evaluate various notch elevations and dimensions, impounding water elevations behind the remaining portions of the spillway/dam for various storm frequencies and to evaluate downstream tailwater effects The exact point in which a structure is no longer considered a dam is not clearly defined in VA regulations, and this study will need to be performed in conjunction with consultation with the Dam Safety regulators of the VA DCR. We recommend that storm frequencies of 10-year, 100-

year, and 90 percent PMF be evaluated at a minimum. We anticipate that this analysis will also need to consider the notch location on the spillway as it relates to stream calming and preventing downstream erosion.

4.2 Concrete Abutment Stability, Spillway Stability & As-Built Configuration Investigation

The as-built configuration and stability of the spillway and the left and right concrete spillway abutments will need to be investigated before finalizing the demolition concepts. The investigation must confirm that the remaining portions of spillway, including the left and right concrete abutments are stable after the spillway is partially removed. It is not currently known whether the slabs of the buttress dam are providing lateral stability for the abutment walls. Further, we do not currently know the foundation profile and in order to provide an accurate set of demolition drawings with accurate quantities, we will need to know the top of foundation elevation in every chamber of the spillway.

To investigate the as-built configuration, we recommend that a concrete core be taken at the bottom of the access shaft to determine the thickness of the concrete and top of rock elevation at each abutment, and a core/boring be taken just beyond the edge of concrete of the manways to determine whether the abutment foundation projects beyond the manway below grade. Within the chambers, a weighted tape will need to be used to measure the depth of each chamber. An exterior survey will also need to be conducted downstream of the dam to determine the stilling basin depths, invert elevation of the outlet pipes, invert elevation of discharge channel and the profile of the existing sewer line that crosses downstream of the dam. In our conceptual sketches we show the foundation and stilling basin at a consistent elevation, however, based upon experience with Ambursen dams we know that this type of construction can accommodate abrupt transition in foundation elevations.

5. References

In preparation of this report, AECOM had the documents listed below available. A major data gap in our preparation of this report is accurate as-built drawings of the concrete spillway. The best available information on the geometry of the spillway was from Sheet 7 of the 2003 Spillway Repairs prepared by Dewberry & Davis, LLC.

- Re-Inspection Report For Class I and Class II Impoundments and Impounding Structures by the Commonwealth of Virginia State Water Control Board. (1986)
- Condition Survey of Lake Accotink (Bathymetry) by Burgess & Niple, Inc. and Waterway Surveys & Engineering, Ltd. (2015)
- “Lake Accotink Sustainability Plan Summary of Potential Alternatives” by Wetland Studies and Solutions. (April 27, 2016)
- Operation and Maintenance Certificate Application For Virginia Regulated Impounding Structures by Chris Kuhn, MS. (March 25, 2013)
- Lake Accotink Dam Operation and Maintenance Manual by Michael Baker Jr., Inc. [Baker] (July 2013)
- Geotechnical Exploration Report by Burgess & Niple, Inc. (February 2003)
- Record Drawings of the Lake Accotink Dam/Spillway Repairs prepared in 2002 by Dewberry & Davis LLC (2008)
- Concrete and Corrosion Condition Survey by SCHNABEL Engineering Associates (July 11, 1997)
- Annual Inspection Report by Michael Baker Jr, Inc. [Baker] (July 2013)
- Lake Accotink Dam Re-Certification Study, Hydrology and Hydraulics Report by Williamsburg Environmental Group, Inc. (March 2013)
- Lake Accotink Dam Phase II Report, Inspection and Repair Recommendations, Dewberry, Nealon & Davis (1976)
- Accotink Dam – Spillway Stability during Renovations by Dewberry (2008)

- Lake Accotink Dam Emergency Action Plan by Williamsburg Environmental Group, Inc. (July 2013)

6. Limitations

This study is intended to provide a preliminary investigation into spillway removal options and costs, and is based upon limited available information. No engineering calculations were performed to verify hydraulic capacity or structural stability of the spillway/abutments. No coordination or discussion has occurred with the Virginia Department of Conservation and Recreation in preparation of this report. For this scope of work it is our understanding that WSSI will be responsible for all aspects regarding sediment management throughout the dam demolition. .

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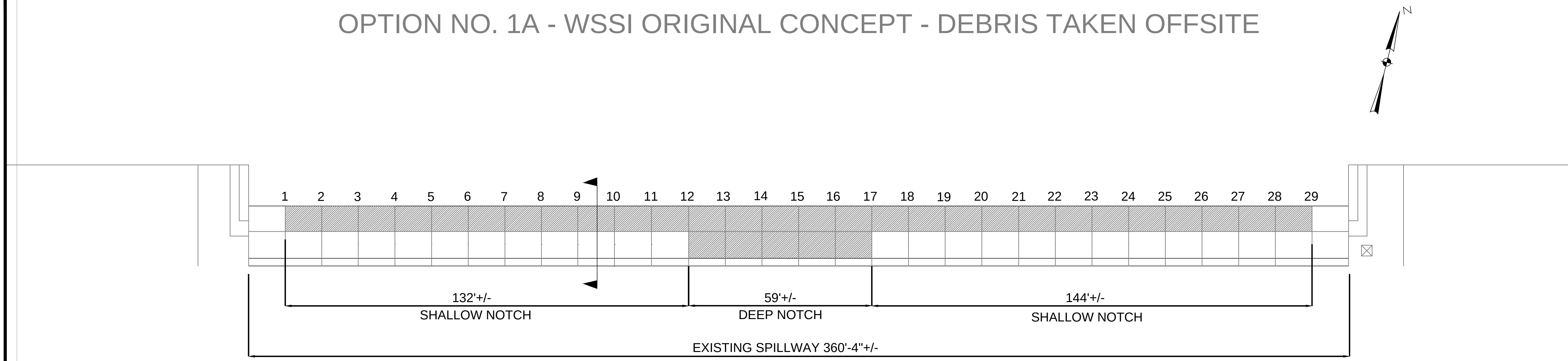
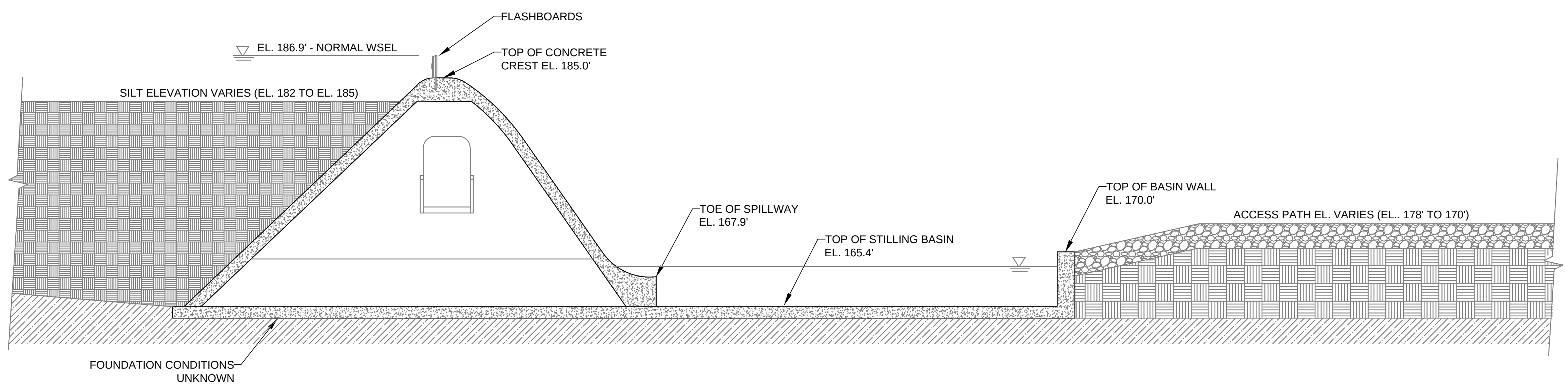
Attachment No. 1

Drawings of Conceptual Spillway Removal Options

OPTION NO. 1A - WSSI ORIGINAL CONCEPT - DEBRIS TAKEN OFFSITE





EXISTING CONDITION - TYPICAL SPILLWAY CROSS SECTION

0' 10' 25' 50'

GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)

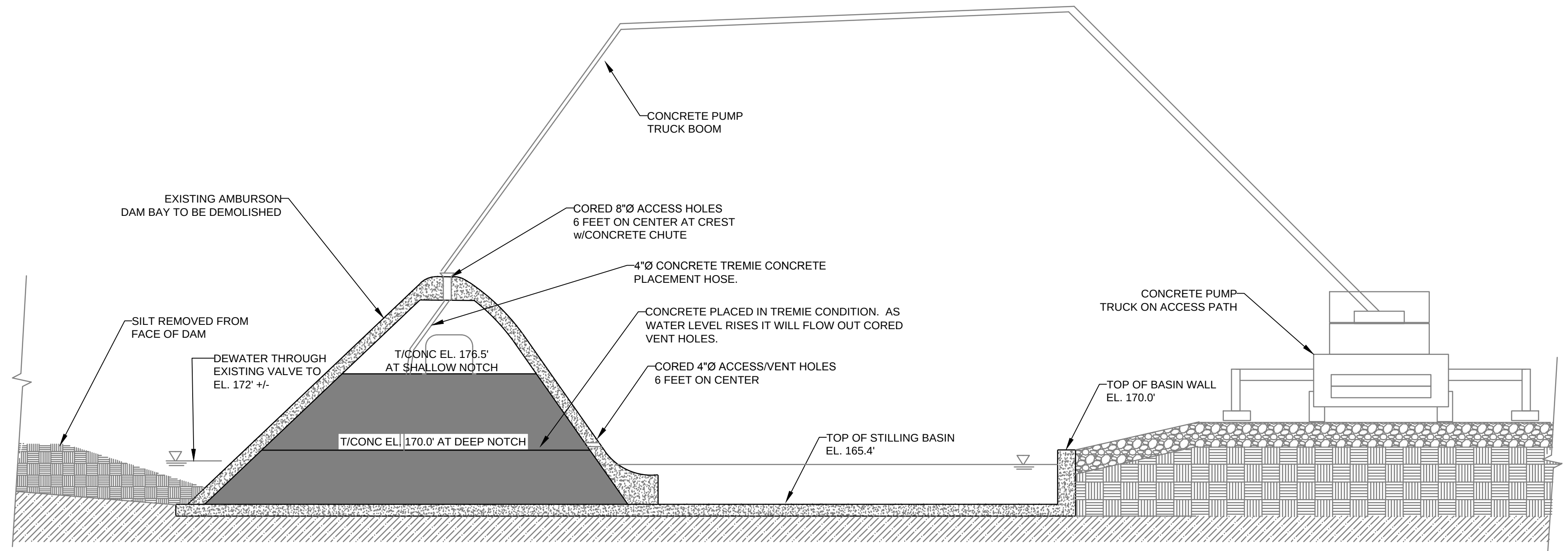
-CONCEPTUAL DRAWING-
NOT FOR CONSTRUCTION

GENERAL NOTES:

1. PROFILE OF SPILLWAY IS BASED UPON GEOMETRY SHOWN ON SHEET 7 OF THE JANUARY 2003 SPILLWAY REPAIRS PREPARED BY DEWBERRY & DAVIS LLC.
2. THE ELEVATIONS AND CONFIGURATION OF THE EXISTING SPILLWAY FOUNDATION IS UNKNOWN.

CLIENT: WETLAND STUDIES & SOLUTIONS, INC. (WSSI)		TITLE LAKE ACCOTINK DAM DEMOLITION CONCEPT	
PROJ LAKE ACCOTINK - DAM REMOVAL CONCEPT			
VA INVENTORY DAM #05609	ENGINEER RPG	AECOM	PROJ NO 60525781
			FIGURE 1

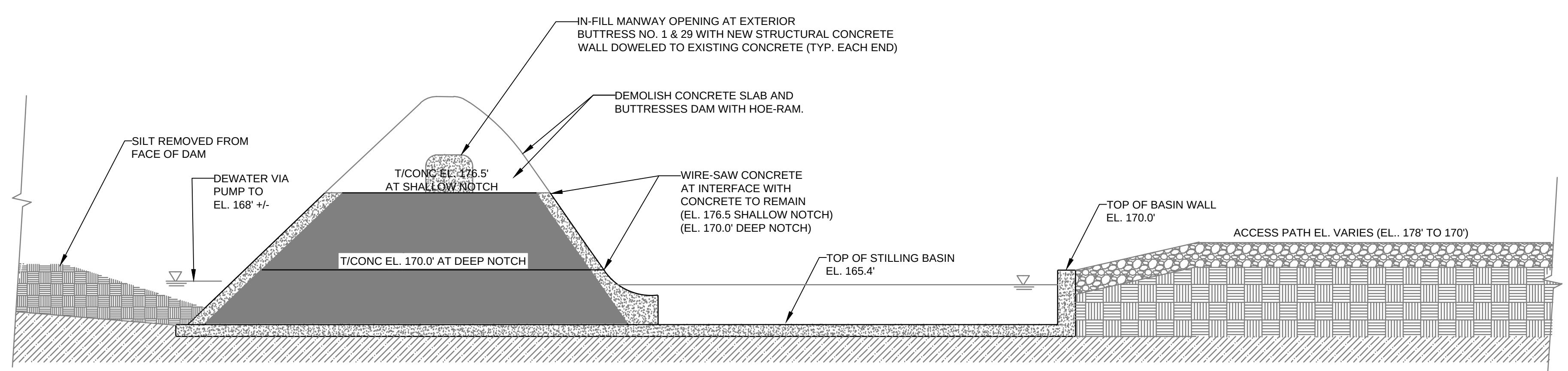
OPTION NO. 1A - WSSI ORIGINAL CONCEPT - DEBRIS TAKEN OFFSITE



PRE-DEMOLITION - TYPICAL SPILLWAY CROSS SECTION

0' 10' 25' 50'

GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)



DEMOLITION - TYPICAL SPILLWAY CROSS SECTION

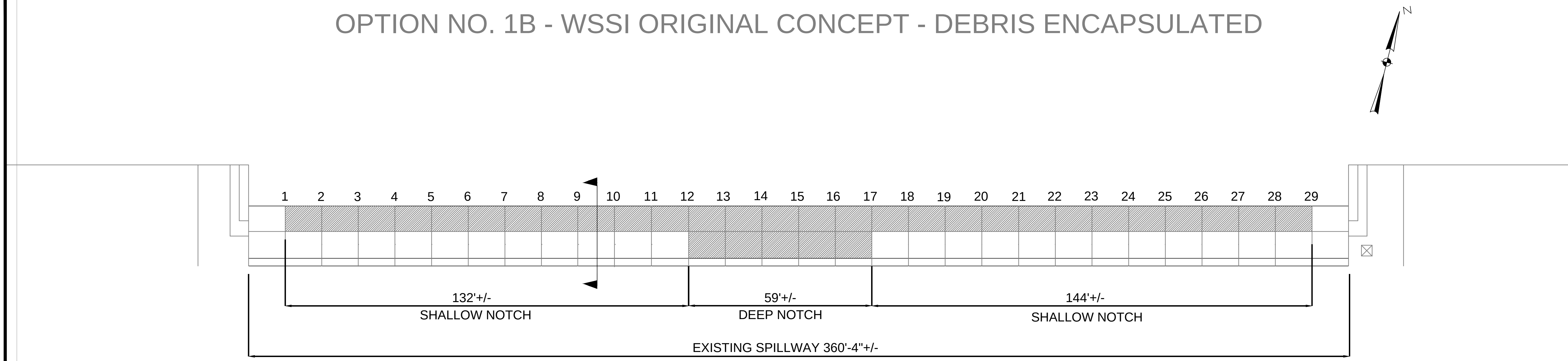
0' 10' 25' 50'

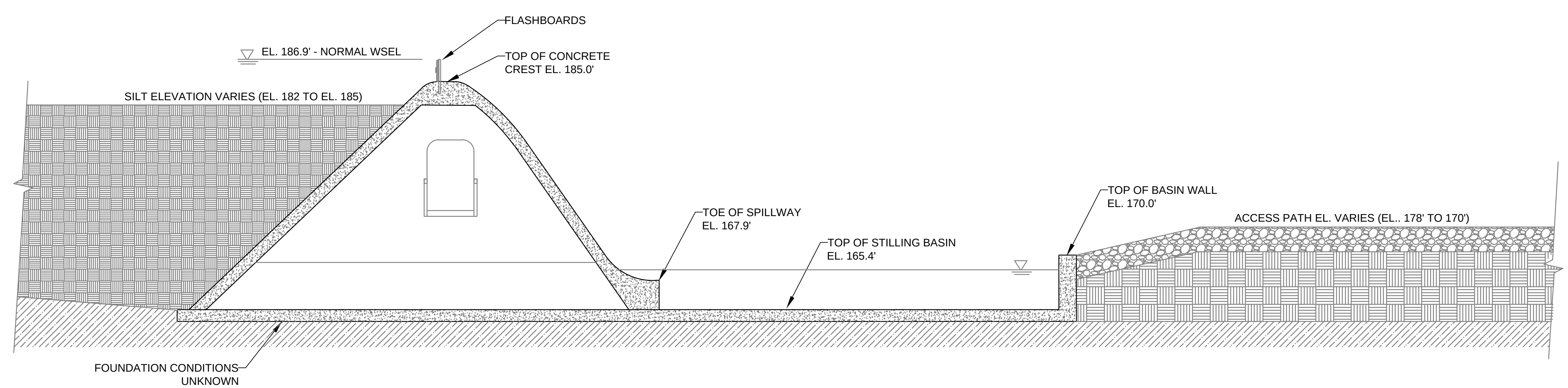
GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)

-CONCEPTUAL DRAWING-
NOT FOR CONSTRUCTION

CLIENT: WETLAND STUDIES & SOLUTIONS, INC. (WSSI)			TITLE LAKE ACCOTINK DAM DEMOLITION CONCEPT	
PROJ LAKE ACCOTINK – DAM REMOVAL CONCEPT				
VA INVENTORY DAM #05609	ENGINEER		AECOM	PROJ NO 60525781
	RPG			FIGURE 2

OPTION NO. 1B - WSSI ORIGINAL CONCEPT - DEBRIS ENCAPSULATED





EXISTING CONDITION - TYPICAL SPILLWAY CROSS SECTION

0' 10' 25' 50'

GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)

-CONCEPTUAL DRAWING-
NOT FOR CONSTRUCTION

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CLIENT: WETLAND STUDIES & SOLUTIONS, INC. (WSSI)		
PROJ LAKE ACCOTINK - DAM REMOVAL CONCEPT		
VA INVENTORY DAM #05609	ENGINEER RPG	

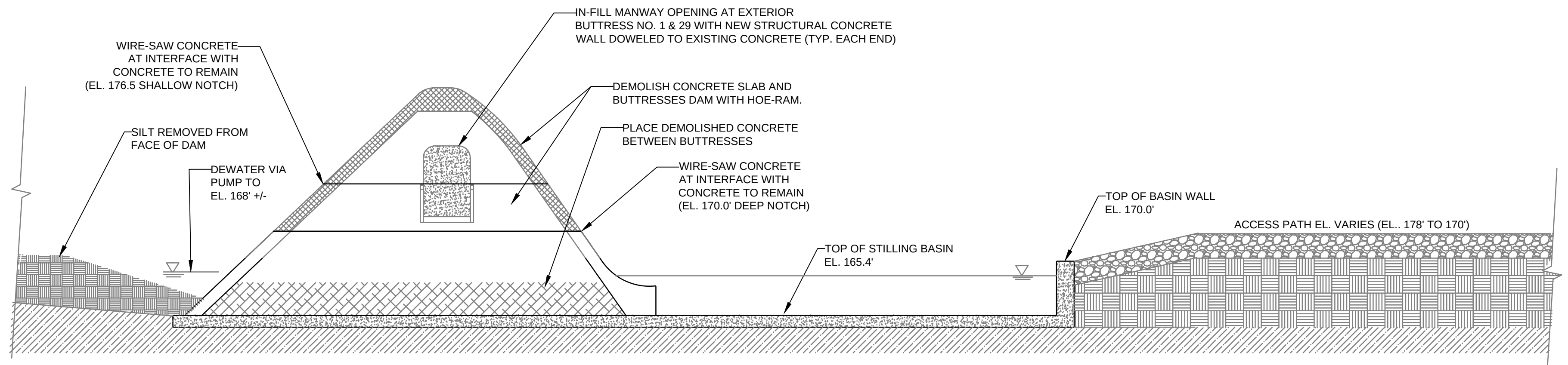
TITLE LAKE ACCOTINK DAM DEMOLITION CONCEPT

AECOM

PROJ NO 60525781

FIGURE 3

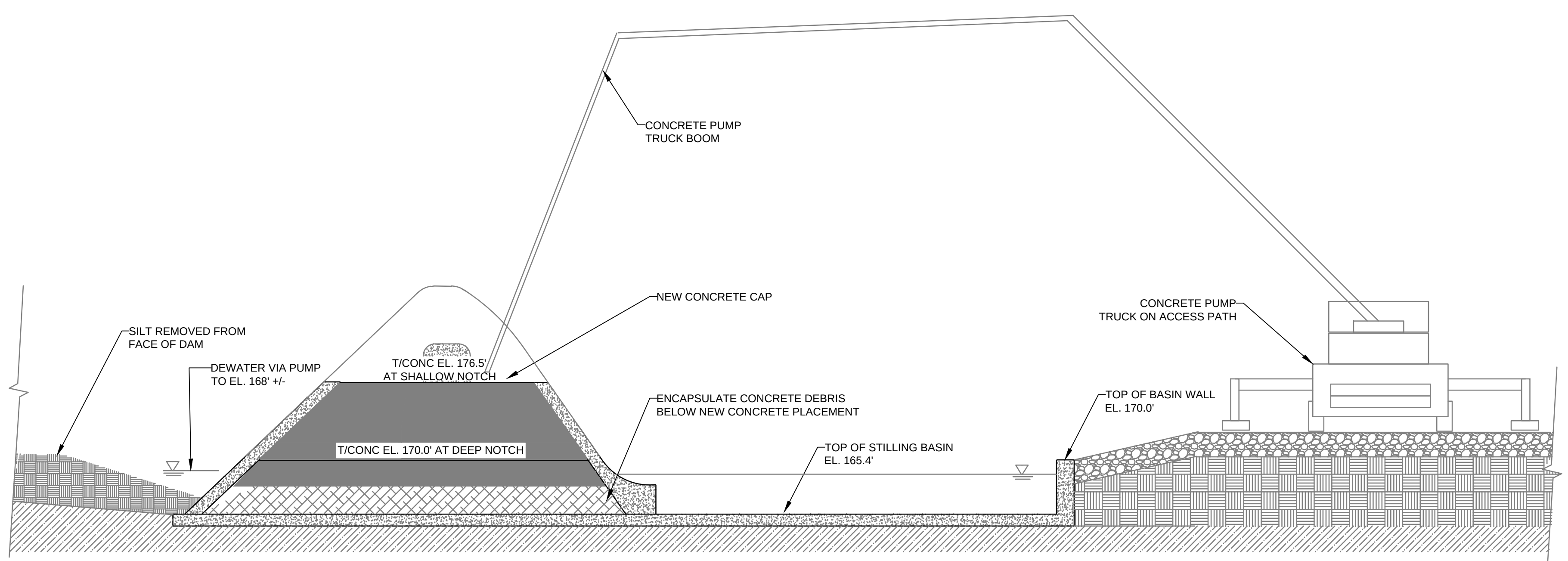
OPTION NO. 1B - WSSI ORIGINAL CONCEPT - DEBRIS ENCAPSULATED



DEMOLITION - TYPICAL SPILLWAY CROSS SECTION

0' 10' 25' 50'

GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)



DEBRIS ENCAPSULATION - TYPICAL SPILLWAY CROSS SECTION

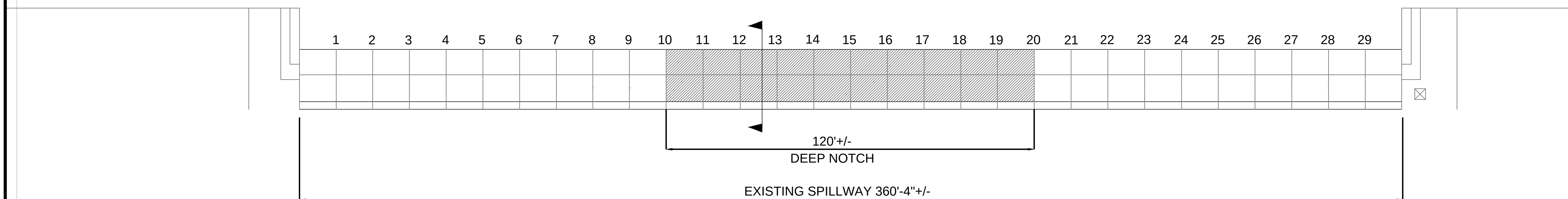
0' 10' 25' 50'

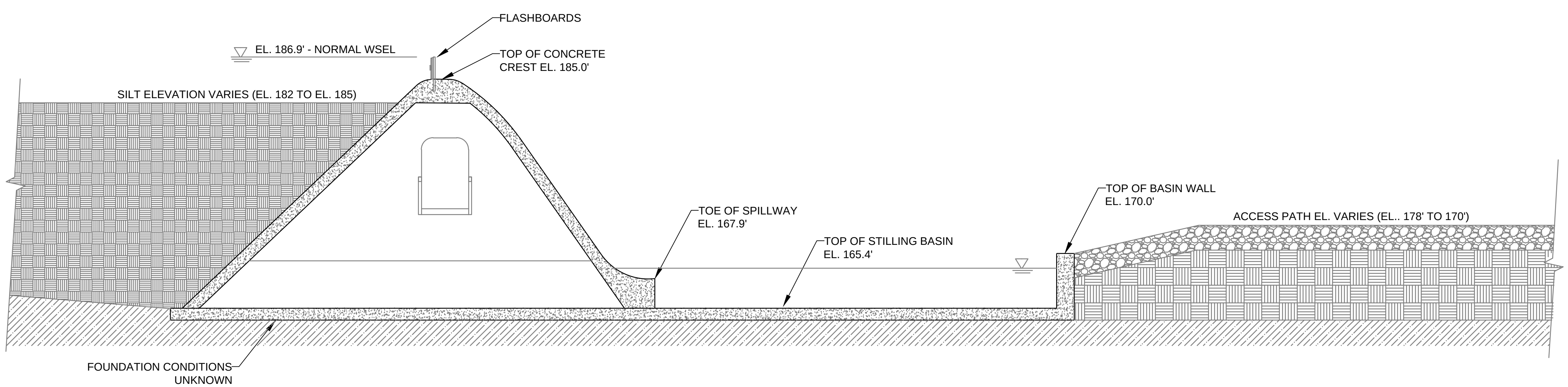
GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)

-CONCEPTUAL DRAWING-
NOT FOR CONSTRUCTION

CLIENT: WETLAND STUDIES & SOLUTIONS, INC. (WSSI)		TITLE LAKE ACCOTINK DAM DEMOLITION CONCEPT
PROJ LAKE ACCOTINK – DAM REMOVAL CONCEPT		
VA INVENTORY DAM #05609	ENGINEER RPG	AECOM
		PROJ NO 60525781
		FIGURE 4

OPTION NO. 2 - SINGLE LARGE NOTCH TO ELEVATION 170.0'





EXISTING CONDITION - TYPICAL SPILLWAY CROSS SECTION

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GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)

-CONCEPTUAL DRAWING-
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CLIENT: WETLAND STUDIES & SOLUTIONS, INC. (WSSI)		
PROJ LAKE ACCOTINK – DAM REMOVAL CONCEPT		
VA INVENTORY DAM #05609	ENGINEER RPG	

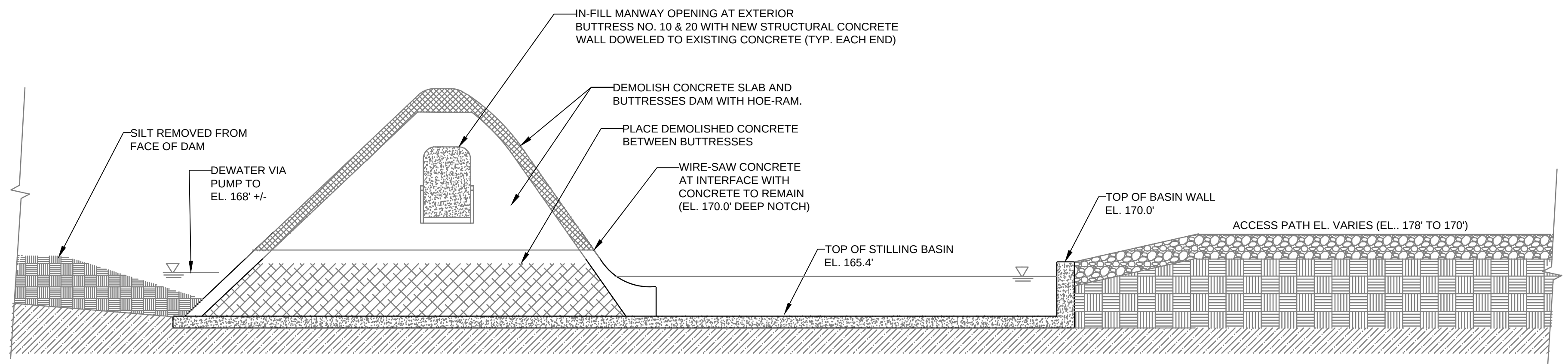
TITLE LAKE ACCOTINK DAM DEMOLITION CONCEPT

AECOM

PROJ NO 60525781

FIGURE 5

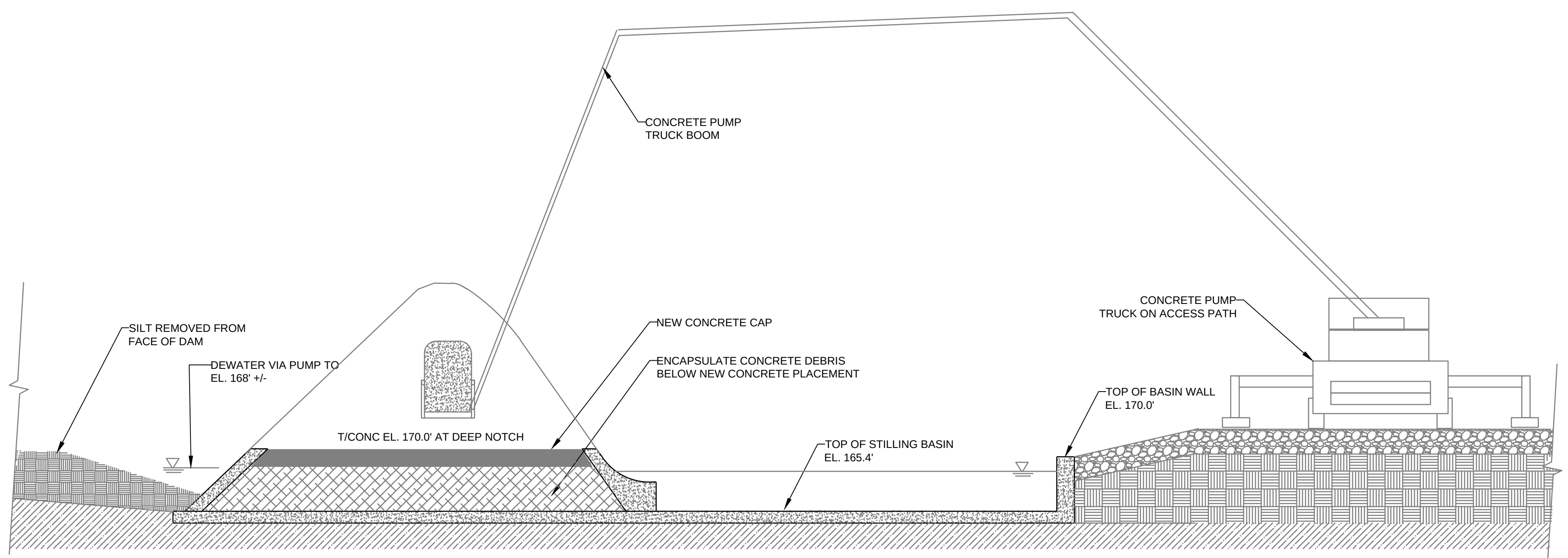
OPTION NO. 2 - SINGLE LARGE NOTCH TO ELEVATION 170.0'



DEMOLITION - TYPICAL SPILLWAY CROSS SECTION

0' 10' 25' 50'

GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)



DEBRIS ENCAPSULATION - TYPICAL SPILLWAY CROSS SECTION

0' 10' 25' 50'

GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)

-CONCEPTUAL DRAWING-
NOT FOR CONSTRUCTION

CLIENT: WETLAND STUDIES & SOLUTIONS, INC. (WSSI)

PROJ LAKE ACCOTINK - DAM REMOVAL CONCEPT

VA INVENTORY DAM #05609

ENGINEER RPG

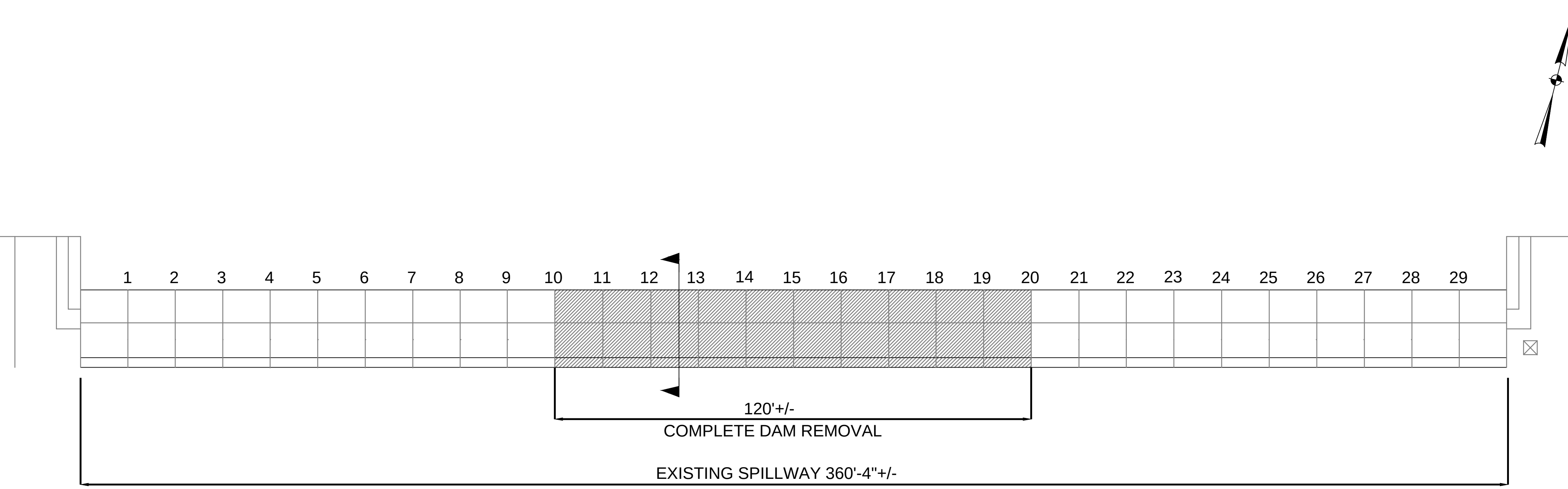
TITLE LAKE ACCOTINK DAM DEMOLITION CONCEPT

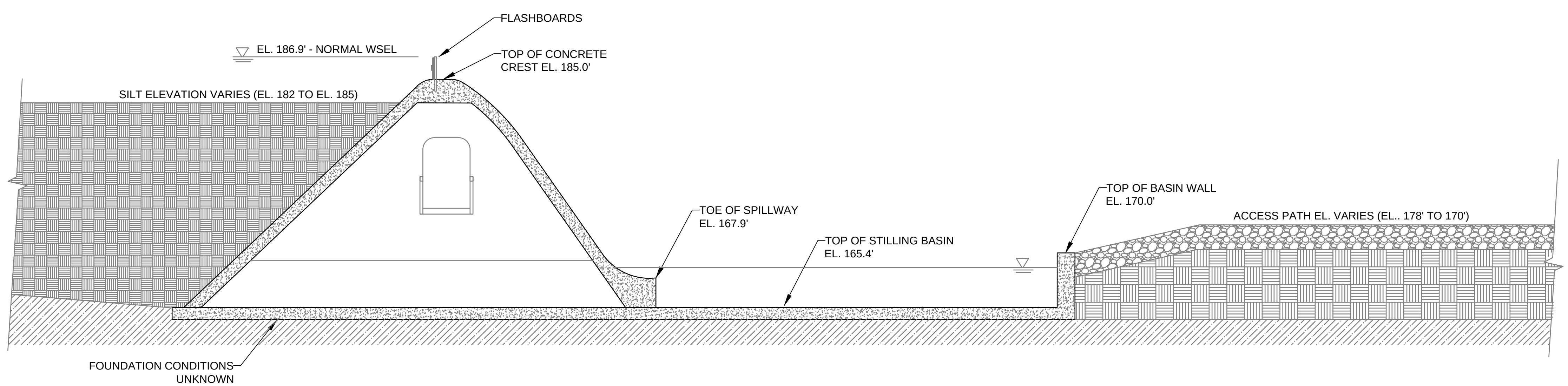
AECOM

PROJ NO 60525781

FIGURE 6

OPTION NO. 3 - FULL HEIGHT SPILLWAY DEMOLITION





EXISTING CONDITION - TYPICAL SPILLWAY CROSS SECTION

0' 10' 25' 50'

GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)

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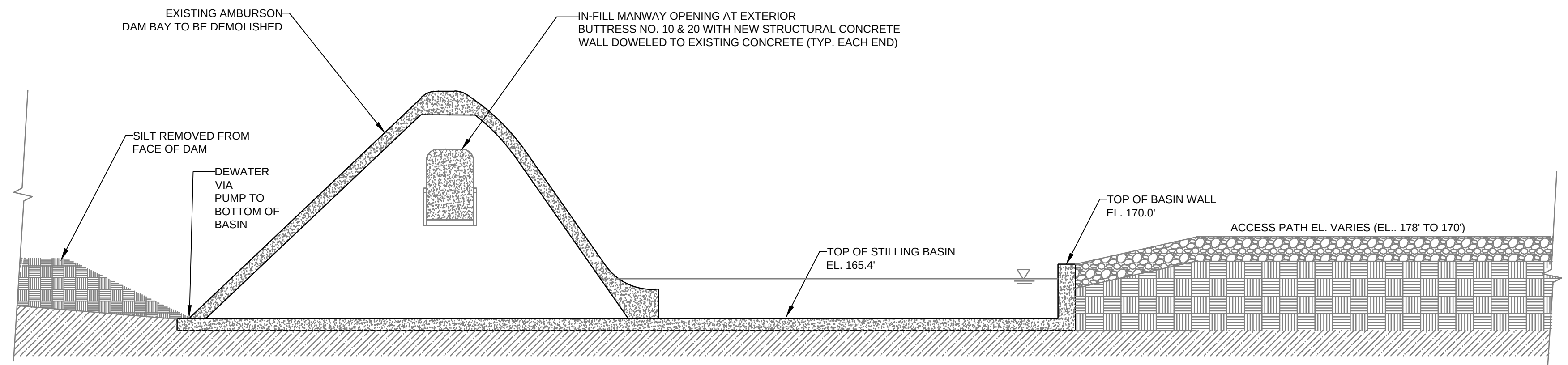
CLIENT: WETLAND STUDIES & SOLUTIONS, INC. (WSSI)		TITLE LAKE ACCOTINK DAM DEMOLITION CONCEPT	
PROJ LAKE ACCOTINK – DAM REMOVAL CONCEPT			
VA INVENTORY DAM #05609	ENGINEER RPG	AECOM	PROJ NO 60525781
			FIGURE 7

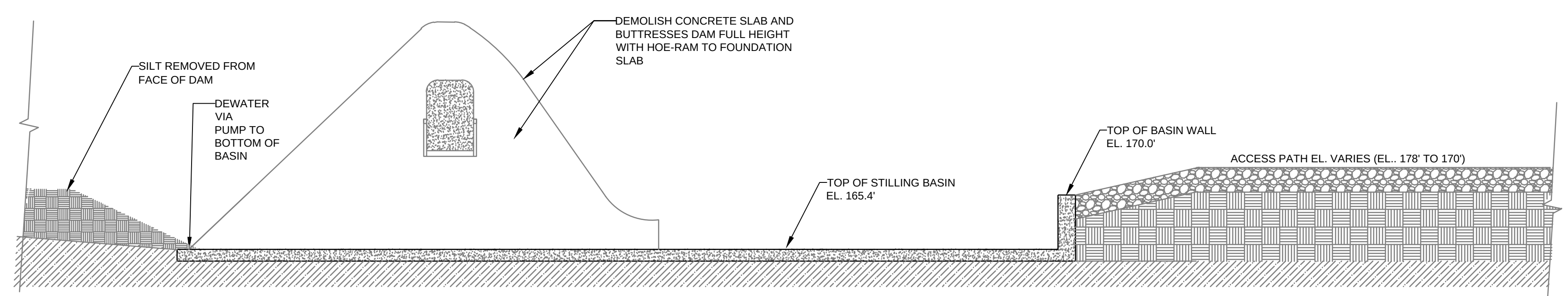
OPTION NO. 3 - FULL HEIGHT SPILLWAY DEMOLITION



PRE-DEMOLITION - TYPICAL SPILLWAY CROSS SECTION

0' 10' 25' 50'

GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)



DEMOLITION - TYPICAL SPILLWAY CROSS SECTION

0' 10' 25' 50'

GRAPHICAL SCALE (1 HORIZONTAL: 1 VERTICAL)

-CONCEPTUAL DRAWING-
NOT FOR CONSTRUCTION

CLIENT: WETLAND STUDIES & SOLUTIONS, INC. (WSSI)		TITLE LAKE ACCOTINK DAM DEMOLITION CONCEPT
PROJ LAKE ACCOTINK – DAM REMOVAL CONCEPT		PROJ NO 60525781
VA INVENTORY DAM #05609	ENGINEER RPG	AECOM FIGURE 8

Attachment No. 2

Engineers Opinion of Construct Cost for Lake Accotink Spillway Removal

ENGINEERS OPINION CONSTRUCTION COST
LAKE ACCOTINK SPILLWAY REMOVAL

DIRECT AND INDIRECT COST
Design: Conceptual - not for construction

Effective Date: 9 Jan 2017

ID	Description	Unit	Quantity	Price ($)	Amount ($)	Assumptions \ Notes
1	Demolition of concrete slabs	ton	596	358.00	213,368.00	slab assumed to be an average of 1-foot thick. Unit cost from six contractor bids, 2011 (escalated at 1% per year)
2	Demolition of concrete buttresses	ton	360	358.00	128,880.00	buttresses assumed to be an average of 1.5-feet thick. Unit cost from six contractor bids, 2011 (escalated at 1% per year)
3	Disposal of concrete in on-site disposal area	cubic yard	651	4.70	3,059.70	RS Means Heavy Construction item: 312316462020 & 312323170020
4	Trucking of concrete to on-site disposal area	cubic yard	472.5	1.06	500.85	RS Means Heavy Construction item: 024119195000
5	Riprap bedding for stabilization upstream of concrete slab	ton	200	65.00	13,000.00	160-ft by 50-ft by 0.5-ft. Unit weight 100 pcf. Unit cost from six contractor bids, 2011 (escalated at 1% per year)
6	Riprap bedding for stabilization upstream of concrete slab	ton	400	85.00	34,000.00	160-ft by 50-ft by 1.0-ft. Unit weight 100 pcf. Unit cost from six contractor bids, 2011 (escalated at 1% per year)
7	Concrete infill of walkways in end buttresses	cubic yard	6	333.00	1,998.00	RS Means Heavy Construction item: 033053404300
8	Concrete infill of walkways in end buttresses (forms)	square foot	200	7.74	1,548.00	RS Means Heavy Construction item: 031113852000
9	Site Reclaimation below dam site	lumpsum	1	10,000.00	10,000.00	
10	Subtotal:				406,354.55	
11	Indirects and General Requirements 20%				81,270.91	
12	Subtotal:				487,625.46	
13	Mobilization & Demobiization 14%				68,267.56	Percentage is average of six contractor bids, 2011
14	Conceptual Contingency 30%				166,767.91	
15	**Total:**				**722,660.93**	

Notes: Costs do not include sediment removal, water management (pumps), erosion measures and other items not specifically listed.

Attachment No. 3

Photolog of AECOM Site Visit

on 11/04/2016

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wetland Studies and Solutions, Inc.	Lake Accotink Dam (VA INV #05906)	60525781

Photo No. 1	Date: 11/04/2016

Description:

Downstream face of spillway looking towards the left concrete abutment.

No spill was occurring during the visit and standing water was observed within the stilling basin.

Photo No. 2	Date: 11/04/2016

Description:

Downstream face of spillway looking towards the right concrete abutment.

No spill was occurring during the visit and standing water was observed within the stilling basin.

AECOM	PHOTOGRAPHIC LOG

Client Name: Wetland Studies and Solutions, Inc.	**Site Location:** Lake Accotink Dam (VA INV #05906)	**Project No.** 60525781

Photo No. 3	**Date:** 11/04/2016

Description:

Right concrete spillway abutment.

Photo No. 4	**Date:** 11/04/2016

Description:

Manway access to the gallery at the right concrete spillway abutment.

AECOM

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wetland Studies and Solutions, Inc.	Lake Accotink Dam (VA INV #05906)	60525781

Photo No. 5

Date: 11/04/2016

Description:

Left concrete spillway abutment.

The discharge point of the low level outlet is visible and partially submerged.

No spill was occurring during the visit and standing water observed within the stilling basin.

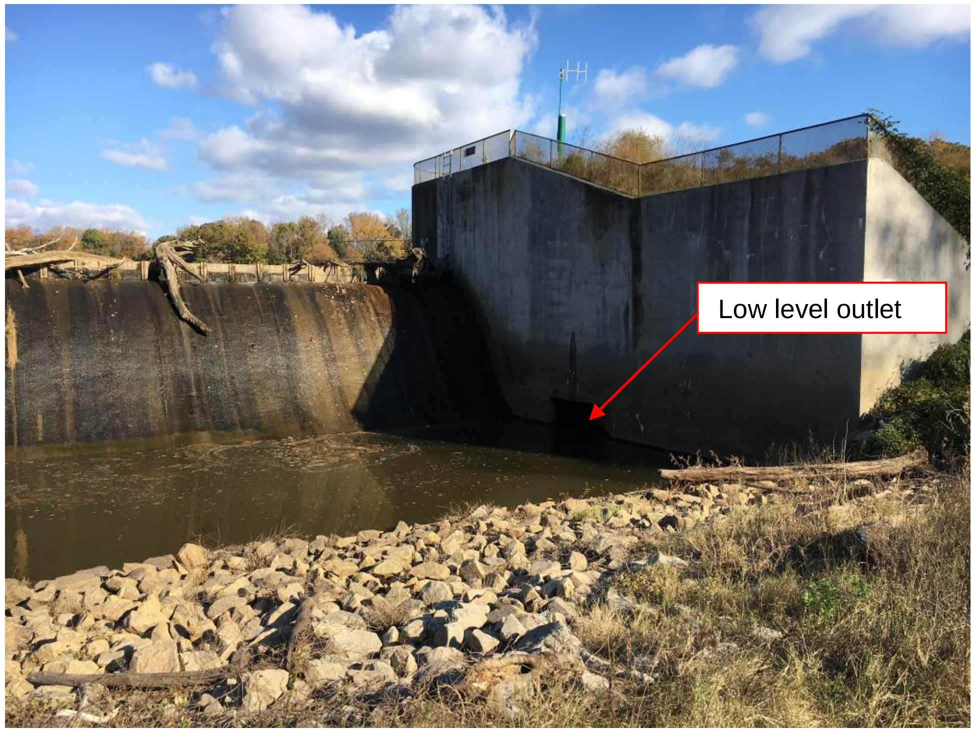


Photo No. 6

Date: 11/04/2016

Description:

Left concrete spillway abutment.

Remote monitoring station, manway access, low level gate actuator and trashrack/stoplog gate slot are visible.

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wetland Studies and Solutions, Inc.	Lake Accotink Dam (VA INV #05906)	60525781

Photo No. 7	Date: 11/04/2016

Description:

Left concrete spillway abutment.

Low level outlet sluice gate actuator. The trashrack/stoplog slot is located directly upstream.

Photo No. 8	Date: 11/04/2016

Description:

Left concrete spillway abutment.

Trashrack/Stoplog slot.

PHOTOGRAPHIC LOG

Client Name:
Wetland Studies and Solutions, Inc.

Site Location:
Lake Accotink Dam (VA INV #05906)

Project No.
60525781

Photo No. 9

Date:
11/04/2016

Description:

Left concrete spillway abutment.

Manway access to the gallery.

Photo No. 10

Date:
11/04/2016

Description:

Downstream channel.

AECOM

PHOTOGRAPHIC LOG

Client Name: Wetland Studies and Solutions, Inc.	**Site Location:** Lake Accotink Dam (VA INV #05906)	**Project No.** 60525781

Photo No. 11

Date: 11/04/2016

Description:

Overview of downstream face of spillway. Three outlet pipes under the access path provide the hydraulic pathway downstream during normal spill conditions.

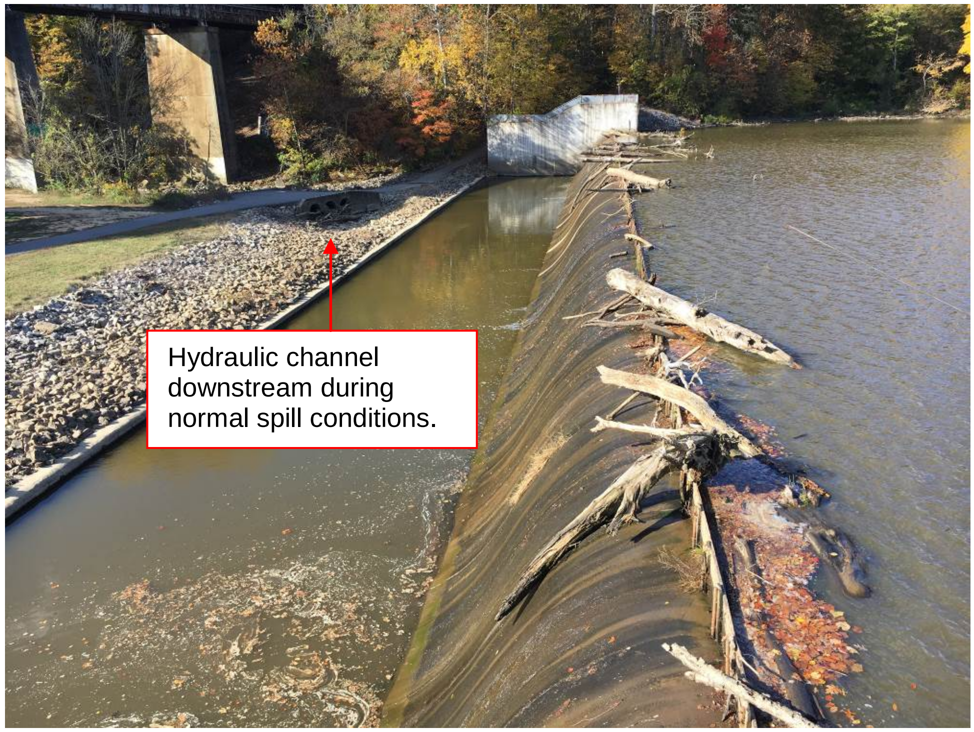


Photo No. 12

Date: 11/04/2016

Description:

Overview of earthen embankment section located to the left of the spillway.