LAYFIELD GEOSYNTHETICS

TECHNICAL PAPER

# Geosynthetic Floating Covers for Protecting Water and Profile of Four of the World's Largest Municipal Water Floating Cover

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## ABSTRACT

This paper discusses the application and advantages of geomembrane floating covers and liners for the protection of water, including potable, produced, and process water. It discusses the use of floating covers, including economics, design, and construction practices. This includes the importance of site conditions, engineered loads, cover tensioning, buoyancy, and appurtenances. It also highlights the various flexible geomembrane materials being used in floating covers and the importance of material selection. The paper also profiles four of the largest municipal water reservoir floating cover projects in the world installed during the past 15 years. This includes details on the material selection, design requirements, and installation challenges. It highlights many of today's best practices being used related to design, fabrication, and construction techniques.

## INTRODUCTION

Population growth, pollution and climate change are increasing water scarcity around the world. In the United States, 51% of our available fresh water is used for industrial applications, 33% for agriculture and 8% for domestic use. According to the United States Bureau of Reclamation, only 3% of the earths current water supply is considered fresh. Of that, 2.5% of earths fresh water is unavailable as a result of being locked up in glaciers, in the atmosphere or too far under the earth's surface to be extracted at an affordable cost. This results in only 0.5% of the earths current total water being available for drinking and agricultural use (USBR 2010). Global population growth, agricultural demands, climate changes, and pollution are resulting in increased water scarcity. As a result, geomembrane liners and floating cover systems are increasingly being relied on around the world to help contain and protect our valuable water resources. Water losses due to seepage and evaporation continue to challenge our limited fresh water supply. Today, governments and industry are increasingly relying on the use of geomembranes and floating covers in the design and construction of ponds and reservoirs to protect water.

## FLEXIBLE GEOMEMBRANES

Geomembranes are flexible barriers designed to control fluid and gas migration. They are produced from different polymers and processes including reinforced and non-reinforced. These flexible geomembranes have very low permeability rates allowing only molecular levels of diffusion through the geomembrane structure. As an example, a standard 30 or 40 mil (0.75 or 1.00 mm)



flexible geomembrane has a typical equivalent hydraulic conductivity rate ranging from 10-12 to 10-15 centimeters per second to water. As a comparison, 36" (91.44 cm) of clay has a typical hydraulic conductivity of 10-9 cm/s. (Weber & Zornberg 2005). This results in the average flexible geomembrane having 3 to 6 times lower order of magnitude permeability rates compared to clay. Geomembranes function as excellent waterproofing barriers in earth excavated ponds and concrete reservoirs to prevent leakage of water and other liquids. Geomembranes are also used to construct floating covers which protect water from environmental contamination. Most thermoplastic flexible geomembranes today are factory and field welded by thermal wedge or hot air welding. It is recommended that field welding be performed and tested in accordance with GRI GM 19 (2020).

The list below shows the most common geomembranes being used today for containment of water and liquids in alphabetic order.

- CSPE – Chlorosulfonated Polyethylene
- F-RPP – Flexible Reinforced Polypropylene
- HDPE – High Density Polyethylene
- LLDPE – Linear Low Density Polyethylene
- PVC – Poly Vinyl Chloride
- PVC/EIA – PVC plus Ethylene Interpolymer Alloy
- RPE – Reinforced Polyethylene

HDPE is defined as a semi-crystalline geomembrane with a typical crystallinity of about 50%. This results in a more stiff and rigid material with very good overall chemical resistance. However, based on its low yield elongation properties and stiffness, it is not recommended for prefabrication with factory folds and should only be field installed.

## GEOSYNTHETIC FLOATING COVERS

Floating covers have been used since the late 1960's when the first covers were installed in Southern California for municipal water applications. Since then, floating covers have been used extensively in many regions of the world for the storage and protection of water. Floating cover systems are normally prefabricated using flexible geomembrane materials and then field installed. The primary function of floating covers is to protect from contamination by preventing external dirt, debris and airborne contaminants from entering the water being stored. There are a number of different floating cover systems used today for covering water surfaces.

One of the main markets for floating covers is municipal water and wastewater which includes government run water districts and private water operators under the direction of Federal and State environmental agencies. In municipal water applications, floating covers are used for both potable water storage and wastewater treatment applications. For potable water applications, floating covers prevent dirt and debris from contaminating the potable water storage. Floating covers are also used for evaporation control. The loss of fresh water due to evaporation has become a major concern for governments and industry around the world. Recent studies in regions of the United States have annual evaporation rates of 68 inches (173 cm) in the Central Valley region of California and up to 97 inches (246.8 cm) in Texas reservoirs. Properly designed and installed, floating covers can eliminate evaporation losses as a result of warmer air temperatures, wind, relative humidity, and large exposed water surface areas. (Fraser and Killian 2015).

By eliminating UV light, floating covers will also help reduce algae growth in the water. This is important to protect mechanical pumping and filtration systems, water quality and odor control. Floating covers also help to reduce the amount of chemical disinfectant dosing required and improve overall water treatment quality. They can also prevent wildlife and bird migration from entering reservoirs and ponds.

In addition to municipal water markets, floating covers are increasingly being used in other markets including energy generation, oil and gas, mining, agriculture, waste and airports for evaporation control, odor control, temperature control, fluid dilution prevention, algae control, biogas containment and security of water.

In comparison to underground concrete reservoirs and above ground steel tanks, floating covers are one of the most economical methods of storing and treating large quantities of water. Excluding the cost of land, the construction costs per gallon for reservoirs with floating covers is typically significantly less than underground concrete reservoirs and steel tanks as shown by project examples in Table 1 below. (Fraser & Lotufo 2021).

**Table 1. Comparison table of construction cost per gallon of water**

| Project Type | Storage Capacity | Construction Cost per gal (USD) |
|---|---|---|
| Upper Chiquita Floating Cover & Earth Reservoir (2011) | 244,000,000 gal (923,000,000 liter) | $0.23 / gal ($0.06 / liter) |
| Kelly Butte, Under Ground Concrete Reservoir (2016) | 25,000,000 gal (95,000,000 liter) | $3.60 / gal ($0.95 / liter) |
| Texas, Above Ground Steel Water Tank (2020) | 4,200,000 gal (15,500,000 liter) | $1.05 / gal ($0.28 / liter) |

Over the lifecycle of a reservoir, floating covers can provide a lower carbon footprint and environmental sustainability advantage compared to concrete reservoirs and steel tanks. An example of this is the Pittsburgh Water & Sewer Authority (PWSA) Herron Hill Reservoir constructed in 1880. This reservoir is a concrete lined reservoir requiring a replacement floating cover approximately every 25 to 30 years. Reservoirs with floating covers typically require limited subgrade or concrete restoration at the time of cover replacement. This helps to provide a reduced carbon footprint over the service life of the reservoir. The PWSA reservoir had a new CSPE geomembrane liner and floating cover system installed in 2019. With proper design, installation and preventative maintenance, a CSPE floating cover can perform for over 30 years.

## DESIGN & CONSTRUCTION PRACTICES

The long-term performance of floating covers requires the cover system to be properly designed by an experienced licensed engineer. The most common floating cover systems are the weighted tensioned floating covers commonly referred to as a defined sump cover. This system uses a series of strategically located troughs to provide the required stability, tensioning and buoyancy in the floating cover. The troughs are designed to compensate for the excess cover material slack and tension the floating cover throughout fluctuating high and low operating levels. The tensioning is required to provide stability to the cover and to support surface loads on the floating cover including surface rainwater, operations and maintenance personnel, and floating cover appurtenances. Weight tensioned systems use troughs consisting of surface floats and ballast weights. In standard shaped rectangular reservoirs, it is common to use either a central double wye or bottom of slope trough configuration. Irregular shaped reservoirs often require a custom trough configuration and design. The location of the troughs needs to be properly determined based on the expected operating levels and reservoir geometry including reservoir depth, corners, floor, ramps, intermediate benches, and curves within the reservoir. Weighted tensioned floating covers are scalable and can be used on small reservoirs up to very large size reservoirs. (Fraser & Hilts 2023)

The design of floating covers requires a properly engineered rainwater surface removal system. With weight tensioned floating covers, this is normally done with surface dewatering sump pumps in conjunction with the designed floating cover troughs. For mechanically tensioned floating covers, the rainwater removal system consists of a submersible pumps or gravity type drains installed on the floating cover. The removal rate for the rainwater removal system should be designed for the greater of the two different storm event scenarios below:

1. 10 year storm, 24 hour rainfall intensity with capacity to remove rainwater 24 hours after the storm has passed, and
2. 25 year storm, 24 hour rainfall intensity with the capacity to remove rainwater 48 hours after the storm has passed.

Important design considerations involve understanding the geometry and capacity of the reservoir including size, shape, depth, slopes, and all interior hydraulic structures. Operating water levels need to be determined including standard freeboard, high and low water levels, and fluctuation intervals. Inlet and outlet pipe flow rates and their location need to be factored into the floating cover design.

Site conditions also need to be factored into the design including whether the reservoir is a concrete, asphalt, compacted earth, or geomembrane lined. For earth lined reservoirs, the subgrade needs to be properly compacted and prepared. Older concrete reservoirs often require restoration and repair work prior to relining with a geomembrane liner and floating cover. Groundwater levels in reservoirs also need to be determined to be acceptable to prevent geotechnical problems with the subgrade which can impact the liner and floating cover system.

Engineered loads need to be calculated for all associated dead and live loads on the floating cover including trough ballasting. Wind loads including wind speeds and wind uplifts need to be factored into the design and potential additional wind ballasting. The floating cover and geomembrane liner should be anchored continuously around the reservoir perimeter above the overflow operating water level plus applicable freeboard. Proper perimeter anchorage of the floating cover and liner is required by means of either mechanical anchorage into a concrete footing structure or an earth backfilled anchor trench.

Specific appurtenances are typically required on most floating cover systems. These include surface vents for release of any entrapped air or gases under the floating cover, access hatches, sampling ports, inflation hatches, dewater sump pumps, textured walkways, access steps, and ladders as shown in Figure 1 to 6 below. These appurtenances need to be properly attached to the floating cover system by means of welding or mechanical attachment following standard geomembrane installation best practices. There are a number of helpful design and construction references available including the American Water Works Association (AWWA) M25 manual for geomembrane liners & floating covers for potable water (AWWA M25).

To help ensure the covers achieve their required service life, operators need to regularly monitor the surface of the floating covers for site anomalies. It is recommended that floating covers undergo regular inspection and maintenance in accordance with prescribed operations and maintenance plans. This should include a surface inspection of the floating cover, rainwater removal pump maintenance, floating cover cleanings, and underwater inspections performed by divers or remote operating vehicles with cameras. Any tears, holes or areas of concern need to be fully documented before and after repair. For further information on operations and maintenance, reference American Water Works Association M25 (2023) publication and the Fabricated Geomembrane Institute (FGI) Operation and Maintenance Guideline for Geosynthetic Lined Water Reservoirs. Material sample coupons should also be designed into geomembrane lined water containment reservoirs. These strategically placed sacrificial coupons allow owners to undertake material property testing to assess the geomembrane at future time intervals to help determine remaining service life. The FGI website provides a helpful technical note on the use of sample coupons.

*Figure 1.*

*Figure 2.*

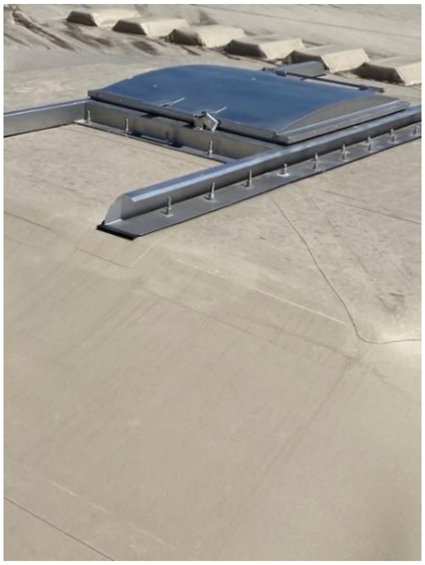

*Figure 3.*

***Figure 1, 2, and 3 shows examples of a floating cover rainwater surface pump system, air vent and access hatch cover.***

*Figure 4.*

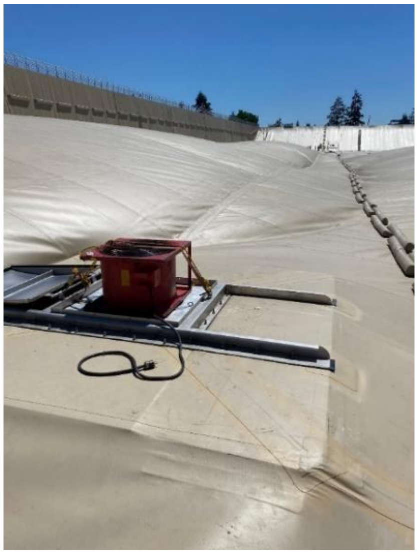

*Figure 5.*

*Figure 6.*

***Figure 4, 5 and 6 shows the field installation of slope access steps, an inflation and access hatch, and a tensioning trough with float caps.***

## MATERIAL SELECTION

The material selection process is also an important part of the design process. This includes determining required mechanical and endurance properties for the geomembrane liner and floating cover. The material selection process in conjunction with a proper floating cover design and installation are important factors required to ensure the required performance of the floating cover throughout its expected service life. In municipal potable water applications, several material types have been used over the years for floating covers. These include CSPE, F-RPP (flexible reinforced polypropylene), PVC with EIA (interpolymer alloy), LLDPE and various other specialty materials. The industry has experienced performance problems with certain materials primarily in municipal potable and wastewater applications. This has primarily been with F-RPP which over the past 25 years has experienced inconsistent performance which have included premature material stress cracking and UV degradation (Gersch 2019). For this reason, it is important for owners and engineers to carefully research their material selection. The material selection process should include ensuring the material has a well-established history of proven performance in the required application. This should be further backed by an acceptable longer term material weathering warranty from the geomembrane manufacturer and a proven performance record of the material (Fraser et al 2019). While HDPE has very good overall chemical and UV resistance, it has limited yield elongation and flexibility properties. For this reason, HDPE is not a suitable material for floating cover applications.

Completing a site assessment and water analysis is an important part of the material selection process. This includes determining pH levels, disinfectant type and levels, other chemicals involved and water temperatures. Chemicals used for disinfectants in municipal water treatment include chlorine and chloramines and can function as accelerators in breaking down or leaching out the protective antioxidant packages of certain geomembranes resulting in environmental stress cracking and premature material failure (Mills 2011). Other related conditions include regions of high UV radiation, warmer ambient temperatures, cold temperatures and material folds and creases. These conditions have been known to further accelerate the degradation of certain geomembrane materials and impact the performance of the floating cover system. Figures 7 and 8 show examples of damaged materials as a result of chemical and UV degradation.

*Figure 7.*

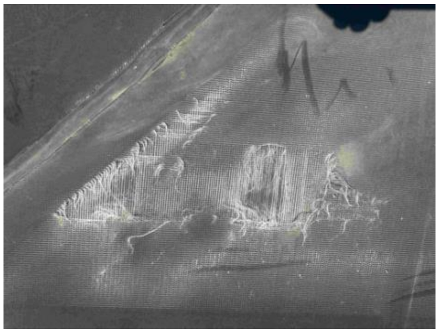

*Figure 8.*

***Figure 7 and 8 show material failures a result of chemical resistance stress cracking and coating UV degradation.***

In addition to flexibility, other important mechanical properties of the material should include tensile strength, elongation, tear, puncture, UV resistance and stress crack resistance. It is important that floating cover materials have the ability to retain key mechanical properties including tensile strengths during the expected life of the floating cover. In potable water applications, the materials should have potable water certification including NSF 61 (2016) and meet other regional regulated requirements.

Additional independent material performance testing in more challenging or unknown project applications should be considered when choosing a geomembrane material. This can include accelerated chemical testing where material samples are immersed in higher temperature liquids and evaluated for various criteria including antioxidant retention levels, tensile strength losses and surface stress cracking. It is recommended that immersion testing be performed for periods of 30 – 180 days for best results. Further references for chemical immersion testing and related environmental stress crack testing include ASTM D5747, ASTM D1693 and the EPA Test Method 9090A.

High ultraviolet (UV) irradiance can also impact the UV and antioxidant additive packages required to protect the material from chemical and environmental degradation. In regions of higher solar irradiance, it is important to ensure geomembranes are properly formulated and tested for long term exposed cover applications. It is recommended that the geomembrane used for floating covers be tested and pass a minimum of a 20,000 hour accelerated UV weathering test in accordance with ASTM D7238. This should be a onetime per geomembrane per formulation test.

The emergence of polyfluoroalkyl substances (PFAS) in drinking water presents challenges for the containment industry. The compounds are highly mobile in the environment and have been detected hundreds of miles away from the original source. As with all emerging contaminants, the durability of geomembrane materials after long term chemical exposure is difficult to predict without either long term exposure or comprehensive accelerated testing being completed. Various geomembrane manufacturers are currently testing their products to ensure proper chemical resistance. This includes testing for diffusion rates, stress crack resistance and retained tensile strength properties. The USA Environmental Protection Agency (EPA) in April 2024, announced final drinking water standards for six different PFAS substances. This includes limiting PFAS and perflourooctane sulfonate (PFOS), to 4 parts per trillion in water.

## FLOATING COVER PROJECT PROFILES

The following section highlights four of the world's largest municipal water floating cover construction projects installed during the past 15 years. This includes highlighting the reservoir history, capacity, material selection and design and construction challenges on these 4 world scale projects.

## R6 RESERVOIR - EL TORO WATER DISTRICT (2023)

The R6 reservoir is owned and operated by El Toro Water in Orange County, California. The reservoir services 350,000 residents in Southern California. It has a storage capacity of 275 million gallons (1.05 ML), is 60' deep (18.3m) and covers 23.7 acres of water surface area. The reservoir was originally constructed in 1967 and its capacity expanded by 20% in 2002. This included raising of the earthen dam wall by 10 feet (3.045m).

*Figure 9. Aerial photo of completed CSPE Defined Sump geomembrane floating cover during water final filling and commissioning in 2023.*

The prior floating cover was a 45 mil F-RPP material installed in 2002. Prior to reaching its 20 year service life, the F-RPP cover started showing signs of UV degradation on the cover surface. Southern California is noted for its aggressive UV conditions with an average annual solar radiation rating of 6.15 kilowatt hours per square meter per day (kW/m2/day). As a result of UV degradation, in 2019 El Toro Water District conducted a replacement study of the floating cover working with a reservoir engineering expert. This included an evaluation of the existing f- RPP cover material. While the mechanical values of the F-RPP material remained satisfactory, the standard oxidative induction time (OIT) testing showed the material to have a 0% OIT value for material evaluated above the water level. Further 2021 testing was conducted of the F-RPP material under the water level which also showed retained OIT values of only 1% to 2%. As a result of the antioxidants being fully depleted, it was expected that the material would see a rapid decline in its mechanical properties. This resulted with a preliminary design report by the owner and engineer to replace the F-RPP floating cover. The engineer conducted a comprehensive review of geomembrane floating covers materials on the market. El Toro Water District required a 30 year weathering warranty and based on the costs involved, required a material with a proven performance record. Based on these criteria, a 45 mil (1.14) CSPE material was specified for the cover replacement and a 60 mil (1.5 mm) CSPE for the bottom liner.

Beginning in October 2022, a total of 2.5 million ft2 (232,300 m2) of CSPE was prefabricated and installed for the liner, floating cover and cover components. The cover design included a complicated conjoined double plate system based on the irregular shape of the reservoir, and compound slope angles. The project challenges included installing the liner in extremely wet inclement winter weather conditions and the complexity the amount of welding and mechanical attachment work involved to attach the cover system to multiple structures, vaults and perimeter anchorage.

The cover system also included 6 robust rainwater removal sumps designed to remove over 3 million gallons of water in a 3 day period*)*. The total project took 11 months to complete including 7 months of installation and was completed in November 2023. The cover required over 9186 ft (2800 meters of floats), 3871 ft (1180 meters)of perimeter battening, 6 stormwater removal pumps and over 7500 prefabricated geomembrane panels and floating cover appurtenances.

## POTTS HILL RESERVOIR - SYDNEY WATER (2023)

The Potts Hill potable water reservoir (Number 2), located in the western suburbs of Sydney, New South Wales, Australia, services over 1.5million customers over an area of 43,145 hectares. Constructed in 1923, the storage has undergone a number of upgrades and alterations, improving water quality and water security. The original concrete lined open storage was reconstructed in 1999, including the installation of a flexible reinforced polypropylene (fRPP) liner and cover. Following Sydney's water crisis in 1998 (as a result of water contamination,) floating cover technology was adopted to reduce contamination concerns, improve water quality and eliminate evaporation losses.

*Figure 10.*

*Figure 11.*

***Figures 10 and 11 show the Potts Hill reservoir full cover in application and during the cover installation phase.***

After 20 years of service, the existing F-RPP cover was showing signs of significant degradation. Sydney Water engaged engineering consultants and industry experts to advise on the suitability of a range of geosynthetic materials for the floating cover, liner and conductive geotextile cushion layer (required for installation quality assurance). Australia in general experiences very high

UV exposure, high ambient air temperatures, and higher than average water temperatures, resulting in accelerated degradation of polymeric materials compared to other regions of the world. Mean daily solar exposure for Potts Hill is 16.5MJ/m2 per day (6000MJ/m2 per annum) and maximum ambient temperatures of 113°F (45° C). In consultation with an independent test laboratory, a comprehensive testing plan was devised to evaluate a range of flexible geosynthetic materials to determine suitability. This testing included chlorine immersion, microscopy, UV weathering, wicking and flexibility. One CSPE product and six PVC-EIA products were evaluated and evaluated to assess their suitability for this particular application. The most suitable floating cover material was determined using a weighted average model. A 1.14mm thick CSPE geomembrane materials was selected, primarily due to its proven actual long term performance in potable water applications in similar environmental conditions.

Between 2022 and 2023 the reservoir was upgraded again and a new CSPE floating cover installed, requiring a total of 2,351,000 ft2 (218,500 m2) of CSPE material. The 872,420 ft2 (81,080m2) inner cover is a defined sump cover featuring an integral baffle curtain suspended under the length of the cover to eliminate short circuiting of the treatment between inlet and outlet flows and improve chlorine contact time. Due to the more complex shape, and presence of various vertical walls, the outer cover is a central plate design.

The cover required over 4.35 miles (7.0 km) of floats, 2.3 miles (3.7km) of ballast tubes, 15 storm water removal pumps and 10 diver inspection hatches.

## UPPER CHIQUITA RESERVOIR - SANTA MARGARITA WATER DISTRICT (2010)

The Upper Chiquita Reservoir is a large potable water reservoir located in Rancho Santa Margarita in Orange County California servicing approximately 170,000 customers. This is an earth lined reservoir that was constructed in 2009. The Upper Chiquita Reservoir is part of the Santa Margarita Water District (SMWD) in Southern California. The reservoir contains 244 million gallons (924 ML) of domestic water with a total water surface area of 18 acres. It was constructed on the western slope of the Chiquita Canyon by creating an earthen dam across the canyon. It is one of the first large emergency potable water reservoirs to be built in Orange County in decades. At its deepest point it is 120 feet (36.6m) deep with side slopes ranging from 3H:1V to 2H:1V. The main purpose of the Upper Chiquita Reservoir was to increase reserve storage capacity to ensure water security to the customers serviced by SMWD. (Mills and Falk 2013).

*Figure 12. Aerial view of completed Upper Chiquita Reservoir in operations.*

The Upper Chiquita Reservoir is one of the larger covered reservoirs in California. It also had a highly irregular configuration. The material selected for the floating cover was a three-ply reinforced 60 mil (1.5mm) CSPE. CSPE was the choice based on its strong performance record in California and having a 30 year weathering warranty. The design of the cover used a defined sump tension trough construction.

The floating cover installation faced a number of challenges based on the large scale of the reservoir, its highly irregular shape, steep multiple slopes angles and the vertical depth of the reservoir. To address this an earth bench was built into the slide slopes at the half-way point. This earth bench provided a flat surface on which to construct the floats and weights that tensioned the cover. The bench also functioned as an intermediate anchor for the long slopes and contained a drain system to monitor leakage for dam safety purposes. This also helped with the safety of installation crew providing an interim platform on the slopes to work from.

The cover system was factory prefabricated to match a detailed panel layout prior to deployment in the field. The normal sequence of operations for cover construction is to complete the liner installation and then to start placing the cover. The cover is usually installed over the entire area of the containment before floats, sump weights, and other details are added. In this project the excessive rain forced changes to this sequence. Since the base of the containment could not be kept free of water the liner and then the cover was advanced down the side slopes with the base remaining open. Only when the base was finally dried out could the liner, and then the cover progress with construction and installation. The Upper Chiquita Reservoir was one of the largest and most complex floating cover projects in terms of design and construction challenges completed in the United States.

The final cover design included 18 access hatches, 71 air vents and 40 rainwater removal pumps. The Upper Chiquita Reservoir was one of the largest and most complex floating cover projects in terms of design and construction challenges completed in the United States.

*Figure 13.*

*Figure 14.*

***Figures 13 and 14 show the reservoir liner and cover under construction and the completed reservoir in operations.***

## HIGHLAND 2 RESERVOIR - PITTSBURG WATER & SEWER AUTHORITY

The Highlands 2 Reservoir is owned and operated by the Pittsburgh Water and Sewer Authority (PWSA) and is located in Pittsburgh, Pennsylvania. The potable water reservoir was originally constructed between 1897 and 1903 with a capacity of 125 million gallons (473 ML). The reservoir services 520,000 residents in the Pittsburgh city center, Squirrel Hill and Westside regions.

***Figure 15. Aerial of Highland 2 Floating Cover in application.***

A new 60 mil (1.5 mm) black geomembrane liner and 45 mil (1.14 mm) tan/black CSPE floating cover and baffle curtain were installed in 2022. This replaced a degrading F-RPP liner, cover and baffle which installed in 2010 was experiencing problems with coating delamination and overall degradation of mechanical properties. The new CSPE liner and floating cover was part of a larger PWSA water treatment upgrade. This included the Highland 2 reservoir being temporarily used as the main disinfection point for the City's drinking water while longer term repairs were being completed to an aging treatment facility. CSPE was chosen for the floating cover based on is proven performance record as a cover system used in potable water and its 30 year weathering warranty. The floating cover used a tensioned trough central plate design for its tensioning and buoyancy. The cover required a total of 802,000 ft2 (74,535 m2) of CSPE material and was prefabricated in Lakeside, California. A 75,000 ft2 (6,970 m2) baffle curtain was also installed between the liner and floating cover to help improve chlorine contact time and direct flows between the inlet and outlet structures. The replacement of the Highland 2 Reservoir liner and cover is part of PWSA's Water Reliability Plan which is a series of once-in-a-generation projects to modernize the City's water distribution system and provide customers with more secure and reliable water services.

The major challenges faced during construction were related to the high level of rain events during construction. Large scale pumping operations were required to regularly dewater the reservoir allowing for the cover material deployment, welding and attachment of cover surface components. Also, the reservoir had a very irregular reverse bend configuration which required a large amount of custom fabricated and installed panels. There were also numerous very difficult mechanical connections required between the floating cover and old historic concrete inlet and outlet piping and building structures. Including time to manufacture, fabricate and installed the CSPE materials, the total project took 250 days to complete.

The cover had 1.62 miles (2.6 km) of floats, 4,593 feet (1.4 km) of ballast tubes, 6 rainwater removal pumps and 28 diver inspection hatches.

## CONCLUSION

The use of geosynthetic floating covers and geomembrane liners will be even more important in our future to help address a warming climate and the growing challenges required to protect our water supply. Further industry innovations and technical advances in geomembrane technology will be important to ensure we develop new generation materials with even better performance properties. These include improved chemical resistance, ultraviolet (UV) stability and higher temperature resistance. In addition, developing improved practices in the design, fabrication and construction of these large scale geosynthetic floating cover systems will be important to ensure longer term performance and protection of the worlds water treatment and storage facilities.

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