Studies of Geosynthetic Asset Acquisitions Failures and Success Strategies

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ABSTRACT
Subtitle D regulations have increased costs to site owners of coal ash facilities. With the onset of Subtitle D regulating how coal ash is disposed of, there comes an array of new regulations and costs that site owners are having to deal with, including the proper construction of containment systems to meet Subtitle D criteria. Whenever there are new regulations, there is often an immediate kneejerk reaction that is not thought through. Owners, consultants, and design engineers with a commodity mindset push to find a “quick fix” that meets the regulatory standards but does little to ensure long-term viability of reducing long-term risk.

The solid waste industry went through the same learning curve and have had nearly 30 years ago to refine their approach. Successful owners have developed an asset mindset that is significantly different from the commodity mindset in that it actively manages the asset to mitigate the potential for long-term risks and costs. This paper illustrates how and why to look at containment systems as an asset as well as the benefits of doing so. Geosynthetics should not be acquired as a construction material/commodity, it is an asset. Geosynthetic systems are crucial components to closure projects that can either protect from or create major environmental liabilities. This study reviewed multiple completed geosynthetic projects constructed throughout the United States that vary in size, intended use, materials and outcomes.

INTRODUCTION
Mining and Energy production are two of the most critical discussions of our times and for many good reasons. These discussions are often framed about “if” we should or should not use various forms of mining or energy production due to environmental concerns. However, the deeper and more productive conversations focus on “how” we utilize these forms of energy, not “if”. When we provide energy in a manner consistent with all of our desires to protect the environment, we change the conversations.

Changing the conversation starts by understanding that containment systems are assets. If each containment system is viewed as an asset, then the unit as a whole, as well as individual segments can be subjected to criteria commonly used for asset acquisitions. In the case of this paper, asset acquisition refers the “purchase” of a containment system – that is the permitting, design, construction, operations, maintenance, and post-closure monitoring of the containment system.

Containment systems for environmentally impactful substances are key components in any environmental protection system. When properly executed, they will
protect the environment from contaminants and the site owner from substantial financial liabilities; and when they fail the results can be catastrophic.

A study by Peggs and Peggs showed a containment system failure costing in excess of $23MM USD that could have been prevented by a $10,000 USD purchase. The results of purchasing choices can be staggering. Containment systems are often purchased by individuals who do not operate in this field on a regular basis and they rely on others for direction. The question becomes: “What separates successful projects from failing projects?” A study of past projects shows that the acquisition approach and maintenance are two key components which often dictate project success. When containment systems are viewed as assets, they must be approached by standard asset acquisition evaluations. While the reality of containment systems as assets and liabilities is evident in financial offices, often times engineering and field practices do not treat them accordingly. This paper looks at standard asset acquisition strategies in the application of containment systems as well as the root cause of project failures thus creating standardized buying criteria.

**CONTAINMENT ASSETS**

The primary goal of most companies is to maximize their profits for their stakeholders with secondary goals that often include social and/or environmental improvements. Corporate profitability is directly impacted by the performance of the corporation’s assets. Containment systems are often utilized by industries that have minimal control of their annual revenue streams. Corporate profitability is more likely dictated by operational efficiencies and the avoidance of unnecessary expenses/liabilities. Thus, asset acquisitions are critical to corporate health because there are limited ways for these corporations to increase revenue to account for increased operational costs.

It is imperative for all parties involved in containment system design, construction and maintenance to understand that “Containment Systems are assets”. If this fact is ever in doubt, just ask any waste company CFO if their landfill cells are listed on their balance sheet. Not only will they give a resounding “yes”, it will likely be accompanied by a look of “How could you even ask me that?” followed by a reminder that they are also a Liability on the corporate Balance Sheet. After all, landfill containment systems falling under the Resource Conservation and Recovery Act’s (RCRA) Subtitle D must have a post-closure maintenance plan implemented for 30 years after closure of the landfill.

Unlike containment systems, most assets are not true fiscal liabilities on a balance sheet. As an asset, containment system acquisitions are complex: they need to help maximize profitability, minimize fiscal liabilities and ensure maximum environmental protection. To further complicate the acquisition process, these systems require highly nuanced design and construction where the smallest lapse in attention to detail can lead to serious environmental contamination which can be fiscally catastrophic for the site owners.

**FAILURES**

Often, discussions of failures can seem judgmental, arrogant, negative or just mean. However, Henry Petroski stated it well when he said “The paradox is that when we
model future designs on past successes, we are inviting failure down the line; when we take into account past failures and anticipate potential new ways in which failure can occur, we are more likely to produce successful designs." Studying both success and failure is critical to future growth and it is the intent of this paper to study the following failures to learn from them and not to criticize individuals or organizations who may have been involved in the projects.

In examining the following failures, it was noted that there was a common theme among the root cause of failure: acquisition strategy. It is easy to look at the surface of any one problem and blame the obvious causes; however, a deep study of the problem will often yield a more accurate point of origin for the failure.

**COST OF FAILURE**

The cost of containment failures varies widely. Site owners can experience failure cost in a number of ways. Hard cost can include: regulator fines, additional construction cost, reduced ability to generate revenue, engineering and inspection costs. Soft cost might entail: additional manpower hours for addressing the failure, project delays, reduced operational efficiencies, public relations concerns, relational strains with regulators, vendors and customers. The cost of failure will vary by project and the severity of the failure. While there is not a universal formula for exact cost if a project were to fail, we can certainly look at past failures to better understand the range of failure costs.

In a 2005 paper, entitled *Geosynthetics Risk Management and Loss Control Program*, Peggs and Peggs investigate the cost of failure versus the cost of prevention of these failures, as well as the component causing the failure. These projects represent the importance of each component throughout the project lifecycle and the impact they can have on ROI. Figure 1 is a table compiled from the Peggs and Peggs data.

<table>
<thead>
<tr>
<th>Cause of Failure</th>
<th>Cost of Failure</th>
<th>Cost of Preventio</th>
<th>Prevention vs. Repair Cost Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improper Design</td>
<td>&gt; $600,000</td>
<td>$20,000</td>
<td>30</td>
</tr>
<tr>
<td>Poor Installation &amp; No CQA</td>
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<td>$15,000</td>
<td>87</td>
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<tr>
<td>Poor Design, Installation &amp; No CQA</td>
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<td>$40,000</td>
<td>525</td>
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<tr>
<td>Material Selection</td>
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<td>$10,000</td>
<td>2300</td>
</tr>
</tbody>
</table>

This table was obtained from the *Geosynthetics Risk Management and Loss Control Program White Paper* and serves as an example of the need to weigh current costs versus long-term costs and ultimately the cost of failures.

As you can see from the table, there are considerable financial ramifications associated with failures, whether they are caused by improper design, improper or incorrect use of
materials, poor installation, lack of or poor CQA efforts or poor post-installation processes. Insurance policies are only effective if they properly mitigate the risk for your specific asset in your specific situation for the duration of the project life cycle.

**ASSET ACQUISITION**

Assets are acquired for specific functions within an organization and should be designed, implemented and maintained to ensure maximum operational functionality while yielding the best possible Return-on-Investment (ROI). Asset acquisitions should always be driven by the organization’s business goals while taking into account the following fundamental questions and/or concerns:

- Required Lifespan
- Operational Functionality
- Ease of Exchange
- Potential ROI

So, the question becomes how do these principals of asset acquisition apply to containment systems?

**LIFESPAN**

Required lifespan will vary depending upon the specific application and should be taken into account during the design process of the system. The first step in addressing Operational Functionality is to understand the role of geosynthetics in containment systems. One example of this would be ballast systems for temporary covers. In situations where the temporary cover will be needed for 1-2 years the ballast system might be comprised of nylon rope or seatbelt webbing and sandbags. However, if the cover needs to stay in place for longer time frames such as 5-10 years, using earth anchors may create a greater longevity. A slight increase in price would be more than offset by the increased lifespan, creating a better ROI.

**OPERATIONAL FUNCTIONALITY: INSURANCE**

In the role of waste containment, geomembranes act as a “pre-paid insurance policy”, a balance sheet asset. The goal of waste containment is to ensure that waste and waste by-products do not contaminate the environment. In this regard, waste containment is an insurance policy that protects the environment and company profits from potential damages or loss due to breeches of containment. Geomembranes are known worldwide to provide superior waste containment protection to all forms of clay liner systems and when implemented correctly yield unsurpassed levels of risk protection.

Purchasing insurance is always an evaluation process of how to achieve the best possible risk protection for the smallest amount of capital possible. Geosynthetic installations need to work through the same asset/insurance evaluation process from design choices through post installation operational procedures in order to ensure appropriate risk coverage. If the system is over designed, then companies are unnecessarily losing their profits with little benefit for the additional expense. However, a failure to adequately evaluate all available options through each life-cycle stage of the
system can come at significant cost. This can be illustrated by looking at a 4-acre landfill cell that elected to use tire shreds for a drainage layer.

The design of this particular landfill cell called for a smooth geomembrane overlain with a biplanar geonet covered with a filtration geotextile (16 oz/square yard) upon which a minimum of 24" of tire shreds was placed. Tire shreds were selected as the drainage layer because they could be acquired at no cost to the site owner providing a huge savings to the owner over the sand and/or gravel more commonly utilized in these designs. Additionally, using tire shreds could be seen as a beneficial reuse of a hard to dispose of entity.

Sand and gravel are often acquired by size and will usually conform to the material specification with fairly uniform composition throughout. The biggest concern for sand and gravel is typically the amount of fines present so the drainage system does not clog. On the other hand, tires, are completely unpredictable – they can be obtained as chips or shreds but the size and composition of either form varies substantially. In addition to size variation, the metal content of tire chips and/or shreds is substantial. The following photos show variation in the metal protrusions that can be found in a standard tire delivery (Note: these were all obtained from stockpiles processed to meet the “Tire Chip” criteria where the tire scrap is commonly between 0.5” and 2” in dimension whereas a “Tire Shred” is between 2” and 12” in dimension). In most cases, even if the rubber remaining on the tire chip meets these rough guidelines (about 40% of this sampling exceeded the 2” dimension), the metal protrudes well beyond the rubber dimension, or in some cases only rogue pieces of metal remain. This metal can be smaller than 30-gauge fine wire or can be thicker than 10-gauge solid wire in lengths exceeding 16”. As is the case with the design of most projects using tires as a drainage layer, there is often an incorrect assumption that the geotextile will provide sufficient puncture resistance and protection for the underlying membrane.

Grab sample of tire chips.
On the study project, tire shreds were placed after installation of the landfill’s geosynthetics systems. As part of the permitting regulations, test pits were conducted upon completion of grading the tire shreds to the final grade. The test pits (a minimum of 10' wide x 10' long were excavated by hand. Upon cutting back the geotextile for inspection and removing a portion of the geonet, each test pit was found to have multiple pinholes and deep gouges. Additionally, the geonet separated in areas and caused additional damage to the geomembrane.

The root cause of the issue was believed to be inappropriate placement practices, such as the equipment grading the tires making sudden stops and sharper than desired turns. However, as a governing EPA guidance document states, a 60-65% reduction in tire thickness can be expected when loaded to 16,000-17,000 psf of compressive strength. Therefore, while a thickness of 24” might be present at the start, a 65% reduction would reduce that thickness to just under 16”. While the tires may in fact compress, the metal will not compress, so where does it go? It went through the textile and net and directly into the liner system. Since the core purpose of the geosynthetic system was to be a “bottom” liner that provided a complete barrier preventing leachate from reaching the subgrade, the thousands of holes now in the system completely nullified the very purpose of the installation.

Remediation of the problem required urgent attention as the landfill was running out of permitted airspace so the resolution was two-part. A portion of the cell was
excavated and repaired, which was both time consuming and yielded an inferior product with a significant amount of extra extrusion welding being required but it did allow the landfill to continue operations without running out of airspace. The remainder of the 4-acre cell was relined, which was a time-consuming endeavor. Subsequently, modifications were made to the design and ultimately the use of tire shreds was stopped as the owner realized the risk far exceeded the reward of a free resource.

While it could be easy to suppose that the point of origin for the failure was operator error, in reality there is actually a deeper-rooted problem. In the acquisition process failure testing for geomembrane protection utilizing shredded tire drainage layers with this specific design was not thoroughly studied. When the core driver for a decision is to make a solution work, typically there is a way to justify the desired solution. However, when the goal is a sound asset where failure is not acceptable the approach to evaluating options changes substantially.

In the case of tire shreds, it does not take extensive studies to realize they are likely to be a source of future failures in this application. It is fairly easy to obtain a bucket of tire shreds or tire chips and use those pieces to test for puncture resistance through a textile. If you test the textile against some of the thicker metal wires found in tire scraps you will find that you can push that wire through the textile by hand rather easily. Because the tire pieces lack uniformity, there is no way to guarantee their orientation during placement, nor how their orientation will change under the compression caused by heavy machinery during placement nor compression from the weight of waste as the landfill is filled and capped. Either of these compression methods has the potential to cause the metal to puncture the liner system which was evident on this project.

The acquisition process treated the liner system as a necessary evil or a commodity. The cheaper the system the more profitable the landfill. Therefore, free tire shreds were better than sand or costly gravel. There was a decided lack of effort to understand the potential impact of tires in this application because the driving force behind the decision-making process was simplified to “project cost”. An asset mentality would have required that the Operational Functionality/Insurance Quality of the asset be the primary driver for the decision-making process. If keeping a strong “insurance policy” in place was a core goal of this asset acquisition, the small cost of gravel or sand would not have outweighed the risks of pushing metal spikes over a geomembrane. In a risk verse reward model, tire shreds fail the test. The risks do not out weigh the rewards of successful containment.

Over buying can be just as problematic as underbuying. The authors have seen projects where overzealous engineers have specified materials that far exceed project requirements costing customers hundreds of thousands of dollars that simply did not need to be spent. In a risk verse reward model the increased material cost did not add any substantial protection, so the risk was small and the reward of the cost savings was worth the very minor risk, if any risk that would be incurred.

**EASE OF EXCHANGE**

In evaluating asset acquisition choices, ease of exchange plays an important role. Some assets such as heavy machinery are fairly easy to exchange. For instance, once a rental forklift’s ROI falls below the desired target, the rental company can easily sell
off the current asset and acquire a new forklift that will have a higher profitability rate. Such assets are easy to exchange if/when the ROI is compromised. However, in most instances, Ease of Exchange difficulty ratings are fairly high for containment projects. Permitting alone can take years and be fairly costly not to mention the cost of mitigating any failures and/or reconstruction work should the asset need to be replaced.

As the ease of exchange difficulty rating increases, the importance of the decision-making process also increases. The harder it is to exchange an asset, the more important it is to get it right the first time. This principle is multiplied in containment systems, because the assets cannot only impact future revenue streams, it is also an insurance policy to protect current and future revenue. A poorly performing containment system will not only be costly in terms of repairs and/or replacement, it will also create substantial financial and environmental liabilities while negatively impacting operational efficiency.

Many failures come simply because people who have no understanding of geosynthetics are put in a position where they are responsible for them at some point in the project. As an example, an earthwork contractor unfamiliar with geosynthetics may off load the materials inappropriately, causing damages or engineers might specify the wrong material. In the case of another project, there were over a dozen underground structures comprising a process solution control system that were designed to use stud liner as the containment layer because it could be joined to the poured concrete. As such, the stud liner needed to be installed prior to the placement of concrete.

These structures (weirs and drainage) required the use of a geomembrane because the caustic fluids they were being utilized for were acidic enough to eat through concrete. So, containment of these fluids was critical. The contractor on this project had not installed stud liner previously. The engineer had not designed or in any way worked with stud liner on previous projects and these materials were new to the site personnel as well.

As could be expected, once the concrete was poured and several structures were put into service, it was determined that every one of the structures was leaking at a phenomenal rate. Further investigation revealed that the engineer had instructed the contractor to nail the stud liner to the frame for the concrete pour. During the ensuing investigation, the contractor stated “we took that as a license to nail the …. out of it”. A quick experiment with water and a piece of swiss cheese reveals that it does not hold water well, and the same can be said for geomembranes made to resemble swiss cheese. In addition to utilizing an exorbitant amount nails, they used finishing nails which were nearly impossible see and repair!

Weeks of patch work on these systems did little to resolve the leaks. Being an integral part of the system design, the structures could not be moved to another location – removal and reconstruction was not an option as the concrete had been poured and the system was already partially functioning therefore an in-place fix had to be created. In the meantime, the process solutions that were meant to be moved to the structures had to be diverted through concrete channels, causing substantial damage to channels. Ultimately each structure was fixed as best worked for that specific location and the client end-up with a functional system, although months behind schedule and with hundreds of thousands of dollars of unneeded cost. There was no need for this site owner to bear the burden of these failures. This was preventable.
If a risk versus reward model had been utilized for the acquisition of this system, the risk of using inexperienced designers and contractors would not have passed the evaluation criteria. However, the buying decisions were made by the “Buddy-Buddy” system. These vendors had done work for the site previously and the site personnel wanted to stay with what was familiar. The risks of utilizing these vendors in this capacity did not outweigh the reward of ease and comfort. The ease of exchange difficulty level was much too high to take this route and unfortunately these decisions were costly.

POTENTIAL RETURN ON INVESTMENT
The importance of asset ROI cannot be overstated. Achieving the optimum ROI is a balancing act between spending and saving. The goal is to allocate expenditures such that funding is spent where it is most impactful on the assets performance but not spent where it diminishes the overall ROI. Vendor selections can have a powerful impact on ROI and sometimes in surprising ways.

In the case of an 8-acre landfill cell, the design work was completed and the site owner had selected an experienced contractor and engineering firm for certification. The liner installer had a foreman who was known for moving quickly on projects and could be a handful to track and keep on top of from a quality assurance perspective. In this case, the certifying engineer who was awarded the project but did not have enough manpower to staff a quality assurance team, nor the budget to outsource the work as a viable alternative.

With the onset of winter, the installer showed up and was ready to deploy – the engineering firm was now stuck between a rock and a hard place so they hired two individuals who had been working for the general contractor on that site as rock-pickers to perform quality assurance on the geosynthetics. These rock-pickers had no prior experience and no training on what to look for – they were simply told to document the installation activities. Is it any surprise that a leak developed in the system after construction was completed? A bottom-liner is critical to environmental protection and the certifying engineer and CQA team are supposed to be the insurance policy for the site owner to protect the site owner from future liabilities while protecting the local drinking water.

If not for a timely rain event before trash placement began, it is doubtful the leak even would have been known as there was no leak detection system on this project. However, when the liner floated over the sump area, the leak became apparent. While the engineering firm employed the use of a leak location system to find the leaks and repair them it came at a cost to client. What would have happened if there was no rain? What does this say about the potential quality of the rest of the project?

The reality is that the leaks should not have been allowed to get that far. That site owner paid a reputable firm with decades of experience to protect him and they in turn provided them with untrained rock-pickers for technicians. This is not in any way a slight on individuals who provide the very important service of removing rocks from subgrade prior to geomembrane deployment – they are important workers; but it is meant to highlight the reality that they had no experience in geosynthetics and the site owner paid for experienced staff. So how does a site owner who is doing the right things address failures like this situation?
The following steps should be implemented in any containment system asset acquisition program to ensure functionality, timelines and budgets.

- Owner sets the expectations and requires accountability throughout all activities
- Owner takes an active approach throughout the duration of the project, from inception through post-closure, instead of a passive approach
- Experienced system designers with several years of construction experience
  - Construction certifications in a specific field are a bonus
- Peer-review of designs from a qualified designer outside of the design firm
- Peer-review of CQA Plan and Project Specifications by a qualified firm outside the design firm
- Constructability review by experienced construction firms (applicable to area of expertise, for instance, geosynthetics installations) outside of the design firm
- Contract with reputable professionals
  - Industry certifications such as IAGI and GCI-ICP are a bonus
- Operational plans should include periodic inspections of components throughout the life-cycle. For instance, the plan should include regular inspections of any exposed geosynthetics for damages. Wildlife damage is often overlooked or forgotten but can be a major contributor to damages that occur after construction and before operations.
- Contract with experience with the specific materials being utilized and a proven track record of success in your specific market. Geosynthetics usage vary widely so do the protocols that govern the installations and post installation performance requirements.

Each stage of the asset acquisition process needs to carefully evaluate the role of the asset, lifecycle, ease of exchange and operational functionality in order to provide the maximum ROI and insurance coverage.

CONCLUSION
Site owners sometimes deal with enormous, unbudgeted costs and stresses associated with failures in geosynthetics containment systems – that could be avoided if the proper planning started prior to the asset acquisition. The failures listed within this document are merely a handful illustration of the types of things that can happen on a regular basis (even more than one can and has occurred on projects) when owners fail to subject each and every component of a containment project thru an asset acquisition equation that gives an accurate picture of the true risk vs the true reward.

While we all wish that there was some “Magic 8 ball” that tells us the best choice, reality is that we need reliable buying criteria. Some of the fundamentals upon which to build that reliable buying criteria are mentioned within this paper. In order for the coal ash industry to be successful in containment system management, it is important to learn from the successes and failures within the solid waste industry which has nearly 30 years of experience dealing with Subtitle D landfills. Given the failures that led to Subtitle D, the unending media attention, and the politics involved, the coal ash industry must properly manage their containment systems and avoid costly failures, not only for
the site owners, but for the coal ash and geosynthetics containment industries as a whole.

If we can ensure a protected environment, we can help change the global conversation from “if” we should mine and produce energy to “how” we can succeed together.

REFERENCES