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An Analysis of the Benefits of Using Underground Tanks for the Storage of Stormwater Runoff Generated at Virginia Department of Transportation Maintenance Facilities

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The purpose of this study was to quantify the monetary benefits of using underground storage tanks for the temporary storage of salt-laden runoff generated at VDOT's salt storage facilities. This was done by way of a simple cost analysis comparing the use of underground storage tanks to the open-pond systems more commonly used now. Information on the costs related to the purchase, construction, maintenance, and operation of both storage types was used to develop a simple cost estimation tool, i.e., a benefit/cost spreadsheet. The tool was structured so that modifications could be made based on site-specific information on precipitation, water disposal costs, brine usage, etc.

The study concluded that although the purchase price of underground storage tanks is substantially higher than that of ponds, the 50-year all-inclusive cost of tanks is similar to the cost of ponds for stormwater storage. Although the costs are highly variable and dependent on site-specific conditions, when the medium default values used in the benefit/cost spreadsheet are used, tanks are slightly cheaper than pond relining or new pond construction. As disposal costs increase above current values, storage by way of tanks will become an increasingly better option.

Based on this information, the study recommends that VDOT's Environmental Division collaborate with the Capital Outlay Section of VDOT's Administrative Services Division, residency administrators, and area headquarters superintendents to evaluate the option of using underground storage tanks for the storage of stormwater runoff from salt loading pads at locations that are replacing (relining) existing ponds or at facilities where new pond construction is being considered.

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FINAL REPORT

AN ANALYSIS OF THE BENEFITS OF USING UNDERGROUND TANKS FOR THE STORAGE OF STORMWATER RUNOFF GENERATED AT VIRGINIA DEPARTMENT OF TRANSPORTATION MAINTENANCE FACILITIES

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ABSTRACT

The Virginia Department of Transportation (VDOT) collects millions of gallons of runoff at its nearly 300 salt storage facilities each year, with some portion of this water being reused for the generation of salt brine. Storing this collected stormwater runoff in tanks rather than ponds affords some advantages in that less water is collected; the water that is collected remains cleaner; and the water is more likely to be properly managed and disposed of when necessary.

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INTRODUCTION

Several studies have been undertaken under the auspices of the Virginia Transportation Research Council (VTRC) to aid the Virginia Department of Transportation (VDOT) with the ongoing challenges presented at the salt storage infrastructure located throughout the state. It is estimated that VDOT captures more than 30 million gallons of runoff at its nearly 300 salt storage facilities each winter (Fitch et al., 2009). These earlier projects resulted in a number of recommendations including one to divert clean water away from the salt-laden stormwater ponds during non-winter months and to reuse captured stormwater for the purposes of brine generation (Fitch et al., 2008). Efforts to implement these recommendations were initiated in 2009 and continue today. However, a number of findings identified in these earlier winter maintenance studies have not yet been addressed. Most of the remaining issues are the result of the dependence of the current salt-laden stormwater control system on open storage ponds. These issues include the unnecessary collection of direct precipitation, high levels of suspended solids in the water that is collected, and the inability to control unwanted outflows.

In addition to these issues, many of the ponds originally constructed to collect the stormwater at the salt storage facilities are nearing the end of their design life (i.e., the rubber membrane and/or the asphalt lining that makes them impermeable is degraded, leaving the integrity of the ponds in question). Because some subset of these ponds may require replacement or repair relatively soon, the question has arisen as to whether it would be beneficial—both from a cost perspective and in terms of better management of stormwater runoff—to replace such ponds with underground storage tanks.

PURPOSE AND SCOPE

The purpose of this study was to determine; document; and, where possible, quantify the monetary benefits of transitioning away from the use of open ponds to the use of underground storage tanks for the capture and storage of salt-laden stormwater runoff collected at VDOT's salt storage facilities.

The scope of the study included a simple cost analysis of underground tanks for stormwater capture and storage as compared to the open-pond systems more commonly used now. The cost analysis for the tanks was limited to data obtained from VDOT maintenance locations that had recently (in approximately the last 5 years) undergone a retrofit from an open-pond system to a tank-based system for storage. In addition, maintenance information including problems or advantages experienced by facilities currently using tanks was documented. This same type of information was collected from a subset of those VDOT facilities that use ponds for the collection and storage of stormwater runoff.

METHODS

To achieve the study objectives, the researchers undertook four primary tasks: (1) collection of purchase and construction cost data for tank and pond stormwater storage systems; (2) collection of maintenance data for these systems; (3) development of a benefit/cost spreadsheet for the analysis and comparison of costs and maintenance data over the anticipated lifespan of a tank or a pond; and (4) an assessment of the potential to convert from ponds to tanks and the resulting impacts.

Task 1: Collection of Purchase and Construction Cost Data

Tanks

An effort was made to collect cost data from each of the VDOT maintenance facilities that had storage tanks installed in the last 5 years. Although the number of tanks installed during this time frame was known to be limited and VDOT does have a number of older tanks, only information pertaining to the recently installed tanks was collected as the researchers assumed the data for the older installations would not be representative of current costs. Specific information requested for installed tanks included the costs of the following:

- underground tank(s)
- oil-water separator
- excavation
- stone
- plumbing
- labor
- equipment rental
- seeding
- miscellaneous items.

The cost information gathered was based on actual invoices when readily available or, if not, bid estimates as provided by the VDOT area headquarters (AHQ) superintendents, residency environmental specialists, or residency administrators.

Ponds

Cost information was also collected for open-pond systems, which are more commonly used by VDOT for the storage of stormwater runoff from salt loading pads. Because most of the more than 200 ponds that VDOT operates have been in use since collection of the salt-laden stormwater runoff from loading pads began, costs related to new pond construction were somewhat limited. An estimate of typical new pond construction costs was obtained from the Capital Outlay Section of VDOT's Administrative Services Division, and actual costs were also collected from specific installations when possible. Components of the cost of open-pond construction included the following:

- excavation
- liner
- plumbing
- labor
- equipment rental
- miscellaneous items.

In addition to new construction costs, the costs for pond relining were collected. Replacing the impermeable rubber membrane on existing ponds is an acceptable method of rehabilitating a pond that is nearing the end of its anticipated service life or that exhibits signs of membrane degradation.

Components included in the cost of liner replacement were as follows:

- liner
- sludge removal and disposal
- labor.

Task 2: Collection of Maintenance Data

Approximately 25 current VDOT tank operators and 79 users of ponds were asked to document the type, frequency, and cost of maintenance practices conducted for their respective salt-laden stormwater storage system. Initial information requests were made by email (or in person if the individual was available during a site visit); follow-up requests were made by telephone or email.

The maintenance data obtained for tanks and ponds were compared to determine if these methods differed, and if so, how this affected the cost of operations. Because of the anticipated limits on the availability of cost information associated with some maintenance practices, estimations were made for the projected volume reductions in stormwater collected when using tanks versus ponds (since tanks receive no direct precipitation) and the assumed corresponding reduction in stormwater disposal costs. Data on pad sizes, pond dimensions, and seasonal precipitation previously collected by one of the researchers for each of VDOT's nine districts were used in these estimations.

Task 3: Development of the Benefit/Cost Spreadsheet

A benefit/cost spreadsheet was developed to automate two cost comparisons. These comparisons corresponded to the two situations in which a maintenance facility is most likely to face a decision: (1) the less common case when the agency constructs a new salt storage and loading facility, and (2) the more common case when the pond liner at an existing salt storage and loading facility has reached the end of its useful life.

Scope of the Life-Cycle Cost Analysis

The cost estimate in the comparison was built around the functional components of the facility and around three operating and maintenance activities:

1. The comparison treats the costs of the following functional components as one-time outlays or as periodic outlays:

   - oil-water separator
   - plumbing
   - pond liner (if present)
   - space
   - pond (if present)
   - underground tank (if present).

2. The comparison approximates the costs of the following maintenance activities as a continuous expenditure flow:

   - periodic clean-out of solids
   - periodic pump-out and disposal of saltwater.

3. The comparison allows for the operating activity of brine production to be counted as an offset against the amount of saltwater that the agency must pay to have pumped out if retained stormwater is used in brine production.

Although they are included in the spreadsheet, some of the functional components, such as the plumbing, turned out to be redundant for purposes of cost comparison as the available historical data did not indicate that the contributions these components make to life-cycle cost depend on the choice between a pond and an underground tank.

The researchers considered building a cost estimate around bid quantities such as cubic yards of excavation, tons of stone, and so forth, but they found that the available historical cost data were too scarce to permit an estimate on this basis. The researchers likewise considered building a cost estimate around engineering inputs such as equipment rental, materials, labor, contingency, and so forth, but they found that the available historical cost data were too scarce to permit an estimate on that basis either. Finally, the researchers opted for a cost estimate that depended chiefly on the capacity specified for the pond or the storage tank.

Data Sources and Default Values in the Spreadsheet

The estimate of costs connected with installation of an underground tank was based on cost figures from six AHQs that installed tanks within the last 5 years: Cluster Springs, Dumfries, Lake Ridge, Smithfield, Stephens City, and Toms Brook. The estimate of costs connected with the replacement of a pond liner was based on cost figures from Kenbridge, Kerrs Creek, Lebanon, Madison, North Bristol, Swoope, Van Dorn, and Willis AHQs. The estimate of costs connected with construction of a new surface pond was based on a historical cost supplied by the Capital Outlay Section of VDOT's Administrative Services Division plus a contractor's estimate given for the Madison AHQ. The estimate of costs connected with the pumping and disposal of wastewater was based on detailed cost information provided for Wytheville, Coeburn, and Blackford AHQs and information from Fitch et al. (2008).

The estimated rate of evaporation from a surface pond was based on a 30-year average for the state as a whole. The estimated service life of a pond liner was based on information requested from the AHQ superintendents. The estimated service life of a fiberglass-reinforced underground tank was assumed to be 50 years based on values found in the literature (Karbhari, 2003; Lieblein, 1981).

The cost model, in the form of a spreadsheet, provides single default values for the costs associated with most of the functional components and operating or maintenance activities. The user can modify these at his or her discretion. In addition, the spreadsheet has separate "low," "medium," and "high" default values for the costs associated with three of the functional components, namely the plumbing, the pond, and the underground tank. The available cost data made it clear that the costs associated with each of these functional components could vary widely because of factors that the researchers could not easily build into the spreadsheet.

The spreadsheet allows for the analysis to be run using the low, medium, or high default values to account for the range of historical costs associated with each of these components. The tank unit cost low was based on cost data from Toms Brook AHQ; the medium on data from Cluster Springs AHQ; and the high on data from Lake Ridge AHQ. The plumbing cost low was based on cost data from Dumfries AHQ; the medium on cost data from Toms Brook AHQ; and the high on cost data from Manassas AHQ. Although the pond unit cost medium was based on a contractor estimate given to the Madison AHQ, the low and the high were not based directly on cost data from the AHQs: the low was based on excavation cost bid data alone, and the high was based on excavation cost bid data plus liner replacement cost data.

Cost Comparison Scenarios

Several different cost comparison scenarios were calculated using the benefit/cost spreadsheet. In each of these, one to several site-specific variables in the spreadsheet were changed; in all cases, the cost of installing a tank was compared to either the cost of a new pond or the cost of a new liner.

New Ponds vs. Tanks

For the rare case when the agency constructs a new facility, the cost computations compared the present discounted value of the costs of a facility with a newly constructed surface pond against the present discounted value of the costs of a facility with a newly constructed underground tank, out to a 50-year time horizon. Three different comparisons were calculated using the low, medium, and high default values described earlier. For all three of the estimates, the break-even pump-out costs—per year or per gallon—that would make the present discounted life-cycle costs of the two options equal (holding other costs and quantities constant) were also calculated. In addition, the break-even total up-front costs of a new tank installation that would make the present discounted life-cycle costs of the two options equal (holding other costs and quantities constant) were calculated.

Pond Relining vs. Tanks

For the more common case where the agency faces the need to replace the pond liner at an existing facility, the cost computations compared the present discounted value of the costs of a facility with a new liner on an existing pond against the present discounted value of the costs of a facility with a newly constructed underground tank, out to a 50-year time horizon. Again, three different comparisons were calculated using the low, medium, and high cost values. For these cases, too, the break-even pond pump-out costs (holding other costs and quantities constant) and the break-even total up-front costs of a new tank installation (holding other costs and quantities constant) were calculated.

Additional Cost Analyses

The researchers wished to determine how sensitive the differences among the three options of ponds, liners, and tanks (see Figure 1) were to changes in the variables in the cost model. They wished also to understand better and predict the anticipated differences in costs assuming some possible changes in associated maintenance costs.

Figure 1. The Three Stormwater Storage Options Considered: New Ponds, New Liners, and Underground Storage Tanks

To address these wishes, additional cost estimations were made with the following changes: increasing and decreasing all up-front construction costs by 5% while holding all other costs equal; adjusting the cumulative maintenance costs up and down 5%; adjusting water disposal costs by 50%; changing the number of events requiring the application of brine; and altering the volume of stormwater runoff captured during the non-winter maintenance season (by reducing the amount of precipitation or by assuming the use of a diversion valve). This limited number of scenarios only highlights the differences among tanks, ponds, and liners and was not intended to account for all site conditions that could be compared.

Task 4: Assessment of Implementation Potential and Impacts of Transitioning to Use of Storage Tanks

To predict better the practicality of VDOT transitioning to the use of storage tanks, the researchers consulted operators of sites currently using underground storage tanks to identify problems or constraints related to installation, operation, or maintenance that are unique to this type of system. In addition, the information on the number of tanks and ponds currently being operated at VDOT's maintenance facilities was used to estimate the costs and benefits of transitioning from ponds to tanks.

RESULTS AND DISCUSSION

Description of Data and Data Sources

A total of seven locations were found to have recently installed underground tanks for the storage of stormwater runoff from salt loading pads (see Table 1, Section A). Tanks purchased ranged in size from 4,000 to 25,000 gallons, and all were constructed of reinforced fiberglass. Although useful information was provided by all seven locations, comprehensive cost information covering all aspects of tank installation was available for only five of the sites. In addition, this limited information was not uniformly itemized. Subsequently, some data categories were combined and, as previously stated, in some cases high, medium, and low values were used for the development of the benefit/cost spreadsheet rather than a median or a mean.

Information pertaining to the operation and maintenance of tanks was requested from 25 tank operators; 18 responses were received (see Table 1, Section B). Information pertaining to the operation and maintenance of ponds was requested from 78 locations; responses were received from 29, with each of VDOT's nine districts represented (see Table 1, Section C).

Cost Estimates

The values used for the general cost estimates in the spreadsheet are shown in Table 2. The costs associated with plumbing varied substantially as did the per gallon purchase cost of the underground storage tanks. The service life or maintenance intervals used in the spreadsheet calculations are also shown.

Table 1. VDOT Maintenance Facilities Providing Cost, Operation, and Maintenance Data

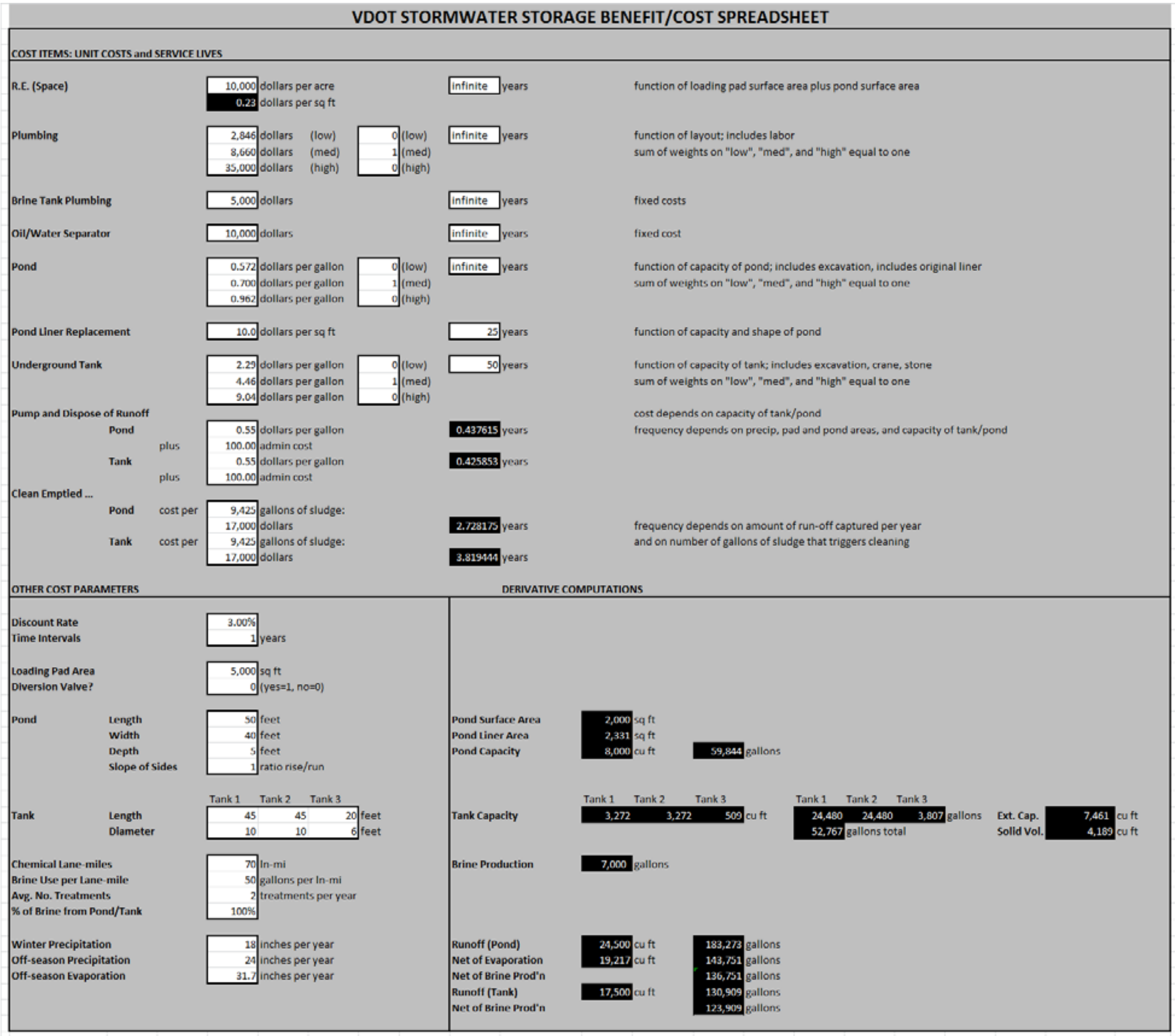
A. Data on Tank Installation	
Cluster Springs	Dumfries
Lake Ridge	Prince George
Smithfield	Stephens City
Toms Brook	
B. Data on Tank Operations and Maintenance	
Basie Road	Bluefield Dome
Bowers Hill	Buchanan
Capron	Covington
Cross Junction	Eastville
Emporia	Expressway
Fairfield	Fancy Hill
Hayfield	Lexington Bridge
Prince George (above ground)	Sturgeonville
Toms Brook	Wards Corner
Wayside	
C. Data on Pond Operations and Maintenance	
Bealeton	Chancellor
Cuckoo	Dryden
Dublin	Front Royal
Hampden-Sydney	Horsepasture
Kenbridge	Kerrs Creek
Lebanon	Madison
Mauzy	Mechanicsville
Montpelier	North Bristol
Nottoway	Powhatan
Rappahannock	Seaford
Shackleford	Surry
Swoope	Van Dorn
Verona	Willis
Windsor	Wytheville

Table 2. Cost Values for Each Item Used in the Benefit/Cost Spreadsheet

Item	Cost			Service Life / Frequency
	Low	Medium	High	
Space	NA	$0.23/ft^2$	NA	Infinite
Plumbing (general)	$2,846	$8,660	$35,000	Infinite
Plumbing (tank)	NA	$5,000	NA	Infinite
Oil-Water Separator	NA	$10,000	NA	Infinite
Pond (new construction)	$0.572/gal	$0.700/gal	$0.962/gal	Infinite
Pond Liner	NA	$10/ft^2$	NA	25 years
Tank (underground)	$2.29/gal	$4.46/gal	$9.04/gal	50 years
Disposal Costs (pond water)	NA	$0.55/gal	NA	0.44 years
Disposal Costs (tank water)	NA	$0.55/gal	NA	0.42 years
Disposal Costs (pond sediment)	NA	$1.80/gal	NA	2.73 years
Disposal Costs (tank sediment)	NA	$1.80/gal	NA	3.82 years

NA = not applicable. Costs of ponds and tanks are shown in dollars per gallon and costs of space and pond liners are shown in dollars per square foot, as these are directly related to the volume of storage and size, respectively.

Although these values served as defaults in the initial cost analysis, each of the inputs can be adjusted if more accurate values become available or to allow for site-specific adjustments. Explicit values for space requirements, maintenance intervals, interest rates, loading pad areas, pond and tank dimensions, chemical lane-miles, brine application rates, treatment times, and precipitation information were included in the calculations and can also be varied to allow for customized comparisons. The input page of the benefit/cost spreadsheet is shown in Figure 2.


VDOT STORMWATER STORAGE BENEFIT/COST SPREADSHEET

COST ITEMS: UNIT COSTS and SERVICE LIVES

R.E. (Space)		10,000 dollars per acre; 0.23 dollars per sq ft		infinite years	function of loading pad surface area plus pond surface area
Plumbing		2,846 dollars (low); 8,660 dollars (med); 35,000 dollars (high)	0 (low); 1 (med); 0 (high)	infinite years	function of layout; includes labor; sum of weights on "low", "med", and "high" equal to one
Brine Tank Plumbing		5,000 dollars		infinite years	fixed costs
Oil/Water Separator		10,000 dollars		infinite years	fixed cost
Pond		0.572 dollars per gallon; 0.700 dollars per gallon; 0.962 dollars per gallon	0 (low); 1 (med); 0 (high)	infinite years	function of capacity of pond; includes excavation, includes original liner; sum of weights on "low", "med", and "high" equal to one
Pond Liner Replacement		10.0 dollars per sq ft		25 years	function of capacity and shape of pond
Underground Tank		2.29 dollars per gallon; 4.46 dollars per gallon; 9.04 dollars per gallon	0 (low); 1 (med); 0 (high)	50 years	function of capacity of tank; includes excavation, crane, stone; sum of weights on "low", "med", and "high" equal to one
Pump and Dispose of Runoff	Pond	0.55 dollars per gallon; plus 100.00 admin cost		0.437615 years	cost depends on capacity of tank/pond; frequency depends on precip, pad and pond areas, and capacity of tank/pond
	Tank	0.55 dollars per gallon; plus 100.00 admin cost		0.425853 years	
Clean Emptied ...	Pond	cost per 9,425 gallons of sludge: 17,000 dollars		2.728175 years	frequency depends on amount of run-off captured per year and on number of gallons of sludge that triggers cleaning
	Tank	cost per 9,425 gallons of sludge: 17,000 dollars		3.819444 years	

OTHER COST PARAMETERS

Discount Rate		3.00%
Time Intervals		1 years
Loading Pad Area		5,000 sq ft
Diversion Valve?		0 (yes=1, no=0)
Pond	Length	50 feet
	Width	40 feet
	Depth	5 feet
	Slope of Sides	1 ratio rise/run
Tank	Length	Tank 1: 45; Tank 2: 45; Tank 3: 20 feet
	Diameter	Tank 1: 10; Tank 2: 10; Tank 3: 6 feet
Chemical Lane-miles		70 ln-mi
Brine Use per Lane-mile		50 gallons per ln-mi
Avg. No. Treatments		2 treatments per year
% of Brine from Pond/Tank		100%
Winter Precipitation		18 inches per year
Off-season Precipitation		24 inches per year
Off-season Evaporation		31.7 inches per year

DERIVATIVE COMPUTATIONS

Pond Surface Area	2,000 sq ft	
Pond Liner Area	2,331 sq ft	
Pond Capacity	8,000 cu ft	59,844 gallons
Tank Capacity	Tank 1: 3,272; Tank 2: 3,272; Tank 3: 509 cu ft	Tank 1: 24,480; Tank 2: 24,480; Tank 3: 3,807 gallons; 52,767 gallons total; Ext. Cap. 7,461 cu ft; Solid Vol. 4,189 cu ft
Brine Production	7,000 gallons	
Runoff (Pond)	24,500 cu ft	183,273 gallons
Net of Evaporation	19,217 cu ft	143,751 gallons
Net of Brine Prod'n		136,751 gallons
Runoff (Tank)	17,500 cu ft	130,909 gallons
Net of Brine Prod'n		123,909 gallons

Figure 2. Input Page of Benefit/Cost Spreadsheet

Cost Comparison Using Cost Estimate Defaults

The results of comparing the costs among the anticipated 50-year costs of purchasing and operating a tank, constructing and operating a pond, and relining an existing pond are shown in Figure 3. Included in this figure are the comparisons assuming the high, medium, and low default up-front purchase cost values provided in the spreadsheet. All other variables were held constant in the comparison. In addition to the price estimates shown in Table 2, this scenario assumed a total pond storage capacity of approximately 60,000 gallons; a total tank capacity of 53,000 gallons (using three tanks); a water disposal cost of $0.55/gallon; a discount rate of 3.00%; a total brine use of 7,000 gallons annually; 42 inches of precipitation annually; and no stormwater diversion.

When the high purchase and construction values were assumed, the tank storage system was the most expensive option (+7.2% vs. pond; +10.7% vs. liner). The pond option was the most expensive option when the average and low purchase and construction values were assumed. The tank option was the lowest of the three options when both average (-2.3% vs. pond; -0.3% vs. liner) and low (-7.6% vs. pond; -6.2% vs. liner) purchase costs were assumed. Although the total costs of each option were relatively close when the three different up-front cost values were used, because the installation costs associated with tanks varied substantially more than those for ponds and liners, the estimated total cost of this system had the greatest change when these inputs were altered.

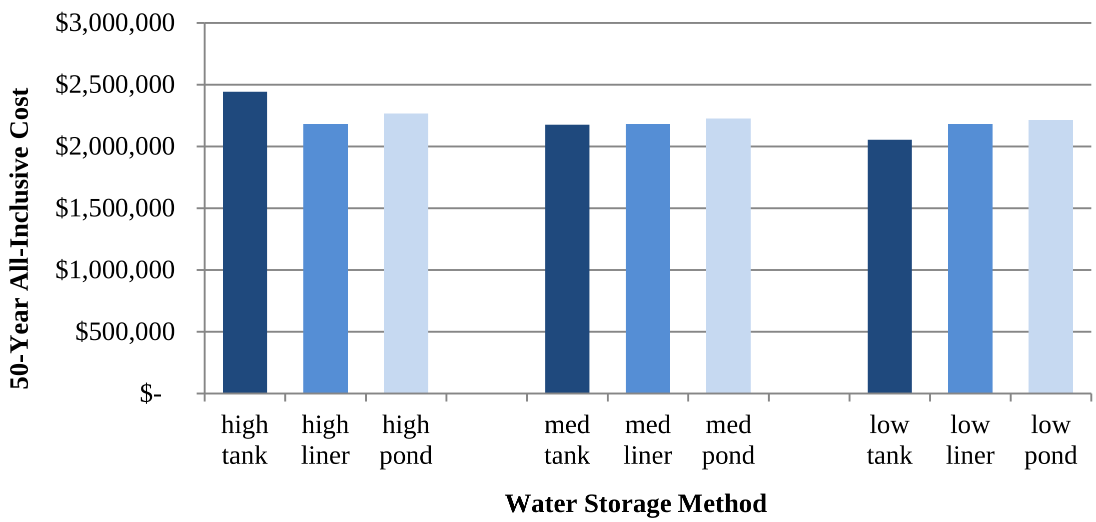


Figure 3. 50-Year Cost Comparison of Tanks, Liners, and Ponds Assuming High, Medium, and Low Up-Front Purchase and Installation Price Estimates

Additional Cost Analyses

Figure 4 shows the results of the cost comparison among the three water storage options when all up-front construction costs associated with each were increased or decreased by 5% from their medium values. In both of these scenarios, ponds were slightly more expensive than tanks or liners. Tanks were slightly less expensive (-0.8%) than liners when default construction costs were increased by 5% and slightly more expensive when up-front purchase and construction costs were decreased by 5% (+0.2%).

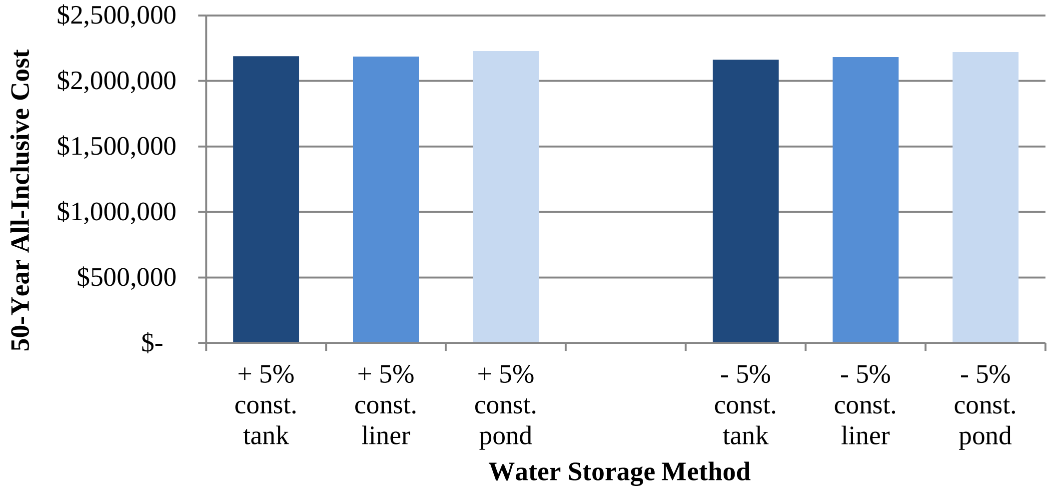


Figure 4. 50-Year Cost Comparison of Tanks, Liners, and Ponds When Increasing and Decreasing Construction Costs by 5%. const. = construction costs.

Similar to the construction cost analysis, to understand better the impacts of the costs of maintenance on the cost of operating the different water storage methods, the maintenance costs for all three options were adjusted up 5% and down 5% from the default values used in the spreadsheet, holding all other costs and site variables constant. As shown in Figure 5, the cost of the tank system was slightly less than the cost of the pond in both scenarios. The cost of the tank was also slightly less (0.8%) than the cost of the liner with the assumption that maintenance charges are increased by 5% but slightly more (+0.2%) with the assumption that maintenance costs are decreased by 5%. These changes highlight the fact that the overall cost estimates developed by way of the spreadsheet are very sensitive to changes in maintenance costs. As maintenance costs decrease, the pond and liner options become cheaper as compared to tanks. Conversely, as maintenance costs increase, the tank option, already the most cost-effective at the default values, becomes increasingly the better option.

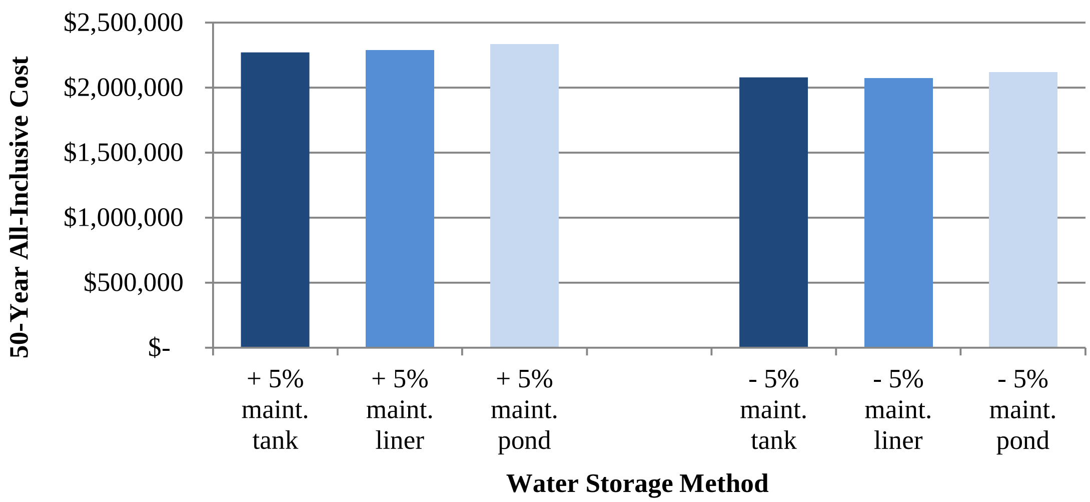


Figure 5. 50-Year Cost Comparison of Tanks, Liners, and Ponds When Increasing and Decreasing Maintenance Costs by 5%. maint. = maintenance costs.

The cost comparisons were further tested by changing only the disposal cost of collected stormwater while holding all other costs—including other maintenance costs—the same. This particular cost variable was adjusted because of its high variability both for different locations and with respect to time. For this analysis, the average value used in the model ($0.55/gallon) was adjusted up or down 50%. The results of this analysis are shown in Figure 6. Tank storage was 3.2% cheaper than the liner option and 4.7% cheaper than the pond option when a water disposal cost of approximately $0.83/gallon was assumed. When water disposal costs were set at $0.37/gallon, the liner option was nearly 7% cheaper than the tank option, indicating that the cost savings resulting from the tank storage option are due to the decrease in the total volume of stormwater requiring disposal. In fact, when all other costs in the spreadsheet are held constant, the break-even water disposal cost is $0.536 for tanks and ponds and $0.549 for tanks and liners. As disposal costs increase above these values, storage by way of tanks becomes an increasingly better option when spreadsheet default values are assumed for all other variables.

The final scenarios run using the spreadsheet estimated how the price of the three storage systems would vary given a substantial change in the water captured and used. The first scenario assumed that the number of brine applications increased from two to four and that no stormwater was captured during the non-winter months (because of diversion), resulting in substantially less stormwater requiring disposal. The second scenario also assumed four brine applications per year but also assumed that 24 inches of water was captured during the non-winter months. As can be seen in Figure 7, the tank storage option was the least expensive for both scenarios; it was 13% cheaper than a new liner and nearly 18% cheaper than the pond option when the non-winter stormwater was diverted. When the non-winter precipitation was captured, the liner and pond options were only 0.3% and 2.4% more expensive than the tank option. This analysis demonstrated that the tank option is still more cost-effective when non-winter precipitation is diverted from the storage systems.

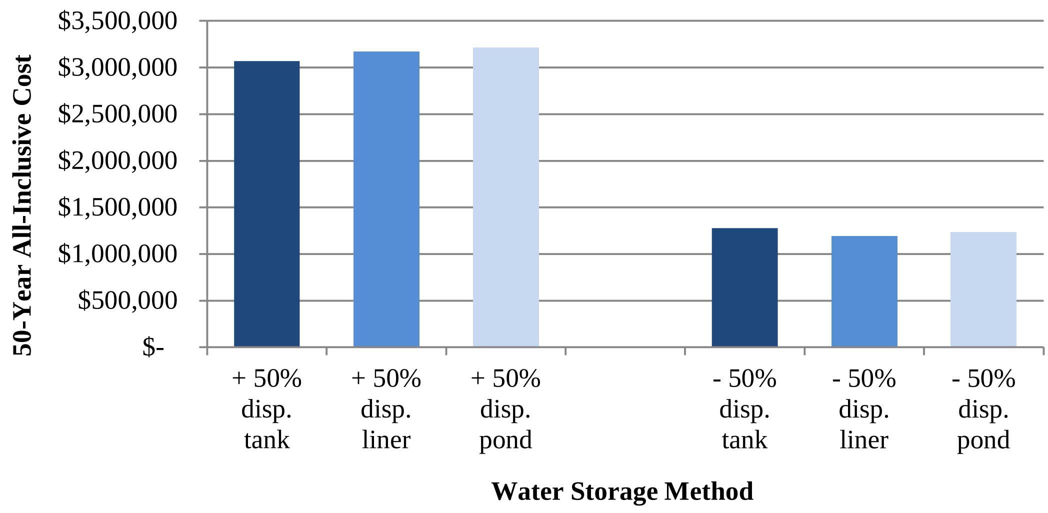


Figure 6. 50-Year Cost Comparison of Tanks, Liners, and Ponds When Increasing and Decreasing Water Disposal Costs by 50%. disp. = disposal costs.

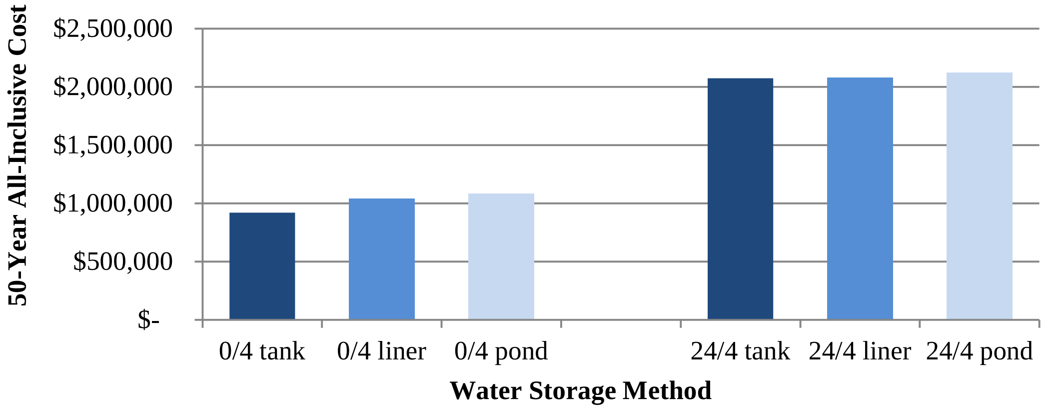


Figure 7. 50-Year Cost Comparison of Tanks, Liners, and Ponds When Increasing Number of Brine Applications and Changing Volume of Non-Winter Precipitation Captured. 0/4 = 0 inches of non-winter precipitation captured and 4 brine applications; 24/4 = 24 inches of non-winter precipitation captured and 4 brine applications.

Implementation Potential of Transitioning to Use of Storage Tanks

Several current VDOT tank operators (n = 5) cited maintenance problems in the information they provided. At least one tank operator stated that managing the captured water volumes during the winter months was difficult. This particular facility had a tank storage capacity of 20,000 gallons. At another site, the tank came to the surface and ruptured after it was pumped. Other problems mentioned included sticking diversion valves and clogged oil-water separators. When asked to rate the level of satisfaction with tanks as their primary stormwater runoff storage option (from 1 to 5, with 5 being the highest), operators gave an average score of 4.1.

CONCLUSIONS

- *Although the purchase price of underground storage tanks was significantly higher (4 to 9 times higher per gallon of storage) with the limited data obtained for VDOT installations, the 50-year all-inclusive cost of tanks is similar to the cost of ponds for stormwater storage.* Depending on the specific characteristics of a maintenance facility, tanks can be a cheaper option.

- *When the medium default values used in the benefit/cost spreadsheet developed as a part of this study are assumed, tanks are slightly cheaper than pond relining or new pond construction.*

- *As disposal costs for captured stormwater increase above the default value used in this analysis ($0.55/gallon), the use of tanks becomes an increasingly cheaper option when all other default values in the benefit/cost spreadsheet are assumed.*

RECOMMENDATIONS

1. *VDOT's Environmental Division should collaborate with the Capital Outlay Section of VDOT's Administrative Services Division, residency administrators, and AHQ superintendents to evaluate the option of using underground storage tanks for the storage of stormwater runoff from salt loading pads for locations that are replacing (relining) existing ponds or at facilities where new pond construction is being considered.*

2. *The Capital Outlay Section of VDOT's Administrative Services Division, residency administrators, and AHQ superintendents at the candidate facilities should use the benefit/cost spreadsheet developed as a part of this study and provided by the researchers to estimate the 50-year all-inclusive costs of each of the applicable stormwater storage methods.* Data used to populate the spreadsheet should be site specific to increase the accuracy of the estimates.

BENEFITS AND IMPLEMENTATION

Benefits

With regard to Recommendation 1, it appears possible that as more aging ponds require rehabilitation in the coming years, some of them will be replaced by underground storage tanks. Transitioning to tanks for stormwater storage results in a reduction in the unnecessary collection of direct precipitation, a decrease in the levels of suspended solids in the water that is collected, and a greater ability to control unwanted outflows.

With regard to Recommendation 2, the use of the benefit/cost spreadsheet developed in this study will allow for a more systematic comparison of the long-term costs of the two methods currently available to VDOT—ponds and underground storage tanks—to store salt-laden stormwater runoff captured at its maintenance facilities associated with salt loading pads. When used with site-specific information regarding size, precipitation, brine use, maintenance, and prices, the spreadsheet will enable the facility operator to quantify the 50-year costs of these alternative systems, allowing the operator to make an informed decision regarding which system is most appropriate for his or her facility.

The use of the spreadsheet would add an element of confidence to each such replace/repair decision. If one were compelled to quantify the value of that added confidence in a given case, the most meaningful measure would probably be the difference between the present discounted values of the 50-year life-cycle costs of the two alternatives, as this difference amounts to an estimate of the cost that can be avoided. This benefit would obviously vary from case to case.

Implementation

With regard to Recommendation 1, VTRC researchers will meet with the Director of Capital Outlay and the Assistant Administrator of VDOT's Environmental Division to deliver the spreadsheet and discuss its applicability. This meeting will take place by January 2018.

With regard to Recommendation 2, the Capital Outlay Section of VDOT's Administrative Services Division, in conjunction with the residency administrators and AHQ superintendents, will be responsible for using the benefit/cost spreadsheet to evaluate the long-term cost of using tanks. To assist with this use, researchers will also make a presentation describing the spreadsheet and how to use it to the Residency Administrators Committee by January 2018.

Based on information collected by VTRC's Research Implementation Coordinator from eight of VDOT's nine districts, 209 maintenance locations currently use ponds and 37 use tanks for the storage of stormwater runoff from salt loading pads (see Table 3). The Hampton Roads and Staunton districts have the most locations using tanks and, correspondingly, fewer ponds. However, each of these districts will likely have ponds (liners) that will need to be replaced and could evaluate the use of tanks as a storage option.

Table 3. Number of VDOT Locations Using Ponds and Tanks

District	Total Pond Locations	Total Tank Locations
Bristol	38	1
Culpeper	23	0
Fredericksburg	25	0
Hampton Roads	10	15
Lynchburg	32	0
Richmond	33	5
Salem	27	1
Staunton	21	15
Total	209	37

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