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The Creation of Additional Space for the Storage of Dredged Materials - A Case History

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SYNOPSIS

Material dredged from the Delaware River is being stored on land in areas surrounded by man-made dikes. In the past, the height of these dikes had been increased in order to provide the needed additional storage space. However, existing land configuration and the high water table in the storage areas, together with the high water content and low strength of the stored dredged materials prohibit further increases of the dike height. A system of interconnected drainage trenches, excavated inside these areas and discharging into the river, was used to lower both the water table and the water content of the dredged materials to a degree that they could be used in the construction of new and higher dikes, thus providing the additional storage space needed.

INTRODUCTION

Every two to two and one-half years, Getty Oil in Delaware City, Delaware, must dredge its refinery's cooling water intake canal through to Delaware River, and also dredge a portion of the river channel to maintain the necessary water depth for access to its three loading and unloading piers. The dredged materials are stored on land, in five areas on either side of the intake canal and along the west bank of the Delaware River, as shown on Figure 1.

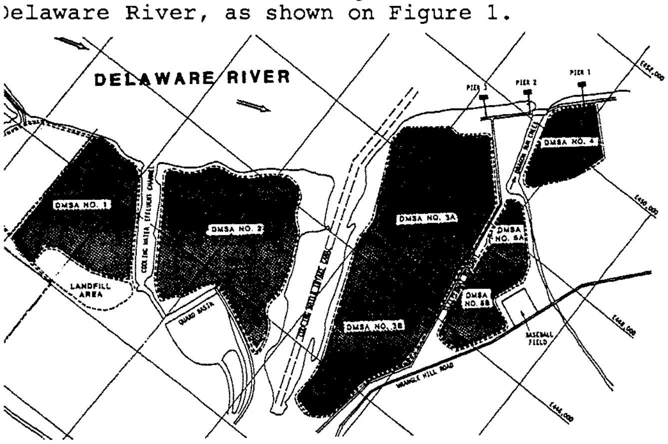

FIGURE 1-LOCATION PLAN

The storage areas are surrounded by man-made dikes, the height of which has been increased more than once in order to provide the needed additional storage space. However, proximity of the dikes to the edge of the river bank and the intake canal precludes extension of the dikes outward; the high water table in the storage areas, and the high water content and low strength of the stored dredged materials limit inward extension of the dikes and the further increase of their heights.

In order to create the needed additional storage space for the disposal of new dredged materials, it was decided to improve soil conditions within two of the five storage areas, thus allowing the construction of new and higher dikes inside these areas using the already stored dredged materials as fill. The implemented method for this improvement consisted of the creation of a system of interconnected drainage trenches excavated inside the disposal areas for the purpose of lowering the high water table and lowering the water content of the stored dredged materials. The resulting water content of these materials allowed access of earthmoving equipment into the disposal areas, and the excavation and use of the drier, stronger materials in the construction of new, higher dikes, thus providing the needed additional storage space.

DRAINAGE TRENCH SYSTEM

The system consists of a series of trenches excavated in the soft and wet dredged materials. The trenches are connected to a number of overflow drainage pipes installed at selected locations along the existing perimeter dike. Water collected in the trenches is directed to the drainage pipes for discharge out of the storage area into the Delaware River and the refinery cooling water canal. The trench dewatering system, a typical cross-section of which is shown on Figure 2, includes the following typical elements:

1. Outer Drainage Trench - This is a "permanent" trench which shall remain open throughout the use of the storage areas. It is located at a distance of about 100 feet parallel to the existing dike. It was the first trench to be excavated and its depth ranged from about 14 to 20 feet. In addition to its drainage and dewatering function, this trench will also help

improve the soil condition and stability of the new dike built about 100 feet from the trench. This and other trenches had to be excavated in two stages, because of sloughing of the wet soils into the trenches, using excavating equipment walking on mats.

2. Overflow Drainage Pipes - These pipes are also considered as "permanent." They are installed in an open cut across the existing dike, connecting the outer drainage trench to the outside of the dike for the discharge of the drained water. Invert elevation of the pipes is higher than the high tide level.

3. New Dike Trench - This trench is located at a distance of about 200 feet parallel to the existing dike. The trench, the depth of which was about 10 to 15 feet, was used as the base for building the new dike.

4. Inner Drainage Trench - It is located at a distance of about 100 feet from the center line of the dike trench, and has a depth of about 10 to 15 feet. The key function of this trench, and of the finger trenches described below, is to dewater and strengthen existing dredged material so that it could be used in the construction of the new dike.

5. Finger Trenches - These trenches are about 200 feet long and were excavated perpendicular to the inner drainage trench. Their depth varies from about 5 to 10 feet.

6. Cross Trenches - These trenches cut across and connect all other trenches so that water collected in the trenches described above may drain out of the storage area.

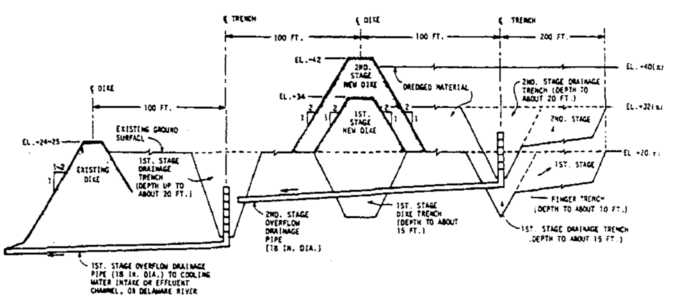

FIGURE 2-DIKE AND TRENCH CROSS-SECTION

In designing this dewatering system, it was believed that it would provide the functions necessary for the improvement of the soft soils and their use in the construction of the new dike, as follows:

1. It would lower and control the high water table in the storage area;

2. It would reduce the water content of the stored soils near the surface and make them suitable for dike construction;

3. It would promote the formation of a dry and strong crust on the surface, thus supporting construction and maintenance activities;

4. It would strengthen the dredged material below and alongside the new higher dike;

5. It would provide additional drainage paths for the dredged materials to be stored within the new dike; and

6. It would serve to intercept flow of water which would otherwise flow into areas adjacent to the storage areas.

The completed construction of the first stage of the new dike in Dredged Material Storage Area (DMSA) No. 1 has already proven the validity of the reasoning that resulted in this plan. For instance, prior to trench excavations six borings were drilled inside DMSA No. 1, at locations shown on Figure 3. At the time of drilling in mid-November 1979, water levels in the borings varied from 1 to 9 inches below ground surface in the three borings the surface elevation of which was about +17 feet above sea level. Water level varied from 16 to 24 inches below ground surface in the three borings the surface elevation of which was about +20 feet MSL. After one year following the excavation of the trench dewatering system, water levels varied from 64 to 76 inches below ground surface in the first three borings and from 44 to 53 inches in the latter three. Prior to dewatering, the Dames & Moore U Type Sampler was advanced into the soils, during drilling, either by the weight of the 300-pound hammer, or by means of one blow of this hammer falling 24 inches. Water contents in the soil varied from 50 to 137 percent, and dry densities varied from 34 to 74 pcf. Bulk soil samples obtained from the locations shown on Figure 3 were compacted in the laboratory using ASTM D-1557-70 Method "A" and resulted in maximum dry densities varying from 100 to 110 pcf, at optimum moistures varying from 14 to 21.5 percent.

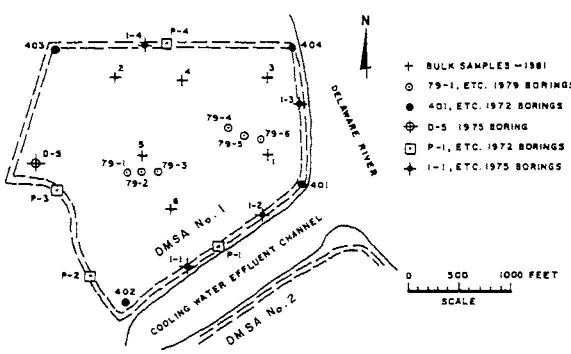

FIGURE 3-BORINGS AND BULK SAMPLES

NEW DIKE DESIGN AND CONSTRUCTION

In order to eliminate transportation and other costs for borrowed fill, it was decided that all dikes would be built using stored dredged materials which would be improved as described above. The use of these on-site materials would also provide the added advantage of creating more storage capacity for new dredged soils in the borrow pits excavated within the storage areas. Taking into account stability requirements, dredging schedules, and the need for the control of capital expenditures, it was also decided to build the new dikes in DMSA No. 1 and No. 2 in two stages: the first with a top elevation of +34 and the second stage with a top elevation of +42 (it should be noted that the maximum allowable top-of-dike elevation for the existing dikes was +25).

Dike Cross-Section - The new dike was designed with its lower section anchored into the soft soil about 10 to 15 feet below existing ground surface. This design together with the trench dewatering system, the dike alignment, and staged construction schedule would collectively contribute to overall dike stability. Thus, soil consistency below and around the dike would improve and the new dikes would be able to resist the anticipated lateral forces acting on them; more soil shearing resistance would be mobilized against deep-seated sliding; post-construction settlements caused by the underlying soft soils would be reduced; and a more stable foundation for the second stage of dike construction would be provided.

Soil Profile - A generalized subsurface profile for dike stability analysis was developed using soil data available from previous soils investigations in the areas. During this synthesis of data it was determined that the stability of proposed dikes alongside the cooling water intake and effluent channels would be comparatively more critical than at other locations. The selected soil files shown on Figures 4 and 5 were considered to be representative of the probable most critical conditions. It should be noted that soil properties shown on Figure 5 were estimated on the basis of anticipated improvements brought about by the surcharge effect of the dike built to +34 acting on the underlying soils for a period varying from 3 to 11 years when additional dredged materials are scheduled to be pumped into the areas enclosed by the new dikes.

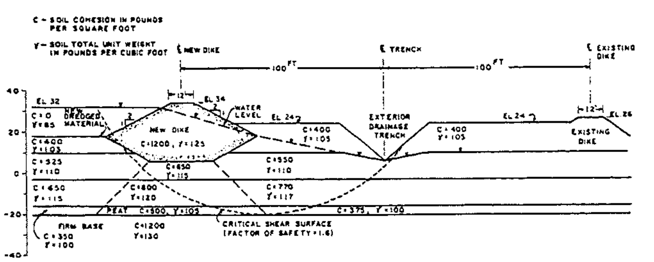

FIGURE 4-SOIL PROFILE AND DIKE STABILITY-STAGE 1

Previous data indicated that a firm clayey soil was present at Elevation -20 in DMSA No. 1. Soils above this firm base were generalized in three categories: previously dredged and stored material, mostly silty with thin sand lenses and thin layers of organic matter; underlain by peat or fibrous organic clay; in turn underlain by silt and clay deposits. The consistency of the material above the firm clayey soil at -20 increases with depth from soft to medium stiff. In the stability study it was assumed that all soils shown on the profiles are cohesive having internal friction angles equal to zero.

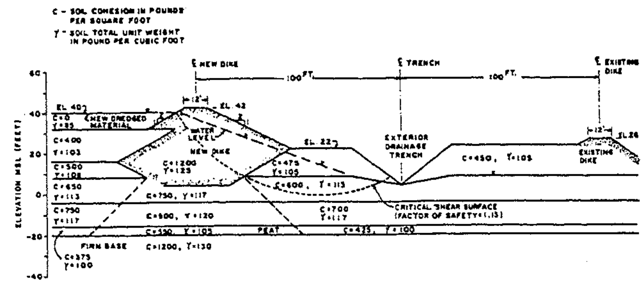

FIGURE 5 -SOIL PROFILE AND DIKE STABILITY-STAGE 2

Dike Stability - The primary concern for this study was for the new dikes (about 17 feet higher than the old existing dikes) to be designed and constructed in such a manner in order to retain additional dredged materials with adequate safeguard of adjacent refinery facilities and the Delaware River. Judging from site conditions and dike design criteria, it appeared that the probable mode of failure would involve a deep-seated circular sliding movement if pressure against the dike exceeded the shearing strength of the relatively weak soils below and surrounding the new dike. If such a situation developed, a segment of the dike might settle excessively and, coupled with a lateral sliding movement, might result in an eventual rupture or breach. The proposed dike may also suffer localized and less critical damages caused by severe weather or weak ground conditions resulting in slope sloughing, cracking of dike surface due to uneven settlements, or washouts due to erosion or seepage. It is believed that the dike, as designed and built, accompanied by a well-managed post-construction maintenance program represent a solution much more preferable and economical than one that might be produced by performing more detailed studies or by costly special design and construction.

Dike stability was analyzed using the Dames & Moore EP1 computer program based on the Simplified Bishop Method. The calculated safety factor against most critical deep-seated circular sliding failure in DMSA No. 1 is 1.6 for dike top elevation of +34 and 1.13 for second stage construction to +42.

Dike Construction - The new dike was built to Elevation +34 according to specifications. They called for the clearing and cleaning of the previously excavated dike trench (completed in late 1979) and pumping of the water encountered in this trench so that dike construction could be performed in the dry. Fill soils obtained from borrow pits within DMSA No. 1 were placed in layers of not more than 12 inches thick and compacted to at least 90 percent of maximum dry density as determined in accordance with ASTM Standard D1557-70. The contractor was particularly directed to exercise care in order to prevent trench bottom heaving and side slope failure during dike construction. Prior to the beginning of dike construction, the soils excavated from within the dike and outer trenches were piled immediately beyond the toes of the new dike, and were subsequently shaped into berms adjacent to the new dike for added safety. Dike construction was initiated in May 1983 and was completed to Elevation +34 on September 15, 1983.

Maintenance and Future Activities - Post-construction maintenance and repair work will be provided for both the trench dewatering system and the new dike in order to keep the former in working condition and to avoid the development of serious problems in the latter. Future construction activities for the second stage of trench dewatering system and the extension of the new dike to Elevation +42 will be performed with adequate quality control. Finally, it is the intent to monitor performance of the new dikes during and after pumping of new dredged material into the enclosed area, and to further analyze dike stability based on new soils data collected prior to the construction of the second stage of the dike.

CONCLUSIONS

The method described in this paper will provide additional dredged material storage space for at least the next fifteen years. This space is created within existing storage areas, making use of materials already stored, or to be stored, in the storage areas. It is created in the most economical manner, by eliminating the cost of borrow material purchase and transportation, while at the same time creating more storage space in the borrow pits excavated within the storage areas. The emphasis on safety and quality control should allow an uninterrupted and problem free refinery operation.

ACKNOWLEDGEMENTS

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