Renewing the Maerkle Reservoir for the City of Carlsbad with Advanced Floating Cover Technology

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ABSTRACT

Maerkle Reservoir is the primary potable water storage reservoir for the City of Carlsbad and provides 10-day operational storage. Carlsbad Municipal Water District (CMWD) is a subsidiary of the City of Carlsbad. Maerkle reservoir was originally constructed in the early 1960s as an earthen, open-air reservoir. In 2019, CMWD decided to replace the existing floating cover and incorporate industry advancements. The 20-year old floating cover was at the end of its useful material life.

CMWD retained Hilts Consulting Group to provide engineering design services, and Raven Engineered Films / Raven CLI Construction for installation services of the Maerkle geomembrane floating cover. Jobsite challenges included an expedited installation schedule while still providing a high-quality, cost-effective solution. The short installation schedule was addressed through the effective use of large factory fabricated panels to increase quality and save time and costs. The unique reservoir geometry with varying slopes provided some design challenges. The design work had to be completed while the reservoir was in-service without the benefit of knowing the reservoir geometry below water level. The reservoir geometry was later verified during construction and the initial design adjusted to actual site conditions.

This project was highly challenging to bring in on time and within budget. Still, through massive teamwork and creative thinking, the collective team overcame obstacles to successful completion. Ultimately CMWD received a high-quality advanced floating cover system to meet their budget and effectively protect one of our most precious resources; clean drinking water.

INTRODUCTION

Carlsbad Municipal Water District (CMWD) is a subsidiary to the City of Carlsbad, California. CMWD purchases potable water through the San Diego County Water Authority (SDCWA) via four metered connections. Water is imported from the Colorado River via the Metropolitan Water District of Southern California. Maerkle Reservoir is the primary water storage reservoir for the City of Carlsbad and provides 10-day operational storage. The capacity is approximately 741 million liters (196 million gallons), with a 69,000 square meters (17-acre) horizontal surface and 18.3-meter (60-foot) maximum water depth. Additional onsite storage is available from an adjacent 38 million liter (10 million gallon) buried concrete tank.

Maerkle Reservoir was originally constructed in the early 1960s as a potable water open-air reservoir with earthen side slopes and floor and meandering shorelines. The reservoir was created with the construction of an earthen dam with a maximum height of 50.3 meter (165 feet) and 243.8 meter (800 feet) long.

In 1996 the reservoir interior was reformed into a defined shape with straight tangents and geometric curves, floor and side slopes were regraded, and a porous asphalt liner was placed on the reservoir slopes and floor. Additionally, a perimeter concrete ringwall was constructed at the top of the slope, and a reinforced polypropylene geomembrane floating cover was installed. The polypropylene floating cover was then anchored to the perimeter cast-in-place concrete ringwall at the top of the slope. The polypropylene floating cover was weight tensioned with defined sumps, included multiple small submersible pumps to serve as the rainwater removal system, and multiple aluminum access hatches. The rainwater removal system included discharge hoses on the floating cover to pump rainwater up to the top of the slope and then discharged onto the existing asphalt perimeter road, sloped down to V-ditches, and buried storm drainpipes.

After approximately 20 years in service, the existing polypropylene floating cover geomembrane had reached the end of its useful material life. CMWD sought to replace the existing floating cover. The principle project objective was to replace the existing floating cover system with a new floating cover that would incorporate the latest industry advancements since the original polypropylene floating cover was installed. All reservoir modifications and improvements were to be performed in compliance with and approved by the California Division of Drinking Water (CA-DDW) and California Division Safety of Dams (CA-DSOD). The objective for the replacement geomembrane floating cover project was to provide a cost-effective solution that would protect and preserve the potable water quality and meet regulatory requirements.

PROJECT DESCRIPTION

The Maerkle Reservoir is formed by an earthen dam on the south end and graded earthen side slopes on the other reservoir sides. Maerkle Reservoir has a potable water storage capacity of approximately 741 million liters (196 million gallons) with a horizontal surface area defined by the top of slope across 69,000 square meters (17 acres). The reservoir shape is unique, with eight straight tangent sections and eight curves. The interior earthen side slopes vary throughout the reservoir ranging from 2½: 1 to 4½: 1. The reservoir interior is over 19.2 meter (63 feet) high with a maximum water depth of 18.3 meter (60 feet), the reservoir floor slopes with a 3 meter (10-foot) height differential. The top of the slope is defined with a cast-in-place concrete ringwall and an asphalt paved perimeter road. Site drainage is provided by catch basins and storm drainpipes located on the reservoir east and west sides.

The reservoir has a single 107 centimeter (42 inch) buried inlet pipe, which terminates in the reservoir floor with an upturned pipe located in a cast-in-place concrete inlet structure covered with a stainless steel grillage cage. The reservoir outlet consists of a single 76 centimeter (30 inch) buried pipeline with three cast-in-place concrete outlet structures covered with stainless steel grillage cages and located along the reservoir interior slope. Within each concrete outlet structure, there is a 76 centimeter (30-inch) valve to control outlet flows and regulate the depth of water introduced into the water distribution system. A cast-in-place concrete overflow structure is located near the top of the slope discharges into a concrete channel. The overflow structure opening is covered with a stainless steel grillage cage.

The reservoir normal operating ranges vary between 7.3 meter to 11.3 meter (24 feet to 37 feet) in water depth. During winter outages for water system maintenance periods, the reservoir will operate at a maximum water depth of 17.7 meter to 18.3 meter (58 feet to 60 feet).

With the prior polypropylene floating cover, CMWD personnel would work on the floating cover several times a week to obtain water quality samples at the cover access hatch locations. The replacement floating cover project consisted of the following major project elements:

- A geomembrane chafer located on reservoir side slopes anchored at the top of the slope ringwall and extending downslope to the below the reservoir low water operating level.
- Weight tensioned geomembrane floating cover system with rainwater removal sumps and pumps, access hatches, vacuum vents, and walkways.
- A remote water quality sample retrieval system.
- Three outlet butterfly valves with hydraulic actuators, hydraulic lines, and a hydraulic power unit located at the top of the slope.
- New buried rainwater removal pipe laterals in perimeter roadway.
- Electrical system upgrades to accommodate larger rainwater removal pump capacity and provisions for possible future mixer equipment.
- Reconditioning of existing stainless steel pipe grillage cages.
- Recoating exposed portions of the existing inlet pipe and outlet pipes within the reservoir.

The project consisted of the following phases:

1. Preliminary Design Report: includes defining project scope, establishing design parameters, selection of critical materials and systems, initial regulatory agency coordination, development of overall project schedule, and construction cost estimates.
2. Final design: includes the performance of detailed design resulting in comprehensive design drawings, engineering calculations, contract documents, technical specifications, engineer's opinion of construction cost, and regulatory agency approvals.
3. Public Bidding and Award: includes project documents issued for public bidding by experienced, knowledgeable, and qualified contractors, submission of sealed bids, Owner's evaluation of bids, and award of construction contract by City council.
4. Construction: includes material procurement, preparation of construction submittals/shop drawings, shop fabrication of geomembrane panels, early procurement of long-lead items, site construction, floating cover inflation, inspection, and implementation of quality assurance provisions.
5. Start-up and Commission: includes equipment testing, reservoir filling and disinfection, water quality testing, and Owner Operations and Maintenance (O&M) training.

DESIGN

Floating covers are generally classified as non-tensioned or tensioned. Non-tensioned floating covers are less efficient in removing rainwater and are less accommodating for personnel access on top of the floating cover. A non-tensioned floating cover for potable water reservoirs is not considered current state-of-the-art practice and, therefore, was not recommended. Tensioned floating covers are either weight-tensioned or mechanically tensioned. Tensioning the floating cover material enhances rainwater removal and permits personnel access on top of the floating cover. Therefore, the preferred method for potable water reservoir applications is tensioned floating covers.

The floating cover type recommended was a weight-tensioned floating cover constructed with minimum 45-mil thick reinforced geomembrane material. Weight-tensioned floating covers consist of rainwater collection troughs located on the reservoir floor near the toe of the slope, reservoir curves, and other key locations where slack floating cover material will develop. Rainwater collection troughs contain a series of weights and floats strategically located throughout the floating cover. The depth of the rainwater collection troughs varies to accommodate slack floating cover material as it develops during reservoir water surface fluctuations. A tensioned floating cover allows personnel to walk on the floating cover while in service to conduct as-needed water quality tests and to perform necessary inspections and maintenance activities. A tensioned floating cover also reduces the amount of wrinkles (see figure 7), ponding of surface water on the top side, and provides more efficient removal of rainwater. The floating cover is tensioned by a series of strategically placed weights and floats, which will also serve as the rainwater removal troughs (see figure 9).

A 45-mil geomembrane chafer was installed between the floating cover and existing asphalt concrete lining. The chafer serves as a sacrificial material to protect the floating cover from incidental punctures and rough subgrade abrasions. The chafer was attached to the perimeter ringwall and extended from the top of the slope downslope to an elevation below the reservoir low water operating range. The chafer enables the floating cover to rest on a similar sacrificial geomembrane material when those portions of the cover are not floating on the water surface.

Total floating cover appurtenances included (18) stainless steel access hatches. A portion of the access hatches have special provisions to accommodate pressure sensors that monitor reservoir water depth, water temperature, and possible future submersible mixers. Five stainless steel vacuum vents were provided at hydraulic structures (inlet, outlets, and overflow). Textured geomembrane material was incorporated in the floating cover to provide personnel access onto the floating cover, especially on the reservoir side slopes.

Geomembrane Material Selection. During preliminary design, several geomembrane material options were investigated for the geomembrane chafer and floating cover components. The initial evaluation considered unreinforced and reinforced geomembranes. Unreinforced geomembranes were eliminated based on required long-term strength, flexibility requirements, and floating cover regulatory requirements. Reinforced geomembrane material options were evaluated based on historical performance, required physical properties, environmental properties, material warranty, material cost, installation, seaming, aged repairs, color options, and NSF 61 approval for contact with potable water. Material advantages and disadvantages were then compared and reviewed with CMWD. Reinforced Chlorosulfonated Polyethylene (CSPE) was ultimately selected as the geomembrane providing the best value for the floating cover and chafer.

Rainwater Removal. The floating cover rainwater removal system was scoped and sized based on two storm-level designs. The first design was based on pumping capacity to remove a 10-year storm, a 24-hour duration 48 hours after the start of the storm. The second design was based on a 25-year storm, a 24-hour duration 72 hours after the start of the storm. Pump redundancy was provided by assuming that one pump may be out of service at any given time. A total of four 5-horsepower submersible pumps were provided. The submersible pumps are located in perforated

PVC pipe sump wells located within the rainwater removal troughs, as part of the floating cover tensioning mechanism (see figure 8).

Remote Water Quality Sampling. Previous practice for CMWD personnel to obtain water quality samples involved walking on the floating cover and manually obtaining water samples through floating cover access hatches. The new floating cover system provides updated remote water quality sampling directly through sampling pumps incorporated at identified hatch locations with flexible tubing installed from the sampling pump to a sample station port located at the top of the slope. Water quality samples can now be conveniently obtained by site personnel at the reservoir perimeter road without entering onto the floating cover.

Outlet Valves & HPU replacement. The older existing pneumatic actuated outlet valves were replaced with new hydraulic operated butterfly valves with submersible actuators. The hydraulic system utilizes food-grade oil to operate the valve actuators. The valve actuators are controlled by a hydraulic power unit located at the top of slope. Stainless steel hydraulic tubing was installed, and the system is pressurized.

Electrical Modifications. The electrical modifications included upgrading the reservoir area electrical system capacity and infrastructure to power the new advanced floating cover rainwater removal pumps. The new pump size was significantly increased in scale, horsepower, and pump capacity from the previous floating cover pumps. The older 120/240 volt transformer/panel was replaced with a new 480 volt, 3-phase electrical distribution system.

Storm Drain Laterals. Four new buried PVC pipe laterals were installed in the reservoir perimeter road to accommodate the rainwater removal pump discharge at the top of the slope perimeter ringwall, and rainwater was conveyed to existing storm drainpipes.

Future Mixer Provisions. Updated provisions were incorporated in the floating cover access hatches, and electrical modifications were made to accommodate up to six submersible electrical mixers. This update was done to allow for future water quality enhancements by reducing stagnant zones and creating a more uniform distribution of disinfectant throughout the water.

CONSTRUCTION

Material Procurement. With a project of this magnitude, procuring the critical path items in a timely manner was crucial to the construction project's success. The CSPE floating cover material and outlet valve components were the largest obstacles to overcome for the Maerkle floating cover construction — it took a highly-collaborative effort to ensure items were submitted, approved, and ordered within the milestone dates of the project. The complex floating cover design required the use of advanced accessories and hardware with extended delivery dates, Hilts Consulting Group worked closely with Raven to ensure the team maintained on top of the procurement process and that items were reviewed weekly with the Maerkle team and tracked closely through completion to align with the delivery and installation dates of the cover material.

Fabrication. Fabrication played a vital role in this project for several reasons. The CSPE material chosen for this project is manufactured in rolls that are 155 centimeters (61 inches) wide. By custom fabricating the panels for this project, the fabricator could maximize their production in a controlled factory environment and significantly reduce the number of field welded seams. The large fabricated panels utilized roll stock that combined seven panels to create one large custom panel. The chafer layer consisted of 101 fabricated panels total (see figure 1) and an additional 117 custom panels for the floating cover (see figure 2). The fabricator was also able to prefabricate all the appurtenances for this project, including sand tubes, float skins, repair floats, sand tube tabs, hatch floats, vent floats, etc., this considerably reduced the field time required for installation.

Installation._As the General Contractor of this project, the installation contractor regularly coordinated with all of the project subcontractors to ensure a smooth installation of work to be done. Starting with the interior fence removal for better site access to allow for demo of the existing floating cover. The installation contractor then coordinated with their subcontractors to remove existing asphalt for new storm drain connections and new electrical trenches for the upgraded electrical system (see figure 4). The installation contractor began deploying the chafer (see figure 3) after the electrical trenches were backfilled and followed the electricians around the reservoir, working together to keep production levels high. Upon completion of the chafer, deployment of the actual floating cover prefabricated panels began (see figure 5). Both the chafer and the floating cover panel deployments went very smoothly due to the cost-effective use of the large prefabricated factory panels provided by the fabrication team (see figure 6). Finally, the floating cover system was closed up; however, it needed to be cut open again to reinstall the valves and actuators due to delays of the advanced valves and actuators. Upon the final closing of the floating cover, the interior fence was reinstalled around the reservoir, and the electrical and storm drain trenches were all tested for compaction, and new asphalt was placed as applicable (see figure 10).

Outlet Valves & HPU. Although the outlet valves and hydraulic power unit (HPU) were fabricated and managed domestically, the actuators needed for the project were manufactured in Italy, posing some coordination and timing issues for the project completion. Due to the timing, being faced with seemingly unreachable goals for overseas shipments, the installation contractor and the Maerkle construction team had to perform many workarounds to accommodate the timing issues and keep the project moving forward. However, with the assistance of subcontractors Rotork and Henry Pratt, the General Contractor was able to get all the valves, actuators, and HPU to site and installed meeting a firm Division Safety of Dams (DSOD) inspection date. With only a few minor issues during the installation process, the system worked flawlessly during the initial start-up and was an excellent addition to the upgraded Maerkle Reservoir project.

Construction Start-up. The reservoir disinfection and fill phase started in late January 2020. The reservoir was disinfected following American Water Works Association (AWWA) Standard C652, Method 3, which consisted of filling the reservoir to 5% of reservoir volume with potable water and an available chlorine concentration of not less than 50 ppm. A target 60 ppm chlorine residual was established for the initial fill. A licensed specialty contractor was used to perform reservoir start-up disinfection by injecting a liquid chlorine solution into the reservoir inlet pipe at a rate dependent on the solution chlorine concentration, reservoir water inflow rate, and desired target chlorine residual. The reservoir water chlorine concentration was monitored every couple of hours at various access hatches located in the floating cover. The water/chorine fill proceeded continuously at a reduced flow rate for approximately 30 hours until it obtained the 5% reservoir volume mark. At this point, the reservoir fill and chlorine injection were temporarily stopped for a 6 hour hold period. At the end of the hold period, the reservoir water chlorine residual was tested to verify that the reservoir water chlorine residual was acceptable to meet standards. At this point, the reservoir fill with potable water resumed at a higher flow rate. The increased flow rate varied based on available potable water due to customer demands, water transmission system hydraulic limits, and operator preferences. Chlorine residual was tested several times per day to monitor the dilution of the initial higher chlorine dose. Chlorine was periodically injected into the inlet pipe to boost chlorine residual as needed to achieve the end target residual of +/- 2-3 ppm. Reservoir fill continued for another 14 days until the reservoir water reached overflow level. The reservoir fill was stopped, and the reservoir was isolated for a minimum of 24 hours. After this hold period, water samples were obtained for water quality testing consisting of chlorine residual, bacteriological, trihalomethanes, volatile organic compounds, and other constituents required by the California Division of Drinking Water. After receiving passing water-quality test results, CMWD was allowed to return the reservoir to service.

Start-up also included O&M training to CMWD personnel for critical components. Contractor provided O&M manuals and followed up with providing onsite training sessions for outlet valves, actuators, and HPU; floating cover rainwater removal pumps; water quality sampling pumps; and overall floating cover maintenance, inspections, cleaning, and repairs.

LESSONS LEARNED

Floating cover designs are typically performed while a reservoir is in service. Accurate as-built drawings and underwater dive inspection photos and videos are essential to document and verify actual existing conditions. Best practices show, and not unique to this project, the information shown on as-built drawings may not always be accurate as a single resource. Existing conditions should always be documented and reviewed by the design engineer once the reservoir is dewatered and existing floating cover is removed. Any unforeseen conditions revealed should be addressed early in the construction phase to avoid potential project delays.

Long-lead components must be identified early and adequately addressed as soon as possible. On this project specifically, the CSPE geomembrane stock material for the chafer and floating cover, along with the outlet valves, actuators, and hydraulic power unit, were all identified as long-lead items. The CSPE manufacturing supply chain for large quantities of geomembrane roll stock materials, which are then used by the fabricator to produce large custom shaped factory panels, require highly coordinated schedules and upfront time to facilitate. This process guarantees the project-specific sized panels deliver to the job site within the project timeline to be installed. The valve actuators were manufactured in Italy, the valves manufactured in Chicago, Illinois, and HPU manufactured in Rochester, New York. All three components were assembled, and shop tested in Chicago before being sent to the reservoir site in Carlsbad, California.

During this project, lessons learned included the sheer-importance of preparation through the coordination of shop drawing submittals, fabrication schedules, different contracting entities, and subcontractors, which all proved to be essential components of success. All of these components should be aggressively pursued right at the project onset.

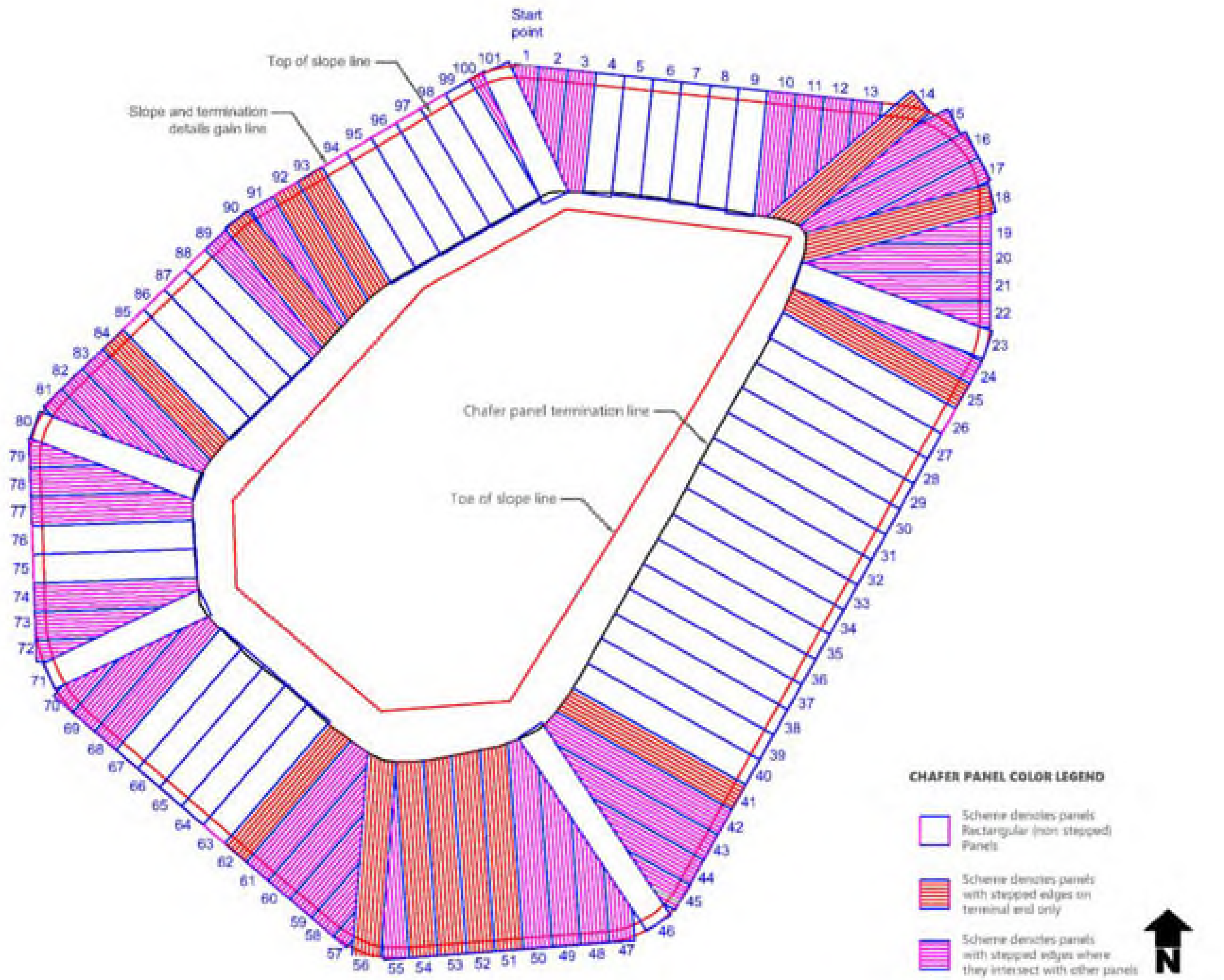

Figure 1. Chafer panel design illustration.

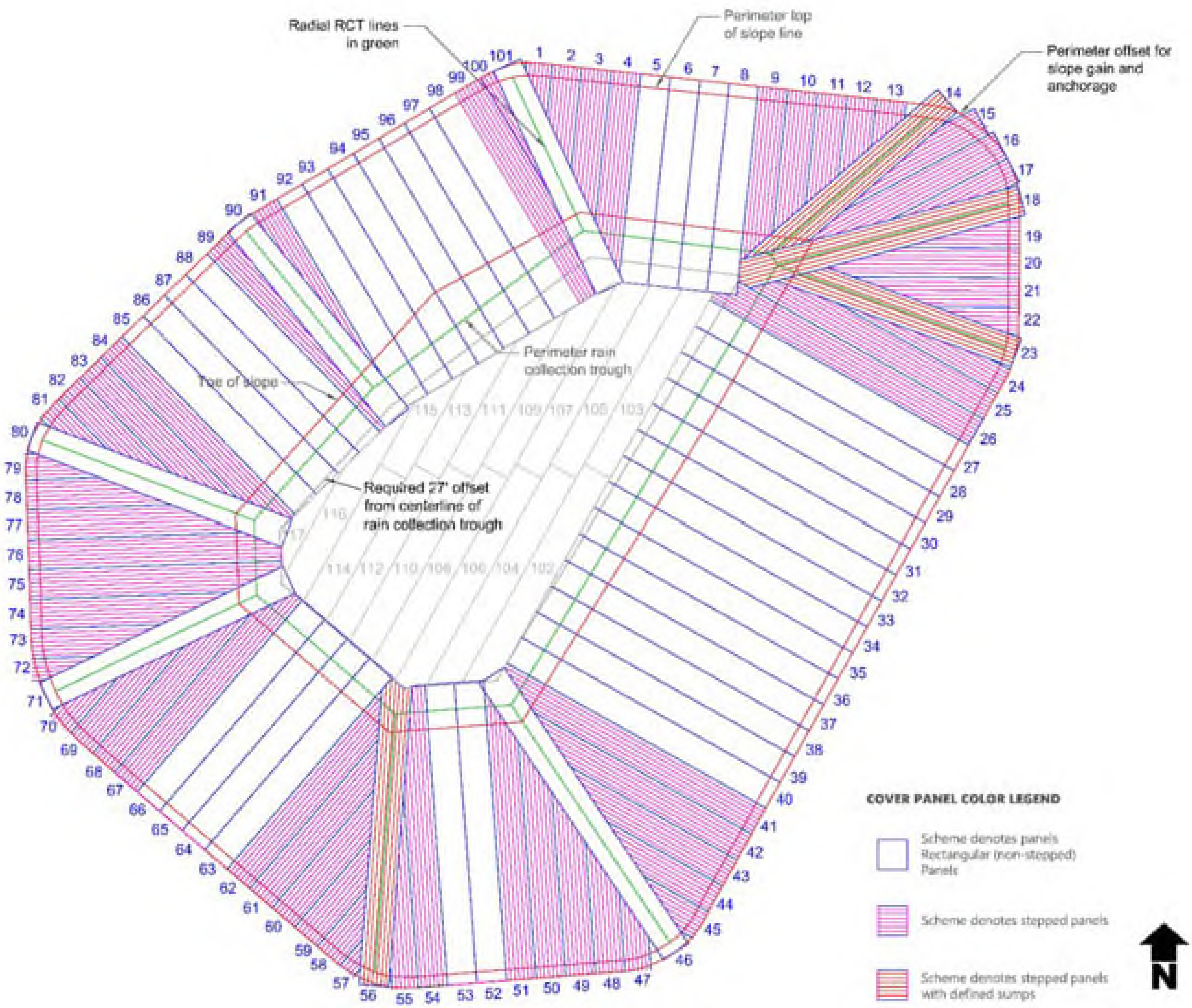

Figure 2. CSPE cover panel design illustration.

Figure 3. Chafer panel installation progress.

Figure 4. Cleaning existing AC subgrade prior to floating cover.

Figure 5. Floating cover panel seaming progress.

Figure 6. Floating cover fabricated panel deployment progress.

Figure 7. Positioning of the floating cover and wrinkle removal.

Figure 8. Floating cover and rainwater collection trough progress.

Figure 9. Floating cover system view with prefabricated appurtenances for the project.

Figure 10. Aerial view of completed floating cover system with high aesthetic value.