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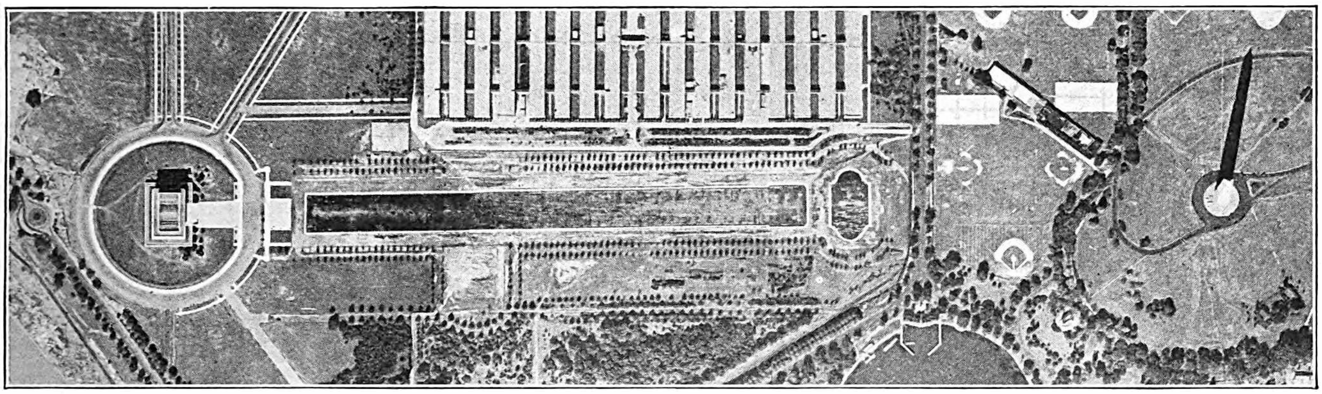

Aeroplane View of Reflecting Pool Area

View shows pool area with Lincoln Memorial on the west, Washington Monument on the east and the temporary Navy and Munition Buildings on the north. The park development is south of the pool with the river showing in the southwest corner and the tidal basin projecting into the area just south of the small pool. The axis of the pool is not on a true east and west line, inclining slightly south.

The Lincoln Memorial Reflecting Pool

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The beauty of reflecting pools has long been appreciated and many magnificent examples are found in the Old World. But the reflecting pool of the Lincoln Memorial is unique not only in its artistic possibilities, but in the engineering problems envolved in its construction. Nestling between its double rows of English elms. It reflects the marble whiteness of the Memorial from the east and the towering shaft of the Washington Monument from the west. Both of these views may be found in this issue, one on the cover and the other in the accompanying article. This pool, though not contemplated by L'Enfant, the French engineer of the American Revolution, who planned the City of Washington, is one of the most beautiful spots in its world famous parks.

The construction of the pool presented an unusual engineering difficulty inasmuch as it was constructed on made ground, pumped from the Potomac, and subject to settlement. This made imperative the use of a flexible flooring which would conform to the surface should settlement occur. Since the city water mains were to be used as the source of supply it was necessary that the covering be impervious, to prevent wastage. Both of these problems were solved by the use of a three-ply fabric impregnated with asphalt, which extends over the entire 2,000 feet of the pool, as ably described in the following article.—Editor.

THE United States Senate, in the year 1901, appointed a committee of expert architects to study the various parks throughout the world and to plan a park system for Washington which would be second to none. The members of the committee were greatly impressed by the beauty and dignity of the waterways and canals in Versailles, France, and the reflecting basins at the Taj Mehal in India. They conceived the idea of creating a body of water between the Washington Monument and the Lincoln Memorial which would reflect these two magnificent monuments in a huge mirror set in a frame of green. The report of the commission, published in 1902, provided for a waterway in this area and the design of the Lincoln Memorial included as one of its features some type of pool or lagoon.

Planning the Pool

The design of the pool presented numerous engineering problems, due to the fact that the area to be occupied was originally marsh land which had been reclaimed, the fill being made by pumping in material dredged from the Potomac River. Experience at the Lincoln Memorial indicated that unequal settlement would occur in any construction supported on this fill. This led to a method of design in which structural features were planned to allow for settlement or were supported on bedrock which lies approximately 40 feet below the elevation of the pool.

The plans for the development provided for two pools, one small pool at the east end of the area and one large pool in the shape of a cross. Because of the presence of the temporary Navy and Munitions Buildings adjacent to the pool site it was necessary to alter the design of the large pool and omit the arms projecting north and south, thus leaving a long rectangular shaped pool. The small pool was planned as a small rectangle with offsets and curved ends.

The pools were designed 160 feet wide, the large pool 2,000 feet long and the small pool 300 feet long. The maximum depth of the pools was planned to be 3 feet, with a granite coping forming the edges and projecting 6 inches above the water surface. The combined volume of the two pools was computed as 7½ million gallons, the small pool having 10 per cent of the total capacity. Supply and drainage systems of sufficient capacity to fill or empty the pools in 24 hours were also planned. The actual construction work, however, was delayed until 1919 because of the World War.

Excavation

The excavation of the pool was not only the beginning or foundation of this beautiful basin, but served the additional purpose of providing 135,000 cubic yards of earth for making the necessary fill around the Lincoln Memorial. This work was a simple problem in excavation and filling. It was handled very economically by the use of steam shovels and a narrow guage industrial railway. The railway was constructed in movable sections so that the track could be kept parallel to the line of operation of the steam shovels. At the dump end of the line the track was shifted as the work progressed and the fill was carried to the required grades for the area around the Lincoln Memorial. The additional expense of securing and hauling in soil to spread over the fill around the Memorial was saved by excavating the top soil separately and depositing it in piles for use in spreading over the filled area.

Drainage System

The construction of the drainage system presented problems which required considerable study and necessitated unusual construction. The first condition to be met was to provide a conduit from the pools to the tidal basin, a distance of 600 feet, which could be used as a drainage conduit in draining the pool and could also be used as a supply line for filling the pools. To meet this condition a 36-inch concrete conduit, built monolithically in the trench, was constructed with its flow line 3 feet below mean low tide in the tidal basin. This portion of the conduit was 450 feet long and extended from the tidal basin to a pumping sump located at a point suitable for a pump installation just south of the pools. The portion of the conduit from the pump sump to a manhole between the pools was built for drainage alone and it consisted of a 30-inch concrete pipe laid on a reinforced concrete mat and encased in concrete up to the spring line of the pipe.

In this construction considerable water was encountered, and it was necessary to lay an 8-inch terra cotta underdrain and install pumps to remove the water during the concreting. The trench varied from 10 to 16 feet in depth and it was necessary to sheet pile and brace the entire excavation.

The second condition which had to be met was to provide a system of drainage for the large pool which would remove all of the water in 24 hours, leave no pockets on the bottom undrained, provide outlets convenient for washing out the pool, drain the subgrade under the bottom of the pool and carry off the adjacent drainage.

Difficulties Encountered

In the solution of this problem the chief difficulties were due to the following physical conditions: First, it was desired to have the pool very shallow and of practically uniform depth; therefore, it could not be graded to drain to one end; second, the difference in elevation between the bottom of the pool and average high tide in the river or tidal basin was only 3½ feet, thereby necessitating a very flat grade on any sewer construction; third, the character of the ground made construction difficult, and the topography of the area added further difficulties in that all surface drainage found its way into the excavations.

The requirements were met and the difficulties overcome by providing a drainage sewer along the axis of the pool, outlets from the pool into the sewer at 70-foot intervals, dry wells for draining the subgrade midway between outlets and laterals for outside drainage at 400-foot intervals. The sewer was constructed of terra-cotta pipe and varied in size from 30 inches at the outlet to 8 inches at the high end. It was laid on a very flat grade (.015%) and was supported on a reinforced concrete slab. The outlets consisted of catch basins fitted with iron gratings and connected to the sewer. The dry wells consisted of openings in the sewer, fitted with iron gratings and encased in washed gravel.

During this construction, ground water was encountered and it was necessary to install underdrains and to operate pumps continuously to keep the trenches dry. The entire excavation was braced to prevent caving and at some points the work was very difficult, due to the presence of running sand. Similar construction to that used in the large pool was employed for the drainage in the small pool.

The third condition to be met was to provide drainage for the area adjacent to the pools. This was accomplished by providing a terra-cotta sewer laid with open joints in a bed of washed gravel competely surrounding both pools. This drain line was connected to the laterals provided in the main sewers. All of the outside drainage had a .5 per cent grade with catch basins 100 feet apart. This outside drain intercepted the ground water and surface drainage flowing toward the pools.

To regulate the maximum height of the water an overflow was constructed between the pools. This overflow consisted of a reinforced concrete chamber with a center wall dividing it into two sections. One section was connected to the pools by means of iron pipes while the other section was connected to the drainage conduit. In the top of the division wall, a metal plate, set at the elevation desired for the water level, was used as a weir to regulate the height of the water.

Water Supply

The first plan of pumping water from the tidal basin for filling the pools was abandoned when work was commenced on the new Washington water supply. By taking the water directly from the District mains the expense and difficulties of an underground electrical pumping unit were eliminated.

The nearest water main was approximately 1,000 feet north of the pool. A 12-inch supply was brought in, with its terminus in a reinforced concrete supply chamber just inside the lines of the pool. This supply chamber was designed to permit the filling of the pool without damage to the bottom. It consisted of a reinforced concrete basin 13 feet square with the inlet so constructed that the water would issue in a vertical column and fall into the inlet basin and thus do no harm to the bottom.

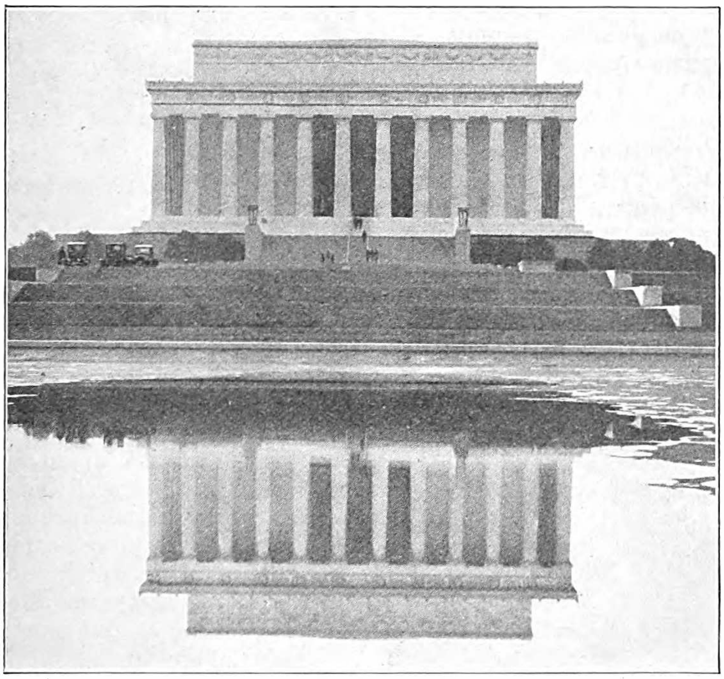
For an additional supply of water the surface drainage from the Lincoln Memorial was connected with the pool so that the rain water from the Memorial and its approaches would flow into the pool.

Work has been started on the construction of a supply line for the fountains to be placed in the small pool and for hose connections for flooding in winter and washing out the pools in summer. This line will be divided into three branches; one supplying two center jets in the small pool; one surrounding the small pool to supply the side jets, and one extending along the north side of the large pool with hose connections at 150-foot intervals.

The fountains are being planned as a huge water display with two center jets sending water high into the air and 150 side jets around the edges with water issuing toward the center. An electrical display is planned which will illuminate the fountains at night.

Coping Foundation

The design of the coping foundation was perhaps the most interesting problem in connection with the entire construction of the pool. It was necessary to provide a foundation that would support a granite coping exactly level around the pools and also maintain true lines on the face of the coping. To accomplish this it was necessary to provide piles to rock with reinforced concrete beam construction between the pile supports. In order to connect the bottom of the pool, in which unequal settlement might occur, to the rigid edges it was necessary to design an apron that would allow for this settlement without damage to the subsequent waterproofing.



The Lincoln Memorial

The design provided for piles 20 feet on centers completely surrounding the two pools, with a reinforced concrete T-beam supported on the piles. Expansion joints were placed in the concrete beam at 100-foot intervals with a pile on either side of the expansion joint. The work required 366 piles, 282 of which were composite piles of wood below elevation zero with concrete from zero to pile cap at elevation plus 7.5 and the remaining 54 were Raymond concrete piles. It was found more economical to use all concrete where short piles were required. All of the piles were driven to refusal.

The T-beam was designed to carry, in addition to its own weight, the weight of a granite coping and one-half of the weight of the attached apron. Reinforcing was also provided to resist any torsional stress set up by the tendency of the beam to rotate. The beam was securely anchored to each of the piles by means of four steel dowels. In addition a pile cap was provided at the head of each pile. The expansion joints between sections were designed to prevent any possible transverse movement of one section on the other at the point of contact.

Coping

To provide the necessary flexible connection between the edges and the bottom a reinforced concrete slab or apron, built on a slope of 18 inches in the 7-foot width, with expansion joints 100 feet apart and at all corners, was provided. A hinged joint was provided between the slab and the coping foundation with the apron reinforcing extending across the joint and into the beam. This joint was completely filled with bituminous waterproofing material to prevent corrosion and to protect the reinforcing.

Mt. Airy granite was selected for the coping because of its reasonable cost and the speed with which it could be secured. The granite was surfaced with a four cut axed finish. It was doweled to the foundation with bronze dowels. End dowels were also used to prevent any transverse movement. Before any of the coping was set all necessary waterproofing on the coping foundation was placed.

Waterproofing

The waterproofing problem was most difficult of all to solve. It was desired to have a bottom which would remain black, or nearly so, to give the best possible reflection. A construction rigid enough to be easily cleaned and yet pliable enough to conform readily to the surfaces if settlement should occur was necessary. Since city water was to be used it was advisable to keep leakage down to a minimum, and this presented a difficult problem.

Every possible method of waterproofing such an area was considered and investigated. Among the methods considered, but rejected as being undesirable and not meeting the requirements, were the use of sheet asphalt paving, bituminous macadam road construction, a 4-inch concrete bottom and a reinforced gunite slab.

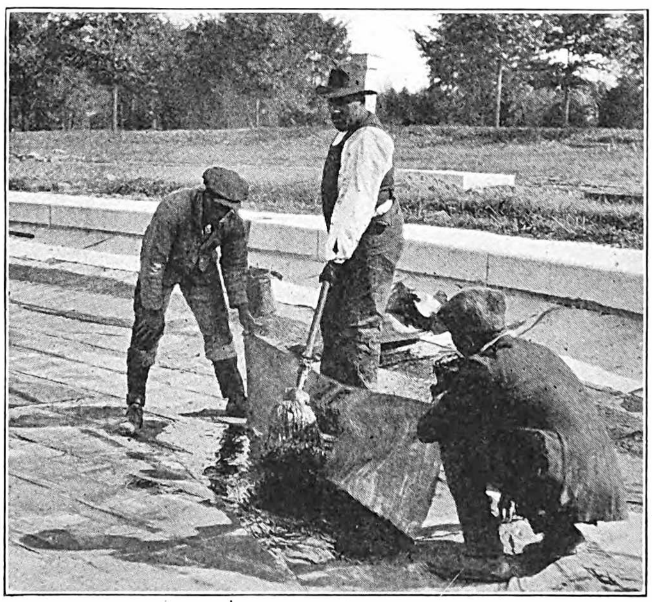
It was decided that a membrane waterproofing supported on a flexible foundation and properly protected would afford the most satisfactory bottom. The question of waterproofing materials was extensively investigated and no definite conclusion could be reached as to whether a high-grade asphalt or a coal tar would be more desirable. It was found that the work cost less by using asphalt for the construction.

The desired foundation for the membrane was secured by means of a 4-inch cinder base impregnated with asphalt. In building this base, a layer of cinders was spread, graded and rolled with a power roller. The cinders were then impregnated with a light asphalt road oil, using one and one-half gallons per square yard. A seal coat of three-quarters of a gallon per square yard of heavy asphalt road oil was applied to the impregnated cinder base and over this was spread a layer of sand. The surface was rolled and all excess sand was removed.

The membrane was constructed of two layers of saturated wool felt, two plies of impregnated fabric and three heavy moppings of waterproofing asphalt. One layer of felt was used as the first ply of the membrane and served to separate the high-melting asphalt in the membrane from the low-melting asphalt in the cinder base. The other layer of felt was used as the top ply of the membrane and served as a protection for the fabric and waterproofing asphalt. The fabric was open-mesh cotton fabric of high tensile strength, impregnated with a waterproofing asphalt. The asphalt used for the moppings was a high-grade waterproofing asphalt with a high ductility and a melting point of 150 to 160 degrees Fahrenheit.

The membrane was constructed to cover the apron and the coping foundation and was extended up the back of the coping in addition to covering the actual cinder bottom of the pool. Where the membrane was constructed on the concrete apron and foundation, the first layer of 15-pound felt was omitted. This felt was used primarily to prevent a fluxing action between the soft asphalt in the seal coat of the cinder base and the harder waterproofing asphalt in the membrane.

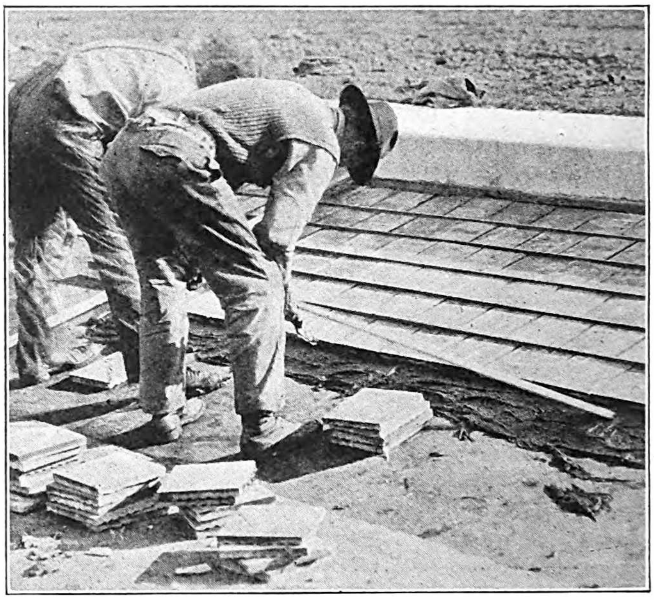
At the point where the apron joins the bottom of the pool the membrane was reinforced with two additional 36-inch longitudinal strips of impregnated fabric laid in heavy moppings of asphalt. The corners were reinforced with two additional strips of fabric in the same manner as the toe of the apron.



Constructing Bituminous Membrane
The open mesh cotton fabric was laid in heavy moppings of high-grade waterproofing asphalt. Two plies of fabric laid in three moppings of asphalt with a layer of asphalt felt both over and under formed the membrane.

Further Difficulties Encountered

When the membrane on the bottom of the pool was over one-half completed the heaviest rain in 40 years occurred with 5 inches of precipitation within a few hours, causing considerable damage to the membrane. This rain occurred at a time of unusually high tide. This condition was responsible for a very slow run-off from the pool area, causing the water to back up in and under the pool. The rising ground water lifted the air in the soil, causing it to lift the membrane in large blisters or bubbles over a considerable portion of the pool. During this rain the water reached a height of over 15 inches in the bottom of the pool and lifted some of the membrane to the same height and in a few instances several inches higher. As the water subsided the membrane returned to its original position on the cinder subgrade, but at the points where the blisters and bubbles had occurred the membrane was uneven and in some instances wrinkled, due to the stretch it had been subjected to and to the fact that the running water under the membrane had displaced some of the cinder subgrade. By experiment it was found that the membrane might be rolled back to its original position without damage by the use of the power roller. A recurrence of this condition during the construction was prevented by regulating the tide gates in the Tidal Basin to maintain a permanent low tide and thus assuring a rapid run-off of all the rain water in the pool area. Under these conditions the membrane was successfully completed without further difficulty.



Laying Cement Tile
As a protection to the membrane on the concrete apron compressed cement tile was laid in an asphaltic plastic cement. This seven-foot tile border gives the effect of a paved floor over the bottom of the pool.

Mastic Applied

The protection mastic was started when the membrane was about 75 per cent completed. Work was begun near the west end of the pool and the first part of the work progressed with little difficulty. It was found that a power roller could not be used because of the fact that the hot mastic softened the asphalt in the membrane and when the power roller passed over this the various layers of membrane slid on each other and destroyed the membrane. This difficulty was overcome by substituting a hand roller for the power roller. Further difficulty was encountered at places by the membrane lifting in blisters when the hot mastic was applied. It was found that this condition was caused by gas contained in the subgrade, which collected in spots due to the heat of the mastic. Samples of this gas were taken and when analyzed proved to be approximately 60 per cent methane or marsh gas. The presence of these blisters made it very difficult to secure a satisfactory job, making it necessary to remove and replace large portions of the mastic. In some spots the blisters subsided as the mastic cooled, while at other places it was necessary to puncture the membrane and patch it in order to eliminate the gas. As the work progressed the conditions became worse, and increasing difficulties were encountered. When the mastic was 30 per cent completed conditions were so bad that the waterproofing contractor requested permission to substitute some other type of protection for the membrane.

The substitute offered was a commercial roofing slate laid in a heavy mopping of waterproofing asphalt with a seal coat of softer asphalt over the slate. In addition to this, the contractor offered to substitute a compressed cement tile laid in asphalt plastic cement in place of the mastic on the apron.

It was decided that the slate in small units of from 6 by 10 inches to 8 by 12 inches would be suitable and would provide ample protection for the membrane. The tile on the apron would also provide ample protection and make a better appearance adjacent to the edges of the pool than the mastic. The substitution was made and a slate and tile protection was completed with practically no further difficulties.

Completion of the Pool

In 1915 and 1916, and before any of the actual construction work was started, 500 English elms were imported from England and planted adjacent to the pool site to form shade for the proposed walks. These trees were planted in four rows, two rows bordering either side of the pool.

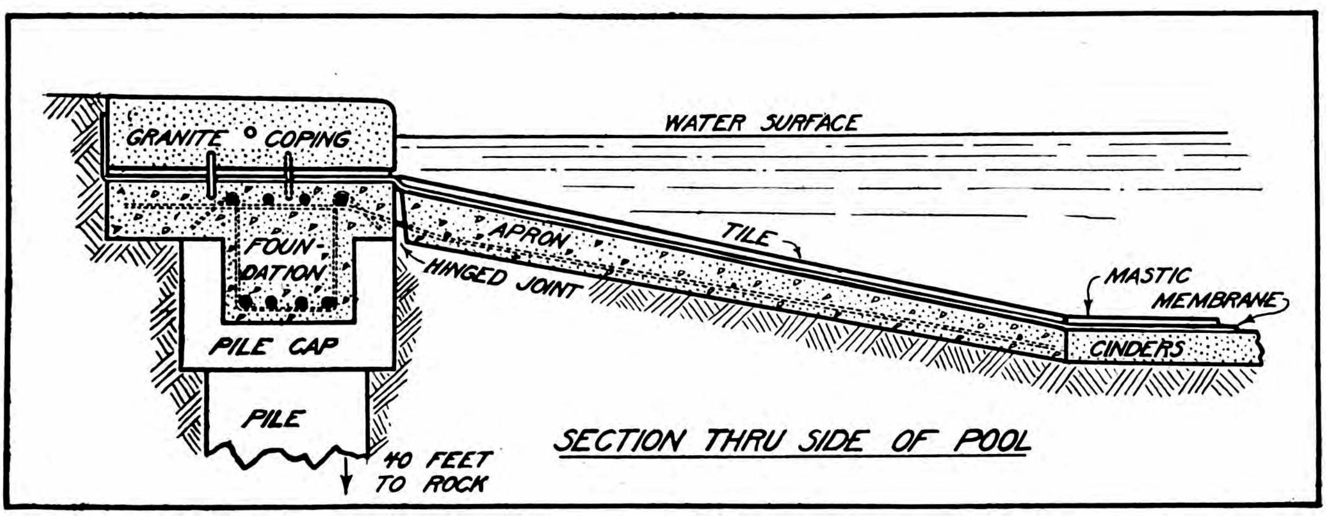
The construction of this pool under the existing conditions was a new problem in the field of engineering since pools and lakes are usually constructed on stable foundations. In addition, the artificial ornamental waterways in other parts of the world are not subject to the variations in temperature and the freezing conditions that occur in Washington. For these reasons each problem required the most careful and detailed study in order to get the most satisfactory construction possible.

In addition to its use as a reflecting basin, the pool will be used as a huge skating rink in winter. It is ideal for this purpose in that it is very shallow and, therefore, not dangerous. Provision is being made for flooding over the ice and keeping it in ideal condition for skating during freezing weather.

The axis of the pool passes through not only the Memorial and the Monument but also the dome of the Capitol, but this is not a true east and west line as originally planned by L'Enfant, as may be seen in the aeroplane photograph. This is caused by the fact, that in 1848, when the Monument was begun, L'Enfant's site was a marsh and the Monument was erected on a mound a few hundred feet to the southeast.

The construction of the walks and approaches is now under way and will be completed this season, thus completing the pool and its surroundings. The reflecting pool was constructed by the Office of Public Buildings and Grounds. Maj. C. S. Ridley was in charge of the early stages of construction. The pool was completed, however, under the direction of Lieut. Col. C. O. Sherrill, C. E.

With the completion of the Lincoln Memorial Reflecting Pool the park system of Washington has acquired the largest artificial pool or lagoon, designed primarily as a reflecting basin, that has ever been constructed. In addition, a link has been established between the Lincoln Memorial and the Washington Monument which connects these two great memorials into one beautiful unit.



Section Showing Pool Construction

The coping foundation is supported on piles to rock with a hinged concrete apron connecting this foundation to the bottom of the pool. The bituminous membrane is continuous over the bottom of the pool, the concrete apron, the coping foundation, and is carried up the back of the coping. The coping is doweled to the foundation and, and in addition, has end dowels connecting the coping stones.