Volume 24, Number 1

Geosynthetics formerly GFR

Saving Prospect Lake

| PVC geomembrane helps restore a Colorado Springs landmark

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Prospect Lake has been a landmark in Colorado Springs Memorial Park for more than 100 years and has been the site of many outdoor activities such as swimming, water skiing, boating, and fishing. However, the severe and prolonged drought in the Colorado area began to make the estimated annual water loss due to seepage (excluding evaporation) of about 215 acre-feet per year unacceptable.

The 53-acre lake has no natural recharge and is filled with relatively expensive, treated water. After several years of drought, the Colorado Springs Department of Parks and Reclamation (CSDPR) realized that the large seepage loss was politically and economically unsustainable but the public still wanted to use the lake.

All photos courtesy of Scientific Site Construction Inc.

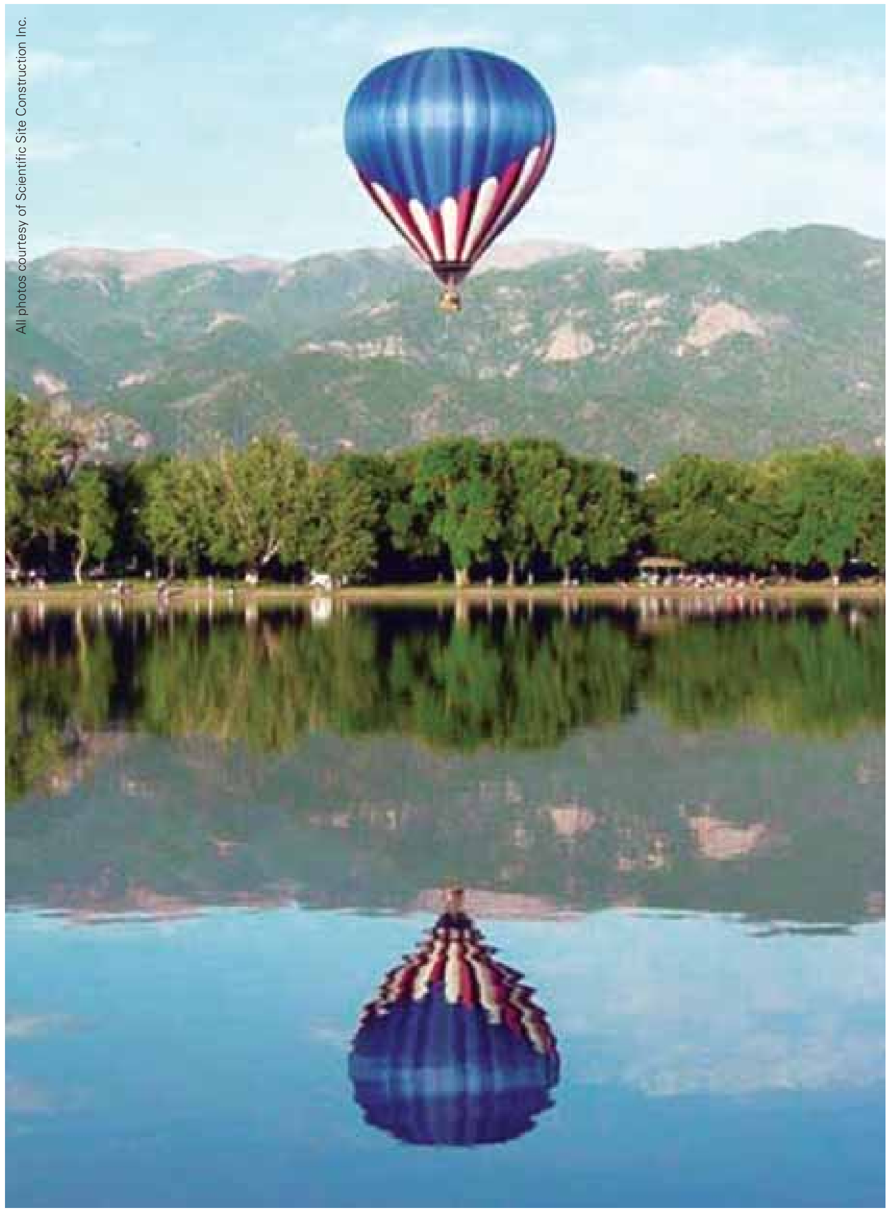

Photo 1 | A hot-air balloon festival helped celebrate the completion of the Prospect Lake rejuvenation project.

Liner system design

Subsurface conditions encountered within the lake consisted of very soft, high plasticity clay with organics **(Photo 2)** overlying interbedded sands and clays, with shallow groundwater and flowing sands prevalent in the deepest part of the lake. The lake was also rich in fishhooks, glass and other debris from 100 years of recreational activity. Initial alternatives for lining the lake included a compacted clay liner (CCL) or soil admixtures to reduce the permeability of the lakebed soils.

The lakebed clay, fishhooks included, was not suitable borrow for a CCL, so importation of clay and stabilization of the very soft subgrade to allow at least 95% Standard Proctor based relative compaction (ASTM D 698) of the 2-ft.-thick CCL would be required. A similar level of compaction would also be needed for a 2-ft.-thick layer of soil admixed lakebed soil, also leading to an unsuitable solution. Difficulties in admixing with the highly variable lakebed soil also were likely, particularly with the soft, highly plastic clays prevalent in the deepest part of the lake where providing a low permeability liner is most critical. Consequently, Kumar and Associates (K+A) recommended that the entire lake be lined with a geomembrane.

A number of different types of geomembrane were considered but K+A recommended a 30-mil PVC geomembrane because of cost, ease of installation, long-term durability, extremely low water-vapor transmission, flexibility that results in significant puncture resistance, and impressive elongation that provides a high tolerance to differential settlement. The puncture resistance was important because great quantities of glass and fishhooks were interspersed throughout the lakebed soils. The differential settlement capability is important because of the many areas of soft clay or lakebed sediment that could continue to settle after the liner was installed, requiring a geomembrane that could elongate in response to settlement. Also, a PVC liner could be placed directly on the soft lake sediments, whereas extensive subgrade stabilization or removal of the soft lake clay would be required to prevent bridging beneath other geomembranes with smaller elongation properties at an unacceptably high cost to the CSDPR.

The lining system selected for Prospect Lake consists from bottom to top of a 30-mil PVC geomembrane placed directly over the prepared lakebed soils, an 8-oz.-per-yd.^{2} cushion nonwoven geotextile, and cover soil mined from the lakebed, which varied in thickness from 12 in. in areas inaccessible to the public to at least 2-ft.-thick in areas that would be accessible by the public. In areas of soft clay or sediment, biaxial Tensar BX1100 geogrid was used to improve subgrade support to allow for compaction of cover soil placed above the PVC geomembrane to at least 92% of the maximum Standard Proctor dry density.

Photos 2 & 3 | Subsurface conditions included soft, high-plasticity clay. Sealed panels were shipped to the project site.

Liner construction

The construction team included: Watersaver Co. Inc. fabricating the PVC geomembrane; Scientific Site Construction Inc. (SSCI) installing all of the geosynthetics; Mullett's Excavating LLC performing clearing, subgrade stabilization, and cover soil placement above the liner; John Bowman Inc. serving as general contractor; and K+A providing full-time quality assurance observation and material testing.

Watersaver fabricated 113 PVC geomembrane panels, each 70 ft. by 300 ft., shipped the sealed panels to the project site **(Photo 3)**. This resulted in Watersaver fabricating about 2.4 million ft.^{2} of PVC geomembrane for this project. The factory fabrication was accomplished with more than 64 miles of factory solvent-welded seams. The panels were sealed and shipped in plastic to protect the liner from dirt, ponding water, and UV exposure during shipping and storage.

SSCI began liner installation in a freezing rain in late April and completed the project in mid-July with PVC sheet temperatures exceeding 170˚F. This resulted in a wide range of geomembrane sheet temperatures for the air-channel testing of field seams discussed subsequently. Prior to site grading, the lakebed was combed to remove glass and other debris that could mix with cover soil mined from the lake and placed above the geomembrane. Prior to placing the liner, the subgrade was compacted and rolled with a smooth drum roller, and inspected by both the liner installer and K+A for sharp objects.

Approximately 6.2 acres of geogrid was used to stabilize the softest lake areas. The geogrid was placed directly on the subgrade and covered with 18 in. of on-site, clayey to sandy material. The shallow groundwater was effectively dewatered to at least 4 ft. below the lake bottom by excavating a longitudinal trench, and interconnecting lateral trenches to a sump where water was removed by pumping, and the wide trenches were subsequently backfilled to provide construction pathways to the softest areas of the lake.

The large PVC panels were quickly unfolded and deployed **(Photo 4)**. The use of large panels greatly reduced the required number of field seams. During the construction phase, weather conditions and the earth-moving contractor's ability to prepare the subgrade, dictated the pace of geomembrane installation and seam testing. SSCI personnel successfully placed, dual-track hot-air welded, and air-channel tested nearly all of the longitudinal and butt seams.

Air-channel testing of field seams

A dual-track field seam was specified as the primary seaming method for the project. Given the high cost of treated water used to fill the lake, a seaming process that allowed for testing the entire length of the field seams was sought, which resulted in the use of dual-track welds with air-channel testing.

The air-channel testing of PVC field seams is gaining popularity and provides a number of advantages over destructive testing of PVC seams **(Photo 5)**. One of the advantages is that the air-channel pressure can be used to verify the PGI specified seam peel strength (PGI 2004) of 2.6 N/mm (15 psi) using the sheet temperature and a relationship presented by Stark et al. (2004). Thus, demonstrating that the air channel holds the required air pressure can be used instead of destructive seam sampling and testing.

Air-channel testing was challenging on this project because the sheet temperatures varied from 40˚F to over 170˚F in response to air temperatures that varied from about 40˚F to 100˚F. In addition, the sheet temperature occasionally varied more than 100˚F in one day. SSCI also conducted a visual examination of the inflated seams, and performed air-lance testing along the exposed outside edge of the dual seam to identify any seam defects or possible burn holes caused by wedge-weld seaming.

Photo 4 | The large PVC panels were unfolded and deployed.

Photo 5 | Air-channel testing has been gaining popularity and has advantages over destructive testing.

The project specifications initially required destructive field seam tests every 1,000 ft. of field seam, but allowed the testing frequency to be reduced to one per 2,500 ft. based on successful air-channel test results. This destructive sampling is significantly less frequent than traditional destructive tests that are conducted every 500 lineal ft. of field PVC geomembrane seam.

Initially air-channel blowouts occurred during air-channel testing at temperatures exceeding 120˚F because of difficulties in controlling the air-channel pressure under high sheet temperatures that varied significantly during the test. Specified burst pressures are currently provided only for sheet temperatures up to about 120˚F (Stark et al., 2004). To overcome this limitation, SSCI was allowed the option of using air-lance testing in place of air-channel testing for sheet temperatures that exceeded 120˚F. This was done to limit damage caused by blowouts at higher temperatures where the required burst pressure could only be extrapolated.

Additional testing is being conducted to extend the air-channel test relationship in Stark et al. (2004) to sheet temperatures greater than 120˚F.

After implementing the changes described above, the number of blowouts during air-channel testing was dramatically reduced. This allowed the frequency of destructive testing to be reduced to one destructive sample per 2,500 ft. of lineal field seam, a 60% reduction in the frequency of destructive testing required for the project and an 80% reduction over that normally required for field testing geomembrane liners.

Photo 6 shows two patches for destructive samples of T or butt seams to ensure an adequate field seaming in the presence of a butt seam. A butt seam occurs when two fabricated panels butt against each other, which usually involves seaming over a pre-existing weld. No problem was encountered wedge welding the T or butt seams on this project.

Another advantage of air-channel testing is the flexible PVC geomembrane allowed visual observation of the inflation of the air channel as the air pressure migrated along the seam and to inspect the entire inflated seam for aneurysms or other seam defects. **Photo 7** shows an inflated field seam and there are no defects in the welds because the inflated air-channel exhibits a uniform shape, i.e., no aneurysms. In addition, the entire length of field seam was tested using the air-channel test procedure to evaluate the integrity of the dual seams, and air-lance testing was used to identify possible defects along the exposed outside edge of the dual seams.

Difficulties were also initially experienced in maintaining a constant seaming speed due to uneven ground conditions beneath the seam, often resulting in seam burns. SSCI solved this problem by folding back the edge of the liner being seamed by about 3 ft., allowing the seam to rest on the underlying fold, which helped to bridge over uneven ground.

To date this is the largest use of air-channel testing for PVC geomembranes in the U.S. Approximately 8 miles of field seams were created and air-channel tested during this project. More than 64 miles of factory seams were used and only 8 miles of field seams. Thus, about 89% of the seams were created in a factory-controlled environment while only 11% were created in the field.

Photo 6 | Two examples of patches for destructive samples.

Photo 7 | An inflated field seam with no defects in the welds.

Multi-tasking with air-channel testing

In the liner system, the geomembrane is overlain by about 2.6 million $ft.^2$ of nonwoven geotextile. Installation of the geotextile was accomplished using 573 rolls of geotextile with dimensions of 15 ft. by 300 ft. The geotextile edges were tacked together using a heat welder, totaling more than 34 miles of tack seams, a labor- and time-saving alternative compared to temporarily anchoring the geotextile using sand bags prior to placing the cover soil. The rate of geotextile deployment and seaming was greatly facilitated by the air-channel testing of the PVC geomembrane seams. The air-channel testing allowed the geotextile to be deployed immediately after the geomembrane instead of waiting for test results on the destructive samples, with the exception of areas where limited destructive testing was performed.

Photo 8 shows the geotextile being deployed over a PVC panel while the panel is still being welded.

Photo 8 | Geotextile was deployed over a PVC panel while the panel is welded.

Summary

Prospect Lake in downtown Colorado Springs was refilled and the city is once again enjoying the beauty of this wonderful urban treasure. Labor Day 2005 festivities, including a hot-air balloon festival **(Photo 1, page 44)**, showcased the rejunevated lake and park.

The use of a PVC geomembrane facilitated the saving of Prospect Lake because the problematic lakebed soils did not have to be excavated, treated, or improved significantly to accommodate the liner. In addition, the liner installation was done quickly, facilitating completion of the entire project in just over three months, which allowed the lake to be filled in time for the Labor Day festivities. The use of air-channel testing resulted in a significant reduction in destructive testing and greater assurance of seam and liner quality. However, both air-channel and air-lance testing were used at sheet temperatures greater than 120˚F to ensure identification of defects along the exposed outside edge of the dual seams.

Prospect Lake represents the largest U.S. PVC geomembrane installation to date that has utilized air-channel testing and limited destructive testing. It is anticipated that successful projects such as Prospect Lake will increase the use of non-destructive tests to enhance the quality of completed liners and the use of PVC geomembranes. G

References

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