

Table 21
Whitefish Point Harbor Breakwaters
Whitefish Point, Michigan

Date(s)	Construction and Rehabilitation History
1968	Construction of a 507-ft-long south breakwater and a 587-ft-long north breakwater was completed at the site (Figure 56). The south breakwater consisted of a 323-ft-long steel sheet-pile cantilever wall and a 184-ft-long sand-filled cellular steel sheet-pile structure (Figure 56). The cells were 25.5 ft in diameter and were capped with reinforced concrete. Riprap was placed on each side of the cells, The entire breakwater was constructed to a +8 ft lwd el. The north breakwater was constructed with sand-filled cellular steel sheet-pile structures that were also capped with reinforced concrete. The shoreward cells were 25.5 ft in diameter, while the lakeward cells had a diameter of 30.2 ft (Figures 56 and 57). Riprap was placed on each side of the structure, and the crest el was +8 ft lwd.
1969	A 270-ft-long interior breakwater was constructed (Figure 56) for wave absorption. This structure consisted of steel sheetpiling installed at an el of +8 ft lwd and riprap installed at 0.0 ft lwd on each side of the structure (Figure 57). The weight of the riprap ranged from 1,600 to 6,000 lb, and about 6,860 tons of stone was used. The cost of this structure was approximately \$112,000.
1986	The breakwaters appear to be functioning well and presently are in good condition. An aerial view of Whitefish Point Harbor breakwaters is shown in Figure 58.

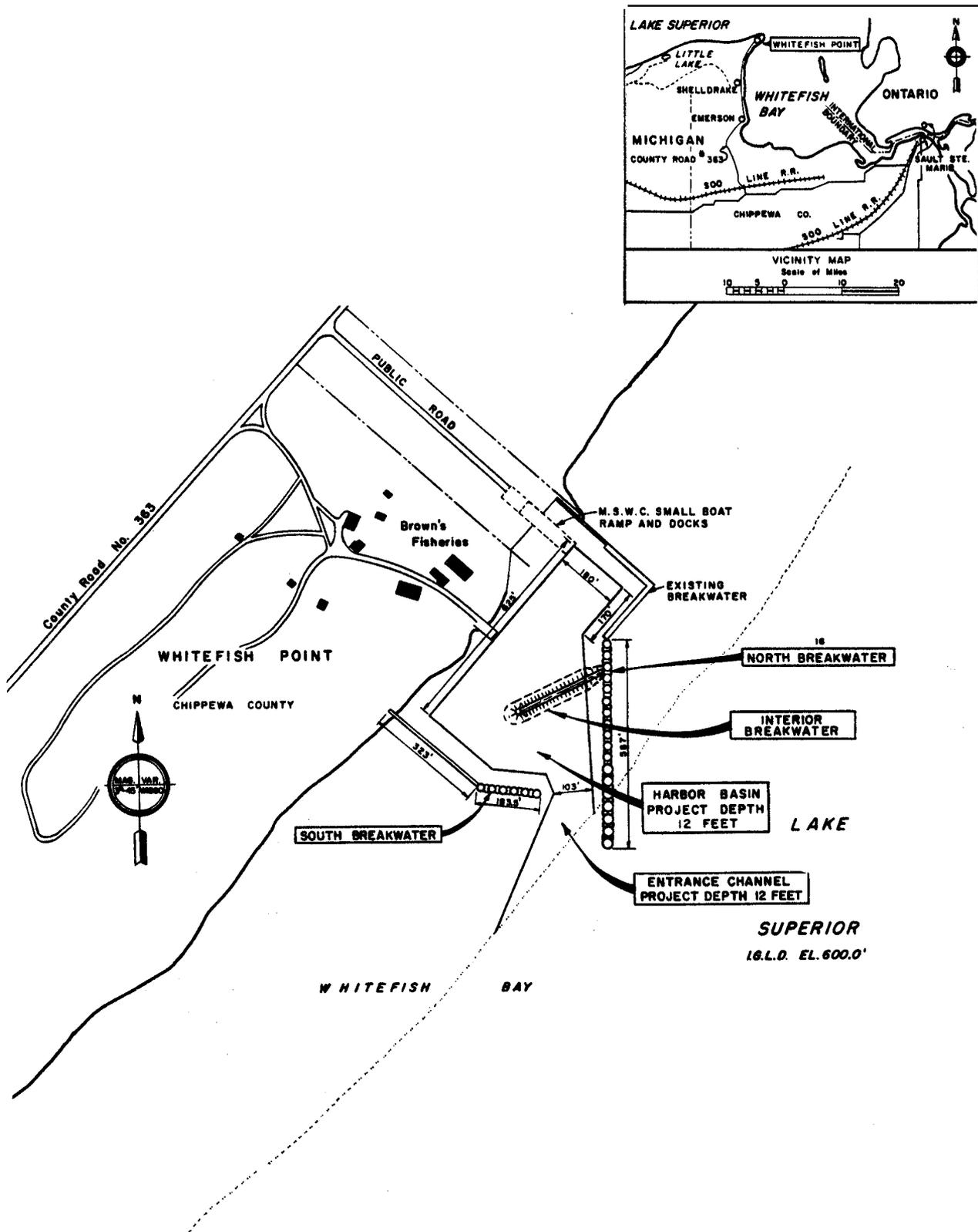


Figure 56. Whitefish Point Harbor, Michigan

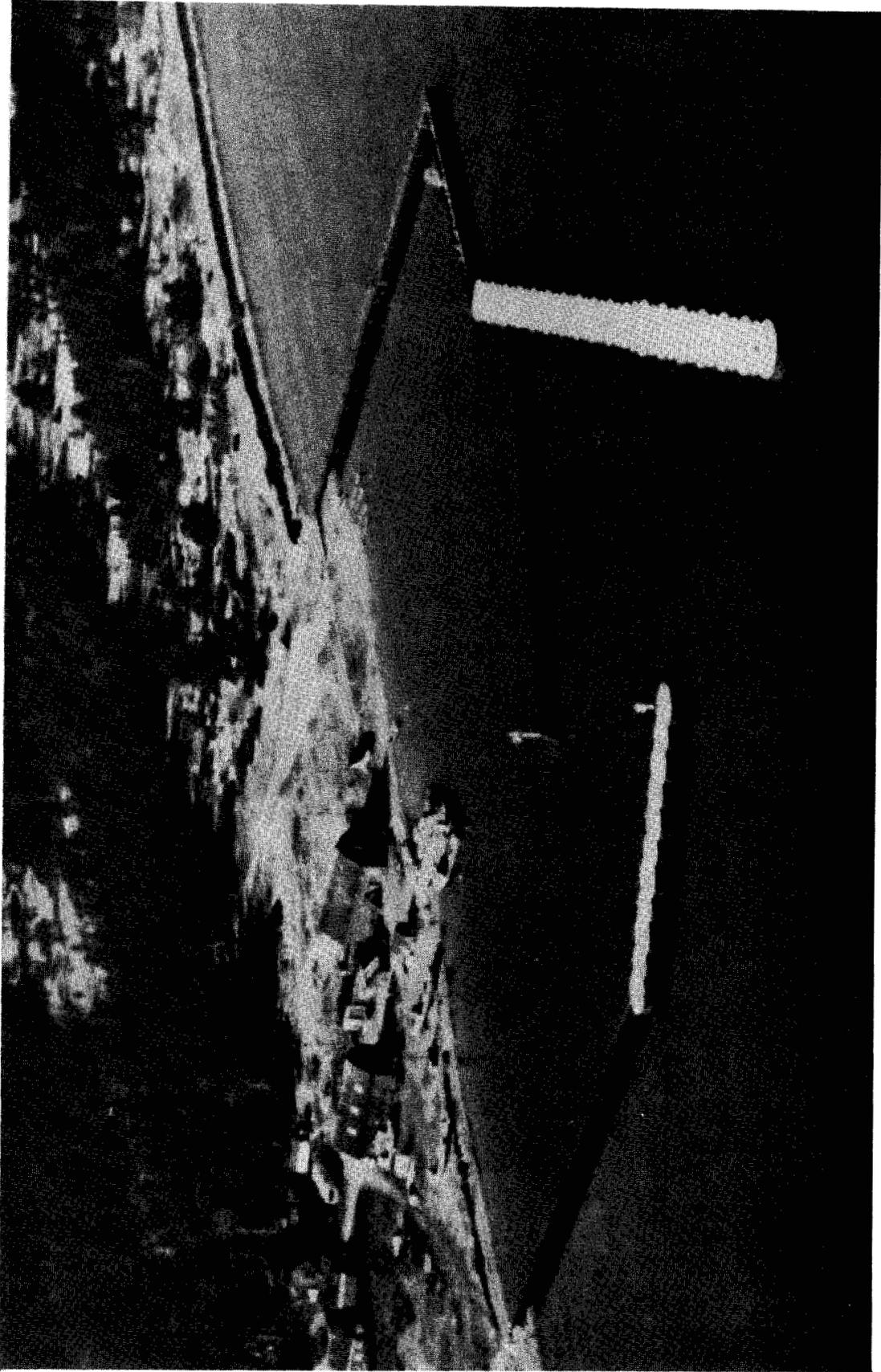


Figure 58. Aerial view of Whitefish Point Harbor Michigan

Table 22

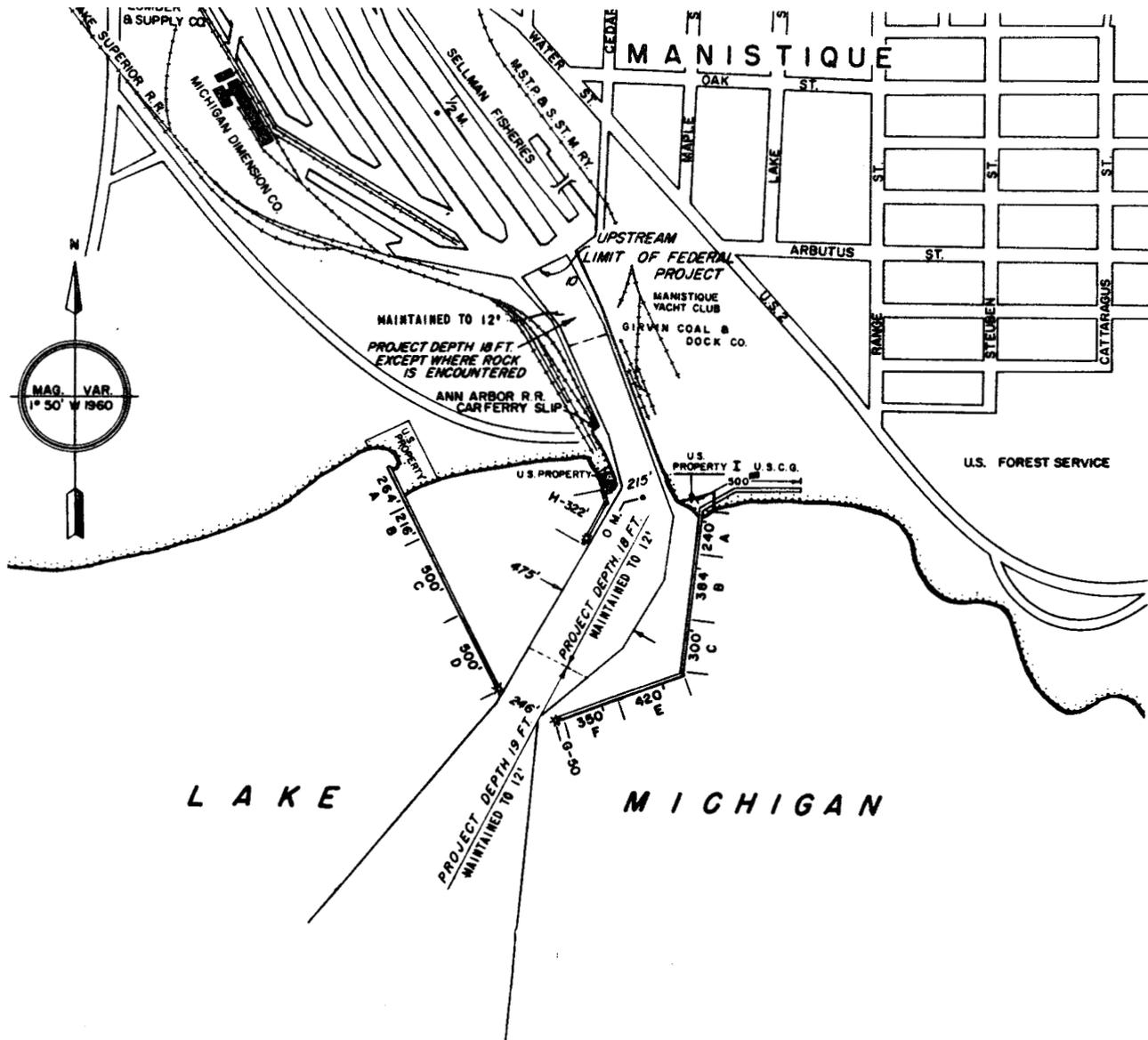
Manistiaue Harbor BreakwatersManistique, Michigan

Date(s)	Construction and Rehabilitation History
1887	A 420-ft-long timber crib breakwater was constructed offshore of the site (Figures 59 and 60, Section E). The structure was about 29 ft wide, and stone was placed on each side of the breakwater. Core stone ranged from 2 to 3 ft in thickness, and cover stone was a minimum of 4.5 ft thick.
1909	A 322-ft-long stone-filled timber crib pier was completed west of the harbor entrance (Figures 59 and 61, Section H). The pier was approximately 20 ft wide and installed at an el of +4 ft lwd. The lakeward portion of the structure included a concrete cap (cast in place) and riprap toe protection. The rest of the pier consisted of a cap of precast concrete blocks and stone.
1911- 1915	During this time, construction of the east and west breakwaters was completed (Figure 59, Sections A-G). The 420-ft-long breakwater (built in 1887) was capped with concrete and became a portion of the east breakwater. The shoreward 624 ft of the east breakwater and 480 ft of the west breakwater (Figure 60, Sections A and B) were constructed of woodpiling and stone. The superstructure consisted of a concrete cap and stone. The shoreward portion (Section A) was 8 ft wide, and the rest of the structure (Section B) was 11 ft wide. The crest el was +7.1 ft lwd, and stone was included on both sides. The 1,000-ft-long lakeward end of the west breakwater and 300 ft of the east breakwater shoreward of the dogleg section (Figures 59 and 60, Sections C and D) consisted of wooden crib construction with concrete caps. The 300 ft of east breakwater and 500-ft-long shoreward end of the portion of the west breakwater (Section C) were 20 ft wide. The outer 500-ft-long portion of the west structure (Section D) was built 24 ft wide. The breakwaters (Sections C and D) had a +7.1 ft lwd crest el. The outer 400 ft of the east breakwater (Figures 59 and 61, Sections F and G) consisted of timber crib construction with concrete caps. The breakwater was 24 ft wide and had a crest el of +7.1 ft lwd.
1953	The shoreward end of the east breakwater was extended 200 ft to shore and 300 ft parallel to the shoreline (Figures 59 and 61, Section I). The structure was of rubble-mound construction with 1V:1.5H side slopes. It had an 8-ft crest width and +7.0 ft lwd crest el. Cover stone on the lakeside ranged from 1 to 3 tons and on the harbor side from 0.5 to 1.5 tons. The structure presently is entirely on shore.
1957	The superstructure of the inner 924 ft of the east breakwater (Figure 59, Sections A, B, and C) was refilled with stone.

(Continued)

Table 22 (Concluded)

Date(s)	Construction and Rehabilitation History
1958	Riprap was placed on both sides of the east breakwater on the outer 100 ft of Section C (Figures 59 and 60). The outer 820 ft of the east breakwater (Figures 59-61, Sections E-G) was reconstructed during this period as rubble-mound breakwaters.
1961	Riprap was placed around the outer end of the west breakwater and for a distance of 200 ft on each side (Figure 59, Section D). Riprap also was placed around the outer end of the east breakwater and 150 ft along each side (Figure 59, Sections F and G).
1963	Rehabilitation of navigation structures included reconstruction of the inner 470 ft and 624 ft of the west and east breakwaters, respectively (Figure 59, Sections A and B). Also included in the rehabilitation was reconstruction of the pier (Figure 59, Section H). The shoreward 88 ft of the pier included a rubble-mound structure (Figure 61, Section H), 8 ft wide, with a crest el of +4 ft lwd and side slopes of 1V:1.5H.
1981	An inspection of the breakwaters revealed that the east breakwater had some areas where the concrete cap was in an advanced state of deterioration, and the stone fill had washed away. The west breakwater required some stone fill also and new concrete in some areas. Breakwater repairs were made subsequent to the inspection.
1986	The structures have been reconstructed and repaired during their history and presently are in fair condition.



Manistique Harbor, Michigan

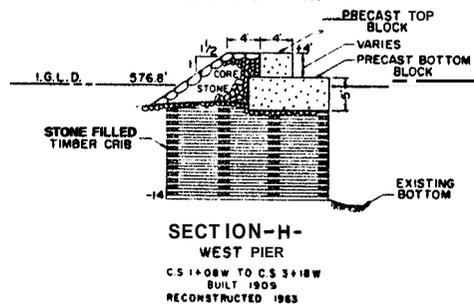
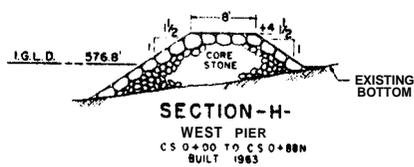
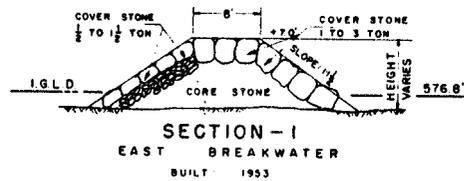
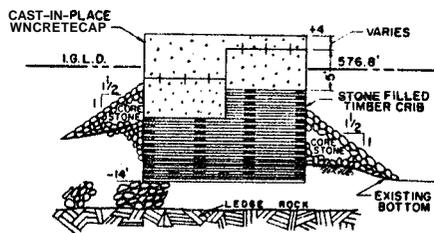
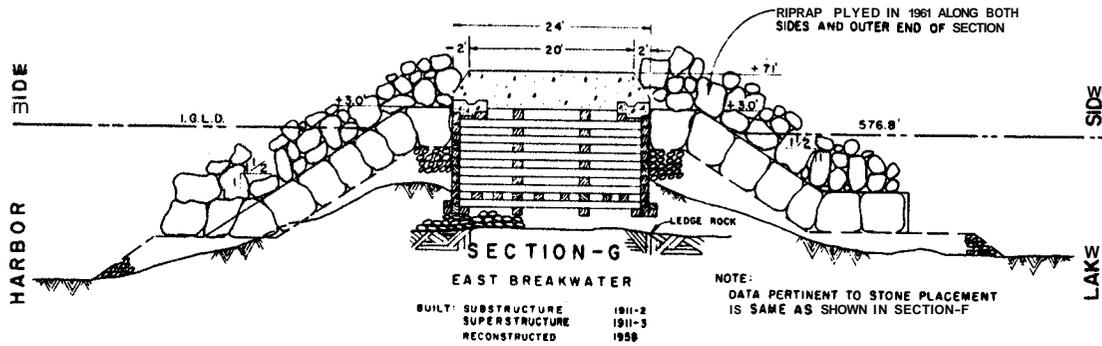
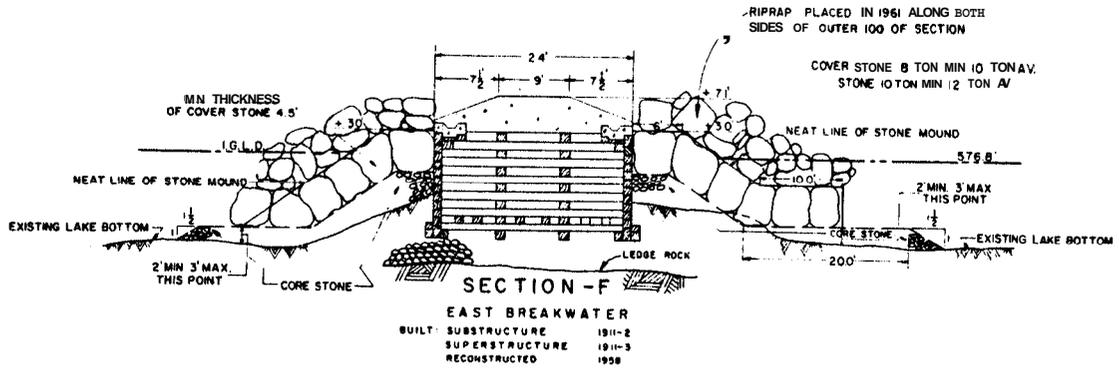


Figure 61. Typical structure cross sections, Manistique Harbor, Michigan

Table 23
Cedar River Harbor Piers
Cedar River, Michigan

Date(s)	Construction and Rehabilitation History
1883-1885	A 750-ft-long west pier and a 350-ft-long east pier were constructed during this period at the mouth of Cedar River (Figure 62). These structures were built with wood piles spaced 14 ft apart (width) and filled with stone (Figure 62). The original crest el was +8.2 ft lwd. A timber cap provided a 16-ft-wide crest width.
1965	Construction of a new west pier and a 2,100-ft-long rubble-mound east pier with a cellular sheet-pile pierhead (Figure 62) was authorized. Construction, however, has not yet occurred.
1986	The existing piers are in ruins.

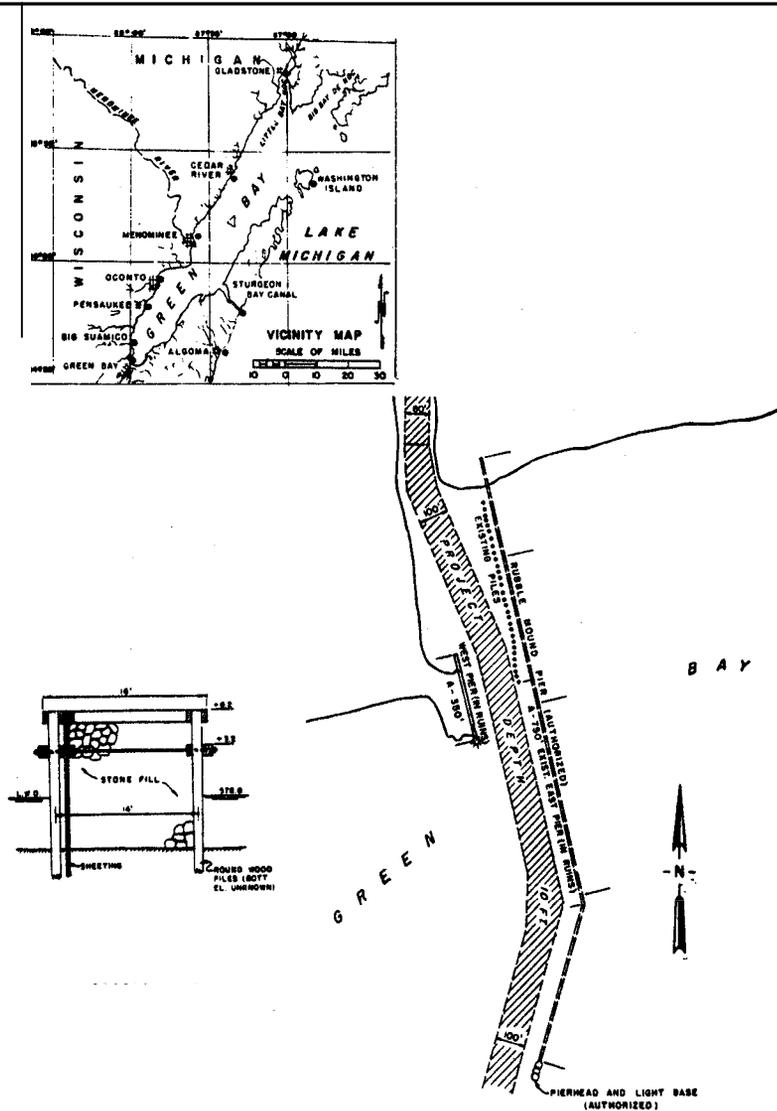


Figure 62. Cedar River Harbor, Michigan

Table 24
Menominee Harbor Piers
Menominee, Michigan

Date(s)	Construction and Rehabilitation History
1871- 1874	Construction of a 566-ft-long north pier (Figure 63, Sections A and B) and a 1,913-ft-long south pier (Figure 63, Sections E, F, A, and B) were completed during this time. The piers were initially constructed with woodpiling and stone. The pilings were installed 13 ft apart on the shoreward ends of the piers (Figure 64, Sections E, F, and A) and 17 ft apart on the lakeward ends of the structures (Figure 63, Section B).
1877- 1879	Extensions of the north and south piers by 596 ft and 613 ft, respectively, were completed (Figure 63, Section C). The extensions consisted of stone-filled timber crib structures (Figure 64, Section Q).
1883- 1884	Construction of the heads of the north and south piers was completed (Figure 63, Section D). The lakeward end of the north pier was 62 ft long and was of stone-filled timber crib construction, while the lakeward end of the south pier was 162 ft long and was of rubble-mound construction (Figure 64, Section D).
1912	The shoreward 566-ft portion of the north pier was reconstructed, (Figure 63, Sections A and B). Steel sheetpiling was installed that resulted in pier widths ranging from 21 to 27 ft. The structures were stone filled and capped with a concrete superstructure at an el of +7.0 ft lwd (Figure 64, Sections A and B). Riprap toe protection also was installed.
1915	A 508-ft-long portion of the south pier (Figure 63, Sections A and B) and a 596-ft-long portion of the north pier (Figure 63, Section C) was reconstructed in a manner similar to that in 1912. Steel sheetpiling was installed, filled with stone, and capped with a concrete superstructure to an el of +7.0 ft lwd (Figure 64, Sections A, B, and C). A 412-ft portion of the south pier had a 20-ft width (Section A) and the remaining 96-ft portion a width of 25 ft (Section B). The north pier portion (596 ft long) had a width of 27 ft (Section C). Riprap toe protection also was placed on each side of both piers.
1922	The 162-ft-long lakeward end of the south pier was modified (Figure 63, Section D). A rock-filled concrete superstructure was built on the existing rubble-mound pier. The superstructure had a crest el of +7.1 ft lwd with an 8-ft width (Figure 64, Section Q).
1927	A 613-ft-long portion of the south pier (Figure 63, Section C) and the 62-ft-long lakeward end of the north pier (Figure 63, Section D) were reconstructed. Steel sheetpiling was placed a width of 30.3 ft apart on the south pier (Figure 64, Section C). The voids were filled with stone, and a concrete superstructure with a crest el of +7.0 ft was installed. Riprap toe protection was also installed. Steel sheetpiling was installed on each side of the north pier which

(Continued)

Table 24 (Concluded)

Date(s)	Construction and Rehabilitation History
	was stone filled and capped. The outer end of the north pier, however, was constructed with a 47.75-ft-diameter cellular sheet-pile structure (Figure 64, Section D). The cell was filled with stone and gravel and capped with a concrete superstructure at an el of +8 ft lwd.
1944	An 880-ft-long portion of the south pier (Figure 63, Section F) was reconstructed similar to other sections of the pier. Steel sheet piles were installed forming a pier width of 22 ft. The voids were stone filled, and the structure was capped with a concrete superstructure installed with a crest el of +7.0 ft lwd (Figure 64, Section F).
1946	The shoreward 525-ft length of the south pier was modified (Figures 63 and 64, Section E). A rubble-mound superstructure was constructed on the existing structure. The crest width of the new superstructure was 4 ft, and it had an el of +4.5 ft lwd.
1954	The cellular sheet pile at the lakeward end of the north pier was repaired (Figure 63, Section D).
1955	A 613-ft-long section of the south pier was repaired (Figure 63, Section C).
1963	Repairs were made to a 508-ft-long section of the south pier (Figure 63, Sections A and B) and a 1,164-ft-long portion of the north pier (Figure 63, Sections A, B, and C).
1965	An 880-ft-long portion of the south pier was repaired (Figure 63, Section F).
1974	The cellular sheet-pile north pierhead was again repaired (Figure 63, Section D).
1977	The lakeward end of the south pier (Figure 63, Section D) experienced some settlement and was observed slightly leaning toward the channel. Additional riprap placement was completed in the area.
1982	A site inspection of the structures indicated that the north pier was in very good condition and that the south pier was generally in good condition. The settlement of the lakeward end of the south structure (Figure 63, Section D) appeared to have stabilized since placement of the riprap in 1977. The concrete superstructure of the portion of the pier needed maintenance however.
1986	The piers have experienced reconstruction, repairs, and maintenance during their lifetime, and they presently are considered in good condition.

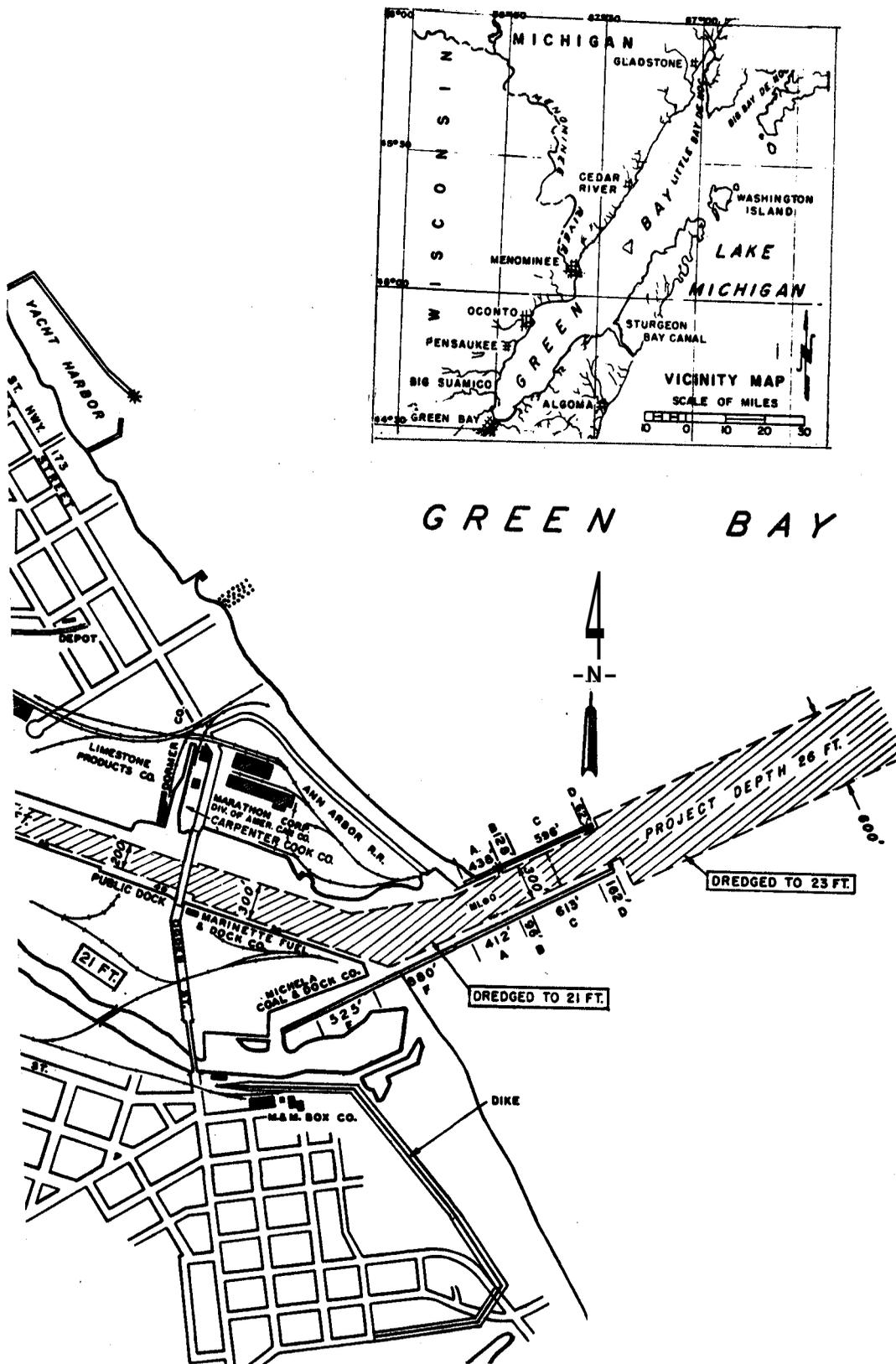


Figure 63. Menominee Harbor, Michigan

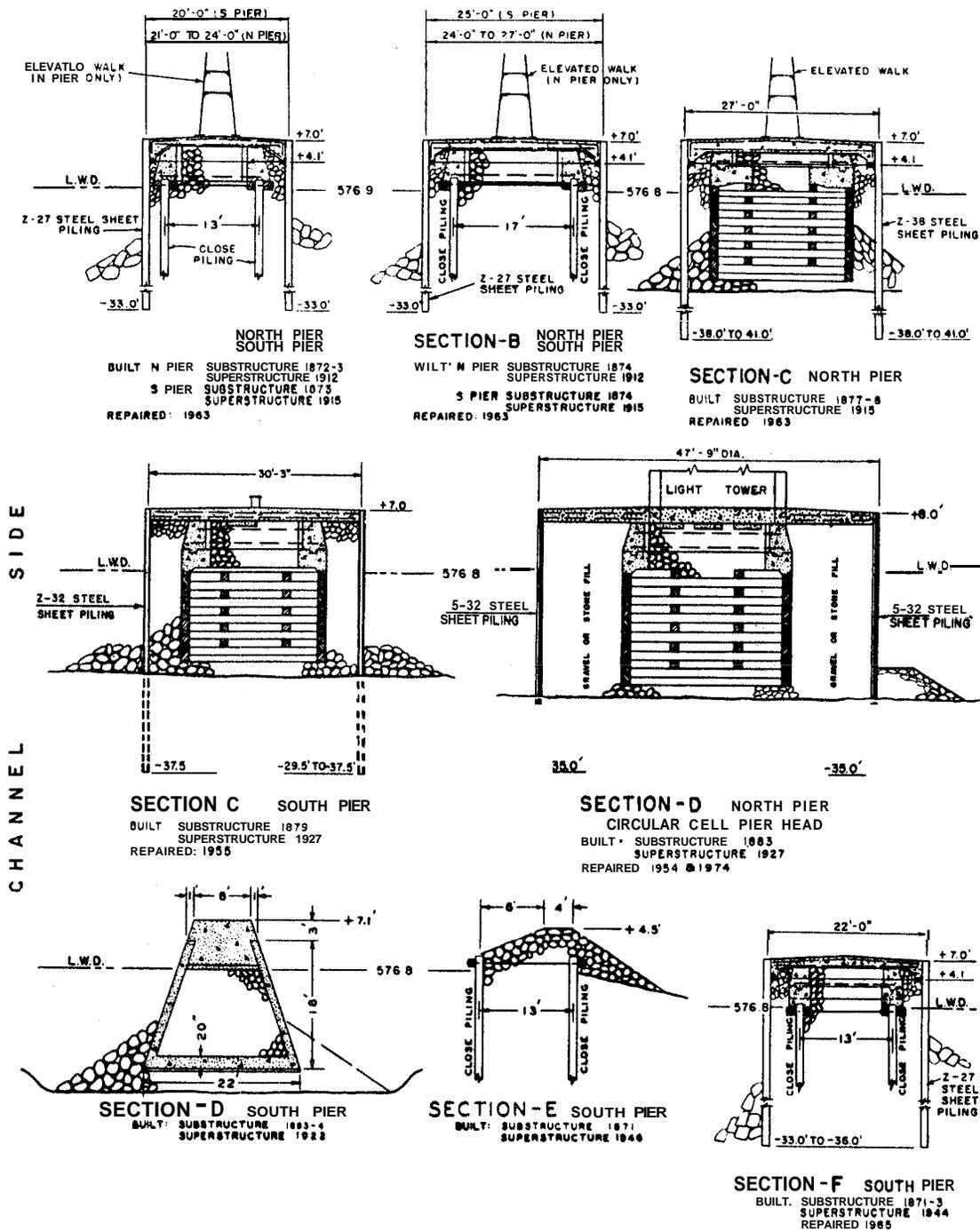


Figure 64. Typical pier cross sections, Menominee Harbor, Michigan

Table 25
Oconto Harbor Pier
Oconto, Wisconsin

Date(s)	Construction and Rehabilitation History
1883	A 2,077-ft-long south pier was completed as a Federal project (Figure 65, Sections B-E). The structure consisted of woodpilings filled with sand and gravel (Figure 66, Sections B-E). A rubble-mound north pier was built by local interests.
1957	Construction of the 67-ft-long lakeward end of the south pier was completed (Figure 65, Section A). The extension consisted of 30.5-ft diameter cellular steel sheet-pile structures. The cells were filled with gravel and stone and had crest els of +8.5 lwd. The lakeward cell was capped with concrete, and the adjacent cell was capped with 3- to 5-ton capstone (Figure 66, Section A).
1974- 1975	The original 2,077-ft-long pier was reconstructed. Ruins of the existing structure were capped with stone. The 227-ft-long lakeward portion of the original structure (Figure 65, Section B) consisted of a rubble-mound structure with a crest el of +10 ft lwd and a width of 9 ft. Side slopes were installed at 1V:1.5H (Figure 66, Section B). The remaining portion of the existing breakwater (Figure 65, Sections C-E) consisted of a rubble-mound structure with a crest el of +8 ft lwd and a width of 7 ft. Stone ranging from 400 to 1,000 lb was used as armor, and side slopes of 1V:1.5H (Figure 66, Sections C-E) were constructed.
1986	The structure is considered to presently be in good condition.

Table 26

Sturgeon Bay Breakwaters
Sturgeon Bay Canal, Wisconsin

Date(s)	Construction and Rehabilitation History
1873-1880	Construction of arrowhead breakwaters was completed at the entrance canal to Sturgeon Bay (Figure 67) during this time. The breakwaters were each constructed 1,344 ft long. The shorewardmost portions of each structure (Figure 68, Sections A and B) were constructed of woodpilings, and the remaining portions of the breakwaters were of stone-filled timber crib construction. Riprap breakwater toe protection was also provided. The shoreward 762-ft lengths of each breakwater (Figure 68, Section A) were constructed to a width of 15 ft. From that point lakeward, the next 32-ft lengths of each structure (Section B) were 20 ft in width; the next 100-ft lengths (Section C) were 18 ft in width; the next 300-ft lengths of each structure (Section D) were 24 ft in width; and the lakeward ends (Sections E and F, 50 ft long each) were 30 ft in width.
1927	The south breakwater was capped with a concrete superstructure (Figure 68). The crest el of the structure was +7.1 ft lwd.
1931	The north breakwater was capped with a concrete superstructure (Figure 68). The lakeward 50 ft of the structure (Section F) was installed at an el of +8.1 ft lwd, and the remaining portion of the breakwater (Sections A-D) had a +7.1-ft lwd crest el.
1983	During a site inspection of the structures no major problems were noted.
1986	The breakwaters have undergone only routine maintenance since construction and are presently considered in good condition.

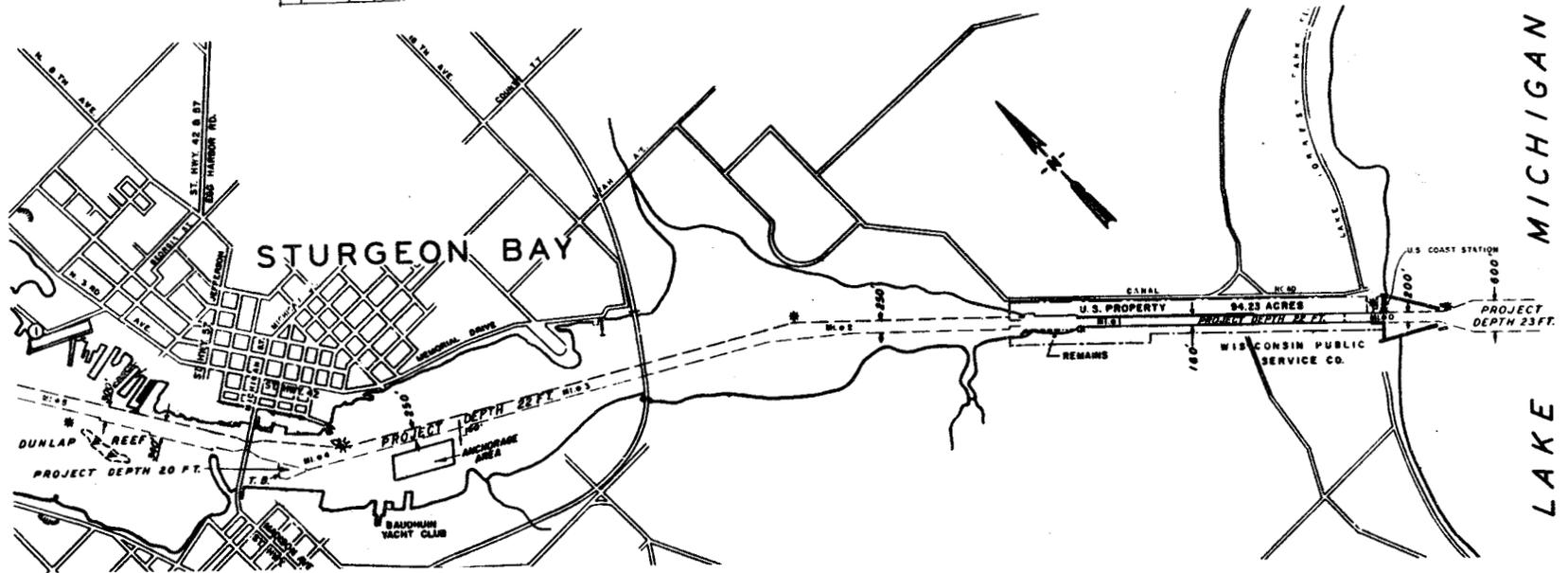
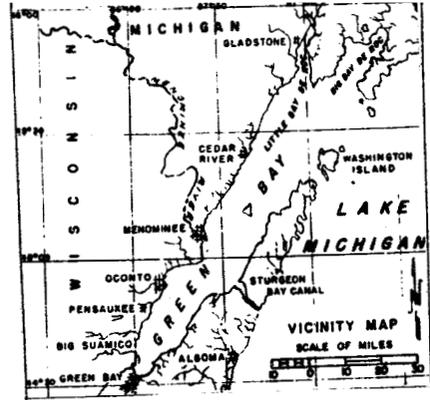


Figure 67. Sturgeon Bay, Wisconsin

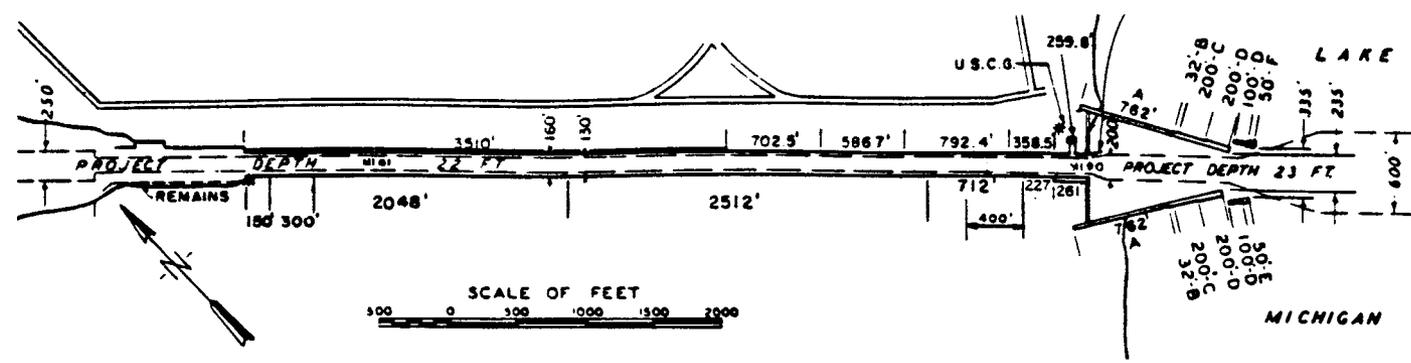
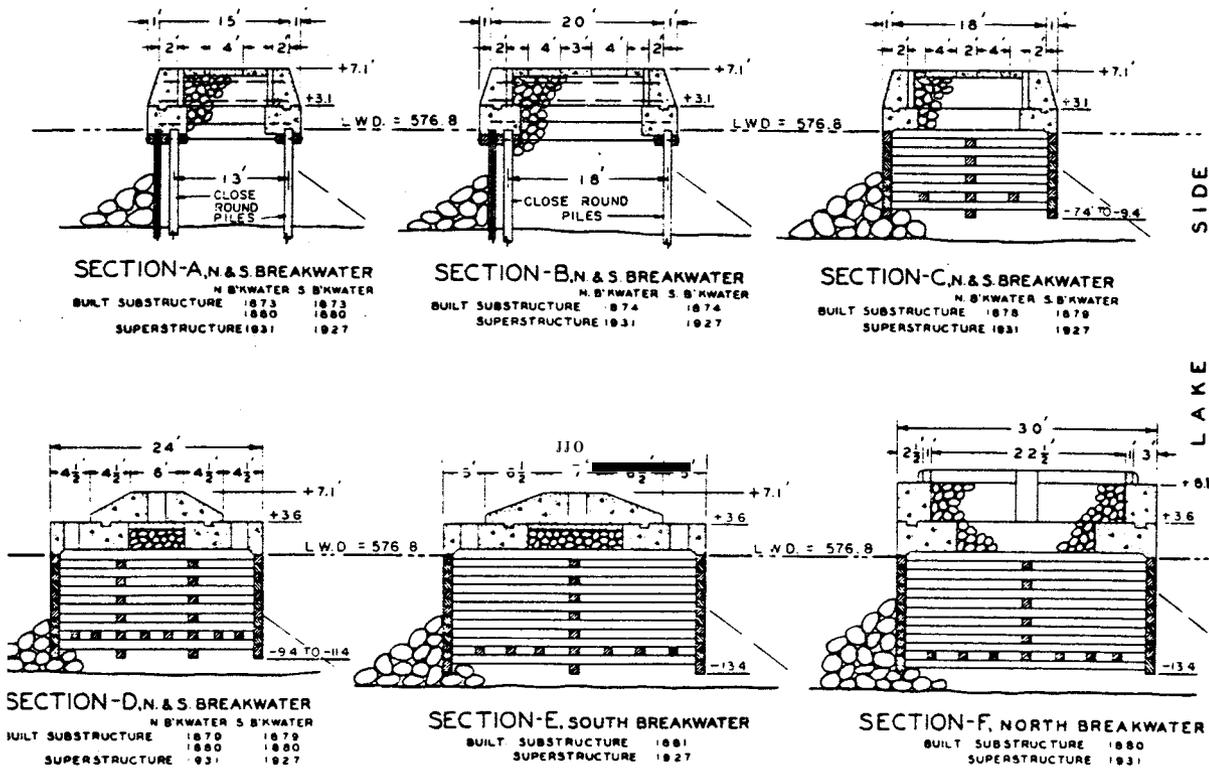


Figure 68. Typical breakwater cross sections, Sturgeon Bay, Wisconsin

Table 27

Algoma Harbor StructuresAlgoma, Wisconsin

Date(s)	Construction and Rehabilitation History
1871	Construction of a 352-ft-long north pier was completed (Figure 69, Sections A and B). The structures were built of woodpilings with stone fill. The shoreward 308-ft length of the pier was 17 ft in width, and the lakeward 44 ft was 23 ft in width (Figure 70, Sections A and B).
1875- 1889	A 450-ft-long extension of the north pier, a 300-ft-long detached north breakwater, and a 101-ft-long south breakwater were constructed during this time (Figure 69, Section C). The structures were built of stone-filled wooden cribs and were 20 ft in width (Figure 70, Section C).
1908	Construction of the 1,429-ft-long shoreward portion of the south breakwater was completed (Figure 69, Sections D-F). The shoreward 200-ft length of the breakwater was a stone-filled timber crib structure (Figure 70, Section F), and the remaining portion of the breakwater was built of woodpilings filled with stone (Figure 70, Sections D and E). The structure ranged from 14 to 17 ft in width (Figure 70, Sections D-F).
1932	The north pier, the detached north breakwater, and the south breakwater, with the exception of the shoreward 200 ft in length, were capped with a concrete superstructure (Figures 69 and 70, Sections A-E). The crest el of the structures was +7.1 ft lwd.
1935	The shoreward 200-ft length of the south breakwater (Figures 69 and 70, Section F) was capped with a concrete superstructure with a +7.1 ft lwd parapet crest el.
1986	The structures have undergone maintenance, but no major repairs, and are presently in good condition.



Figure 69. Algoma Harbor, Wisconsin

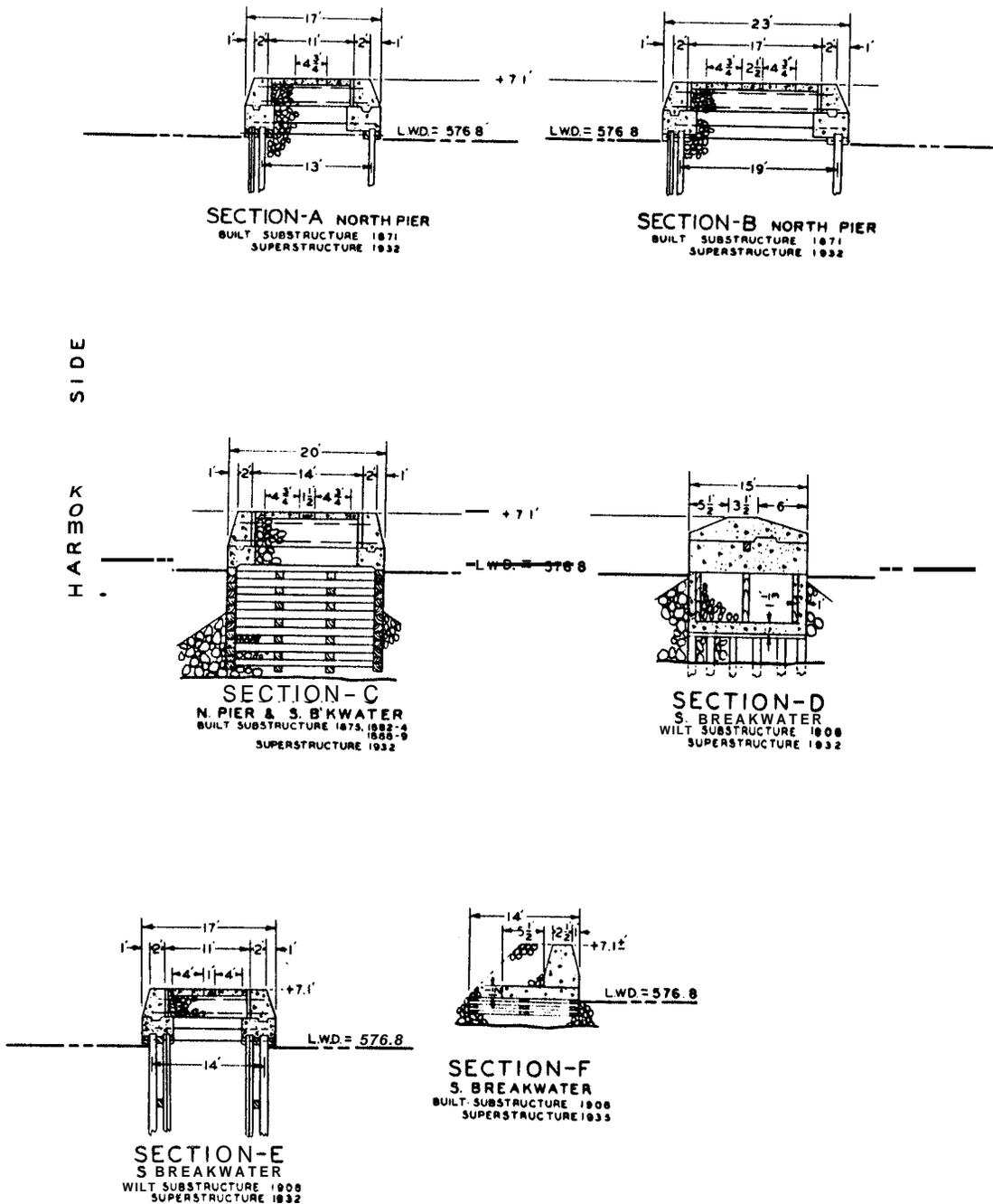


Figure 70. Typical structure cross sections, Algoma Harbor, Wisconsin

Table 28
Kewaunee Harbor Structures
Kewaunee, Wisconsin

Date(s)	Construction and Rehabilitation History
1881- 1883	Construction of a 626-ft-long north pier (Figure 71, Section A) and the shoreward 70-ft-long portion of the south pier (Figure 71, Section C) was completed during this time. These piers were built with woodpilings installed to form a structure 14 ft wide (Figure 72, Sections A and C).
1885- 1891	A 289-ft-long portion of the south pier (Figure 71, Section B) with wood piles (Figure 72, Section B) formed a structure 14 ft wide.
1893- 1897	Construction of a 1,070-ft-long portion of the south pier (Figure 71, Sections D and D1) was completed during this period. The piers were built 18 ft in width with woodpiling that was stone filled (Figure 72, Sections D and D1),
1910- 1912	A 1,359-ft-long portion of the south pier (Figure 71, Sections B, D, and D1) was capped with a concrete superstructure.
1928	The 626-ft-long north pier was capped with a stone and concrete superstructure (Figure 72, Section A). The crest el of the pier was +7.1 ft lwd, and the width was 17.25 ft.
1933	The 70-ft-long shoreward end of the south pier had a superstructure installed which consisted of concrete on the channel side backfilled with rock (Figure 72, Section C). The crest el was +7.1 ft lwd.
1936- 1937	A 2,980-ft-long north breakwater (Figure 71, Sections F, G, and H) was constructed during this period. The shoreward 2,440 ft of the structure consisted of rubble-mound construction (Figures 71 and 72, Section H). The breakwater was constructed at a +7.0 ft lwd crest el with a width of 10 ft and side slopes of 1V:1.5H. The outer 540 ft of breakwater (Figure 71, Sections F and G) was constructed on woodpilings installed to form a width of 20 to 22 ft. A stone-filled concrete superstructure was included which was 7.3 ft wide at the crest with a +7.0 ft lwd crest el (Figure 72, Sections F and G). The outer 54-ft length of the breakwater consisted of two rectangular caissons. Stone was installed on each side of the structure to an el of -4 ft lwd.
1949	A 210-ft-long inner portion of the south pier (Figure 71, Section M) was completed. This structure consisted of steel sheetpiling (el +7.0 ft lwd) installed parallel to the shoreline and backfilled with earth (Figure 72, Section M).

(Continued)

Table 28 (Concluded)

Date(s)	Construction and Rehabilitation History
1954- 1958	Reconstruction of 45 ft of the lakeward end of the south pier (Figure 71, Section D1) occurred during this period. Steel sheetpiling was installed on each side of the existing structure forming a pier width of 26.5 ft (Figure 72, Section D1). The voids were filled with gravel and stone, and a concrete superstructure was installed at an el of +8.0 ft lwd. Riprap toe protection was installed on each side of the structure.
1956	A 211-ft-long inner portion of the south pier (Figure 71, Section E) was constructed. The pier section consisted of steel sheetpiling installed adjacent to the shoreline at an el of +7 ft lwd and back-filled with earth (Figure 72, Section E). Riprap was placed along the toe of the structure.
1966	A 969-ft-long portion of the south pier was reconstructed (Figure 71, Sections B and D), Steel sheetpiling was installed on each side of the existing pier a distance of 26.75 ft apart. The void between the sheet pile was filled with stone, and a concrete superstructure was installed (Figure 72, Sections B and D) at an el of +7.67 ft lwd.
1983	A site inspection revealed that the structures were generally in good condition. Minor concrete repairs and the placement of additional riprap were recommended for the north breakwater. The work has subsequently been completed. It was noted also that settlement of the north pier on the channel side had occurred.
1986	During their lifetime the structures have undergone reconstruction and normal maintenance repairs. Presently they are considered in good condition.

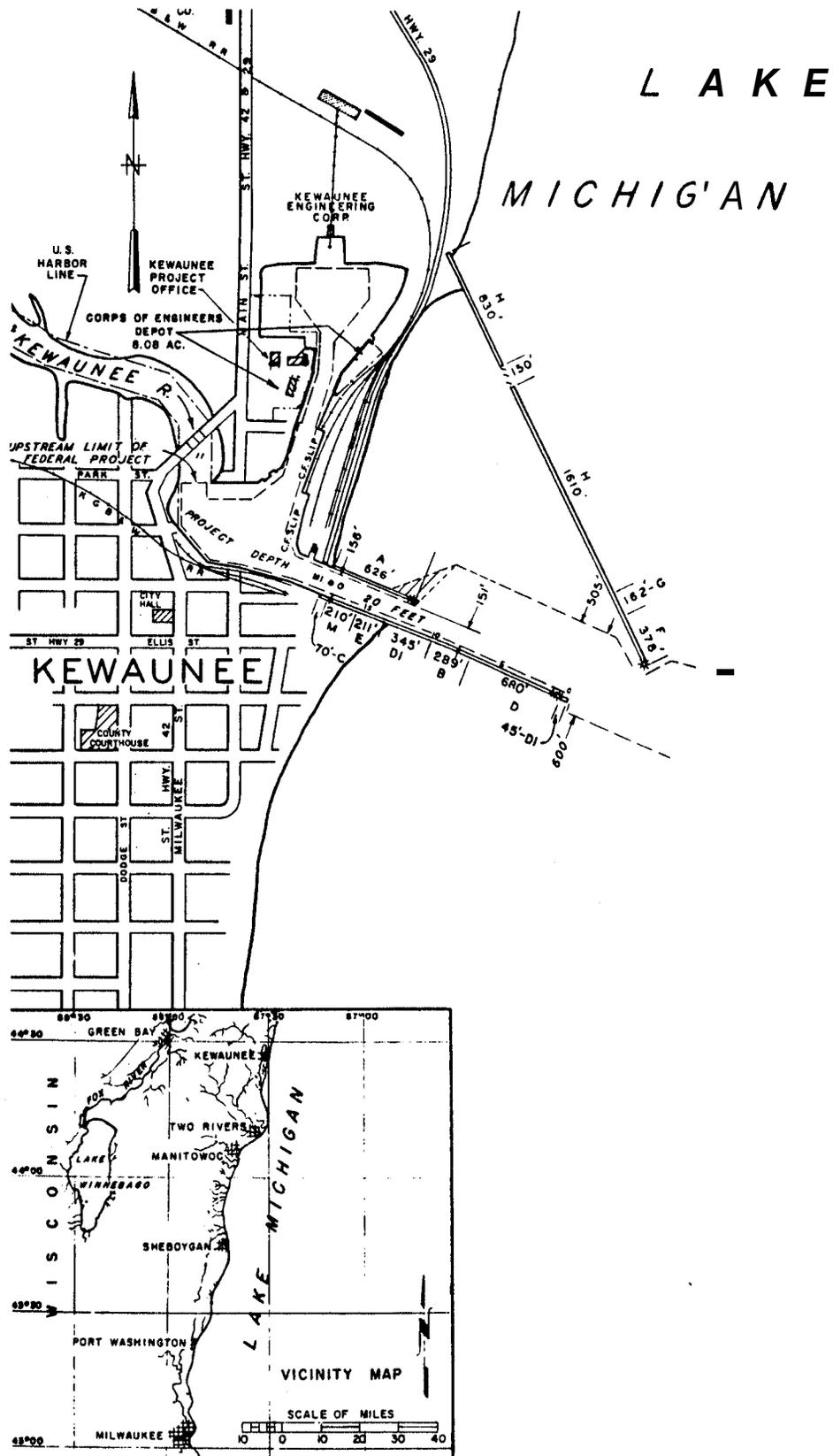


Figure 71. Kewaunee Harbor, Wisconsin

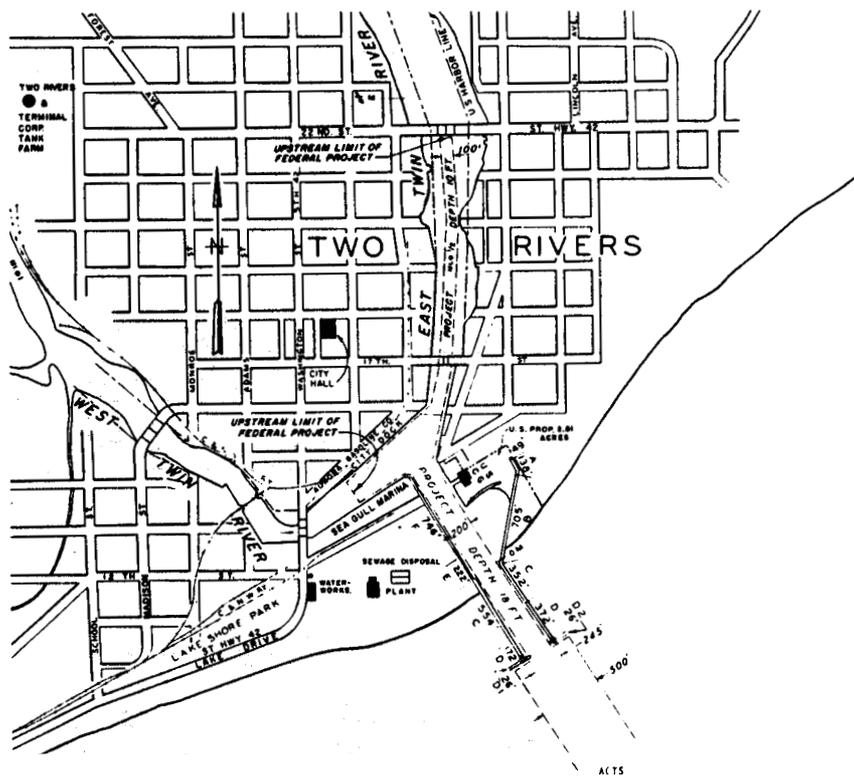
Table 29
Two Rivers Harbor Piers
Two Rivers, Wisconsin

Date(s)	Construction and Rehabilitation History
1872- 1874	The shoreward 968-ft-portion of the south pier (Figure 73, Sections E and F) was constructed during this period. These were woodpiling structures (Figure 74, Sections E and F) that were stone filled.
1875- 1874	Construction of the lakeward 752 ft of the south pier and 750 ft of the north pier (Figure 73, Sections C, D, D1, and D2) were completed during this time. The structures were of stone-filled timber crib construction (Figure 74, Sections C, D, D1, and D2) and were 18 ft in width.
1875- 1883	Construction of the lakeward 752 ft of the south pier and 750 ft of the north pier (Figure 73, Sections C, D, D1, and D2) were completed during this time. The structures were of stone-filled timber crib construction (Figure 74, Sections C, D, D1, and D2) and were 18 ft in width.
1907- 1908	The shoreward 843-ft portion of the north pier (Figure 73, Sections A and B) was constructed of woodpiling (Figure 74, Sections A and B) that was stone filled. The width of the pier was 14 ft.
1929- 1931	The shoreward 843-ft portion of the north pier (Figure 73, Sections A and B) was capped with a stone and concrete superstructure (Figure 74, Sections A and B). The width of the pier was 15 ft, and the crest el was +7.3 ft lwd. The lakeward 398-ft length of the north pier and 198-ft length of the south pier were also capped with a concrete superstructure (Figures 73 and 74, Sections D, D1, and D2). The trunk portion of the structures (Section D) had a crest el of +7.3 ft lwd. Steel sheetpiling was installed around both head sections (Sections D1 and D2). The north pier head (Section D2) was 23 ft in width with a crest el of +8.25 ft lwd, and the south pier head (Section D1) was 21 ft in width with a crest el of +7.0 ft lwd. Riprap stone was placed around the pierheads for toe protection.
1937- 1941	Superstructures were constructed for the shoreward 968-ft portion of the south pier. these consisted of concrete poured to an el of +7.0 ft on the channel side and backfilled with stone (Figure 74, Sections E and F). Two trunk sections, one 352 ft long and the other 554 ft long, of the north and south piers, respectively, (Figures 73 and 74, Section C) were capped with a stone and concrete superstructure. The crest el of these structures was +7.3 ft lwd.
1951	The south pierhead (Figure 73, Section D1) was repaired.
1953	The north pierhead (Figure 73, Section D2) was repaired.

(Continued)

Table 29 (Concluded)

Date(s)	Construction and Rehabilitation History
1984	A site inspection revealed the north pier to be in very good condition and the south pier to be in fair to poor condition. The south pier had sheeting boards that were deteriorated and loose in some areas and not effectively retaining fill material,
1986	The overall condition of the structures is presently considered fair.



LAKE MICHIGAN

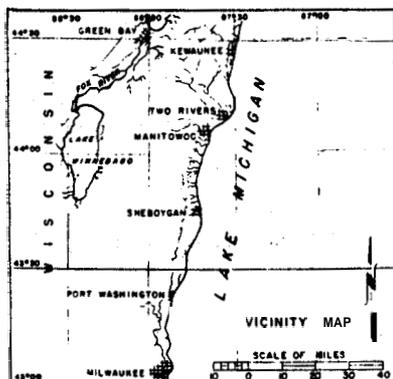


Figure 73. Two Rivers Harbor, Wisconsin

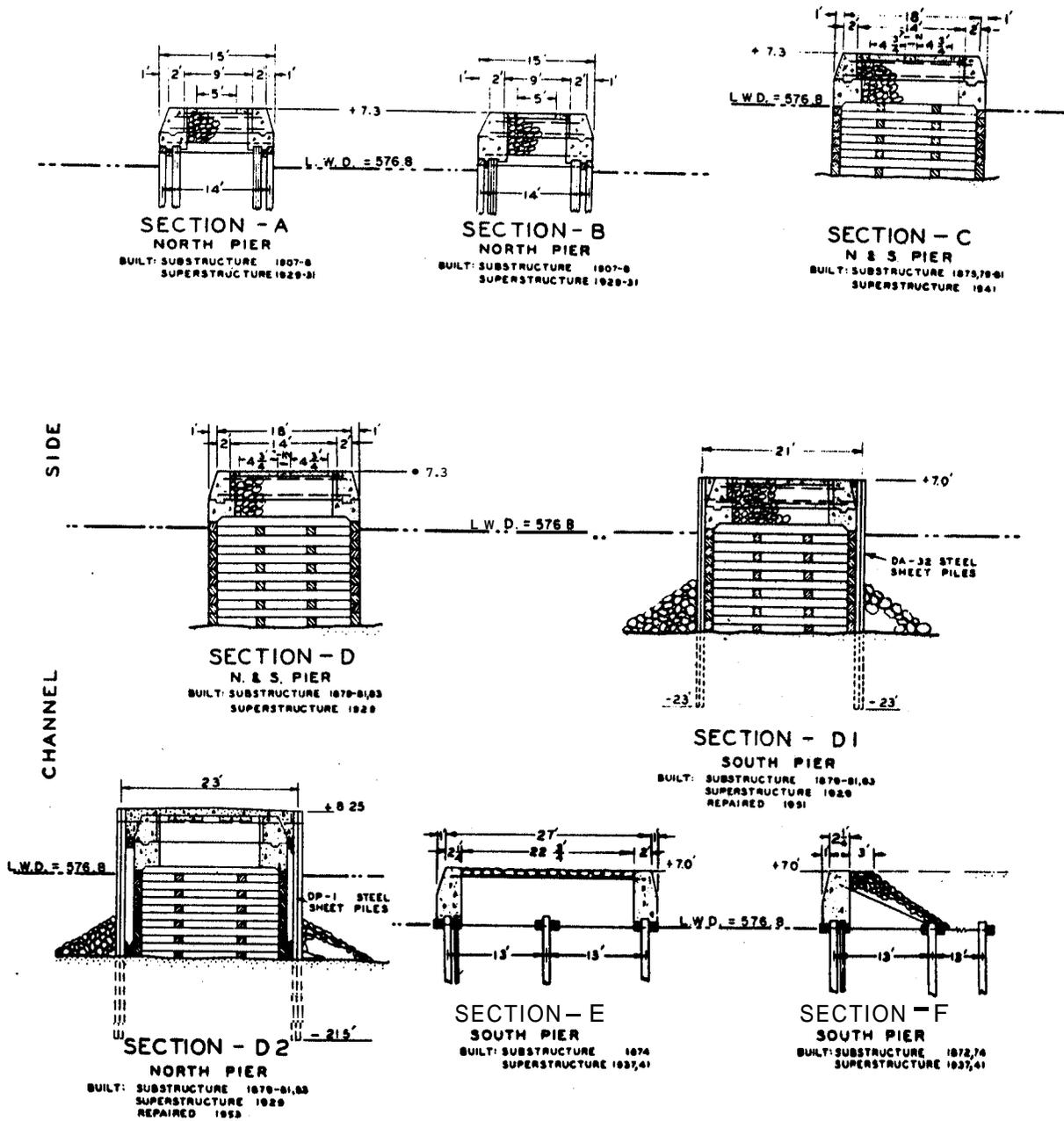


Figure 74. Typical pier cross sections, Two Rivers Harbor, Wisconsin

Table 30

Manitowoc Harbor BreakwatersManitowoc, Wisconsin

Date(s)	Construction and Rehabilitation History
1895	Construction of the lakeward 800-ft portion of the north breakwater (Figure 75, Sections C and D) was completed. The breakwater consisted of stone-filled timber crib construction (Figure 76, Sections C and D). Riprap toe protection was included around the base of the structure.
1907- 1910	The shoreward 1,740-ft portion of the north breakwater and the entire 2,290-ft south breakwater were constructed during this time (Figure 75, Sections A, B, E, F, and F1). The shoreward 1,450- and 1,200-ft lengths of the north and south breakwaters, respectively, (Figures 75 and 76, Sections A and E) were constructed of wood piles and were 14 ft in width. The adjacent 290-ft lengths of breakwater extending lakeward on each structure (Figures 75 and 76, Section B) were constructed of stone and concrete and were also 14 ft in width. The remaining 800 ft of the south breakwater was built of timber cribs filled with stone (Figures 75 and 76, Sections F and F1). They were 24 ft in width. Riprap was placed along each side of the structures for toe protection.
1918	The 100-ft-long north breakwater head (Figures 75 and 76, Section D) was capped with a concrete superstructure. The elevation of the breakwater was +7.1 ft lwd.
1924	The shoreward 1,450-ft-long portion of the north breakwater (Figures 75 and 76, Section A) was capped with a stone and concrete superstructure. The total width of the cap was 17 ft, and the crest el was +7.1 ft lwd.
1925	The shoreward 1,200-ft-long portion of the south breakwater (Figures 75 and 76, Section E) was capped with a stone and concrete superstructure. The total width of the cap was 15 ft, and the crest el was +7.1 ft lwd.
1926	A 700-ft-long portion of the north breakwater (Figures 75 and 76, Section C), and the lakeward 800 ft of the south breakwater (Figures 75 and 76, Sections F and F1) were capped with stone and concrete superstructures. The structures were 24 ft in width with crest els of +7.1 ft lwd.
1933- 1934	The 290-ft-long trunk portions of the north and south breakwater (Figures 75 and 76, Section B) were capped with concrete superstructures with +7.1 ft lwd crest els.

(Continued)

Table 30 (Concluded)

Date(s)	Construction and Rehabilitation History
1948- 1949	A 74-ft-long stone-filled timber crib north pier was constructed in 1948. (Figure 75, Section G). In 1949 the pier was rebuilt by installing steel sheet piles on each side, filling the voids with gravel, and capping the structure with stone (Figure 76, Section G). The pier was 24 ft in width and had a crest el of +7.0 ft lwd.
1951- 1960	A 148-ft-long portion of the south breakwater (Figures 75 and 76, Section F1) was repaired. Steel sheet piles were installed along each side of the breakwater, and 3-ft-thick precast concrete blocks were placed in the superstructure.
1982	A site inspection made of the structures indicated that the north pier and north breakwater were in good to excellent condition. The shoreward 1,200 ft of the south breakwater was also in good condition; however, the lakeward portions (Sections B, F, and F1) were in need of repair. Settlement of Section B had occurred, and portions of the concrete cap had deteriorated and required patchwork. Sections F and F1 were in fair to poor condition. Stone fill was required under the concrete cap, and in some areas the cap needed replacement.
1983	Repair of the deficiencies noted during the 1982 site inspection was completed.
1986	The structures are presently in good condition.

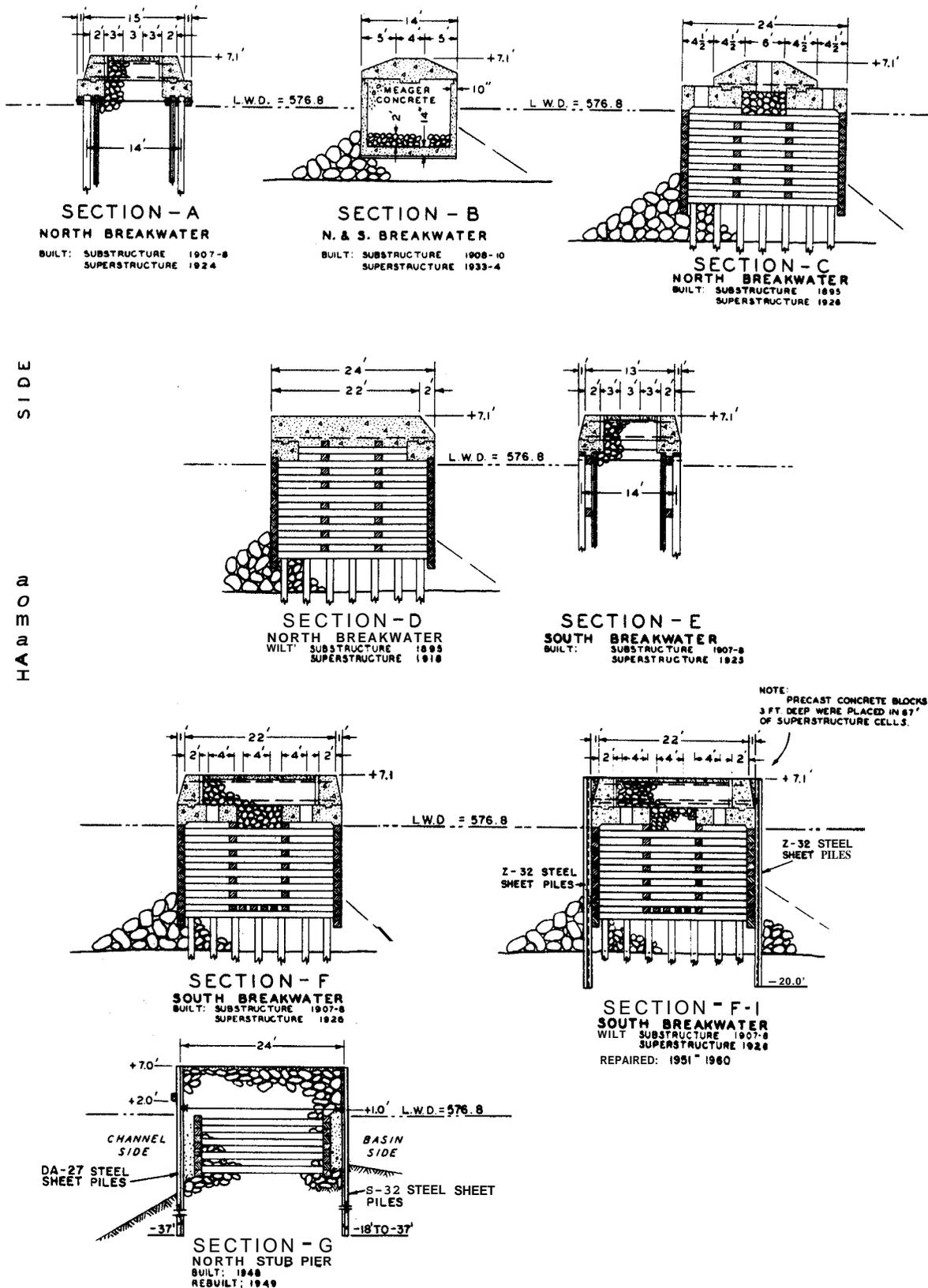


Figure 76. Typical structure cross sections, Manitowoc Harbor, Wisconsin

Table 31
Sheboygan Harbor Structures
Sheboygan, Wisconsin

Date(s)	Construction and Rehabilitation History
1873	Construction of an initial 50-ft-long portion of the south pier was completed (Figures 77 and 78, Section J). This was a stone-filled timber crib structure that was 30 ft wide. Riprap toe protection also was provided.
1881- 1882	The original pier was extended 132 ft lakeward (Figures 77 and 78, Section K). The extension consisted of woodpiling installed to form a pier 19 ft in width. The structure was filled with stone. An additional 100-ft lakeward extension was completed during this time (Section L). This was a 20-ft-wide stone-filled timber crib structure with riprap toe protection.
1885- 1893	Another lakeward extension of the pier was completed. This construction entailed a 650-ft-long stone-filled timber crib structure that was 20 ft wide with riprap installed along its base (Figures 77 and 78, Section M).
1895- 1897	Construction of the shoreward 958-ft portion of the south pier was completed during this period (Figures 77 and 78, Section I). It was a 14-ft-wide structure built with woodpiling and a stone fill. Riprap was placed on the lakeside of the pier,
1900	Construction of the lakeward 600-ft portion of the north breakwater was completed (Figures 77 and 79, Sections G and H). The breakwater was built of stone-filled timber cribs 30 ft in width, which included stone along the base on each side of the structure.
1903 1904	Construction of a 120-ft-long north pier (Figures 77 and 78, Section P) and a 600-ft-long extension of the south pier (Figures 77 and 78, Section N) was completed. The north pier was constructed of woodpiling installed 14 ft apart and was stone filled. The south pier extension was a stone-filled timber crib structure. It was 24 ft wide and included stone toe protection.
1908	A 196-ft-long shoreward extension of the north breakwater was constructed (Figures 77 and 79, Section F). The structure was of stone-filled timber crib construction and was 30 ft in width with stone installed on each side of its base.
1913- 1915	Construction of the shoreward 3,037-ft portion of the north breakwater was completed (Figures 77 and 79, Sections A, B, B1, C, D, and E). The structure was built with wood piles and filled with stone, and the width of the structure varied from 11 to 20 ft. The breakwater was also capped with a concrete superstructure at a crest

(Continued)

Table 31 (Concluded)

3)	Construction and Rehabilitation History
<p>el of +7.1 ft lwd and riprap installed on both sides of the structure. The 100 ft wide lakeward end of the north breakwater Section H) was also capped with a concrete superstructure in 1950.</p>	
1918	The north pier was capped with a concrete superstructure with a crest elevation of +7.3 ft lwd (Figure 78, Section P).
1925- 1926	A concrete and stone superstructure was installed on 1,250 ft of the south pier (Figures 77 and 78, Sections M and N) and 696 ft of the north breakwater (Figures 77 and 79, Sections F and G). The crest elevation of these structures was +7.1 ft lwd.
1933	A stone and concrete superstructure was installed on the shoreward 1,240 ft of the south pier (Figures 77 and 78, Sections J, K, L, and I). The widths of the superstructure ranged from 15 to 20 ft, and the crest elevation was +7.1 ft lwd.
1963	A 1,728-ft-long portion of the north breakwater was repaired (Figure 77, Sections C, D, and E).
1964	The 958-ft-long shoreward end of the south pier was repaired (Figure 77, Section I), and the north pier was rebuilt (Figures 77 and 78, Section P). Steel sheet piles were driven on each side of the existing north pier forming a width of 23 ft. The voids were filled with stone and concrete to an elevation of +7.3 ft lwd. An 843-ft-long portion of the north breakwater also was repaired during this year (Figures 77 and 79, Sections B and B1). Riprap was installed to the elevation of the superstructure (+7.1 ft lwd) on both sides of Section B with 1-V:1.5-H side slopes. Stone was installed over Section B1 to an elevation of +6.75 ft lwd. The crest was 20 ft wide, and the stone was grouted in place. Side slopes were 1V:1.5H.
1980	Toe stone was placed along the outermost section of the south pier (Figure 77, Section N) to stabilize settling of the structure. Concrete repair work was completed on the north pier.
1984	A site inspection of the south pier indicated the channel side of the structure was in good condition. Fill rock was needed, however, in some areas, and the concrete cap was leaning toward the channel in one area.
1986	The structures presently are considered to be in good condition overall.

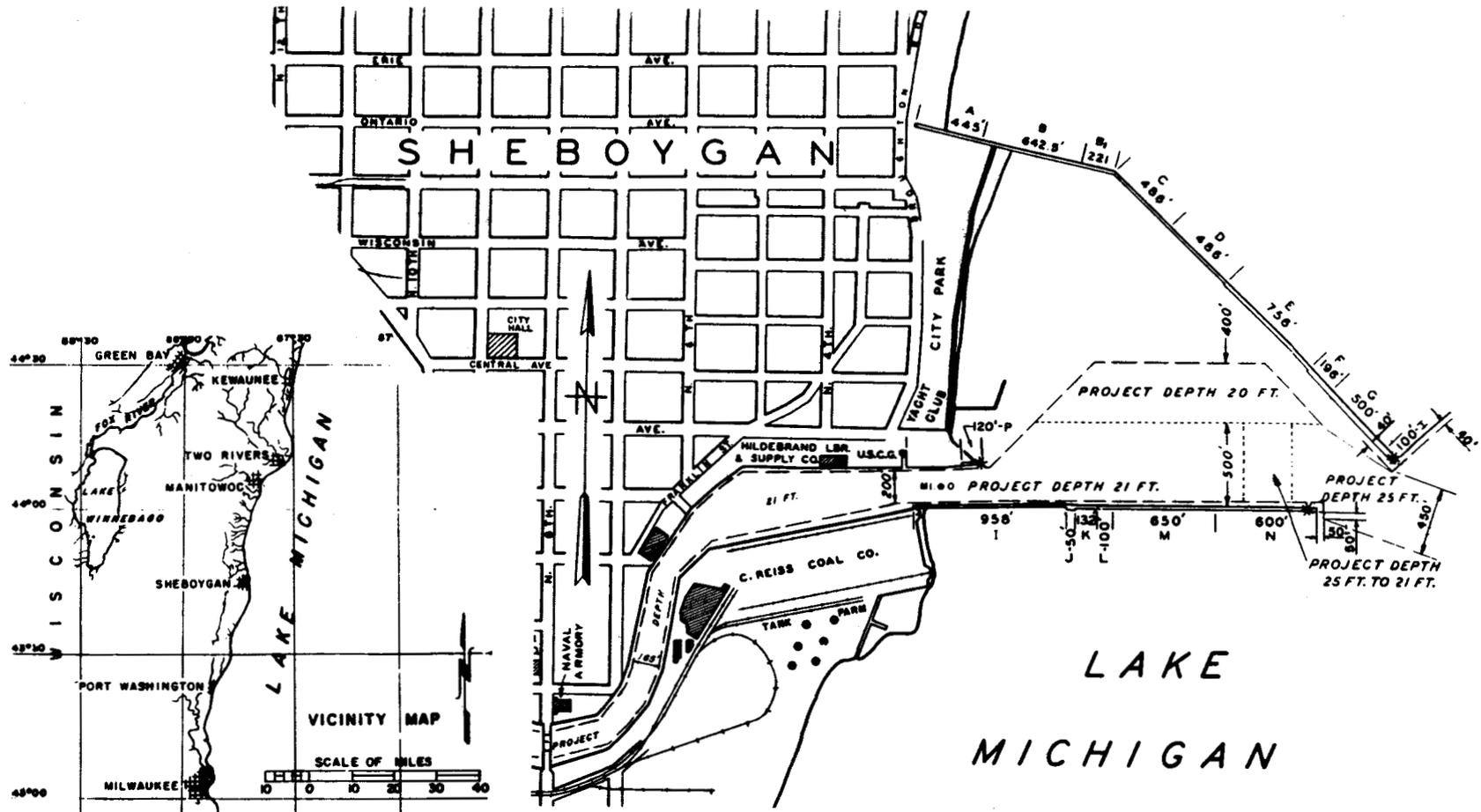


Figure 77. Sheboygan Harbor, Wisconsin

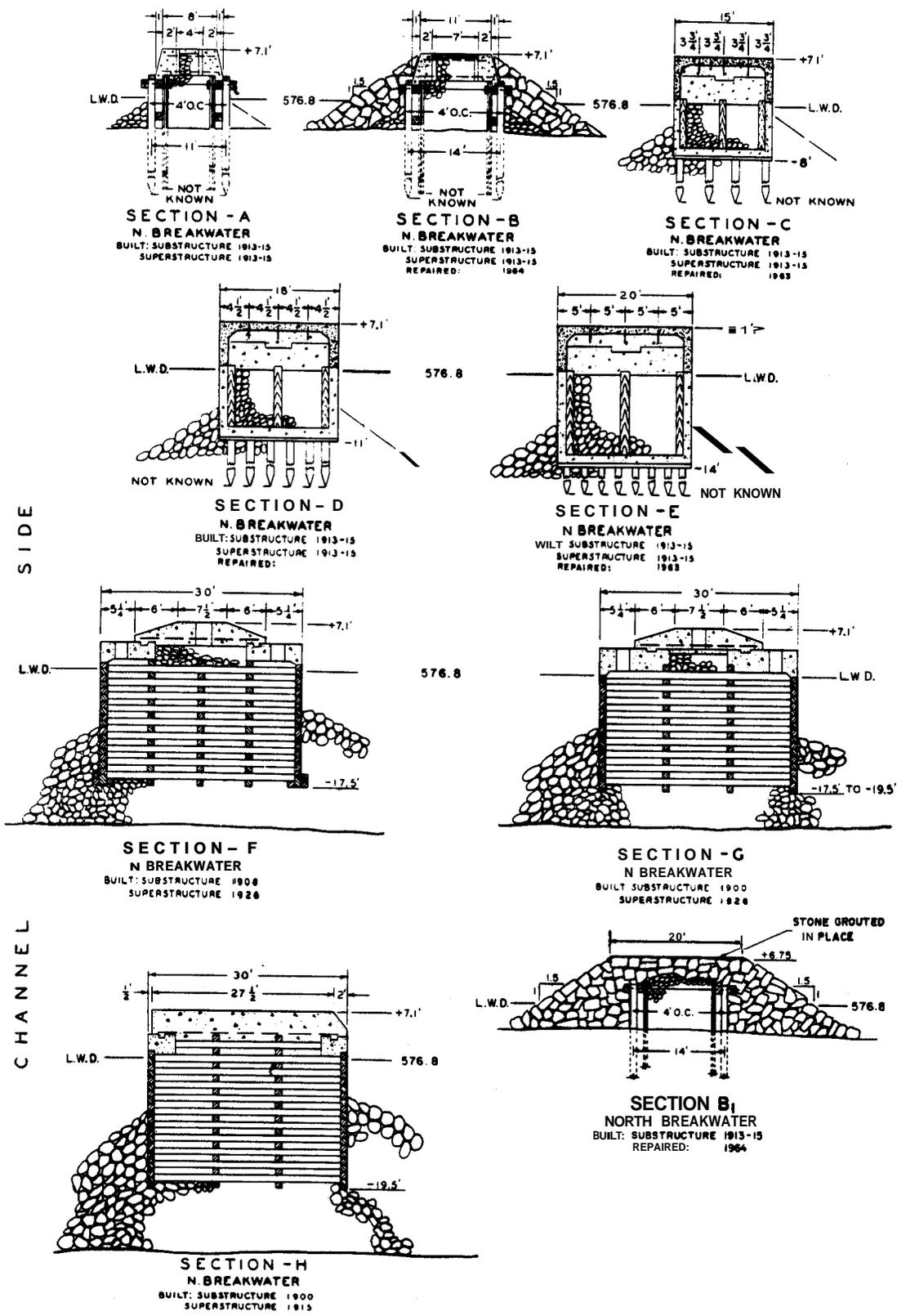


Figure 79. Typical structure cross sections, Sheboygan Harbor, Wisconsin

Table 32
Port Washington Harbor Structures
Port Washington, Wisconsin

Date(s)	Construction and Rehabilitation History
1934	Construction of a 2,537-ft-long north breakwater was completed (Figure 80, Sections A-E). The shoreward portion of the breakwater was composed of single-wall steel sheet piles installed at an el of +7.0 ft lwd with riprap placed on both sides to a 0.0-ft lwd el (Figure 81, Section E). The next lakeward 990-ft-long portion of the north breakwater (Section D) was constructed on stone-filled cellular sheet-pile structures (arch cell type). Capstone was grouted in place at an el of +7.5 ft lwd. The structure ranged from about 14 ft in width to over 22 ft. Riprap was placed along both sides of the structure (Figure 81, Section D). The lakeward portion of the breakwater consisted of a concrete superstructure on a rubble-mound base (Figure 81, Sections A, B, and C). The width of the superstructure was 6.2 ft, and the crest el was +8.0 ft lwd. The rubble-mound portion had side slopes of 1V:1.5H . The outer 54 ft of the north breakwater consisted of two rectangular caissons.
1936	Construction of the 1,006-ft-long south breakwater was completed (Figure 80, Sections A, I, and J). The lakeward 392.5-ft portion of the breakwater consisted of a concrete superstructure on a rubble-mound base similar to the outer end of the north breakwater (Figure 81, Section A). The remaining structure was of rubble-mound construction with a crest el of +8.0 ft lwd and a crest width ranging from 6 to 7 ft. Side slopes were constructed 1V:1.5H (Figure 82, Sections I and J).
1940	Construction of the north pier was completed (Figure 80, Sections F and G). The structure included timber cribs with woodpiling on the channel side with an el of +8.0 ft lwd (Figure 82, Sections F and G). The structure was capped with sand and earth fill (Section F) and stone fill (Section G).
1950	Because storm waves caused damage to harbor facilities and because of difficulties to navigation since breakwater construction, the harbor was modeled (Fortson 1951). Model tests for improving wave conditions involved placement of rubble-wave absorbers at critical locations in slips, placement of rubble on the lakeside of the north and south breakwaters, construction of a small-boat basin for pleasure craft, and extension of the lakeward end of the north breakwater.
1976	Model tests involving the use of Igloo wave absorber units (Bottin 1976) were conducted to determine if wave heights in the inner slip areas of the harbor could be significantly reduced, if the Igloos could be substituted for rubble-mound structures in the proposed small-boat harbor, and if the absorbed units could be used as an alternative to rubble absorbers proposed for the small-boat harbor.

(Continued)

Table 32 (Concluded)

Date(s)	Construction and Rehabilitation History
1980	A site inspection of the structures indicated that they were in good condition but required minor repair in the form of a finishing touch on the grouted cap to improve their appearance. The work was subsequently completely.
1982	Construction of breakwaters and other improvements within the existing harbor was completed (Figure 83). A 725-ft-long west breakwater, a 320-ft-long east breakwater, an absorber, and a parapet wall were installed. The east and west breakwaters were rubble-mound structures with a 12-ft-wide crest width covered with 4.2-ton armor (Figure 84). Side slopes were 1V:1.5H . The crest el of the west breakwater was +8 ft lwd, and steel sheet pile was included to make the structure impervious. The east breakwater had a crest el of +12 ft lwd. An absorber and a parapet wall were installed along the existing north breakwater adjacent to the harbor (Figure 84). The absorber, installed at an el of +4 ft lwd, was comprised of 2-ton cover stone. The crest el of the parapet was +7 ft lwd. The improvements were model tested (Bottin 1977) prior to construction.
1986	The structures presently are in good condition.

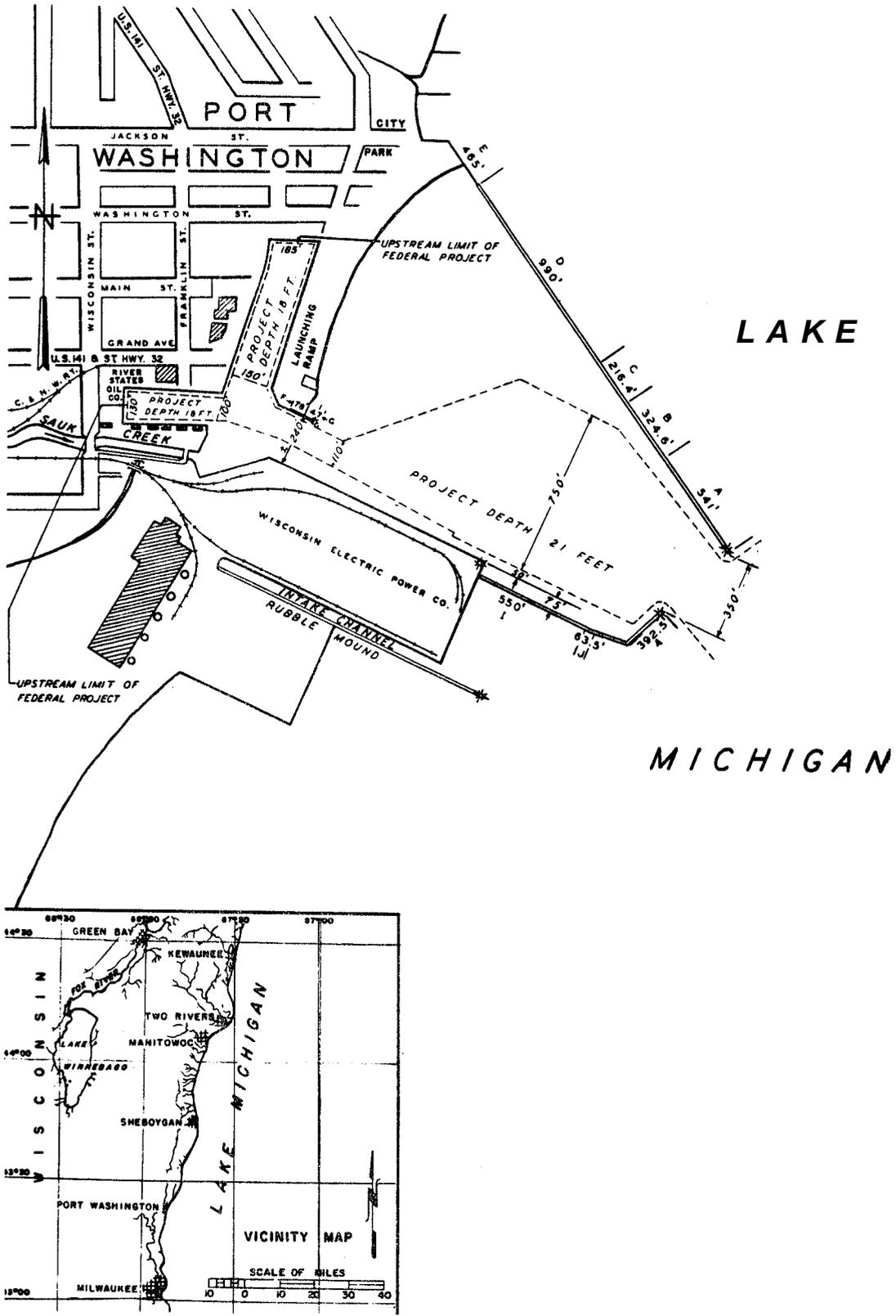
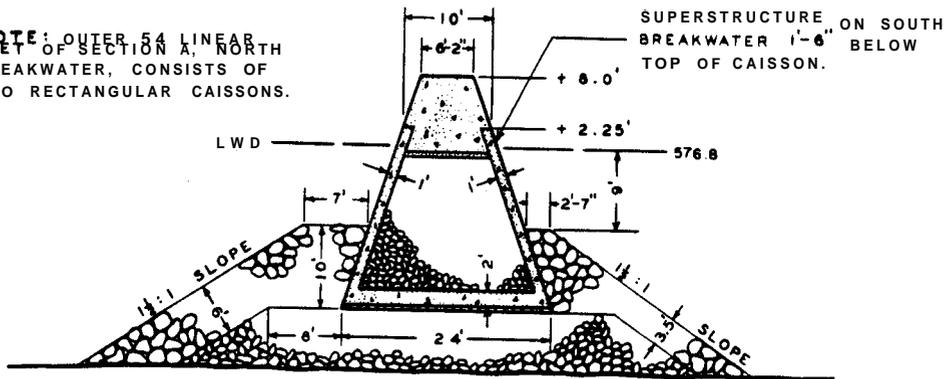


Figure 80. Port Washington Harbor, Wisconsin

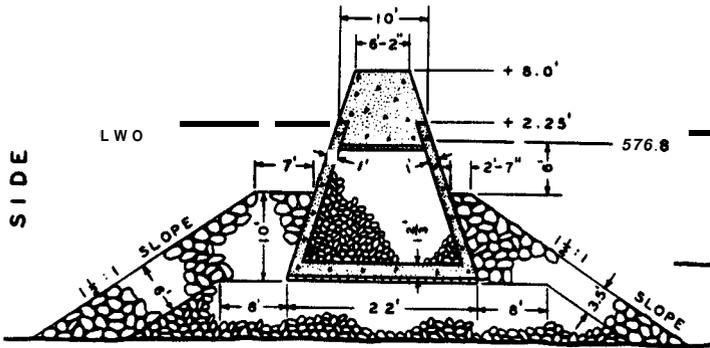
NOTE: OUTER 54 LINEAR FEET OF SECTION A, NORTH BREAKWATER, CONSISTS OF TWO RECTANGULAR CAISSONS.



SECTION-A

NORTH & SOUTH BREAKWATER

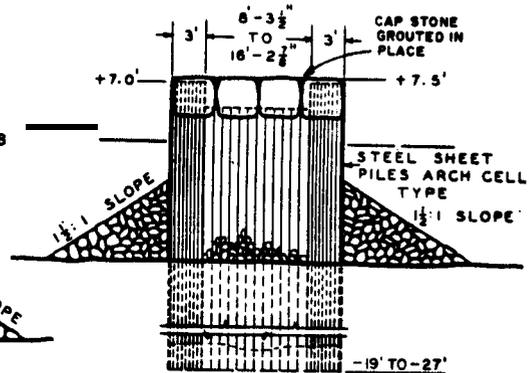
BUILT SUBSTRUCTURE 1934
SUPERSTRUCTURE 1934



SECTION-B

NORTH BREAKWATER

BUILT SUBSTRUCTURE 1934
SUPERSTRUCTURE 1934

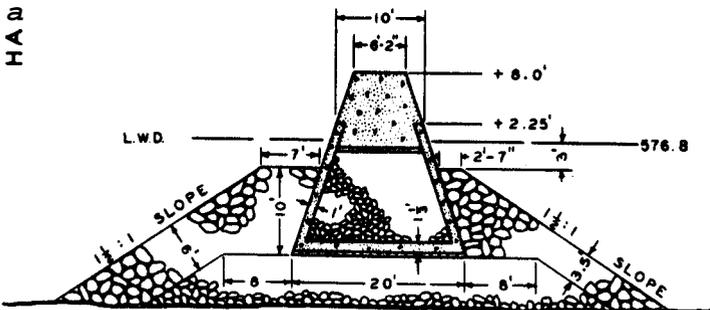


SECTION-D

NORTH BREAKWATER

BUILT: 1934

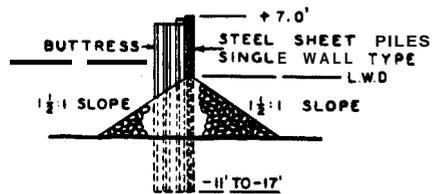
HARBOR



SECTION-C

NORTH BREAKWATER

BUILT SUBSTRUCTURE 1934
SUPERSTRUCTURE 1934



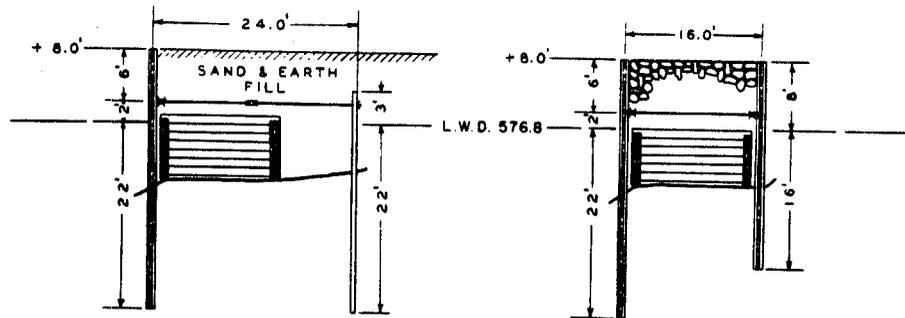
SECTION-E

NORTH SHORE CONNECTION

BUILT 1934

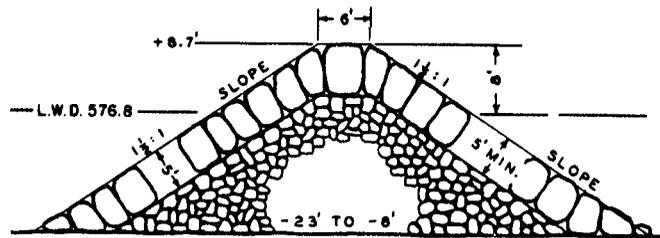
Figure 81. Typical breakwater cross sections, Port Washington Harbor, Wisconsin

CHANNEL OR HARBOR SIDE

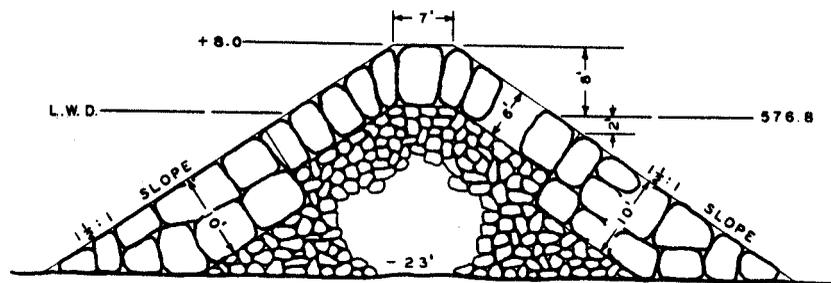


SECTION-F
NORTH STUB PIER
BUILT: 1940

SECTION-G
NORTH STUB PIER
BUILT: 1940



SECTION-I
WISCONSIN ELECTRIC POWER CO.



SECTION-J
SOUTH BREAKWATER
BUILT: 1926

Figure 82. Typical structure cross sections,
Port Washington Harbor, Wisconsin

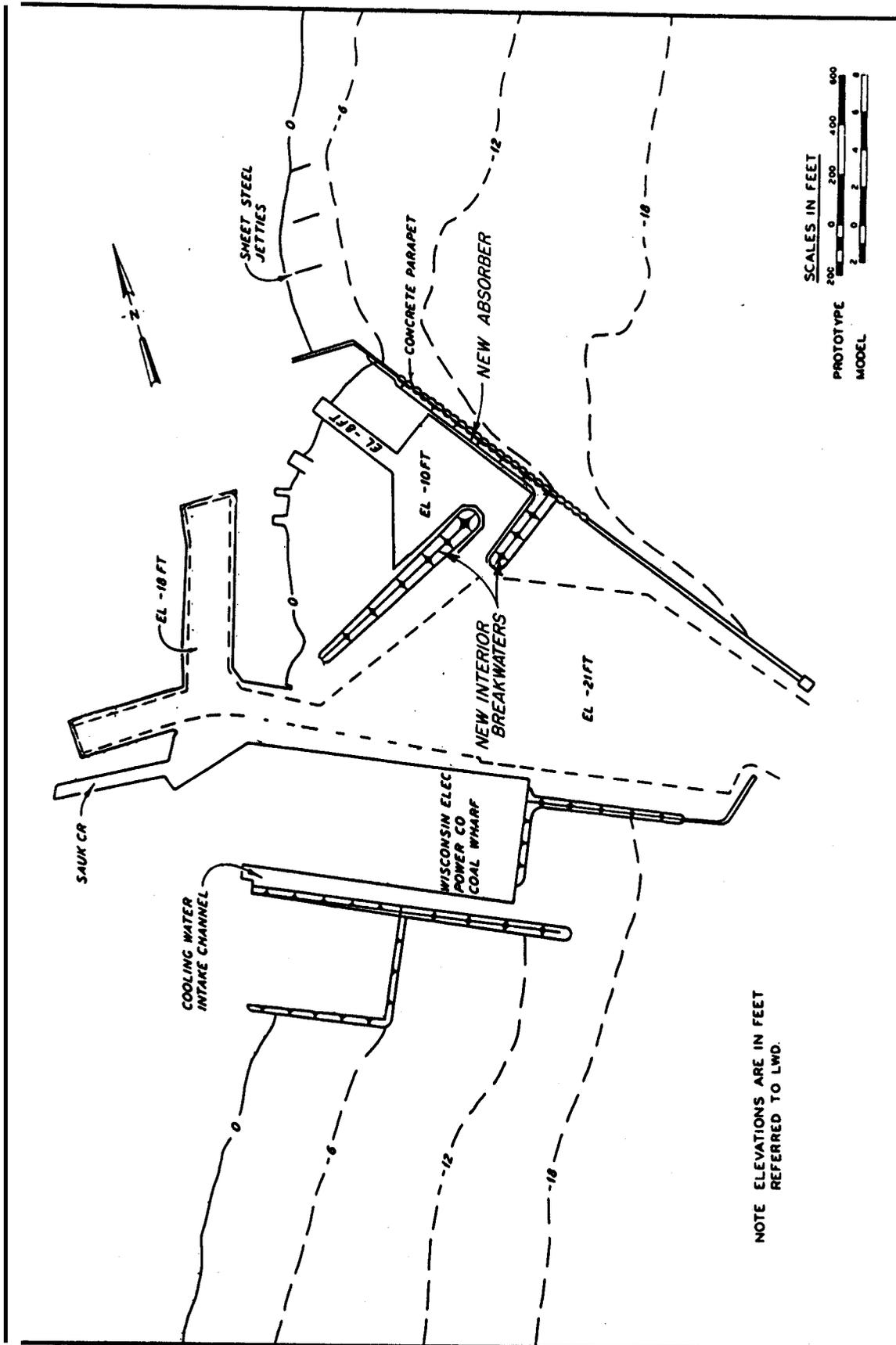
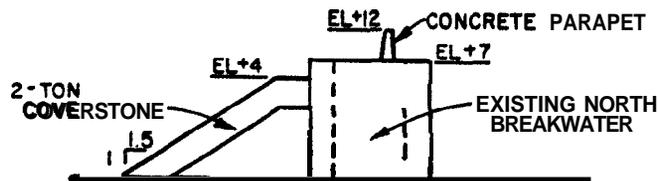
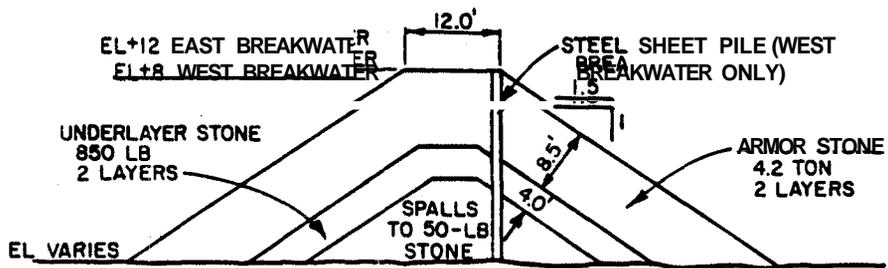
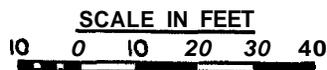


Figure 03. Improvements for small-boat harbor at Port Washington, Wisconsin



MODIFICATIONS TO NORTH BREAKWATER
ADJACENT TO NEW HARBOR



NEW EAST AND WEST
INTERIOR BREAKWATERS

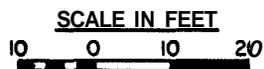


Figure 84. Cross sections of small-boat harbor structures at Port Washington, Wisconsin

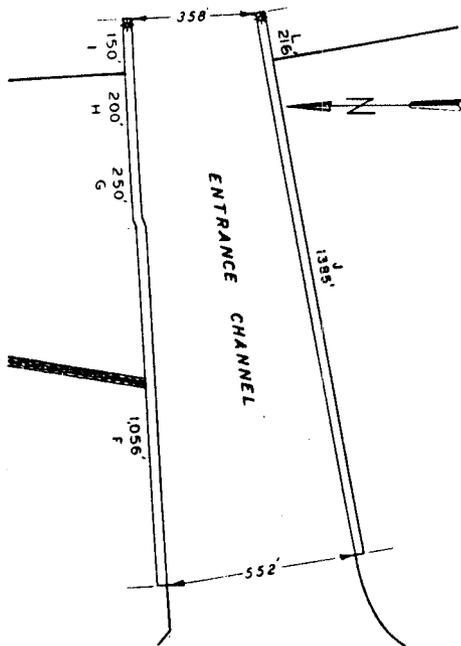
Table 33
Milwaukee Harbor Structures
Milwaukee, Wisconsin

Date(s)	Construction and Rehabilitation History
1855- 1866	Construction of a 1,056-ft-long north pier at the entrance (Figure 85) progressed during this period. The pier was a stone-filled timber crib structure and was 24 ft in width (Figure 86, Section F).
1868- 1869	A 250-ft lakeward extension of the north pier was completed (Figure 86, Section G). The extension was a stone-filled timber crib structure that was 28 ft in width.
1871	An additional 200-ft extension of the north pier was constructed (Figure 86, Section H). The extension was also a stone-filled timber crib structure with a total width of 33.5 ft.
1881- 1893	Construction of the shore-connected portion of the north breakwater was completed during this time (Figure 85). The breakwater was built with stone-filled timber cribs. The outer 1,756 ft was built on a stone foundation, and the width of the structure ranged from about 20 to 32 ft (Figure 87, Sections A, B', B'-1, B-2, and B-5). Riprap was placed along the base of most of the remaining structure.
1888- 1899	Construction of the northern 3,780 ft of the detached portion of the north breakwater was completed during this period (Figure 87, Sections B'-3, C, and C-1). The structures were also built with stone-filled timber cribs and ranged from 23 to 30 ft in width. Riprap was placed along the base of the structure.
1903- 1906	During this time the north pier was extended an additional 150 ft (Figure 86, Section I). The extension was a 28-ft-wide stone-filled timber crib structure built on woodpilings with riprap installed along the base on each side. The entire north pier was capped with a concrete superstructure. The shoreward 1,056 ft (Section F) had a crest el of +9.0 ft lwd, and the remaining portion of the structure (Sections G, H, and I) had an el of +11.5 ft lwd. The shore-connected portion of the north breakwater was capped with a concrete superstructure (Figure 87, Sections A, B', B'-1, B2, and B5). The shoreward 1,472-ft length (Sections A and B5) also included a 3-ft-wide concrete parapet wall at an el of +11.4 ft lwd. The remaining portion of the breakwater (Sections B' and B'-1) had a crest el of +8.1 ft lwd. the 450-ft-long outer end (Section B'-1) had riprap installed on each side of the structure. The el of the stone was +3. ft lwd, and it had side slopes of 1V:1.5H.
1907- 1910	The detached portion of the north breakwater was extended southerly by 980 ft (Figure 87, Section D). The extension was constructed of stone-filled timber cribs and was 30 ft in width. The existing detached portion of the north breakwater at this point (Figure 87, Sections B'-3, C, and C-1) was capped with a concrete superstructure, which resulted in a crest el of +8.2 ft lwd.

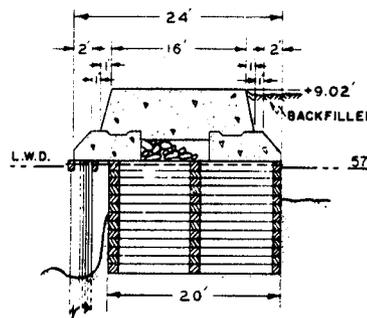
(Continued)

Table 33 (Concluded)

Date(s)	Construction and Rehabilitation History
1909- 1910	A 216-ft-long south pier extension was constructed (Figure 86, Section I). The pier was a stone-filled concrete structure built on woodpilings and stone. It was 18 ft in width and had a crest el of +8.1 ft lwd.
1923- 1924	A 980-ft portion of the detached north breakwater was capped with a concrete superstructure (Figure 87, Section D). The crest el of the structure was +8.6 ft lwd.
1924- 1929	Construction of the southerly 1,744-ft portion of the north breakwater and the entire south breakwater (Figure 87, Section E) was completed during this time. The breakwater was a stone-filled concrete structure built on stone. It had a crest width of 6.7 ft and an el of +8.6 ft lwd. The outer 54 ft of the north breakwater consisted of three rectangular caissons.
1950- 1952	A 530-ft-long section of the attached north breakwater (Figure 87, Section B5) and a 68-ft-long portion (Section B2) were repaired. Steel sheet piles were driven on both sides of the existing timber crib structure.
1953	The 1,385-ft-long south pier was constructed by the City of Milwaukee (Figure 86, Section J). It consisted of steel sheet piles on the channel side which were backfilled with earth. The existing pier (time of construction unknown) was completely covered by the new structure.
1957- 1959	A 1,940-ft-long portion of the north breakwater was repaired (Figure 87, Section B ¹ -3 and C-1). Steel sheetpiling was driven adjacent to both sides of the timber crib structure.
1962- 1964	A 1,840-ft-long portion of the north breakwater (Figure 87, Section C) was repaired. Steel sheet piles were installed on each side of the existing timber crib.
1976- 1977	A portion of the north breakwater was rebuilt (Figure 87, Section B5). Steel sheet piles were installed on each side of the existing structure with the width varying from 30 to 32.5 ft. The voids were filled with stone, and the concrete cap and parapet wall were reconstructed. A parapet wall also was installed on an adjacent portion of the breakwater (Section B2).
1984	A site inspection of the north breakwater revealed some sections in good shape and others requiring repair and maintenance.
1985	Repair of the head of the south breakwater was completed for a cost of \$810,942. A new caisson was constructed and capped with concrete. Stone, ranging from 3 to 6 tons, was placed around the new caisson for toe protection.
1986	The breakwaters and piers are presently considered to be in fair condition.

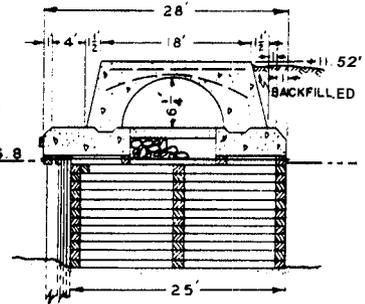


ENTRANCE PIERS
SCALE OF FEET
100 0 100 300 500



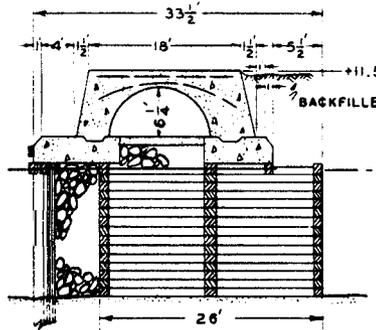
SECTION - F

NORTH PIER
BUILT: SUBSTRUCTURE 1835-88
SUPERSTRUCTURE 1903-4



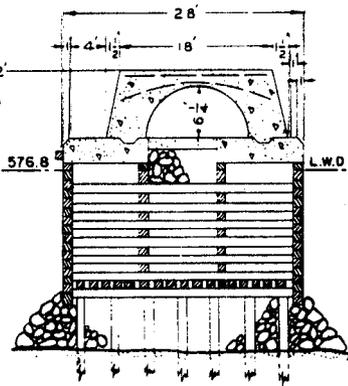
SECTION - G

NORTH PIER
BUILT: SUBSTRUCTURE 1868-8
SUPERSTRUCTURE 1903-8



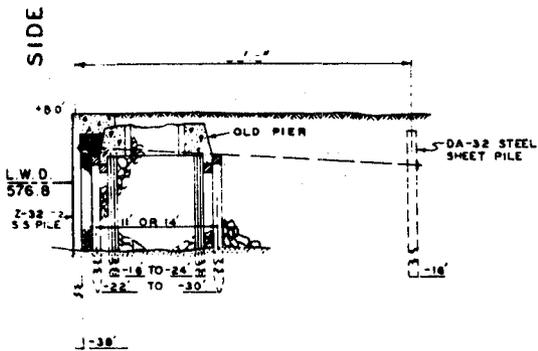
SECTION - H

NORTH PIER
BUILT: SUBSTRUCTURE 1871
SUPERSTRUCTURE 1903-6



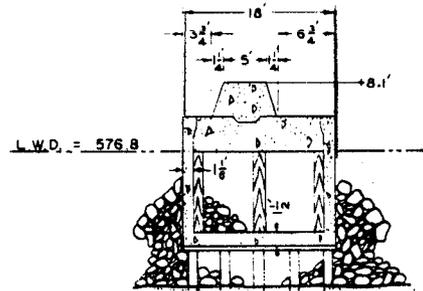
SECTION - I

NORTH PIER
BUILT: SUBSTRUCTURE 1903
SUPERSTRUCTURE 1903-6



SECTION - J

SOUTH PIER
BUILT: 1953 BY CITY
OF MILWAUKEE



SECTION - L

SOUTH PIER
BUILT: SUBSTRUCTURE 1908-10
SUPERSTRUCTURE 1908-10

CHANNEL

Figure 86. Typical pier cross sections, Milwaukee Harbor, Wisconsin

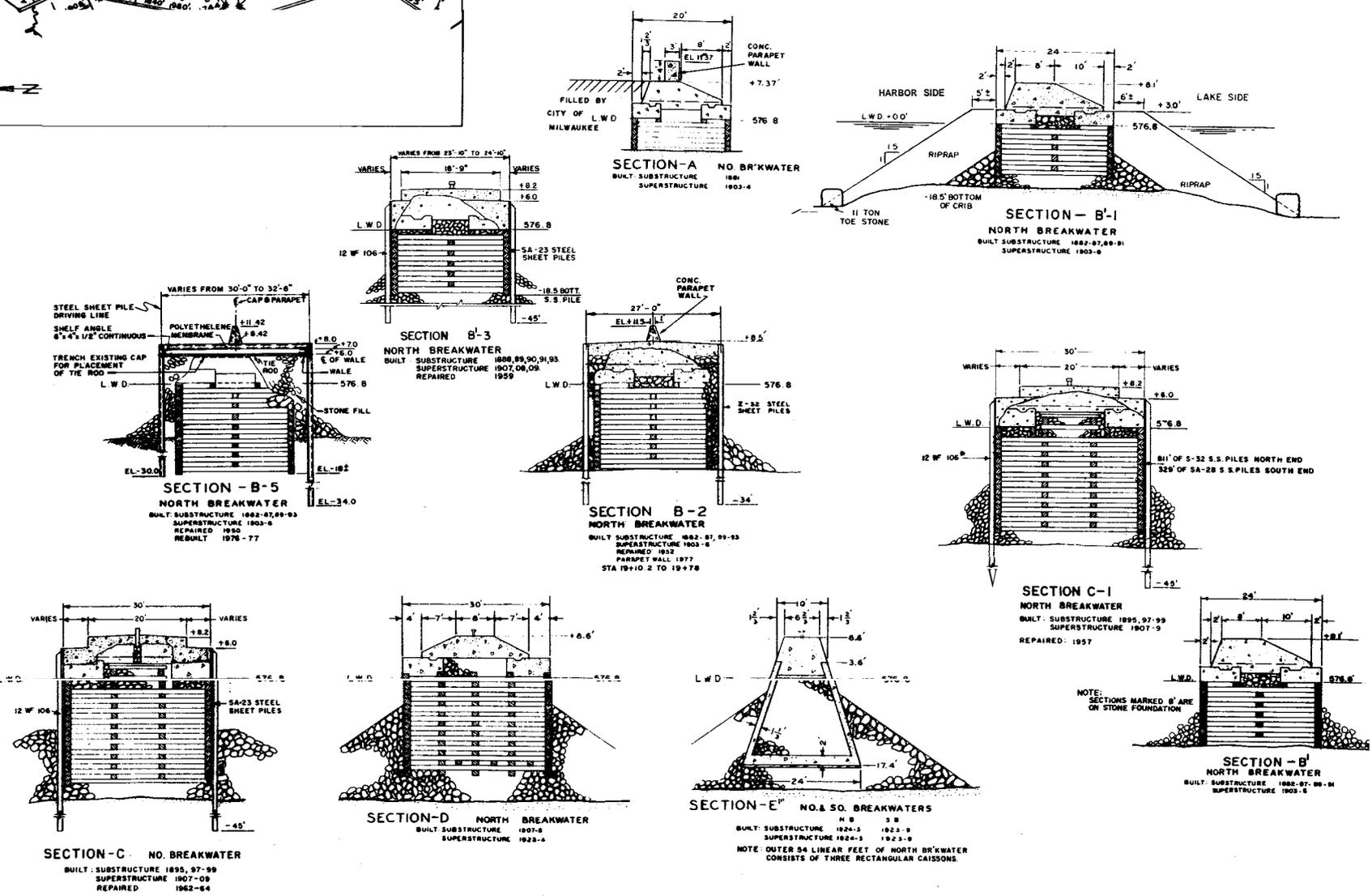
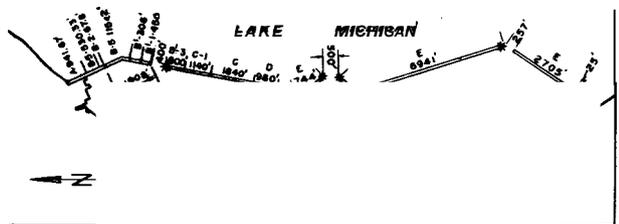


Figure 87. Typical breakwater cross sections, Milwaukee Harbor, Wisconsin

Table 34
Racine Harbor Structures
Racine, Wisconsin

Date(s)	Construction and Rehabilitation History
1900	Construction of the 796-ft-long outer portion of the north breakwater (Figure 88, Section F) was completed. The breakwater was a stone-filled timber crib structure (Figure 89, Section F). It was 30 ft wide, and riprap toe protection was placed on each side.
1912- 1913	Construction of the 1,844-ft shoreward portion of the north breakwater was completed during this time (Figure 88, Sections A, A', B, B', C, D, and E). The shoreward 800 ft of the structure (Figures 89 and 90, Sections A, A', B, and B') were constructed with woodpilings driven from 11 to 14 ft apart and stone filled. The breakwater was capped with a stone and concrete superstructure installed at an el of +7.1 ft lwd. Riprap toe protection was placed on both sides of the breakwater. The adjacent 1,044 ft of breakwater extending lakeward (Figure 89, Sections C, D, and E) was constructed of a stone-filled concrete structure built on wood piles. The crest el of the breakwater was 1-7.1 ft lwd, and the crest width ranged from 15 to 20 ft. Riprap toe protection also was installed on both sides of the breakwater.
1917- 1919	Construction of the 1,512-ft-long lakeward portion of the south breakwater (Figure 88, Sections H, I, and J) was completed during this period. The breakwater consisted of a concrete superstructure built on stone. The superstructure was either sand or stone filled (Figure 89, Sections H, I, and J). The crest el of the structure was +7.1 ft lwd, and it had a 10-ft crest width. The outer portion of the structure (Section J) was covered with riprap ranging from 6 to 16 tons (9-ton average) to an el of 1-4 ft lwd. The slope of the riprap was 1V:1.5H .
1924	Construction of the shoreward 1,104-ft-long portion of the south breakwater (Figure 88, Sections B and G) and the south pier (Section M) was completed. The breakwater was constructed with a stone-filled concrete superstructure built on woodpilings (Figure 89, Sections B and G). The pilings were 14 ft (Section B) or 17 ft (Section G) apart. Riprap toe protection was included on both sides of the breakwater. The north pier also consisted of a stone-filled concrete superstructure built on woodpilings that were spaced 15.5 ft apart (Figure 89, Section M). The crest el of both the breakwater and pier built during this time was +7.1 ft lwd.
1925	The lakeward portion of the north breakwater (Figure 88, Section F) was capped with a concrete superstructure. The crest el of the structure was +7.1 ft lwd (Figure 88, Section F).

(Continued)

Table 34 (Concluded)

Date(s)	Construction and Rehabilitation History
1940	Construction of the north pier (Figure 88, Sections K and L) was completed. The inner 105-ft-long portion was a timber crib structure with a sand cap. It was 24.5 ft wide and had a crest el of +7.5 ft lwd (Figure 89, Section K). The outer 75 ft of the pier (Section L) was a wood-pile structure that was 19.5 ft in width and +7.5 ft lwd in height. It was capped with stone.
1959	A 252-ft-long portion of the north breakwater was repaired (Figure 88, Section C).
1966	A 50-ft-long portion of the south breakwater was constructed (Figure 88, Section G-1). The breakwater was built with stone and had a 14-ft-width crest with an el of +7.1 ft lwd. Side slopes were 1V:1.5H . The stone along the crest was grouted in place.
1971	The shoreward 1,104 ft of the south breakwater (Figure 88, Sections B and G) were repaired, and riprap was installed on each side of the structure to an el of +4 ft lwd (Figure 89, Sections B and G). Side slopes of the riprap were 1V:1.5H .
1973	The lakeward 796-ft-long portion of the north breakwater was repaired (Figure 88, Section F). Riprap was installed on each side of the structure (Figure 89, Section F) to an el of +4 ft lwd. The riprap was placed with side slopes of 1V:1.5H .
1974	Two sections of the north breakwater (Figure 88, Sections A' and B') were rebuilt. Steel sheetpiling was driven on the lakeward side of the 183-ft-long portion of Section A' (Figure 90). Filling the voids with stone and capping the breakwater with concrete resulted in a breakwater section that was 17.5 ft in width with a crest el of +7.5 ft lwd. The 60-ft-long portion of Section B' (Figure 90) was covered with stone. It had a 15-ft-wide crest with an el of +7.1 ft lwd. Concrete was poured between the stones on the crest to form a walking surface. The existing concrete superstructure was removed because of its deteriorated condition prior to placement of the stone. Side slopes of the structure were 1V:1.5H .
1986	The structures have undergone repair and maintenance during their lifetime; however, they are presently in good condition. The President signed an act to deauthorize the project at Racine, and the title to any facilities constructed by the United States has been transferred, without consideration, to Racine County.

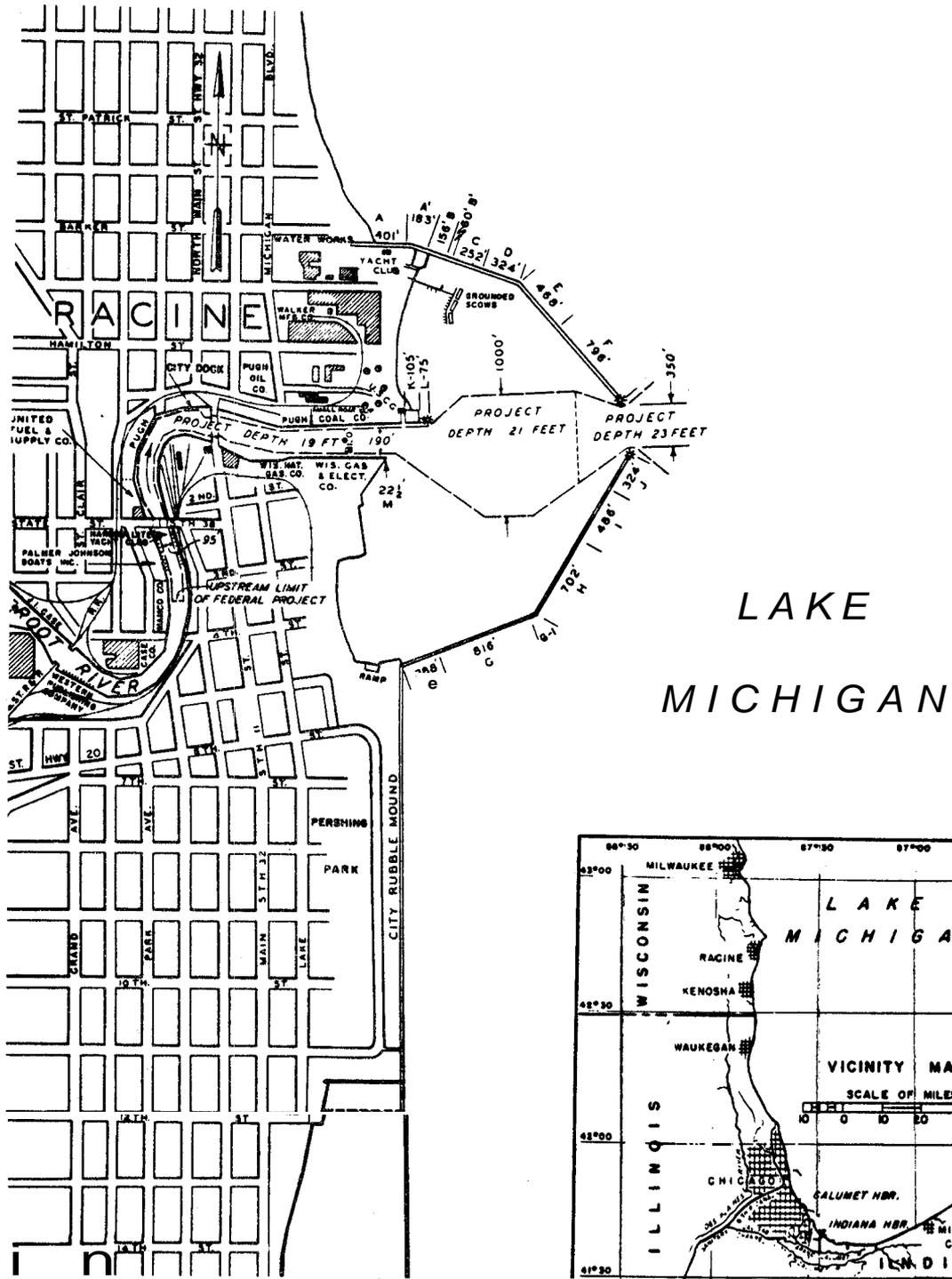


Figure 88. Racine Harbor, Wisconsin

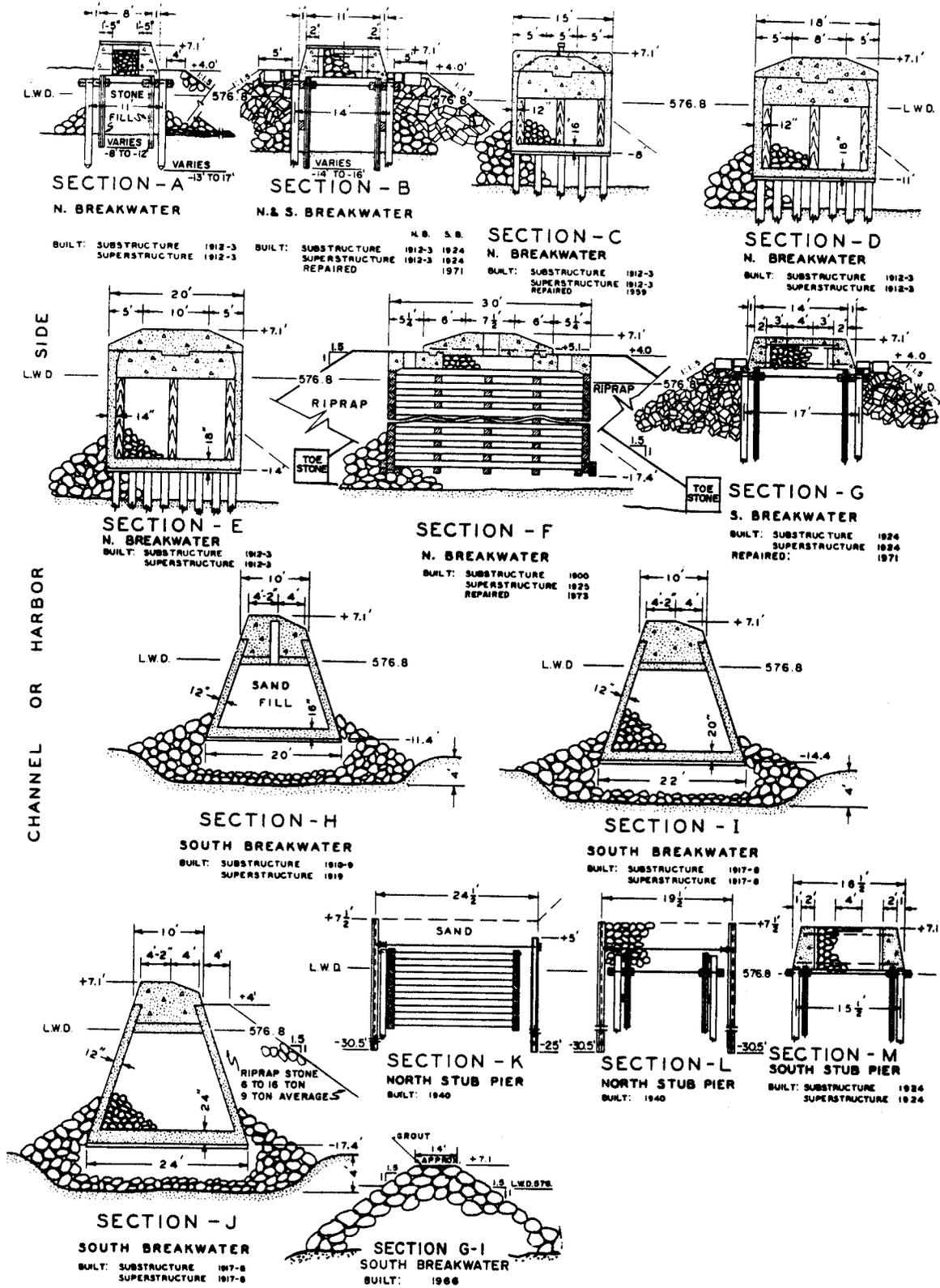
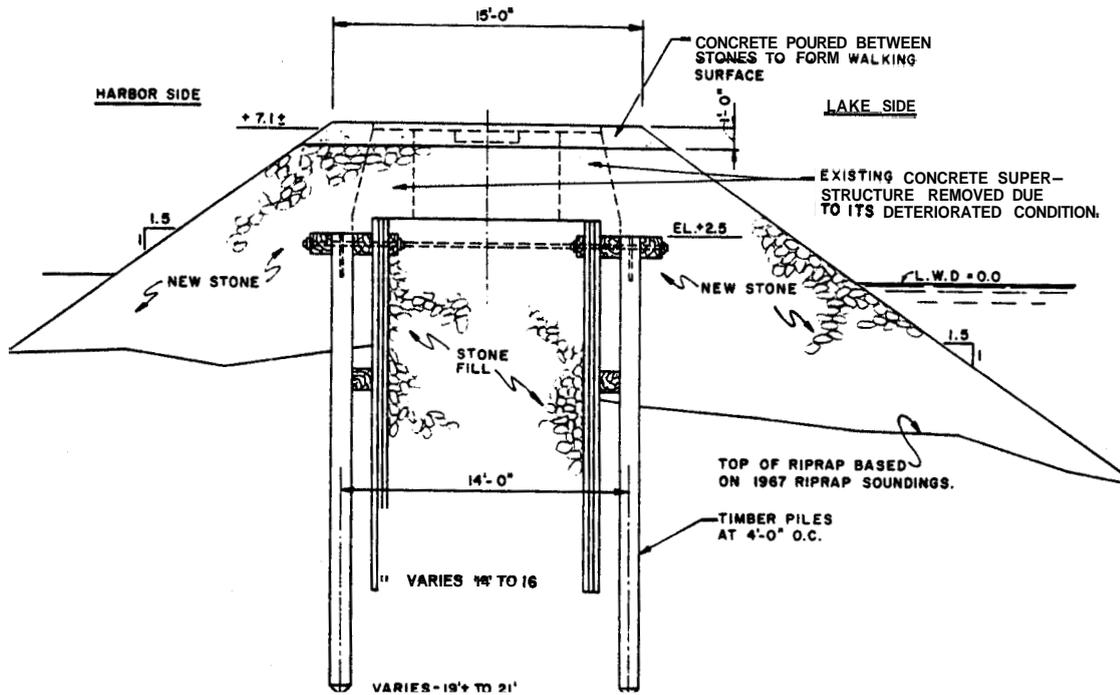
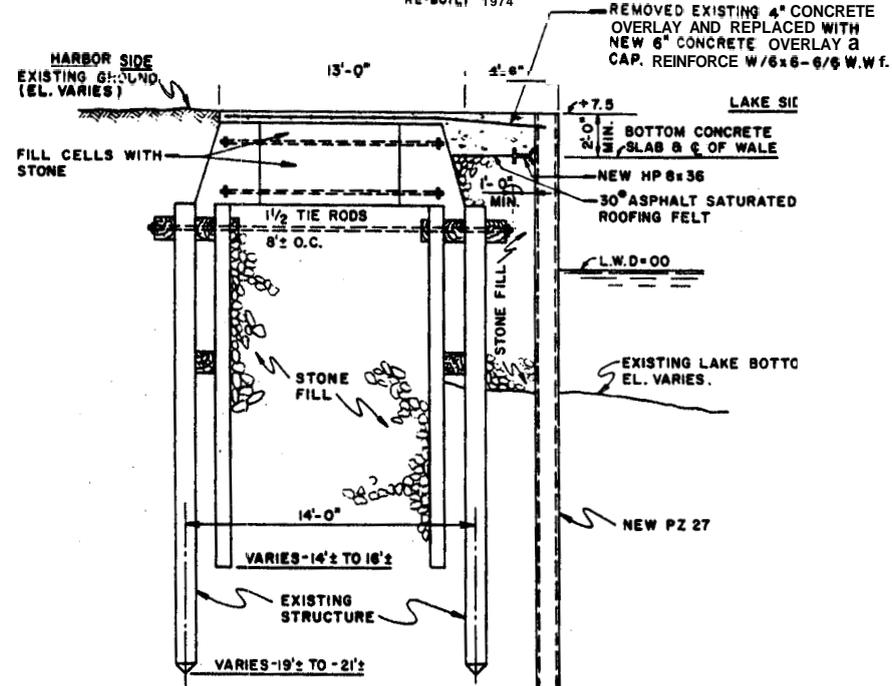


Figure 89. Typical breakwater and pier cross sections, Racine Harbor, Wisconsin



SECTION - B'

BUILT: SUB-STRUCTURE 1912-13
 SUCCI-STRUCTURE 1912-13
 RE-BUILT 1974



SECTION - A'

BUILT: SUB-STRUCTURE 1912-13
 SUPER-STRUCTURE 1912-13
 RE-WILT 1974

Figure 90. Typical structure cross sections, Racine Harbor, Wisconsin

Table 35

Kenosha Harbor StructuresKenosha, Wisconsin

Date(s)	Construction and Rehabilitation History
1899- 1900	Construction of a 1,077-ft-long portion north pier, a 1,175-ft-long south pier, and a 796-ft-long offshore breakwater was completed (Figure 91). The shoreward 927 ft of the north pier consisted of a wood-pile structure with widths of 14 ft (Figure 92, Section A) and 18 ft (Section B). The outer 150-ft-long portion of the north pier (Figure 92, Section C), the south pier (Figure 92, Section E), and the offshore breakwater (Figure 92, Section H) were stone-filled timber crib structures. Riprap toe protection was installed on each side of the timber cribs.
1916	Stone and concrete superstructures were constructed on the north and south piers to an el of +6.8 ft lwd (Figure 92, Sections A, B, C, and E).
1923	A stone and concrete superstructure was built on the detached breakwater (Figure 92, Section H) to a crest el of +7.1 ft lwd. The structure was 30 ft wide.
1969- 1970	The north and south piers were rehabilitated during this time (Figure 92, Sections A, B, C, and E). Steel sheetpiling was driven on each side of the north pier resulting in a structure 30 ft wide. Voids were filled with stone, and a concrete cap was installed at a crest el of +8.5 ft. Riprap was installed on each side of the structure. Steel sheetpiling was installed on the lakeward side of the south pier. The void and the existing pier were filled with 50-lb stone. A parapet wall was installed on the lakeward side of the structure to an el of +10 ft lwd. (This was adjacent to a confined dredging disposal area).
1977	The detached breakwater (Figure 92, Section H) was rebuilt, and 1- to 6-ton (3-ton average) riprap stone was placed on each side of the structure to an el of +4 ft lwd. Side slopes of the riprap were 1V:1.5H.
1980	A site inspection of the structures revealed them to be generally in good condition. Spalling of concrete was noted in several areas; however, the problem was not critical at that time.
1986	The structures presently are considered to be in fair condition.

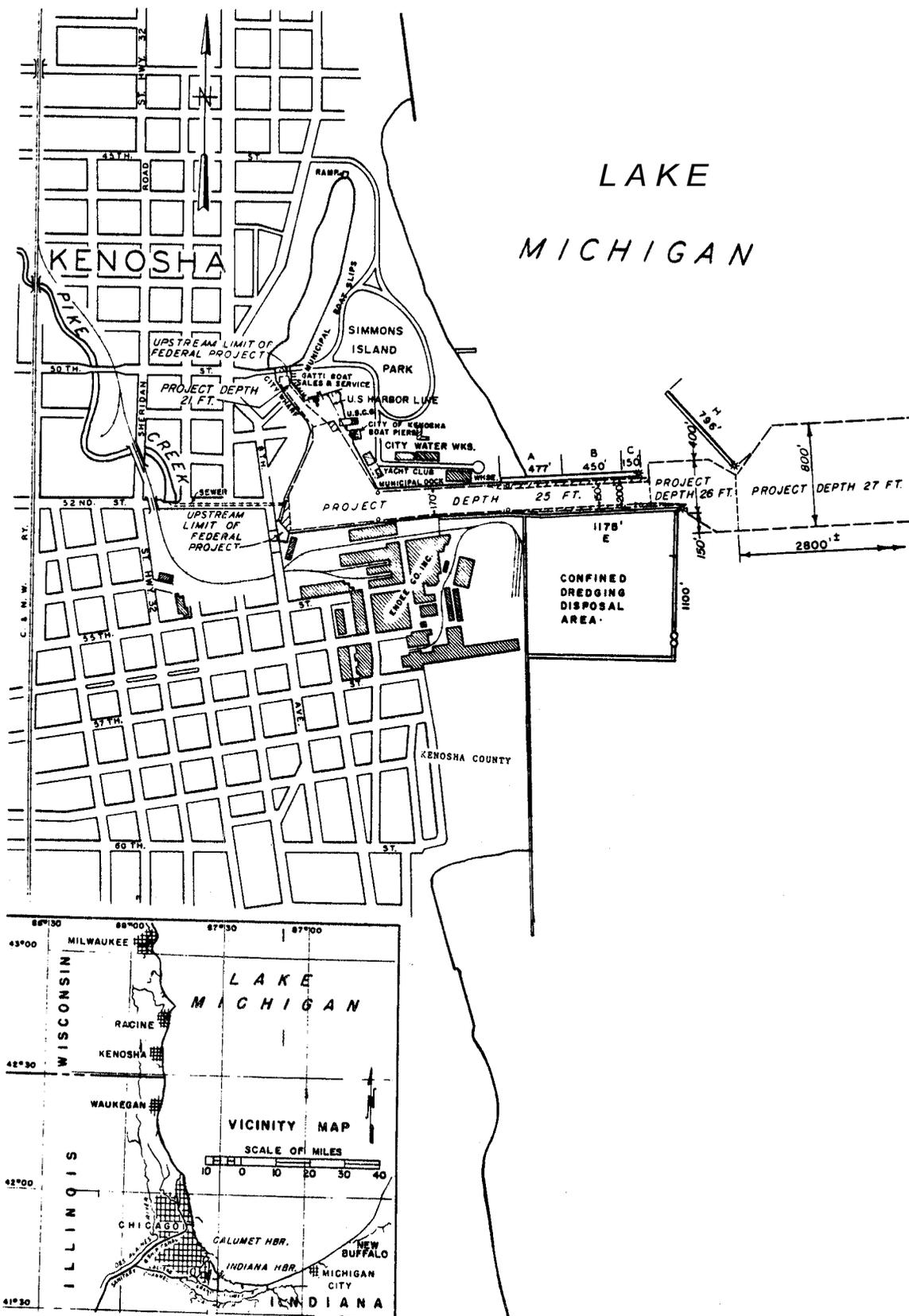


Figure 91. Kenosha Harbor, Wisconsin

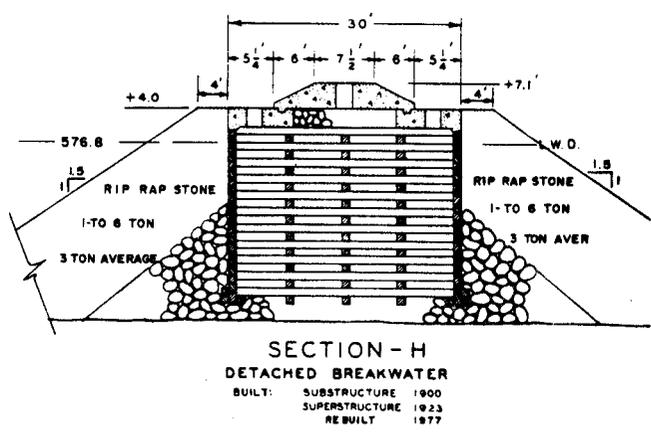
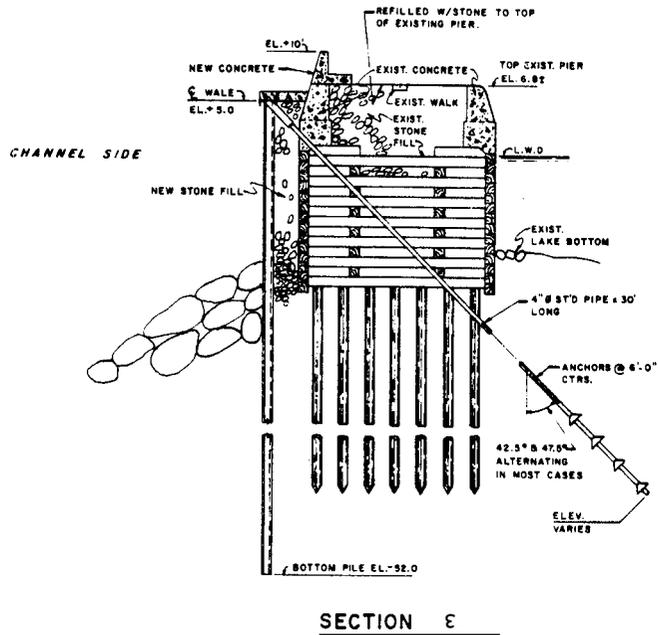
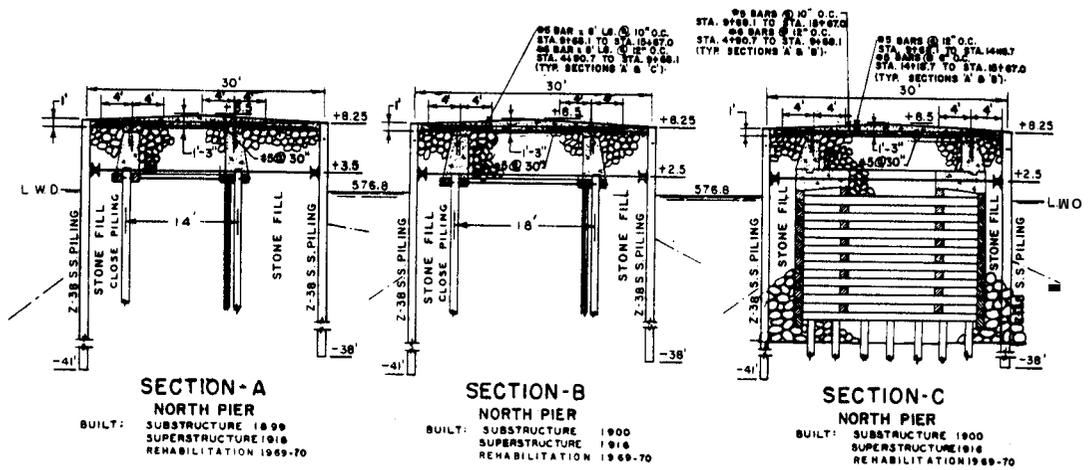


Figure 92. Typical structure cross sections, Kenosha Harbor, Wisconsin

Table 36

Waukegan Harbor StructuresWaukegan, Illinois

Date(s)	Construction and Rehabilitation History
1903	Construction of the 3,211-ft-long south pier (Figure 93, Sections L, M, N, O, P, and R) was completed. The shoreward 1,812 ft of the pier consisted of a wood-pile breakwater filled with stone (Figure 94, Sections L, M, N, and O). The structure was 14 ft in width. The outer 1,399 ft of the pier was a stone-filled timber crib structure (Figure 94, Sections P and R) with a width of 24 ft. With the exception of the shoreward 226 ft (Section L), riprap toe protection was placed along the toe of the pier.
1904	The lakeward 998 ft of the north pier (Figure 93, Section K) and 588 ft of the north breakwater (Figure 93, Section F) were constructed. The pier and breakwater consisted of stone-filled timber crib structures (Figure 95, Sections F and K). The widths of the pier and breakwater were 24 and 30 ft, respectively. Riprap toe protection was placed on both sides of the structures.
1906	The shoreward portion of the north pier (Figure 93, Section J) was constructed. The structure consisted of parallel timber walls with rock fill and a timber superstructure. The structure was 15 ft in width.
1930	The shoreward 1,573 ft of the south pier (Figure 93, Sections L and M) was capped with a stone and concrete superstructure. The crest el of the pier was +7.85 ft lwd, and it had a width of about 17 ft (Figure 94, Sections L and M).
1931	The existing north breakwater (Figure 93, Section F) was capped with a concrete superstructure and extended 271 ft shoreward (Figure 93, Section E). A 1,033-ft-long shore connection (Sections A, B, C, and D) was also constructed. The shoreward extension of the breakwater included a stone-filled concrete structure built on a stone base (Figure 95, Section E). The el of this extension and the new breakwater superstructure (Figure 95, Section F) was -7.1 ft lwd. The shoreward 398 ft of the shore connection consisted of steel sheetpiling with riprap on each side (Figure 95, Section A). The remaining portion of the shore connection consisted of parallel steel sheet piles ranging from 12 to about 17 ft in width (Figure 95, Sections B, C, and D). The area between the sheet piles was stone-filled and capped with concrete. The shore connection portion of the structure (Sections A, B, C, and D) had a crest el of +6.1 ft lwd.
1932	Concrete superstructures were built on the lakeward ends of the north (Figure 93, Section K) and south (Figure 93, Sections N, O, P, and R) piers. The north pier had a parapet wall installed to an el of

(Continued)

Table 36 (Concluded)

Date(s)	Construction and Rehabilitation History
	+7.1 ft lwd on the channel side (Figure 95, Section K). The south pier superstructure had crest els ranging from +7.6 to 8.85 ft lwd (Figure 94, Sections N, O, P, and R).
1960	A portion of the south pier (Figure 93, Section M-1) was repaired. Steel sheet piles were driven on each side of the existing structure. The voids were filled with stone, and the pier was capped with concrete at an el of +7.85 ft lwd (Figure 94, Section M-1). Stone toe protection was placed on each side of the structure.
1961	The shoreward portion of the north pier (Figure 93, Section J) was removed and rebuilt. Steel sheetpiling was installed at an el of +7.1 ft lwd and backfilled with earth fill (Figure 95, Section J). Riprap toe protection was also installed on the channel side of the pier.
1977	Portions of the south pier (Figure 93, Sections M and O) were rebuilt.
1978	An underwater intersection was made along the north pier which indicated that the structure was intact with the exception of construction joints. There were holes and gaps about 5 in. across at each construction joint along the wall. It was also noted that wood had rotted underneath the concrete cap at several locations. Maintenance repairs were made subsequent to the inspection.
1981	A superstructure condition survey indicated that the structures were in good condition.
1986	The structures have undergone rehabilitation and maintenance during their lifetime; however, they are presently considered to be in good condition. An aerial photograph of the harbor structures is shown in Figure 96.

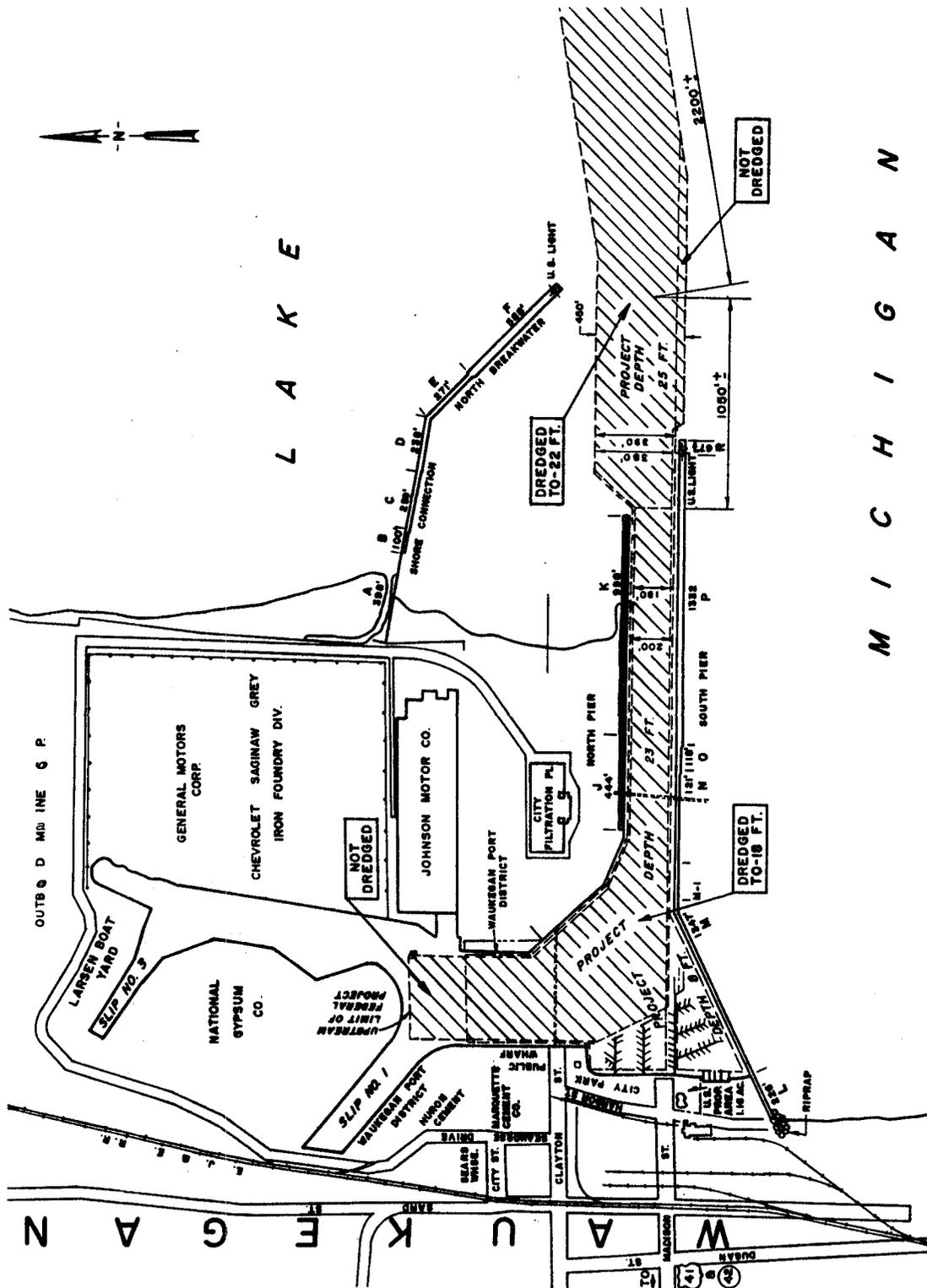


Figure 93 Waikewan Harbor, Illinois

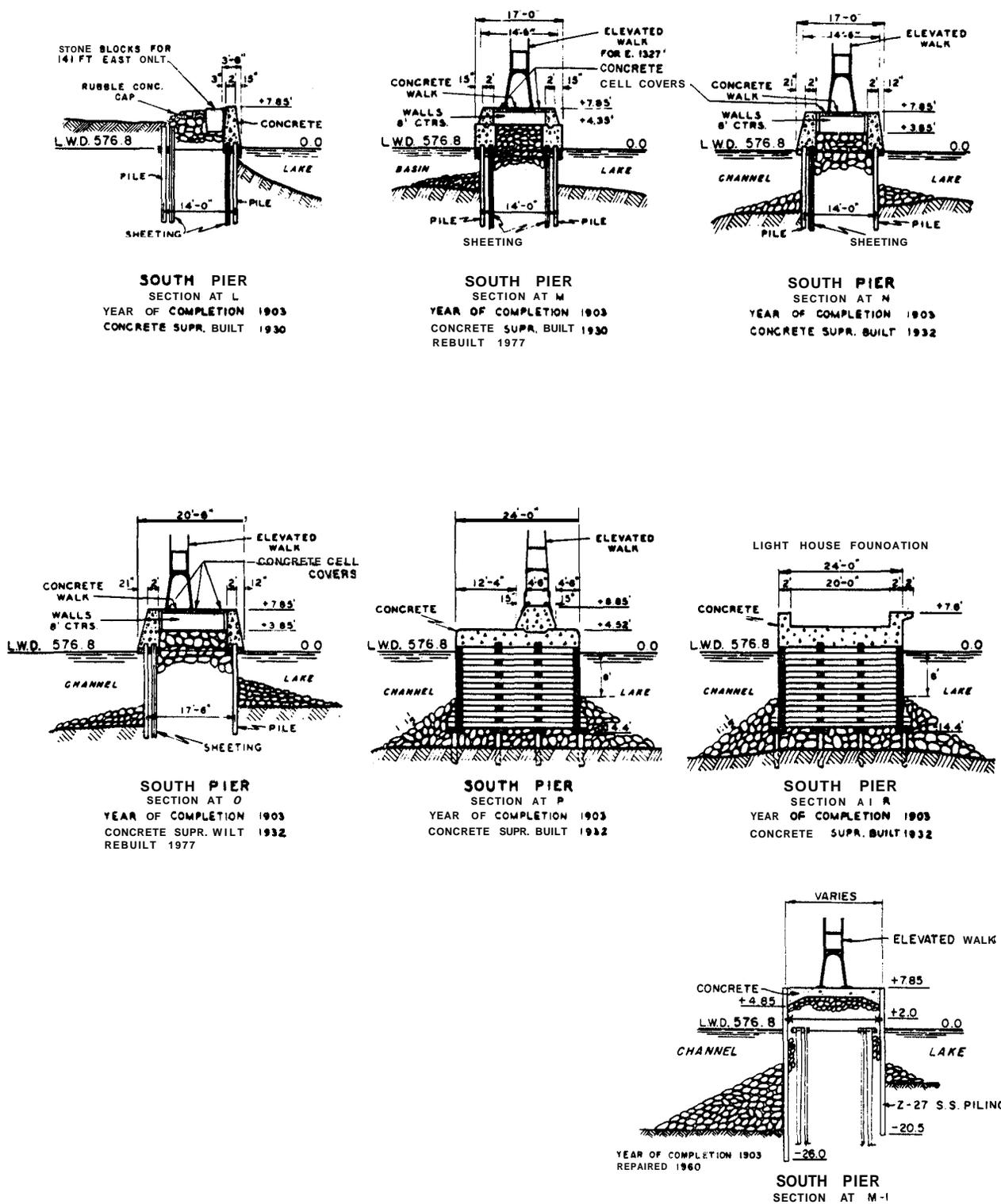
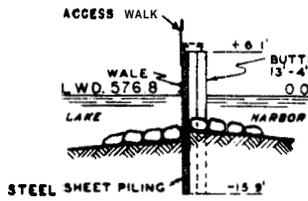
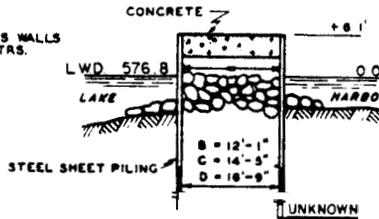


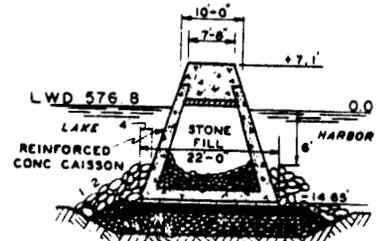
Figure 94. Typical pier cross sections, Waukegan Harbor, Illinois



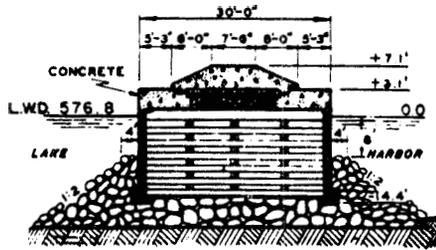
SHORE CONNECTION
SECTION AT A
YEAR OF COMPLETION 1931



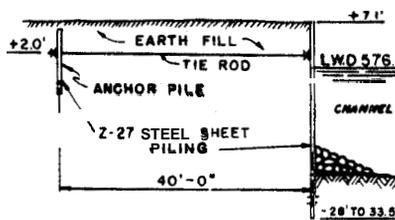
SHORE CONNECTION
YEAR OF COMPLETION 1931



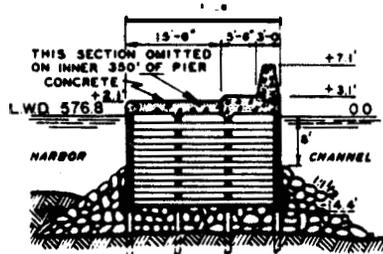
NORTH BREAKWATER
SECTION AT E



NORTH BREAKWATER
SECTION AT F
YEAR OF COMPLETION 1904
CONCRETE SUPR BUILT 1931



NORTH PIER
SECTION AT J



NORTH PIER
SECTION AT K
TSAR OF COMPLETION 1904
CONCRETE SUPR BUILT 1932

ORIGINAL STRUCTURE REMOVED
REBUILT 1961

Figure 95. Typical structure cross sections, Waukegan Harbor, Illinois

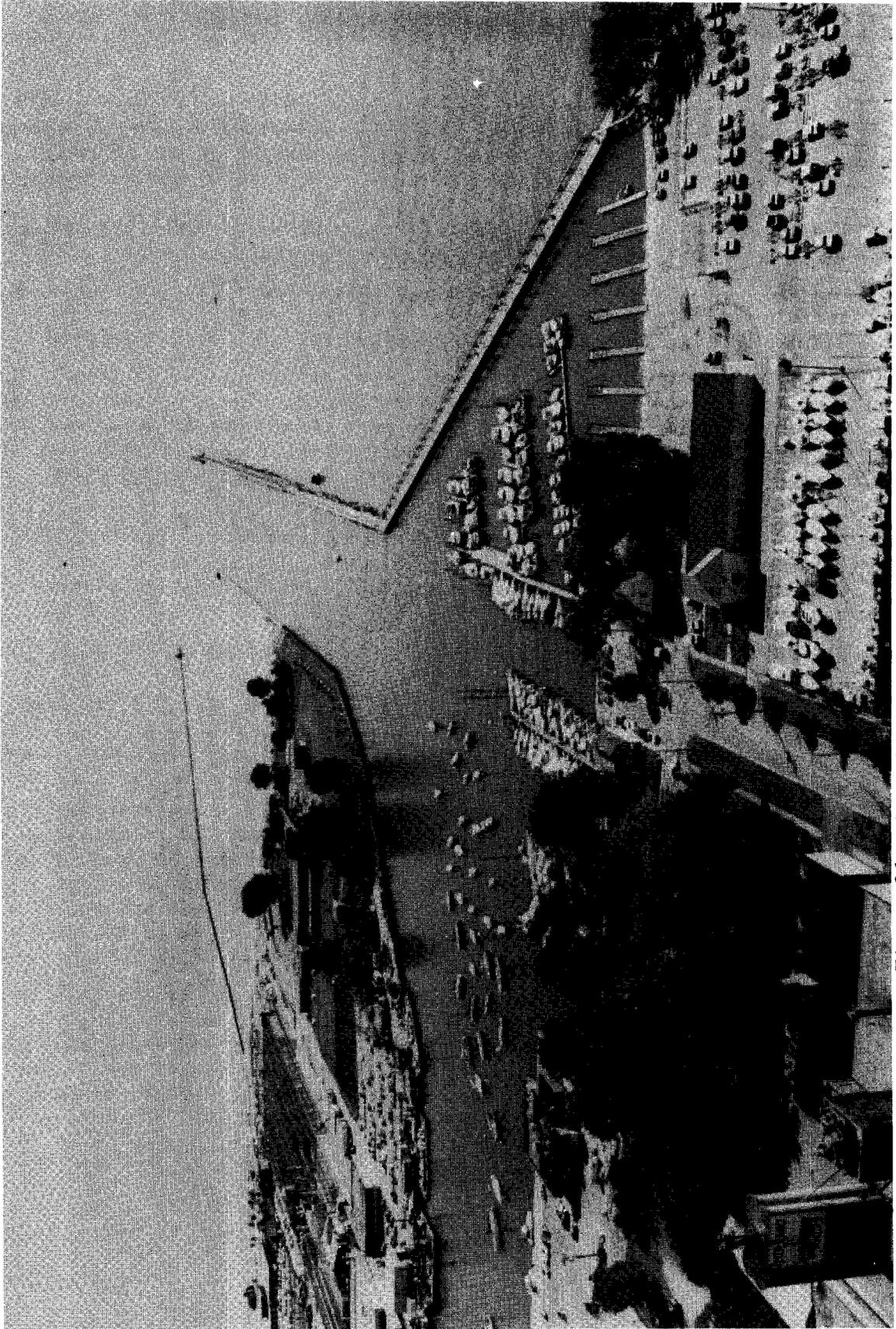


Figure 96. Aerial view of Waukegan Harbor, Illinois

Table 37
Chicago Harbor Structures
Chicago, Illinois

Date(s)	Construction and Rehabilitation History
1874	Construction of the 4,338-ft-long northern portion of the inner breakwater (Figure 97, Sections K, L, M, N, O, and U) was completed. The breakwater was constructed of stone-filled timber cribs on a stone base. It was 30 ft in width (Figure 98, Sections K through O and U).
1876	Construction of the 960-ft-long north pier (Figure 97) was completed. The pier was of stone-filled timber crib construction (Figure 98, Section J). It was built on a stone base and was 30 ft in width.
1880	The 2,544-ft-long southern portion of the inner breakwater (Figure 97, Sections P, R, and S) was constructed. These structures also were stone-filled timber cribs built on a stone base (Figure 98, Sections P, R, and S). The southern 2,244 ft of breakwater was 16 ft in length (Sections R and S), and the remaining 300-ft portion (Section P) was 30 ft in width.
1889	Construction of a 5,321-ft-long extension breakwater (Figure 97, Sections C, D, and E) was completed. This was a stone-filled timber crib breakwater (Figure 99, Sections C, D, and E) built on a stone base with a 30-ft width.
1908	The north pier was capped with a concrete superstructure (Figure 98, Section J) with a crest el of about 4-11 ft lwd.
1917	A 2,250-ft-long shore arm extension (Figure 97, Sections A, B1, B2, and B3) and a 2,227-ft-long southerly extension (Figure 97, Section F) of the exterior breakwater were constructed. The shore arm extension was constructed with stone-filled timber cribs (Figure 99, Sections A, B1, B2, and B3) built on a stone base. The shoreward 750-ft-length (Section A) was 24 ft in length, and the remaining breakwater (Sections B1, B2, and B3) was 30 ft wide. The southerly extension was a rubble-mound breakwater with 1V:1.5H side slopes (Figure 99, Section F). Its crest el was +8.44 ft lwd, and armor stone sizes were 3 tons (minimum) from el 4-1.72 ft lwd to the lake bottom and 7 tons (minimum) from el +1.72 to +8.44 ft lwd.
1920	An additional 1,532-ft-long portion of the southerly extension (Figure 97, Section G) was constructed. The extension was a rubble-mound structure with a crest el of +6.1 ft lwd and 1-V:1.5-H side slopes (Figure 99, Section G). Armor stone sizes ranged from 3 tons (minimum) from el 0.0 ft lwd to the lake bottom to 7 tons (minimum) from el 0.0 ft lwd to +6.1 ft lwd.

(Continued)

(Sheet 1 of 3)

Table 37 (Continued)

Date(s)	Construction and Rehabilitation History
1923	Construction of the southern end of the southerly extension (Figure 97, Section H) was completed. It consisted of a stone-filled concrete breakwater (Figure 99, Section H) built on a stone base. The crest el of the extension was +6.1 ft lwd, and its width was 8.3 ft.
1928- 1929	The exterior breakwater (Figure 97, Sections C, D, and E) was capped with a concrete superstructure. The crest el of the breakwater was +7.1 ft lwd. Riprap (7-ton average) was placed on the lakeside of the structure (Figure 99, Sections C, D, and E) to an el of +4.6 ft lwd on a 1-V:1.5-H slope. Seven-ton riprap also was placed on the harbor side in some areas (Figure 97, Sections C-4 and E).
1930	Portions of the inner breakwater (Figure 97, Sections O, P, R, and S) were capped with a concrete superstructure. The 150-ft-long portion of section O (Figure 98) included a parapet with an el of +8.85 ft lwd, and the 300-ft-long portion of P had a crest el of +7.1 ft lwd. The remaining portions (Sections R and S) were constructed with crest els of +6.43 ft lwd.
1934	The remaining sections of the inner breakwater (Figure 97, Sections K, L, M, N, and U) were capped with concrete superstructures. The longest length (3,488 ft) of structure (Section N) included a parapet with an el of +8.85 ft lwd (Figure 98). A 100-ft section of the breakwater (Section U) also included a parapet, but the crest el was +8.58 ft lwd. This portion of the breakwater also included the installation of steel sheetpiling on each side of the timber cribs and riprap toe protection (Figure 98, Section U). The northernmost end of the inner breakwater had a crest el of +5.1 ft lwd (Figure 98, Section K), and the remaining portions of the structure (Sections L and M) involved a +7.1-ft-lwd crest el.
1950	The inner end of the shore arm extension (Figure 97, Section A) was capped with a concrete superstructure. The superstructure included a parapet with an el of +7.0 ft lwd (Figure 99, Section A).
1955	A 1,000-ft-long portion of the shore arm extension (Figure 97, Section B2) was capped with a capstone superstructure. The minimum size of the capstone was 4 tons (Figure 99, Section B2), and the crest el was +7.0 ft lwd. A portion of the inner breakwater was repaired (Figure 97, Section R). Riprap (7-ton average) was placed on each side of the existing breakwater (Figure 98, Section R). The stone extended above lwd and had side slopes of 1V:1.5H.
1958	Riprap (7-ton average) was installed on each side of the southern end of the inner breakwater (Figures 97 and 98, Section S). The stone protruded above lwd and had 1-V:1.5-H side slopes.
1960	A 300-ft-long portion of the shore arm extension (Figure 97, Section B1) was capped with a concrete superstructure which included a parapet installed at an el of +7.0 ft lwd (Figure 99, Section B1).

(Continued)

(Sheet 2 of 3)

Table 37 (Concluded)

Date(s)	Construction and Rehabilitation History
1965	<p>The lakeward end of the shore arm extension (Figure 97, Section B3) was capped with a concrete superstructure. The breakwater included a parapet installed at an el of +7.0 ft lwd (Figure 97, Section B3). Rubble (7-ton average) was added on each side of a portion of the inner breakwater (Figures 97 and 98, Section P), and the north pier (Figures 97 and 98, Section J) was repaired. The north pier and portions of the inner breakwater (Figure 98, Sections J, M, and N) were modified by the Metropolitan Sanitary District of Greater Chicago. This modification included the creation of wider structures by constructing a wall, filling voids with clay, and installing stone (Figure 98).</p>
1979	<p>A site inspection of the structures indicated cracks in the parapet walls of the shore arm extension (Figure 97, Sections A, B1, and B3). In Section B2 of the shore arm extension fill stone had settled; and cap stone was either settled, broken, or missing in some areas. Spalling at construction joints and along the edges of the exterior breakwater (Figure 97, Sections C, D, and E) was observed. Along Section E the timber structure in some places had deteriorated, and fill stone was missing. Cover stone was missing and/or deteriorated along Sections F and G (Figure 97) of the exterior breakwater southerly extension. Spalling at construction joints and along the edges of the inner breakwater (Figure 97, Sections M, N, P, and S) was noted. Maintenance of the breakwaters was performed subsequent to this inspection.</p>
1981	<p>A condition survey of the structures indicated that the shore arm extension (Figure 97, Sections A, B1, B2, and B3) were in good condition. The exterior breakwater (Sections C, D, and E) was also in good condition except for an area in Section E where failure of the crib substructure resulted in the superstructure's caving in. The exterior breakwater southerly extension was in good condition at Section H; however, in many locations along Sections F and G concrete fill between the armor stone had been lost. Also, many of the stones were split in pieces and disintegrating. In many locations stone was low (either lost or subsided). The north pier was in good condition except for minor spalling and weathering of concrete. The inner breakwater (Sections K, L, M, N, U, O, P, R, and S) was in good condition except for Sections N, U, and O where the concrete base slab was severely spalled and eroded with reinforcing bars exposed at the edges in many locations.</p>
1983	<p>Rubble-mound areas of the southerly extension (Figure 97, Sections F and G) were rehabilitated, and maintenance of the other faults noted in the condition survey of 1981 was performed.</p>
1986	<p>The structures are presently considered to be in good condition.</p>

(Sheet 3 of 3)

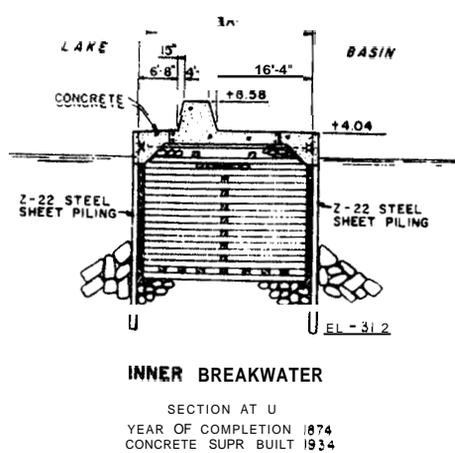
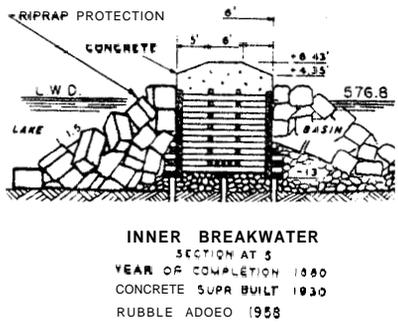
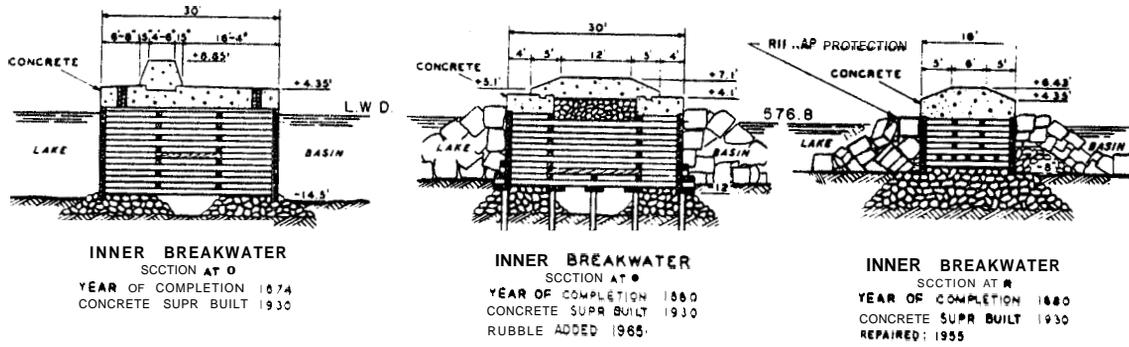
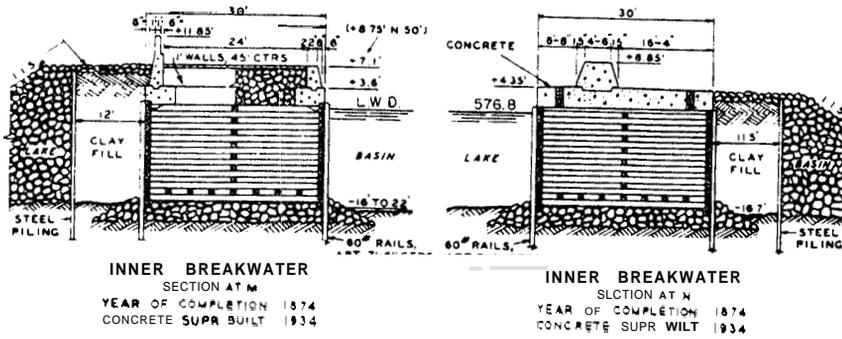
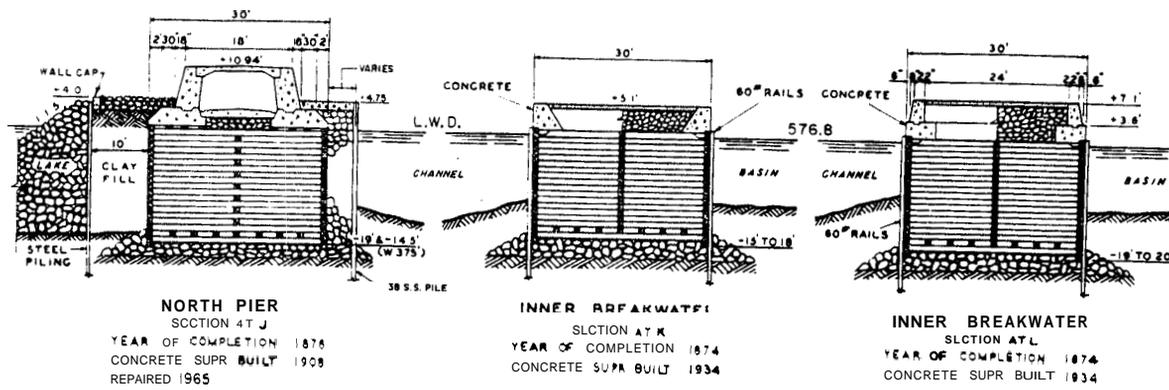


Figure 98. Typical structure cross sections, Chicago Harbor, Illinois

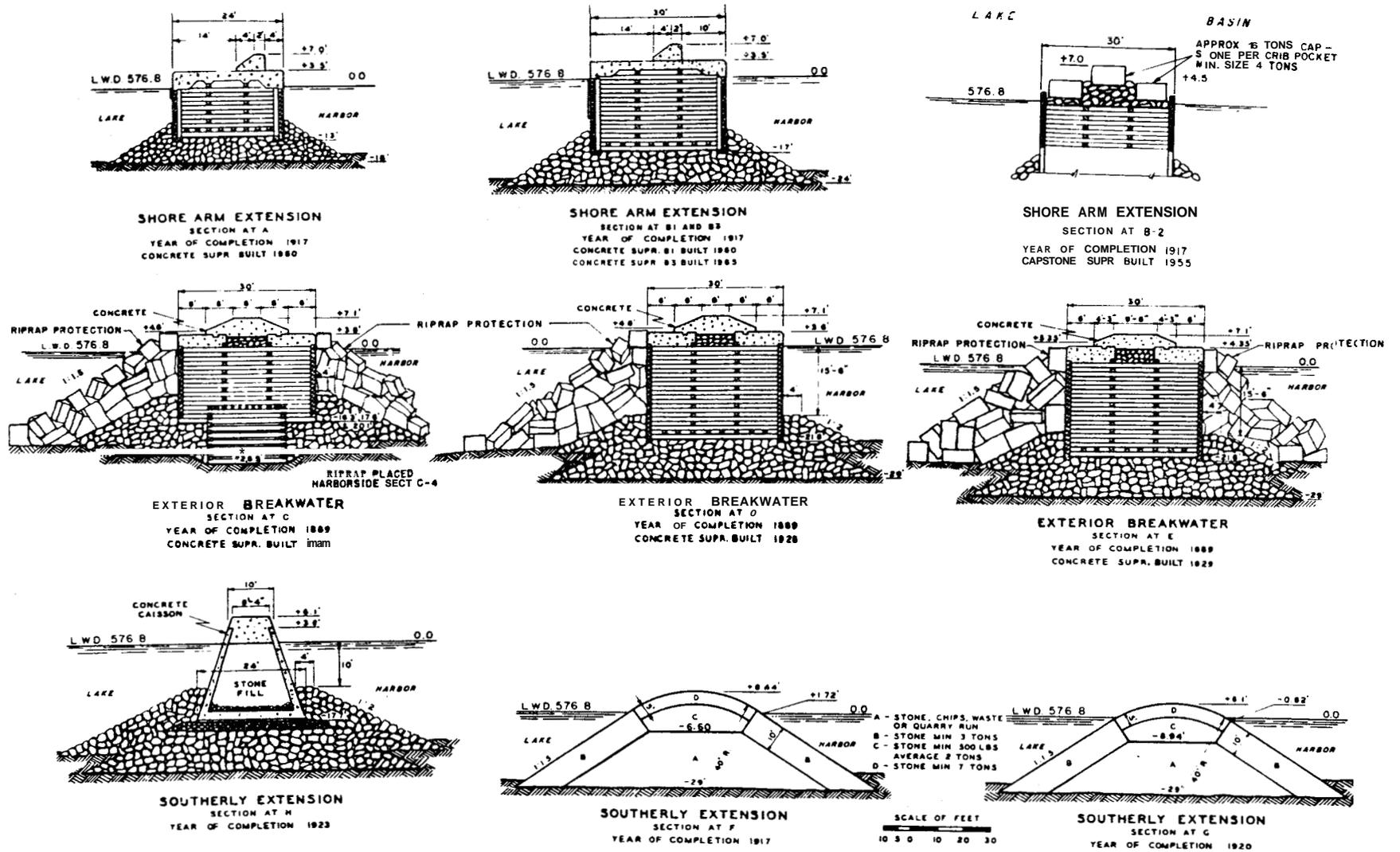


Figure 99. Typical breakwater cross sections, Chicago Harbor, Illinois

Table 38

Calumet Harbor BreakwatersCalumet Harbor and River, Illinois and Indiana

Date(s)	Construction and Rehabilitation History
1904	Construction of a 6,714-ft-long attached breakwater was completed (Figure 100, Sections A and B). The breakwaters were stone-filled timber crib structures built on a stone base. Riprap toe protection was installed on each side of the breakwater. The shoreward 1,700-ft length was 24 ft in width (Figure 101, Section A), and the remaining breakwater was 30 ft wide (Figure 101, Section B).
1921	The inner 1,700-ft portion of the breakwater (Figure 100, Section A) was capped with a stone and concrete superstructure, resulting in a crest el of +7.1 ft lwd (Figure 101, Section A).
1924	The outer 5,014-ft portion of the timber crib breakwater (Figure 100, Section B) was capped with a stone and concrete superstructure. The crest el of the breakwater was +7.1 ft lwd (Figure 101, Section B).
1935	Construction of a 5,007-ft-long cellular steel sheet-pile detached breakwater (Figure 100, Section C) was completed. The cells had a radius of 40 ft and were stone filled. Riprap toe protection was placed on each side of the breakwater. The structures were capped with stone (7 to 20 tons each) and had a crest el of +7.6 ft lwd (Figure 101, Section C).
1957	Portions of the detached breakwater (Figures 100 and 101, Sections C-1 and C-2) were repaired. Heavy riprap stone was placed on each side of the structure at the northern end (Section C-1) and on the lakeside of the breakwater on the southerly end (Section C-2).
1961- 1962	Portions of the attached timber crib breakwater (Figures 100 and 101, Sections A-1 and B-1) were repaired. Riprap protection was placed on the lakeside of the breakwater at Section A-1 and on the harbor side at Section B-1.
1984	A severe storm occurred in February with estimated wave heights of 15 ft. Two cells at the southern end of the detached breakwater failed, and the fill stone was lost under the impact of the storm waves. Stones ranging from 6 to 23 tons were placed on the ends of the damaged cells in October to stabilize them and prevent damage to adjacent cells. A total of 3,938 tons of stone was used during these repairs. During November a site inspection of the attached timber crib structure revealed damaged concrete with exposed rebar, spalling, concrete deterioration, fractured concrete, voids, and erosion of some cribs on the harbor side.
1985	A reconnaissance report for breakwater rehabilitation was published by NCC recommending conversion of the attached breakwater to a rubble-mound structure as an attempt to preserve the detached breakwater with rubble-mound berms installed on each side.

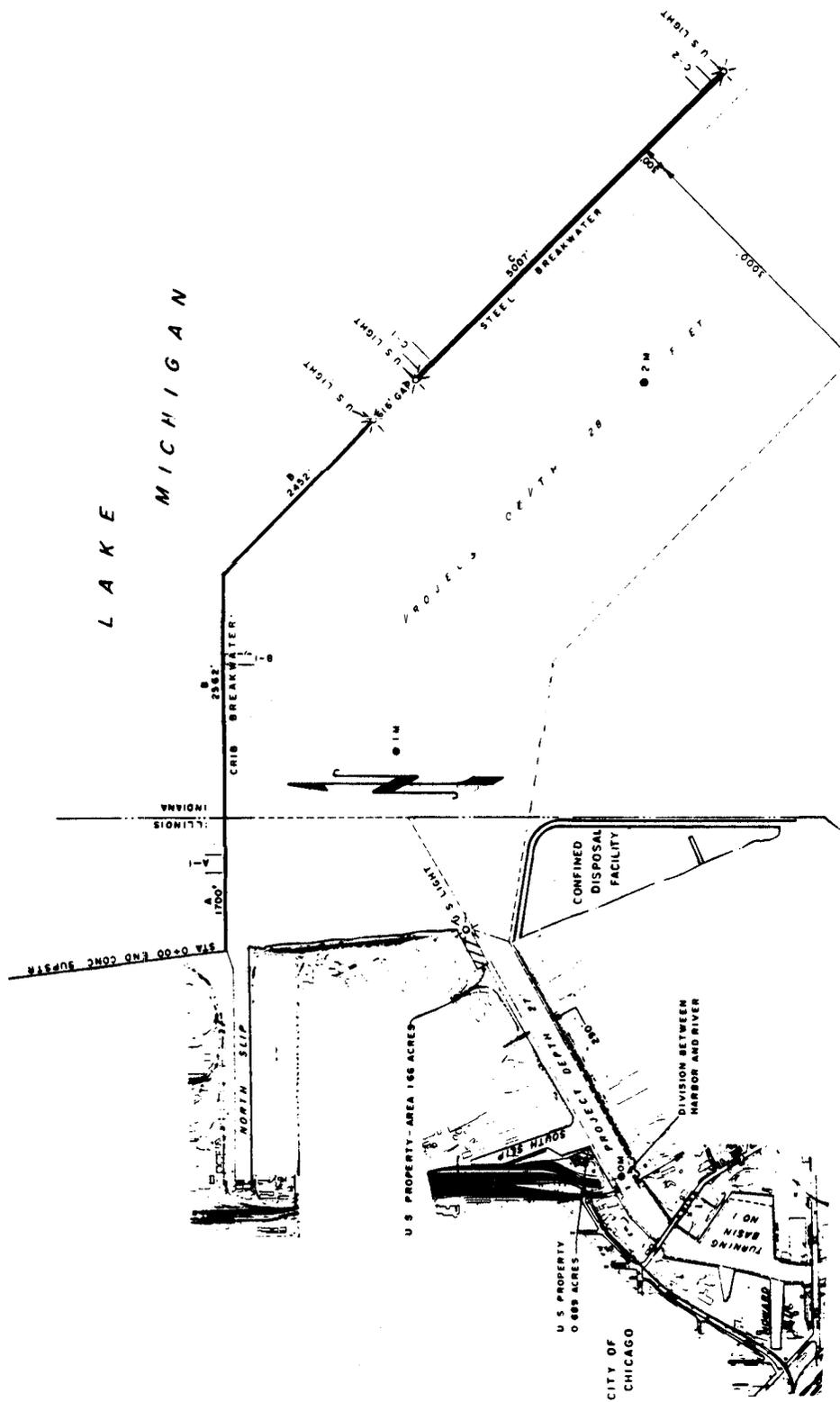


Figure 100. Calumet Harbor, Illinois and Indiana

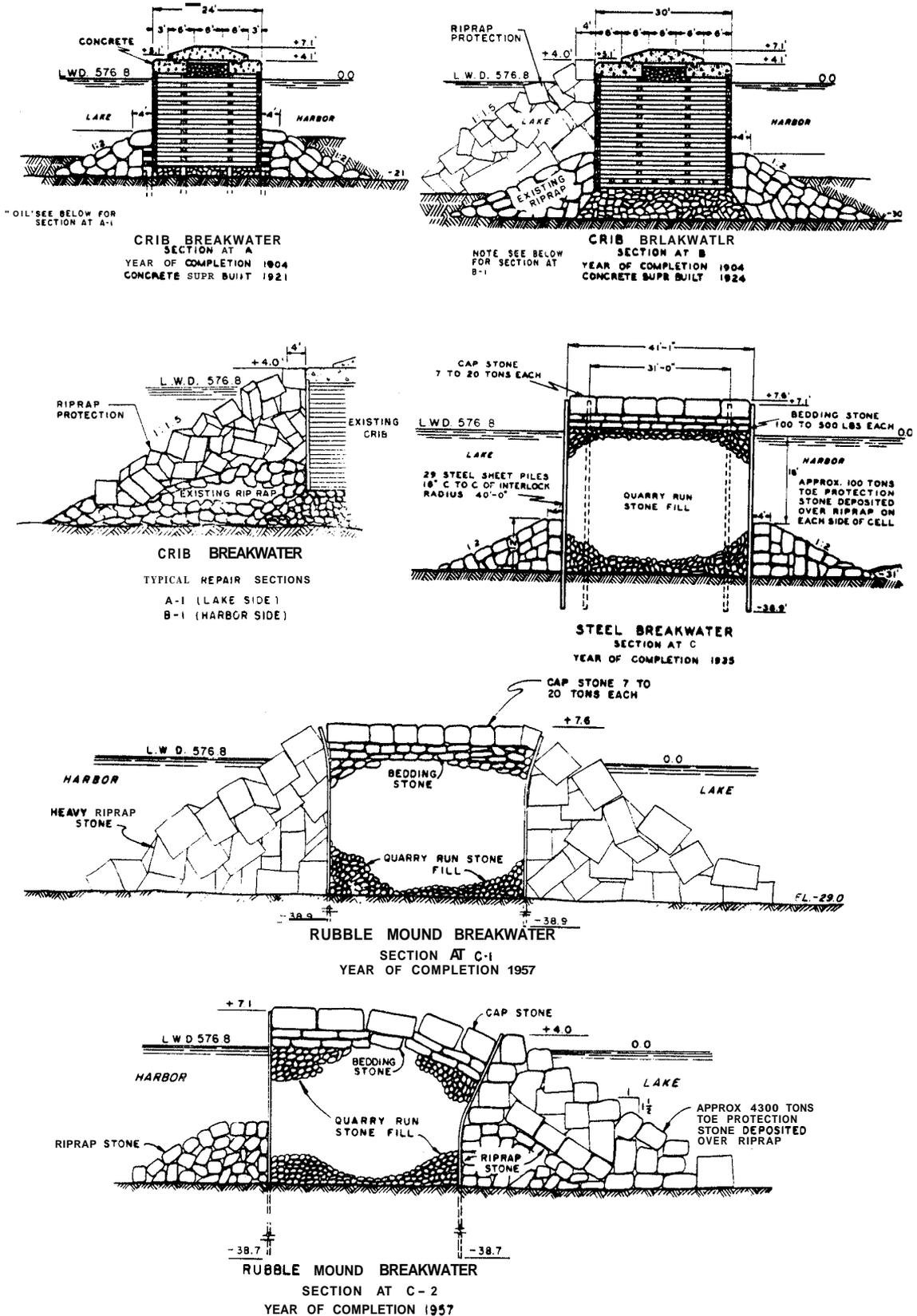


Figure 101. Typical structure cross sections, Calumet Harbor, Illinois and Indiana

Table 39

Indiana Harbor BreakwatersIndiana Harbor, Indiana

Date(s)	Construction and Rehabilitation History
1922	Construction of a 1,120-ft-long north breakwater (Figure 102, Section A) was completed. The breakwater was built of rubble-mound construction. It had a crest el of +6 ft lwd and side slopes of 1V:1.5H (Figure 103, Section A). Armor stone sizes along the crest were 7 tons (minimum), and armor stone along the slope (beneath the water surface) ranged from 1 to 7 tons with an average weight of 3 tons.
1926	Construction of a 201-ft-long east breakwater (Figure 102, Section B) was completed. The breakwater was a stone-filled concrete structure (Figure 103, Section B) built on a stone base. It had a crest el of +6.1 ft lwd and a width of 8.3 ft.
1935	A 2,324-ft-long lakeward rubble-mound extension of the each breakwater was completed (Figure 103, Section C). It had a crest el of +9.0 ft lwd, a crest width of 10 ft, and 1-V:1.5-H slide slopes. Armor stones along the crest ranged from 7 to 20 tons, and armor along the slope (beneath the water surface) ranged from 2 to 7 tons (Figure 103, Section C).
1951- 1957	A series of model tests was conducted (Hudson and Housley 1959) to determine the extent of reflected waves in the navigation channel and remedial measures required to alleviate the problems.
1986	Maintenance costs have been low throughout the lifetime of the breakwaters, and the structures are presently in good condition.

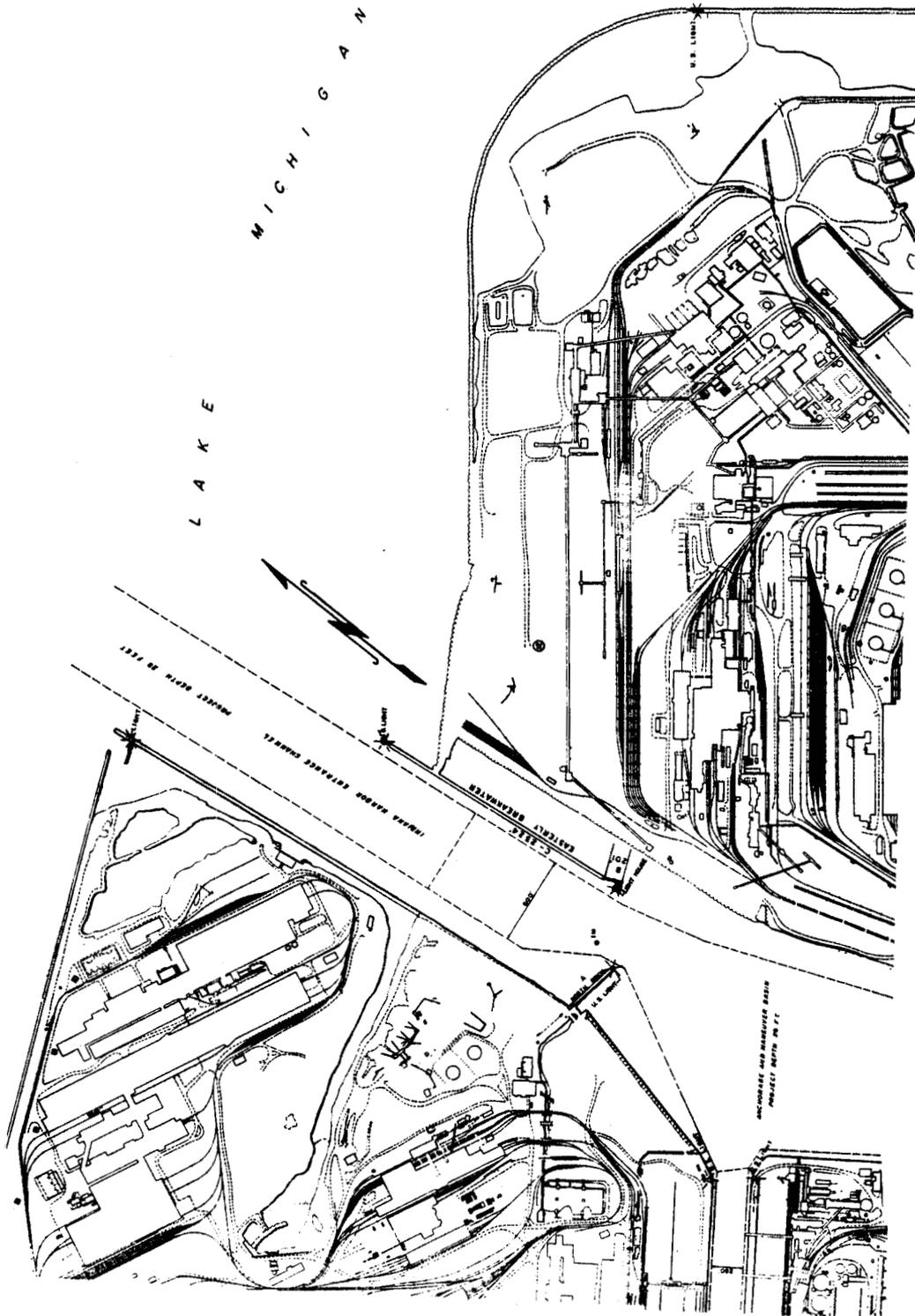
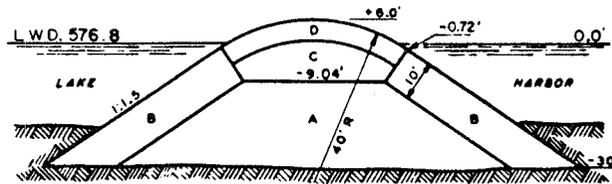


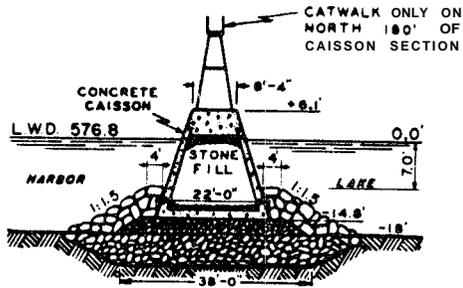
Figure 102. Indiana Harbor, Indiana



NORTHERLY BREAKWATER

SECTION AT A

YEAR OF COMPLETION 1922
 A STONE-QUARRY RUN
 B STONE-1 TO 7 TONS AV 3 TONS
 C STONE-MIN 500# MAX. 2000#
 D STONE-MIN 7 TONS

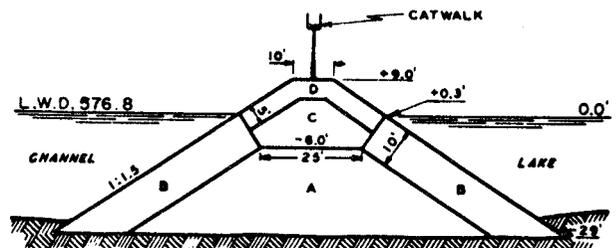
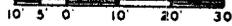


EASTERLY BREAKWATER

SECTION AT B

YEAR OF COMPLETION 1926

SCALE OF SEC B



EASTERLY BREAKWATER

SECTION AT C

YEAR OF COMPLETION 1935
 A STONE-DUST TO 1 TON
 B STONE- 2 TO 7 TONS
 C STONE- 500# TO 1 TON
 D STONE- 7 10 20 TONS

Figure 103. Typical breakwater cross sections, Indiana Harbor, Indiana

Table 40
Burns Harbor Breakwater
Burns Waterway, Indiana

Date(s)	Construction and Rehabilitation History
1968	Construction of a 5,830-ft-long, rubble-mound breakwater (Figure 104) was completed. The structure had a crest el of +14 ft lwd with a width of 17 ft. Armor stones ranging from 10 to 16 tons were placed with side slopes of 1V:1.5H . Model tests were conducted to determine breakwater stability (Jackson 1967).
1975	An inspection of the breakwater indicated that settlement of the structure in several locations below the constructed +14-ft-lwd crest el had occurred, and the breakwater was subsequently being overtopped during all seasons by less than the design waves. A total of 16,730 tons of stone was placed during the year. Stone sizes ranged from 3 to 16 tons having a 9-ton average.
1976	A total of 17,267 tons of stone ranging from 3 to 16 tons (9-ton average) was placed on the breakwater.
1977	A total of 10,027 tons of stone ranging from 3 to 16 tons (9-ton average) was placed on the breakwater.
1978	A total of 14,340 tons of stone ranging from 3 to 16 tons (9-ton average) was placed on the breakwater.
1980	A total of 47,334 tons of stone ranging from 3 to 16 tons (9-ton average) was placed on the breakwater.
1984	A storm in March caused damage to the breakwater dislodging armor stone in many areas and the overall integrity of the above-water stone placement.
1986	The breakwater has undergone extensive maintenance and rehabilitation since its construction because of structure slumping. The exact cause of the slumping is not known. A study is presently being conducted to identify the cause of the problem where remedial measures can be taken.

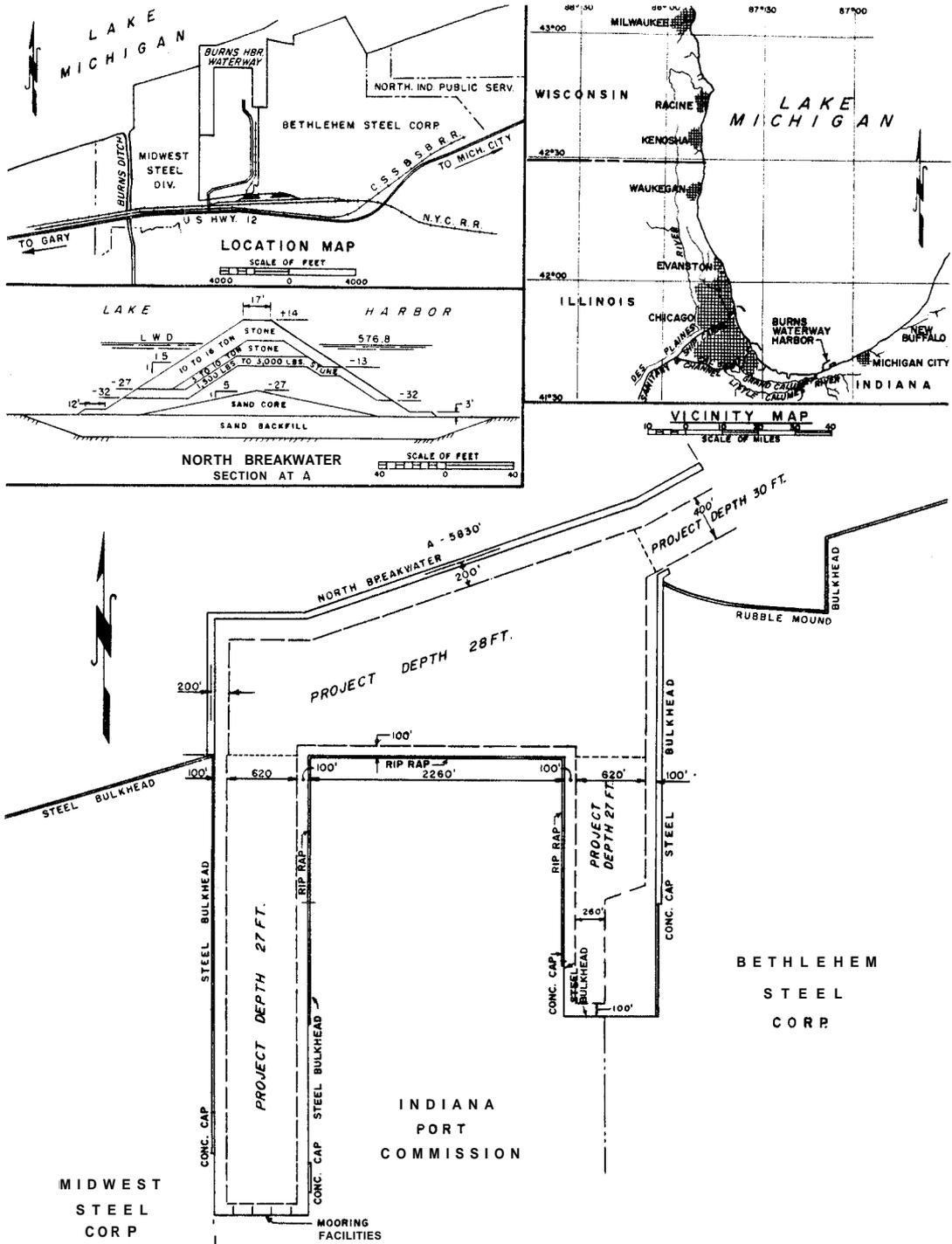


Figure 104. Burns Harbor, Indiana

Table 41
Michigan City Harbor Structures
Michigan City, Indiana

Date(s)	Construction and Rehabilitation History
1884	Construction of the 1,000-ft-long east breakwater (Figure 105, Section N) was completed. The breakwater was a timber crib structure with a width of about 29 ft (Figure 106, Section N).
1902	Construction of the 2,276-ft-long east pier (Figure 105, Sections G, H, J, K, L, M-1, and M) was completed. The pier was stone-filled timber crib structures (Figure 106) that ranged from about 18 to 34 ft in width.
1903	Construction of the 1,304-ft-long detached breakwater (Figure 105, Sections A, B, and C) was completed. This breakwater also was a timber crib structure (Figure 107, Sections A, B, and C) built on a stone base and was 30 ft in width.
1909	Construction of the 835-ft-long west pier (Figure 105, Sections D, E, and F) was completed. The pier consisted of a stone fill between woodpilings (Figure 107, Sections D, E, and F) that ranged in width from about 1.4 to 20 ft.
1911	The lakeward head of the detached breakwater (Figures 105 and 107, Section C) was capped with a concrete superstructure. The crest el of the breakwater was +10.5 ft lwd.
1923	The shoreward head of the detached breakwater (Figures 105 and 107, Section A) was capped with a concrete superstructure to an el of +6.1 ft lwd.
1925	The trunk section of the detached breakwater (Figures 105 and 107, Section B) was capped with a concrete superstructure to an el of +6.1 ft lwd.
930	The shoreward portion of the east pier (Figures 105 and 106, Sections G, H, J, K, and L) was capped with concrete and/or stone superstructures. The crest el of the pier was installed at +7.85 ft lwd, and the crest widths ranged from 18 to 34.25 ft in width.
931	The lakeward portions of the east (Figures 105 and 106, Sections M and M-1) and west (Figures 105 and 107, Sections E and F) piers were capped with stone and concrete superstructures. The crest el of the east pier was +10.1 ft lwd (Sections M and M-1). The crest of the lakeward portion of the west pier (Section F) was +10.52 ft lwd and the adjacent portion (Section E) was installed at an el of +7.85 ft lwd.

(Continued)

Table 41 (Concluded)

Date(s)	Construction and Rehabilitation History
1939- 1940	Riprap was placed on each side of the lakeward head of the detached breakwater (Figure 107, Section A). The crest of the riprap was placed at an el of +5.1 ft lwd, and side slopes of 1V:1.3H were installed. The east breakwater (Figures 105 and 106, Section N) was capped with a concrete superstructure to an el of +11.4 ft lwd.
1948	The shoreward end of the west pier (Figures 105 and 107, Section D) was reconstructed resulting in a pier that was 21 ft in width.
1968	Riprap was placed along both sides of the outer 1,106 ft of the detached breakwater (Figure 105, Sections B and C); both sides of the outer 537 ft of the west pier (Figure 105, Sections E and F); and along the outer 1,146 ft of the east pier (Figure 105, Sections M and M-1). Section M-1 included riprap on the lakeside only (Figure 106) with the crest at an el of +4 ft lwd. The outer end of the east pier (Figure 106, Section M) included riprap with a +4 ft lwd berm on the lakeside and a -2 ft el on the harbor side. Side slopes were 1V:1.5H. Riprap along the west pier (Figure 107, Sections E and F) was installed with side slopes of 1V:1.5H and an el of +4 ft lwd on the lakeside and below the surface of the water on the harbor side for toe protection. Riprap installed along both sides of the outer end of the detached breakwater (Figure 107, Sections B and C) was installed at an el of +4 ft lwd with side slopes of 1V:1.5H, with the exception of the head (Section C) which had a slope of 1V:2H on the lakeside.
1972	The shoreward portion of the west pier (Figure 105, Section D) and a portion of the east pier (Figure 105, Sections H and J) were rehabilitated. Steel sheetpiling was driven on each side of the existing piers, and the voids were filled with stone. The west pier (Figure 107, Section D) was capped with concrete with a crest el of +7 ft lwd and a new width of 28 ft. The east pier (Figure 106, Sections H and J) consisted of a concrete and stone cap installed at a cost el of +7.85 ft lwd. The inner portion (Section H) was 34 ft in width and remaining portion (Section J) was built 38 ft wide.
1978	The concrete cap on the shoreward end of the detached breakwater (Figures 105 and 107, Section A) was rebuilt.
1979	An inspection of the structures indicated that the east breakwater was in fair condition and the other structures generally were in good condition. Riprap on the lakeside of the detached breakwater was low in areas, and the concrete cap on the east pier had deteriorated in areas. Subsequent maintenance repairs have been performed.
1986	The structures are presently in good condition.

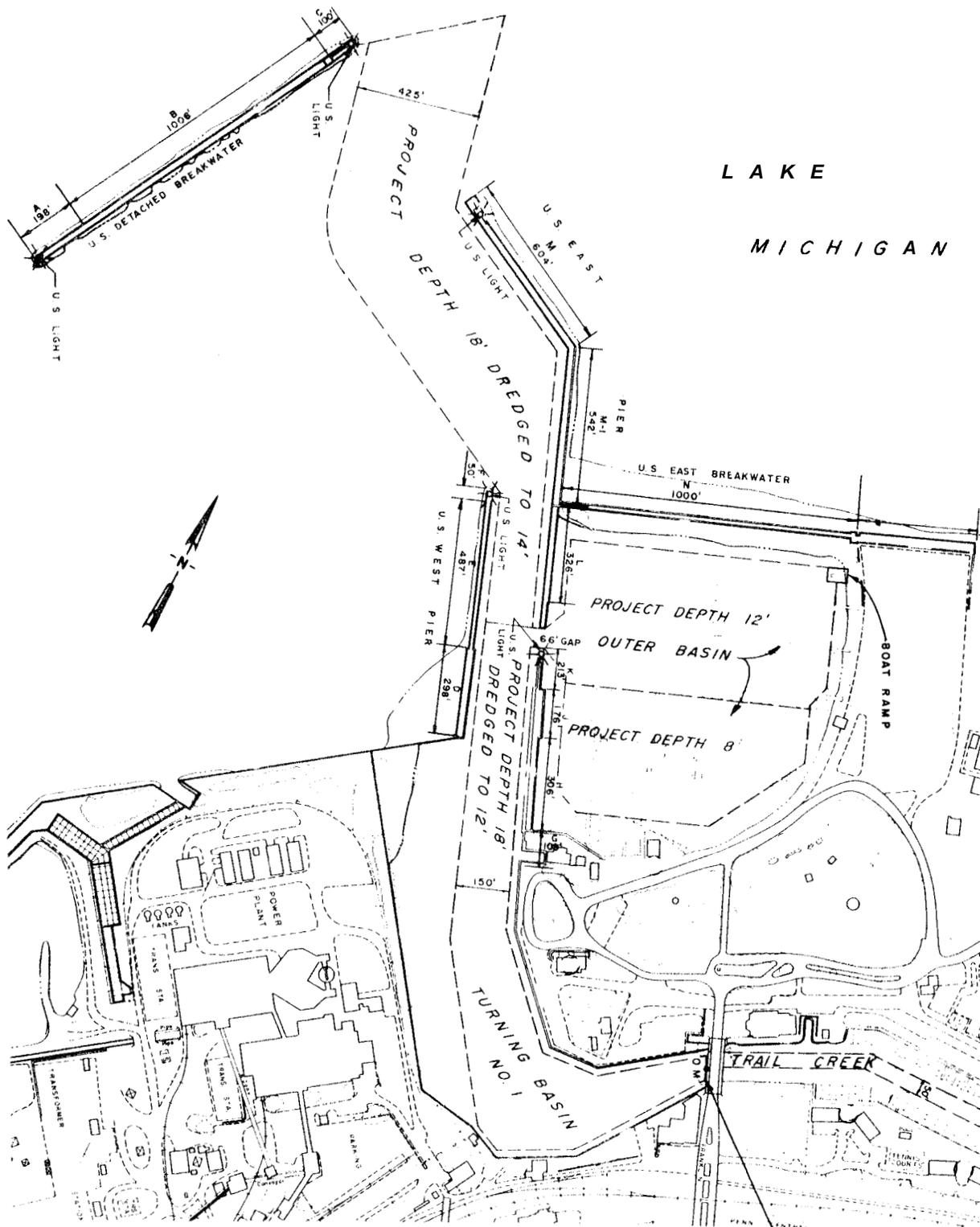
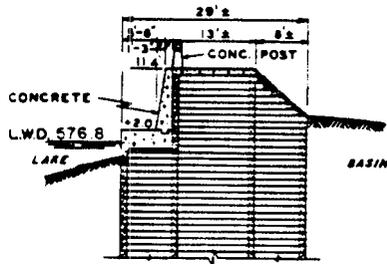
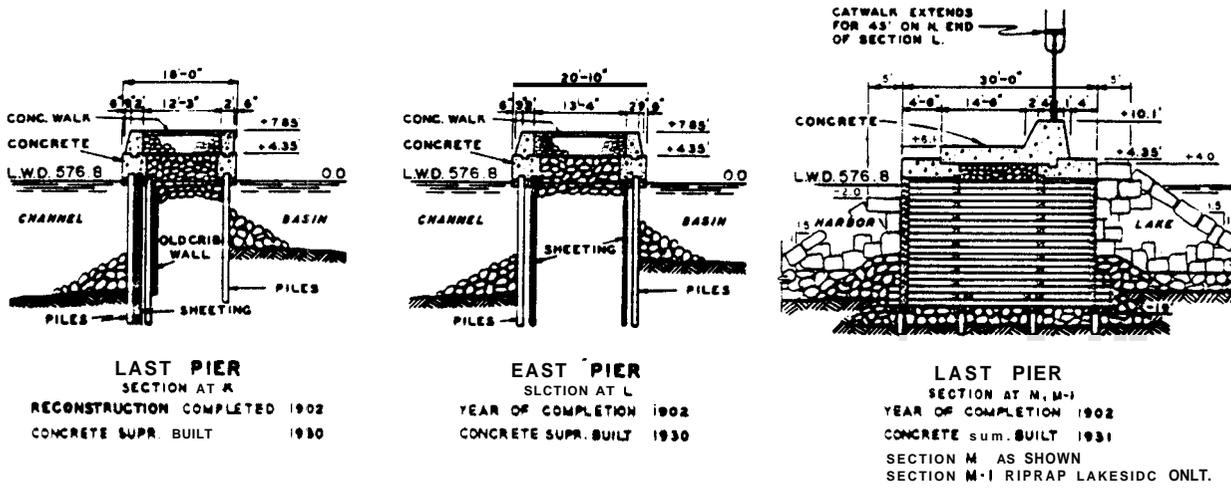
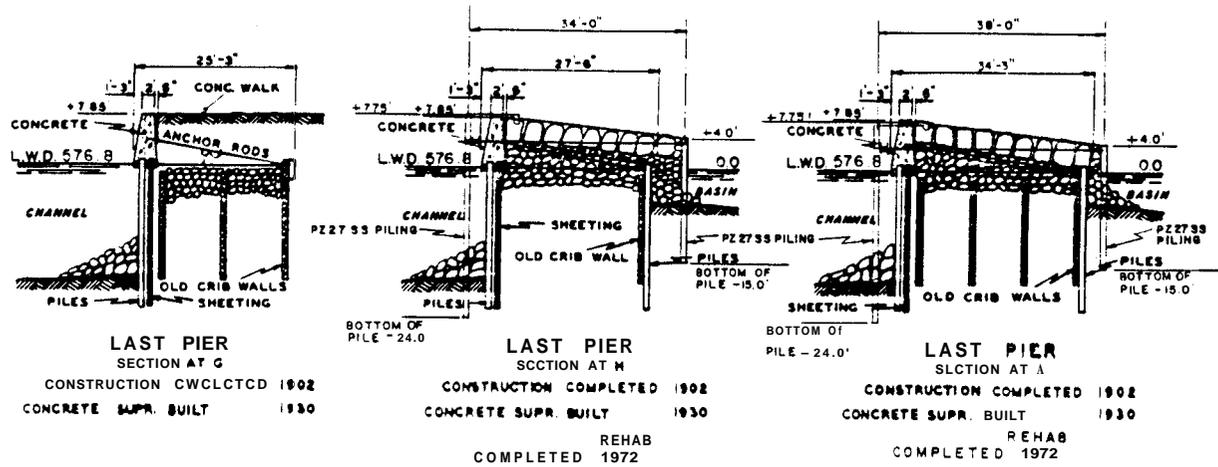
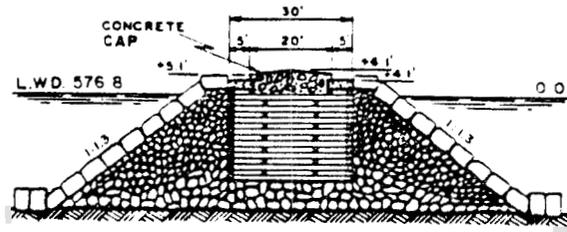


Figure 105. Michigan City Harbor, Indiana

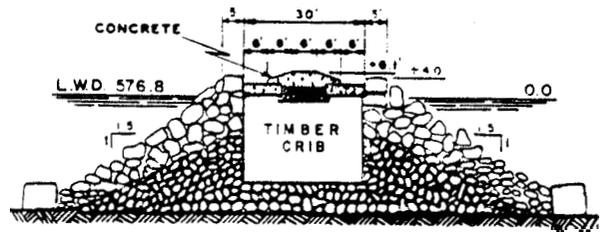


CAST BREAKWATER SECTION AT N
 YEAR OF COMPLETION 1884
 CONCRETE SUPR. WILT 1940

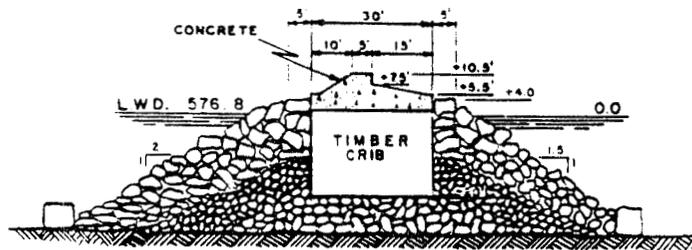
Figure 106. Typical east structure cross sections, Michigan City Harbor, Indiana



DLTACHCD BREAKWATER
SECTION AT A
YEAR OF COMPLETION 1903
CONCRETE SUPR BUILT 1923
RIPRAP PLACED 1939-40
CONCRETE CAP REBUILT 1978

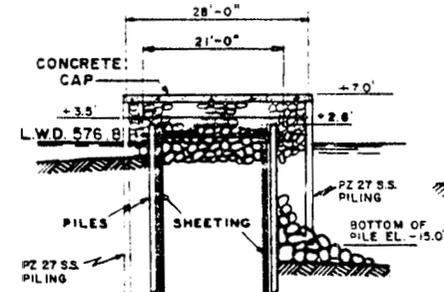


DETACHED BREAKWATER
SECTION AT B
YEAR OF COMPLETION 1903
CONCRETE SUPR BUILT 1923
RIPRAP PLACED 1968-69

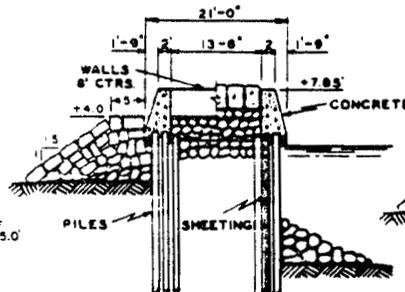


DETACHED BREAKWATER
SECTION AT C
YEAR OF COMPLETION 1903
CONCRETE SUPR BUILT 1911
RIPRAP PLACED 1968-69
SCALE OF SECTIONS A,B,C

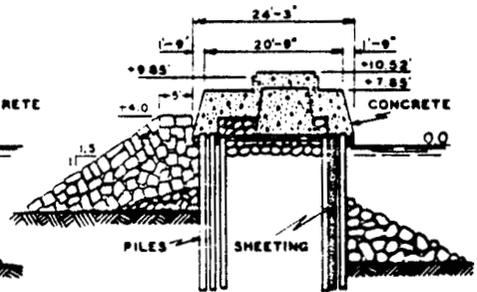
10' 0 10' 30' 50' 70'



WEST PIER
SECTION AT D
YEAR OF COMPLETION 1909
RECONSTRUCTION COMPLETED 1948
REHAB COMPLETED 1972



WEST PIER
SECTION A? E
YEAR OF COMPLETION 1909
CONCRETE SUPR BUILT 1931
RIPRAP PLACED 1968-69



WEST PIER
SECTION AT F
YEAR OF COMPLETION 1909
CONCRETE SUPR BUILT 1931
RIPRAP PLACED 1968-69

Figure 107. Typical structure cross sections, Michigan City Harbor, Indiana

Table 42

New Buffalo Harbor BreakwatersNew Buffalo, Michigan

Date(s)	Construction and Rehabilitation History
1975	<p>Construction of two breakwaters totaling 2,045 ft in length (Figure 108) was completed at the mouth of the Galien River. The outer 480 ft of the north breakwater (Figures 108 and 109, Reach-A) consisted of a rubble-mound structure with a crest el of +9.0 ft lwd and a width of 12 ft. Armor stone ranged from 10 to 16 tons (12-ton average). The adjacent shoreward portion of the north breakwater and the outer end of the south breakwater (Figures 108 and 109, Reach B) consisted of a rubble-mound structure with a crest width of 10 ft and an el of +8.0 ft lwd. Armor stone on this portion of the breakwater ranged from 5 to 10 tons (6-ton average). The adjacent shoreward portions of both structures (Figures 108 and 109, Reach C) involved a rubble-mound breakwater with a crest el of +8.0 ft lwd and a crest width of 8 ft. Armor stone ranged from 3 to 5 tons (4-ton average). The adjacent shoreward portions of the breakwaters (Figures 108 and 109, Reach D) included a rubble-mound structure with a crest el of +7.0 ft and a crest width of 6 ft. Armor stone ranged from 2 to 4 tons (3-ton average). All rubble-mound portions of the breakwaters had side slopes of IV:1.5H. The inner ends of both breakwaters (Figure 108, Reach E) consisted of vertical steel sheetpiling with an el of +7 ft lwd. Riprap was placed on each side of the sheetpiling for toe protection. The breakwater configuration was model tested prior to construction (Dai and Wilson 1967).</p>
1980	<p>An inspection of the structures at the site indicated that voids existed in the outer reach (Reach A) of the north breakwater and minor Settlement had occurred, particularly around the head of the structure adjacent to the navigation lights. The remaining portion of the rubble-mound north breakwater also consisted of many voids with some stones deteriorating (cracking or crumbling into smaller pieces). The outer portion of the south breakwater (Reaches B and C), although in better condition than the north structure, also had experienced some settlement and contained some gaps where waves washing through the structure was noted. The inner portion of the breakwaters was in good condition.</p>
1983	<p>Stone was placed in the voids of the outer portions of each breakwater (Reaches A and B, north breakwater, and Reach B, south breakwater, Figure 108). A site inspection in the latter part of the year revealed that some of the smaller stone (used to fit the voids) had washed out. Voids in the trunk sections of the breakwater (Reaches C and D, north structure, and Reach C, south structure) still existed along with settlement of 1 to 2 ft in some areas.</p>
1986	<p>The structures are presently considered in fair condition. Maintenance repairs of the breakwater have been recommended but not yet implemented.</p>

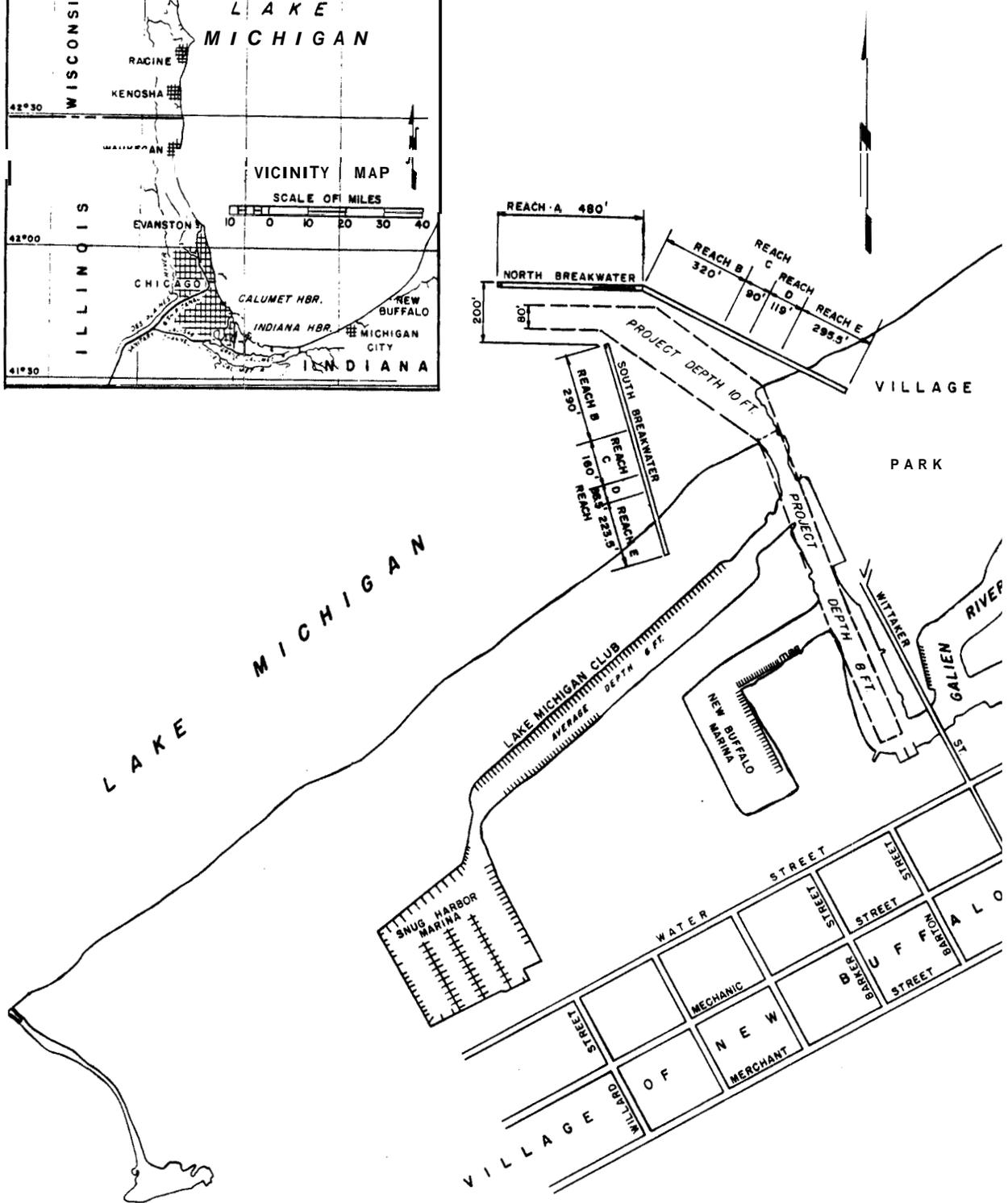
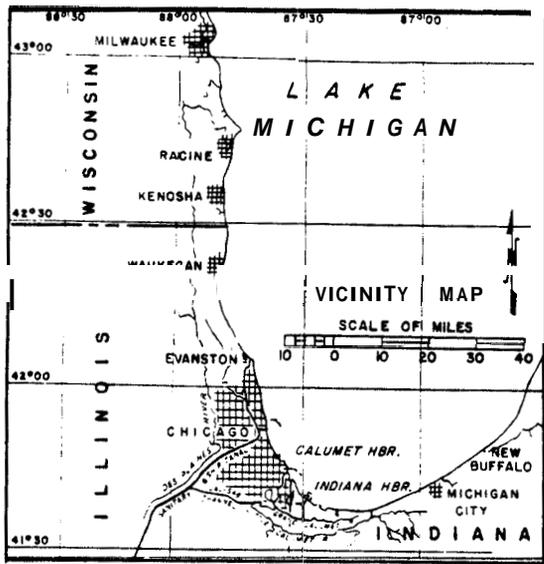
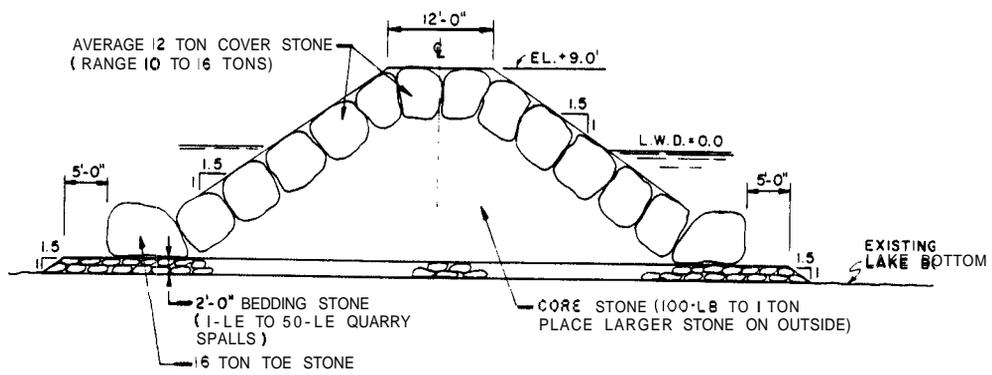
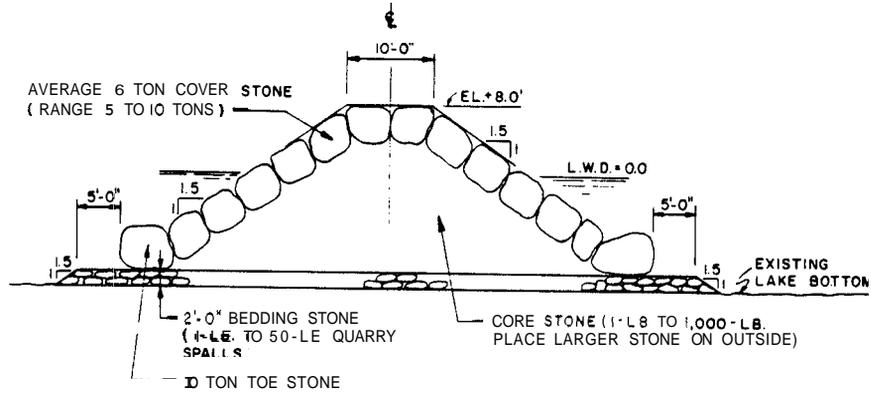


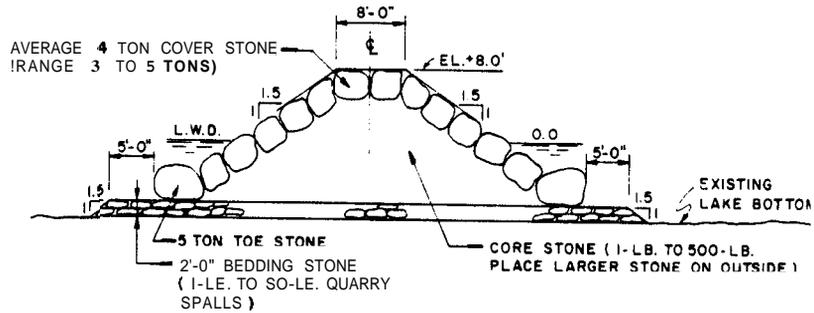
Figure 108. New Buffalo Harbor, Michigan



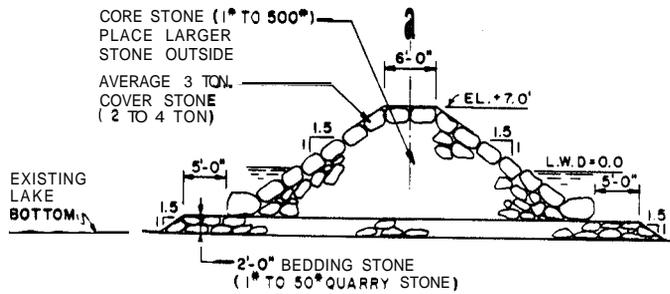
REACH A
BUILT 1975



REACH B
BUILT 1975



REACH C
BUILT 1975



REACH D
BUILT 1975

Figure 109. Typical breakwater cross sections,
New Buffalo Harbor, Michigan

Table 43
Saint Joseph Harbor Piers
Saint Joseph, Michigan

Date(s)	Construction and Rehabilitation History
1836- 1866	Construction of the inner 948 ft of the north pier (Figure 110, Sections C, D, and E) was completed during this time. (Figures 110, 111, 112, and 113 illustrate structures at St. Joseph Harbor.) The shoreward 573-ft portion was constructed of woodpilings spaced about 12 ft apart and filled with stone (Figure 112, Section E). The remaining portion of the work consisted of stone-filled timber crib structures that were 24 ft wide (Figure 112, Sections C and D).
1875- 1979	The north structure was extended lakeward by 354 ft (Figure 110, Section B) during this period. The pier extension consisted of a 24-ft wide, stone-filled, timber crib structure (Figure 112, Section B).
1880- 1881	The north structure again was extended lakeward (Figure 110, Sections A and A4). The length of the pier extension was 747 ft, and the structures were built of stone-filled timber cribs that were 30 ft in width (Figure 111, Sections A and A4).
1889- 1900	Construction of the inner 819 ft of the south pier (Figure 110, Sections I, J, K, and L) was completed during this time frame. The pier was constructed of woodpilings spaced from 26 to 34 ft apart and filled with earth and stone (Figure 113, Sections I, J, K, and L).
1901- 1903	Construction of the lakeward 709 ft of the north pier (Figure 110, Sections A1, A2, and A3) and the lakeward 1,784 ft of the south pier (Figure 110, Sections F, G, and H) was completed during this period. Both piers were constructed of stone-filled timber cribs built on a stone base. The entire north pier extension consisted of timber cribs that were 30 ft in width (Figure 111, Sections A1, A2, and A3). The south pier extension was 30 ft wide at its lakeward end (Figure 112, Section F) and 24 ft wide where it extended shoreward (Figure 112, Section G and Figure 113, Section H).
1911	The lakeward portion of the south pier (Figure 110, Section F) was capped with a concrete superstructure (Figure 112, Section F).
1918- 1919	The inner portion of the north pier (Figure 110, Section E) was capped with a concrete superstructure to an el of +7.0 ft lwd (Figure 112, Section E).
1924- 1925	A 426-ft-long portion of the south pier (Figure 110, Section H) was capped with a concrete and stone superstructure (Figure 113, Section H) to an el of +7.5 ft lwd.

(Continued)

(Sheet 1 of 3)

Table 43 (Continued)

Date(s)	Construction and Rehabilitation History
1927	Portions of the north (Figure 110, Sections C and D) and the south pier (Figure 110, Section I) were capped with concrete and stone superstructures. The crest el of the north pier was +7.0 ft lwd (Figure 112, Sections C and D) and the south pier had an el of +7.5 ft lwd (Figure 113, Section I).
1931	The lakeward end of the north pier (Figure 110, Sections A1, A2, A3, A4, A, and B) were capped with a concrete superstructure (Figure 111, Sections A1, A2, A3, A4, and A, and Figure 112, Section B).
1934	A 376-ft-long portion of the south pier (Figure 110, Section G) was capped with a concrete superstructure (Figure 112, Section G).
1941	The shoreward portion of the south pier (Figure 110, Sections J, K, and L) was capped with a concrete superstructure on the channel side (Figure 113, Sections J, K, and L). The crest el of the cap was 7.0 ft lwd, and it was backfilled with earth and stone.
1952- 1953	Portions of the north pier (Figure 110, Sections A1 and A2) were repaired by enclosing the structure in a steel sheetpiling encasement (Figure 111, Sections A1 and A2). Voids were filled with concrete, and the pier was recapped with concrete. The outer portion (Section A1) had a crest el of +8.0 ft lwd and was 35.5 ft wide, while the other portion (Section A2) was +7.1 ft lwd with a width of 35.5 ft. Riprap toe protection was also installed on each side of the piers adjacent to the new sheet-pile walls.
1961	Additional portions of the north pier were repaired (Figure 110, Section A4, C, D, and E) by using steel sheetpiling. The shoreward portions of the pier were repaired by installing sheetpiling on the channel sides of the existing structures (Figure 112, Sections C, D, and E) and 'backfilling the voids with stone prior to capping the area with concrete. The el of this portion of the pier was +7.0 ft lwd. The remaining portion of the pier was repaired by enclosing the structure in a steel sheet-pile encasement (Figure 111, Section A3). Voids were filled, and the structure was capped with concrete to an el of about +7.6 ft lwd. The pier width was approximately 36 ft.
1963	A portion of the north pier (Figure 110, Section A4) and a portion of the lakeward end of the south pier (Figure 110, Section F) were repaired by enclosing the structures in steel sheetpiling encasements (Figure 111, Section A4 and Figure 112, Section F). Voids between the sheetpiling were filled with stone, and the piers were capped with concrete. The structures were about 36 ft wide and had crest els of approximately 7.0 ft lwd after repairs were made. Riprap toe protection was also installed on each side of the piers.

(Continued)

(Sheet 2 of 3)

Table 43 (Concluded)

Date(s)	Construction and Rehabilitation History
1972	Additional portions of the south pier (Figure 110, Sections F, G, K, and L) were repaired. Section G and a portion of Section F were enclosed in a steel sheet-pile encasement (Figure 112). The voids between the sheetpiling were filled with stone, and the pier was capped with concrete to an el of about +7.0 ft lwd. After repairs the width of the structures was 36 ft (Section F) and 31 ft (Section G). Steel sheetpiling was installed on the channel side of the shoreward end of the south pier (Figure 113, Sections K and L). The voids were filled with stone, and a concrete cap installed.
1976	Another portion of the south pier underwent repairs (Figure 110, Sections I and J). Steel sheetpiling was installed on the channel side of the pier (Figure 113, Sections I and J), and the voids were filled with stone. The pier was capped with concrete to an el of +7.5 ft lwd.
1982	Stone fill in portions of the north pier (Figure 110, Sections A1, A, and B) was replenished, and new concrete caps were installed in these areas.
1985	An inspection of the structures revealed that fill stone was 3 to 6 ft low in areas of the north pier and that cracking of the superstructure was prevalent in places. It was also noted that fill stone in the south pier was settling which was also causing cracking of the concrete superstructure. Maintenance repair of the structures has been recommended but not yet performed. The piers are considered to be in fair condition.

(Sheet 3 of 3)

LAKE MICHIGAN

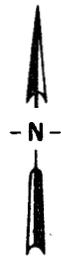


Figure 110. Saint Joseph Harbor, Michigan

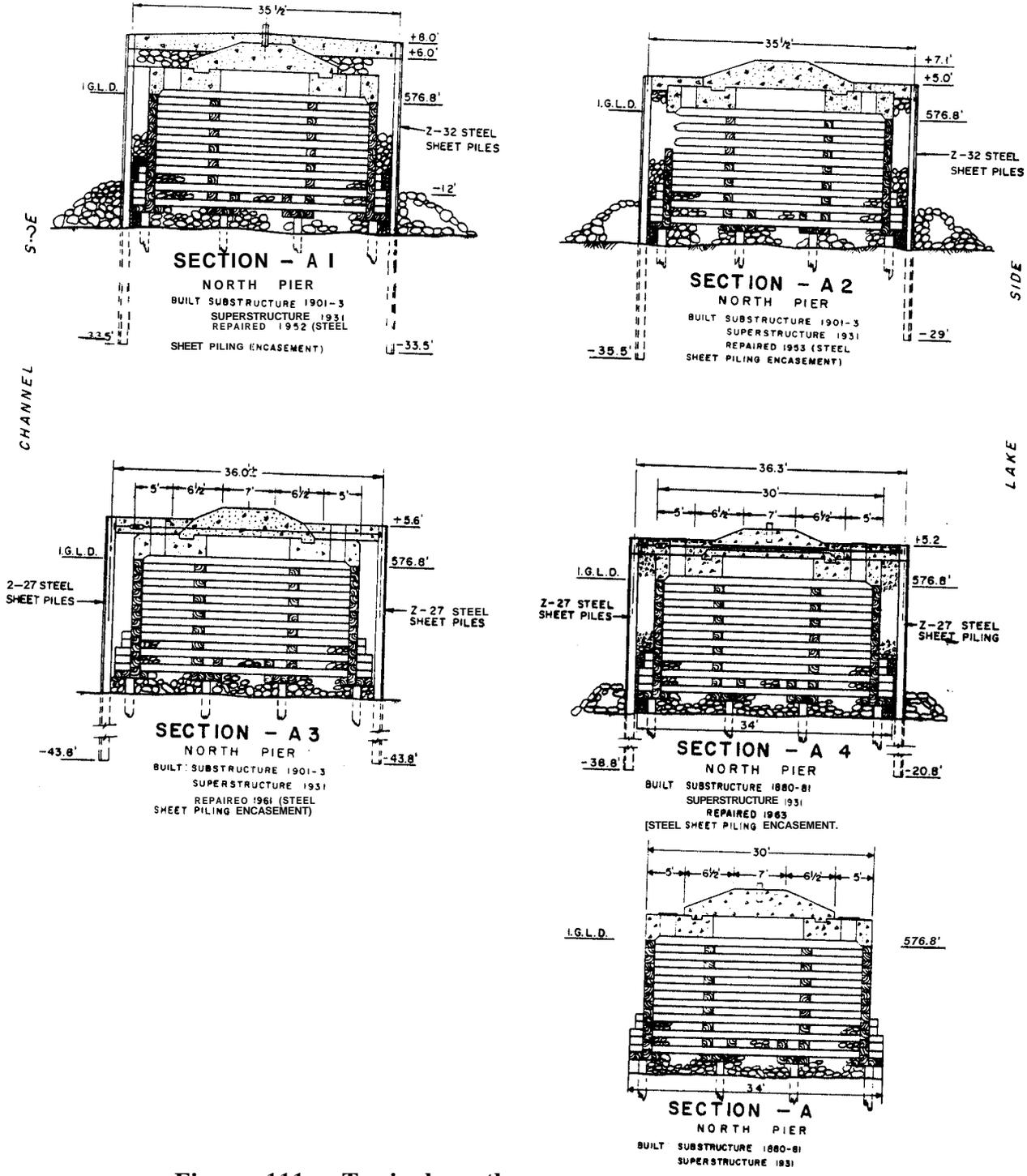


Figure 111. Typical north pier cross sections, Saint Joseph Harbor, Michigan

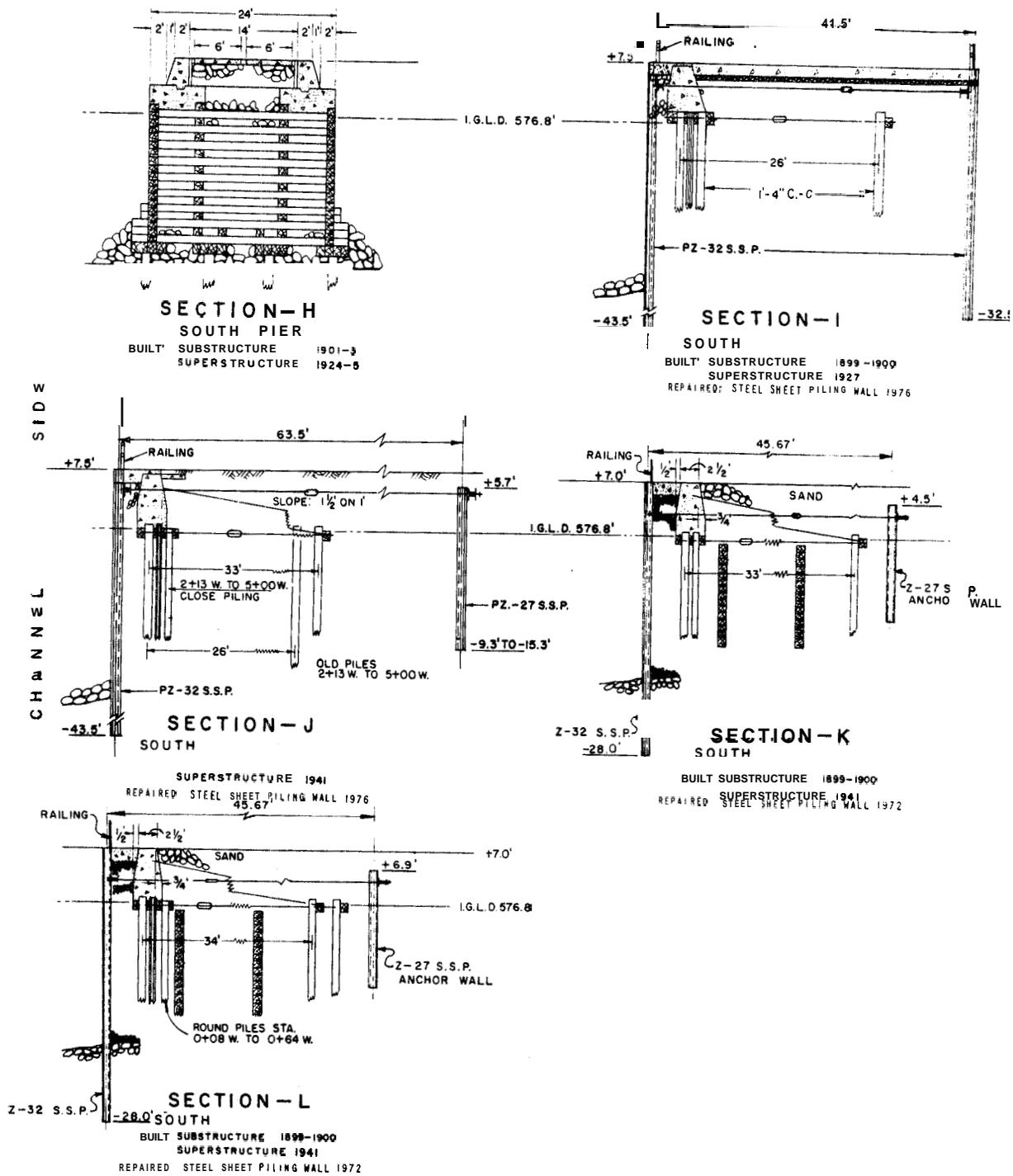


Figure 113. Typical structure cross sections, Saint Joseph Harbor, Michigan

Table 44
South Haven Harbor Piers
South Haven, Michigan

Date(s)	Construction and Rehabilitation History
1868	Construction of the shoreward portion of the south pier (Figure 114, Section L) was completed. (Figures 114, 115, 116, and 117 illustrate structures at South Haven Harbor.) The pier was built with stone-filled timber crib structures and was about 20 ft in width (Figure 117, Section L).
1870- 1874	Construction of a 287-ft-long portion of the north pier (Figure 114, Section C) was completed. The structure consisted of a stone-filled timber crib that was 23 ft in width (Figure 115, Section C).
1871- 1874	Extension of the south pier by 150 ft (Figure 114, Sections K and K2) was completed during this period. The pier extension consisted of a 32-ft-wide, stone-filled timber crib structure (Figure 117, Sections K and K2).
1887	An additional 50-ft extension of the south pier (Figure 114, Section K1) was completed. The extension consisted of a stone-filled timber crib structure that was 30 ft in width (Figure 117, Section K1).
1888	Construction of the shoreward 320 ft of the north pier (Figure 114, Sections D and D1) was completed. These structures were 20-ft-wide stone-filled timber cribs (Figure 115, Sections D and D1).
1897- 1898	An additional 179-ft-long lakeward extension (Figure 114, Section J) of the south pier was constructed. The extension consisted of stone-filled wood-pilings spaced 25 ft apart (Figure 116, Section J).
1899	Another 200-ft lakeward extension of the north pier (Figure 114, Section H) was completed. The pier was built of a stone-filled timber crib structure which was 24 ft in width (Figure 116, Section H).
1900	A 200-ft lakeward extension of the north pier (Figure 114, Section B) was constructed. The pier was constructed of stone-filled timber cribs that were 24 ft in width (Figure 115, Section B).
1912- 1913	Construction of the lakeward portions of the north and south piers (Figure 114, Section A) was completed. Both these structures were 24-ft-wide, stone-filled timber cribs (Figures 115 and 116, Section A).
1924- 1925	The shoreward 784 ft of the south pier (Figure 114, Sections H, J, K1, K, K2, and L) was capped with a stone and concrete superstructure. The crest el of this structure ranged from +5.5 to +7.1 ft lwd (Figure 116, Sections J and H; and Figure 117, Sections K1, K, K2, and L).
1930- 1931	The shoreward 807 ft of the north pier (Figure 114, Sections B, C, D, and D1) was capped with a concrete superstructure. Crest els ranged from +6.5 to +7.0 ft lwd (Figure 115, Sections B, C, D, and D1).

(Continued)

Table 44 (Concluded)

Date(s)	Construction and Rehabilitation History
1940	The landward portions of the north and south piers (Figure 114, Section A) were capped with stone and concrete superstructures resulting in pier crest els of +7.0 ft lwd (Figures 115 and 116, Section A).
1962- 1963	The entire north pier (Figure 114) was repaired during this time frame. Repairs consisted of installing steel sheetpiling on each side of the existing structures, filling the voids with stone, and capping the structure with concrete. Widths of the pier ranged from 31.5 to 40.5 ft (Figure 115, Sections A, B, C, D, and D1).
1964- 1965	A 179-ft portion of the south pier (Figure 114, Section J) was reconstructed. Steel sheetpiling was installed on each side of the existing pier forming a 32.7 ft-wide structure (Figure 116, Section J). The voids were filled with stone, and a concrete cap was installed.
1970- 1972	Additional portions of the south pier (Figure 114, Sections H, K1, K, K2, and L) were repaired during this period. These piers were repaired similar to the earlier ones by the installation of steel sheetpiling on each side of the existing pier. Voids were again stone filled and the structure capped (Figure 116, Section H; and Figure 117, Sections K1, K, K2, and L). Widths of the rehabilitated structure sections ranged from 30 to 42 ft.
1981	Riprap ranging from 1 to 6 tons was placed along the lakeside face of the north pier (Figure 114, Section A). Approximately 1,788 tons of stone was used that extended from the head of the pier 600 ft shoreward. Also, 38 tons of 2- to 4-in. stone was placed under the caps to replenish fill stone.
1982	Approximately 1,029 tons of riprap was placed along the north pier (Figure 114, Sections A and B) and 2,054 tons along the south pier (Figure 114, Section A). Three- to sixteen-ton stone was used for the purpose. Additionally, 40 tons of 1- to 3-ft stone was placed under the caps of the south pier to replenish fill stone.
1983	About 600 tons of 6- to 12-ton riprap was placed along the lakeside of the north pier shoreward of the riprap placement of 1981 and 1982.
1985	An inspection of the structures revealed that the north pier was in good condition. The lakeward end of the south pier (Figure 114, Section A) appeared stable and in fair condition. Separation, settlement, and cracking of the superstructure was noted, and maintenance repairs have been recommended. The remaining portions of the south pier were in good to excellent condition. An aerial view of the South Haven Harbor piers is shown in Figure 118.

1191

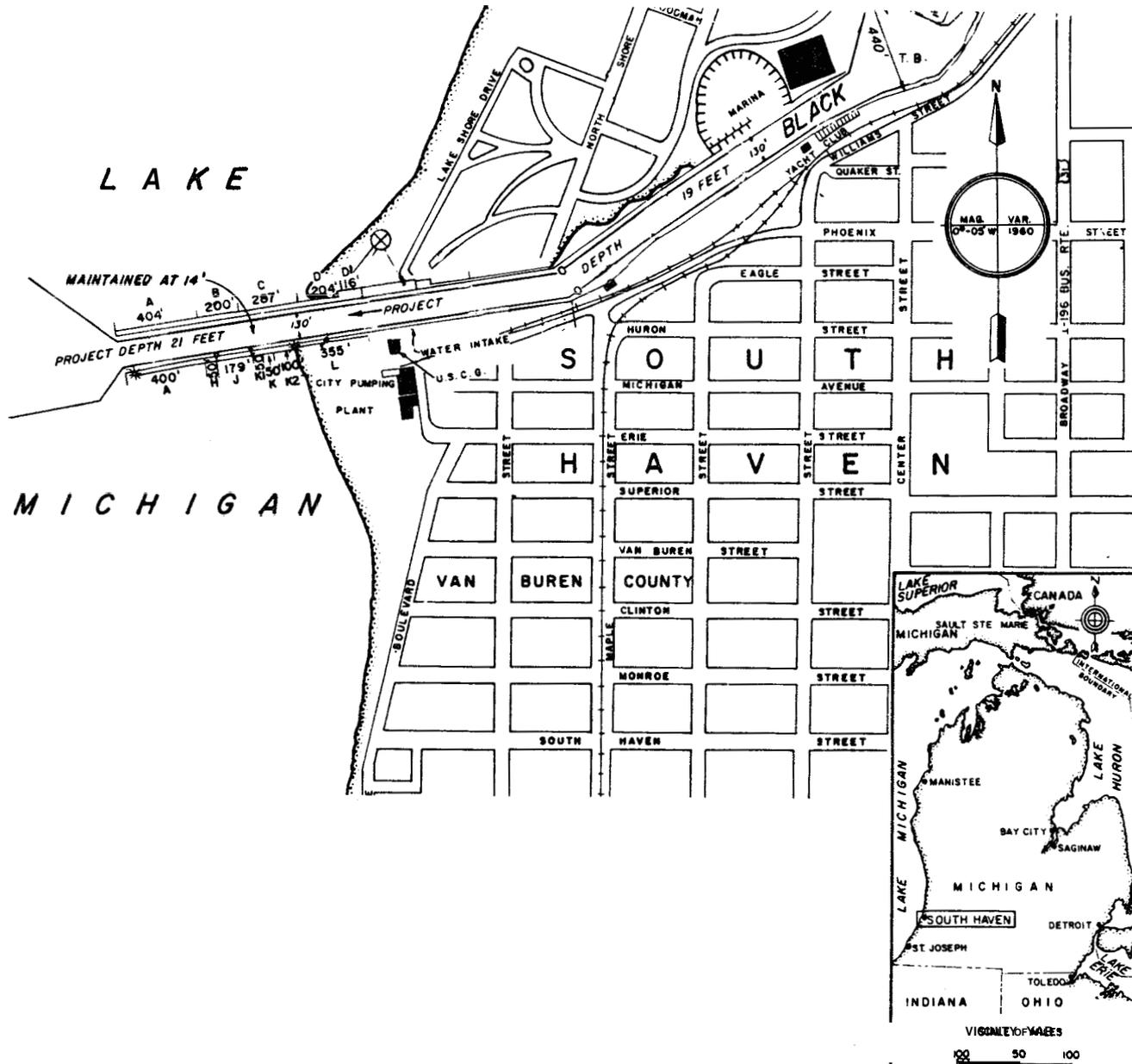
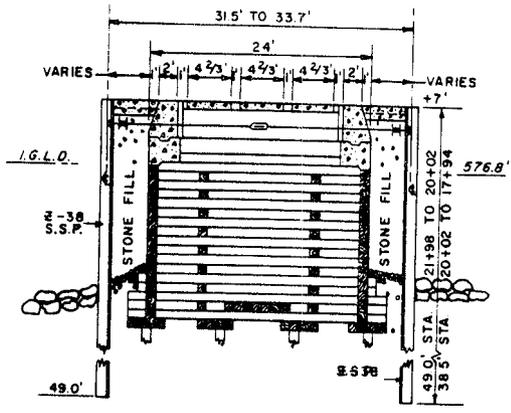
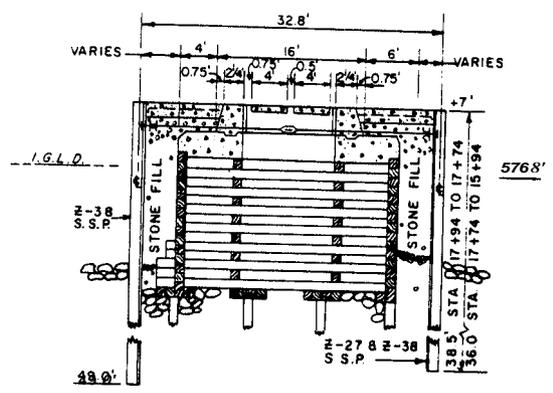


Figure 114. South Haven Harbor, Michigan



SECTION-A
NORTH PIER

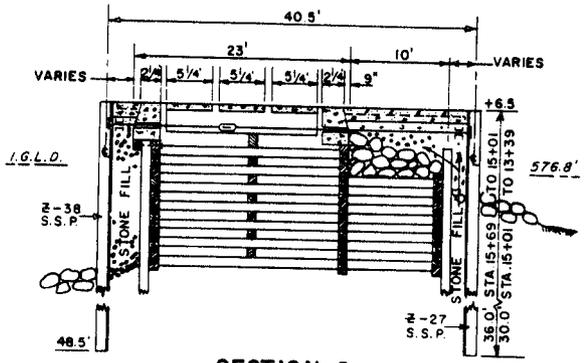
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SUPERSTRUCTURE 1940
REPAIRED 1962



SECTION-B
NORTH PIER

BUILT: SUBSTRUCTURE 1900
SUPERSTRUCTURE 1930
REPAIRED 1962

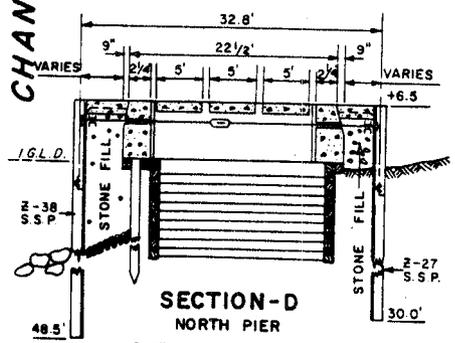
SIDE



SECTION-C
NORTH PIER

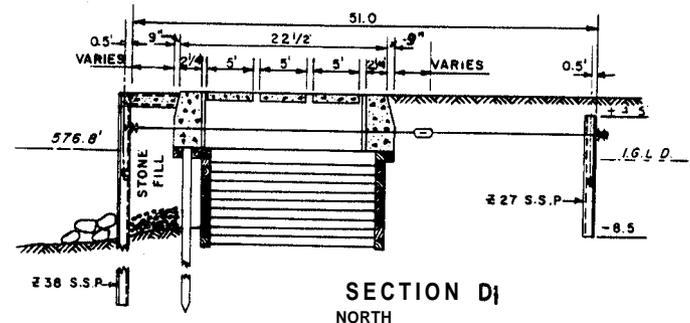
BUILT: SUBSTRUCTURE 1870-71, 73-74
SUPERSTRUCTURE 1930
REPAIRED 1962

CHANNEL



SECTION-D
NORTH PIER

BUILT: SUBSTRUCTURE 1888
SUPERSTRUCTURE 1931
REPAIRED 1963

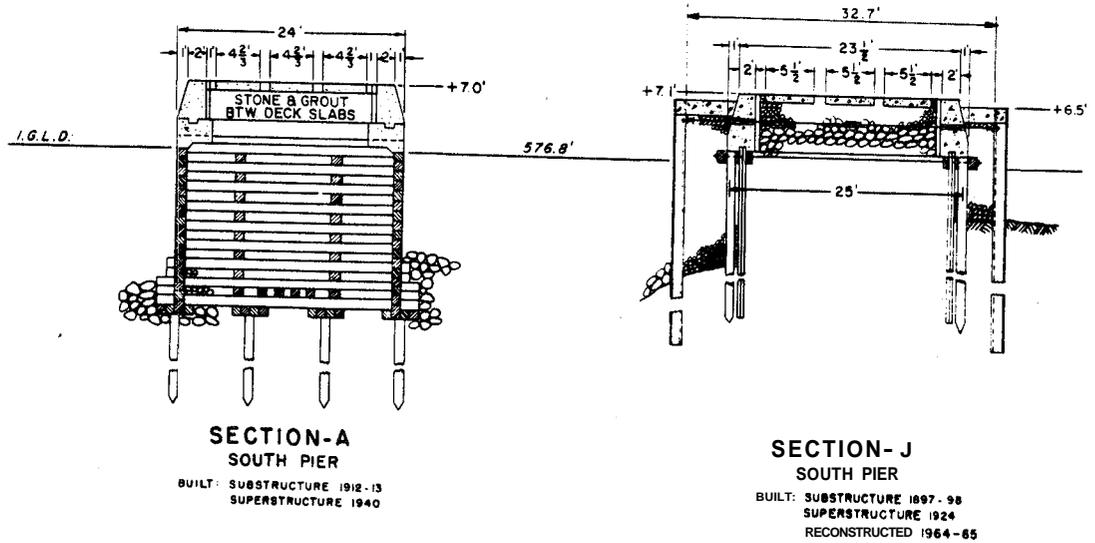


SECTION D1
NORTH

BUILT: SUBSTRUCTURE 1888
SUPERSTRUCTURE 1931
REPAIRED 1963

Figure 115. Typical north pier cross sections, South Haven Harbor, Michigan

SIDE



CHANNEL

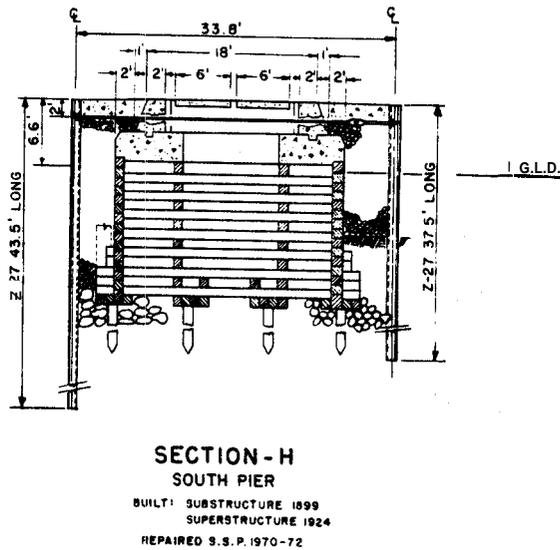
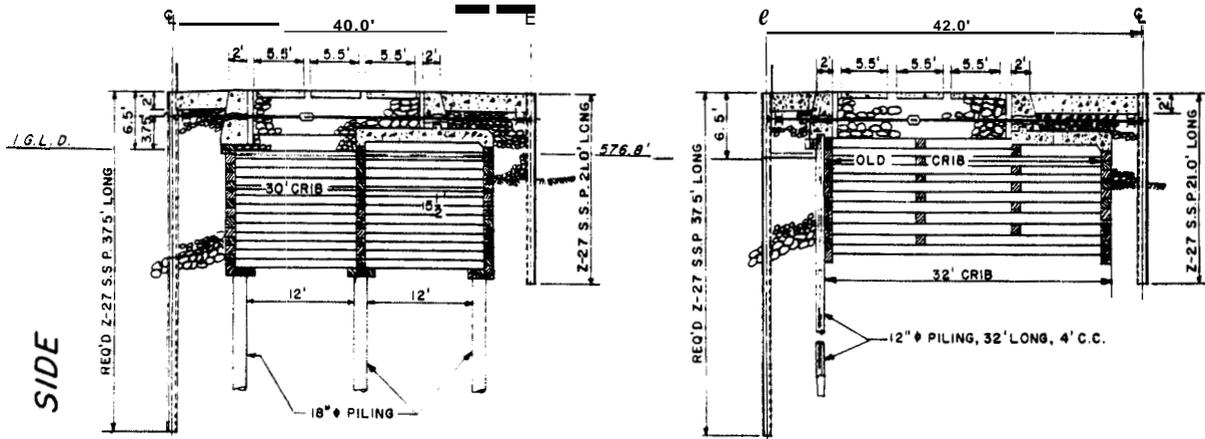
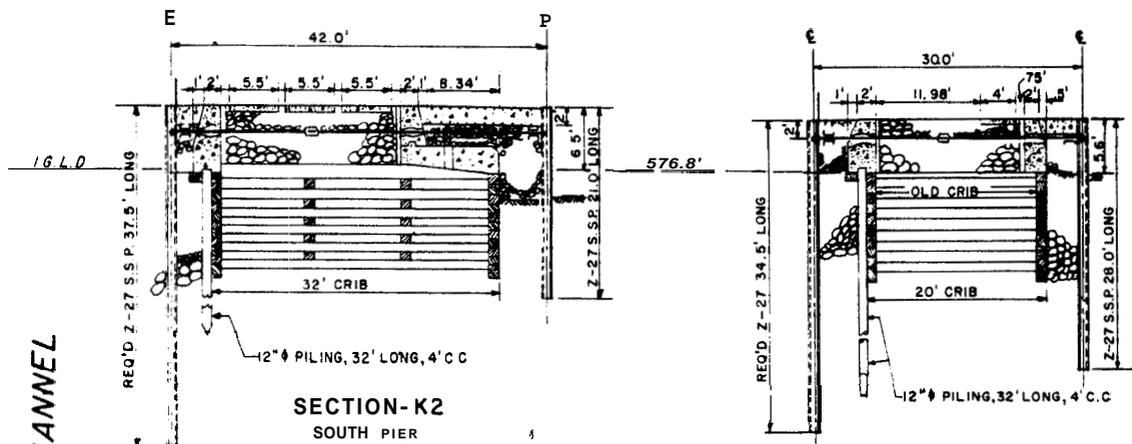


Figure 116. Typical south pier cross sections, South Haven Harbor, Michigan



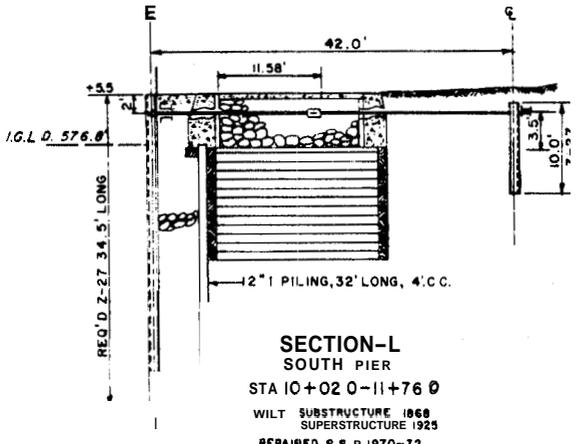
SECTION-KI
SOUTH PIER
BUILT SUBSTRUCTURE 1887
SUPERSTRUCTURE 1924
REPAIRED S S P 1970-72

SECTION-K
SOUTH PIER
BUILT SUBSTRUCTURE 1871-74
SUPERSTRUCTURE 1924-25
REPAIRED S.S.P 1970- 2



SECTION-K2
SOUTH PIER
BUILT SUBSTRUCTURE 1871-74
SUPERSTRUCTURE 1924-25
REPAIRED S S P. 1970-72

SECTION-L
SOUTH PIER
STA. 11+77.5-18+53.0
BUILT SUPERSTRUCTURE 1868
SUPERSTRUCTURE 1923
REPAIRED S. S. P. 1970-72



SECTION-L
SOUTH PIER
STA 10+02 0-11+76 0
WILT SUBSTRUCTURE 1868
SUPERSTRUCTURE 1923
REPAIRED S S P 1970-72

Figure 117. Typical pier cross sections, South Haven Harbor, Michigan

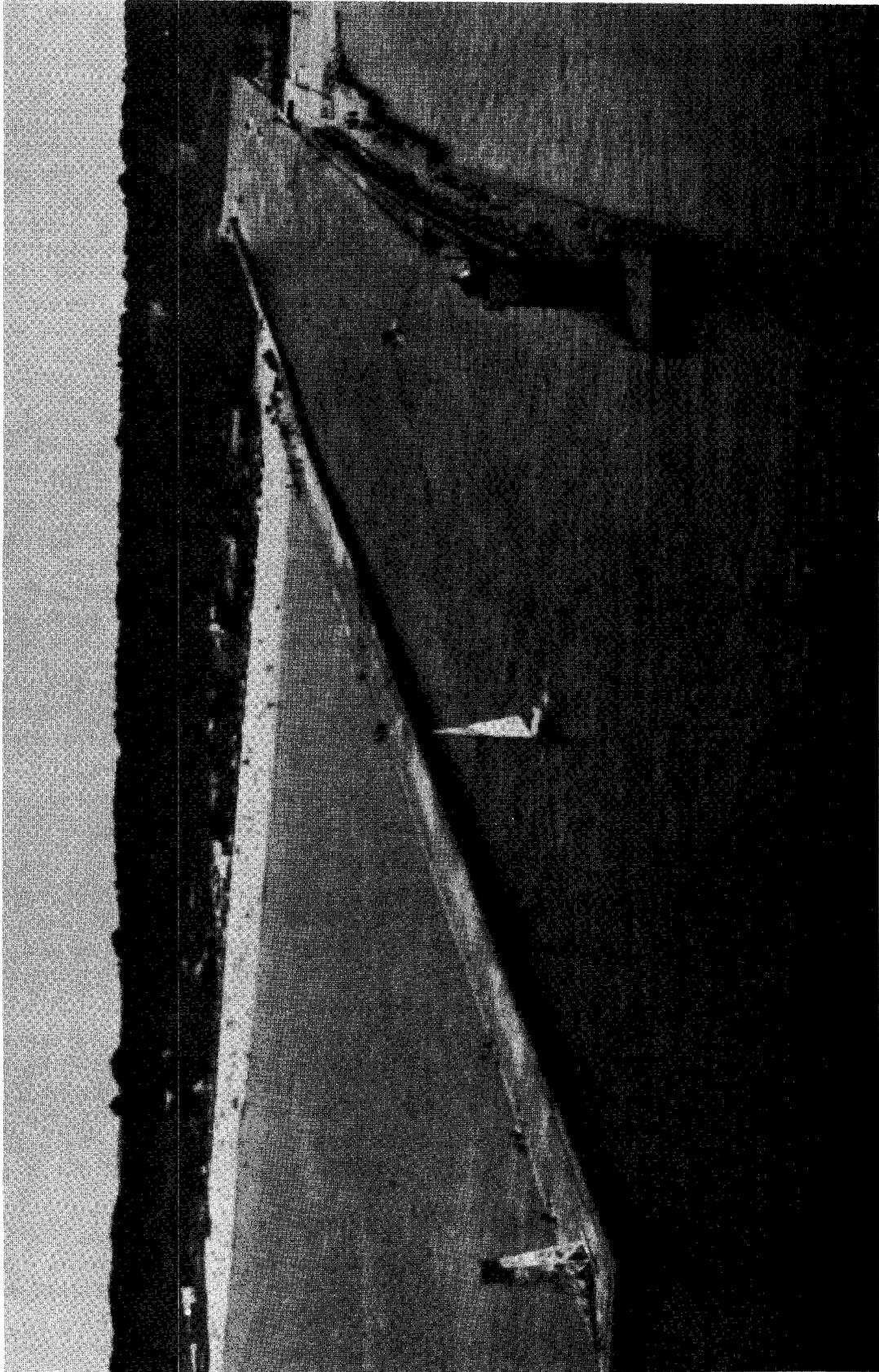


Figure 118. Aerial view of South Haven Harbor, Michigan

Table 45
Saugatuck Harbor Piers
Saugatuck, Michigan

<u>Date(s)</u>	<u>Construction and Rehabilitation History</u>
1904- 1905	Construction of the lakeward portions of the north and south piers (Figure 119, Sections A, B, and C) was completed during this time frame. The extreme outer portions were constructed of 24-ft-wide stone-filled timber cribs (Figure 120, Section A). Riprap toe protection was placed on each side of the timber cribs. The remaining portions of the pier (Sections B and C) were constructed of wood-piling spaced 13 ft apart (Figure 120, Sections B and C) and filled with stone.
1906- 1908	Construction of the shoreward portions of the north and south piers (Figure 119, Sections D, E, and F) was completed during this period. These piers ranged from 13 to 14 ft in width and were built with woodpilings (Figure 120, Sections D, E, and F).
1936- 1938	The north and south piers (Figure 119) were capped with concrete and/or stone superstructure. The lakeward portions of the piers were installed at a crest el of +7.0 ft lwd (Figure 120, Sections A, B, and C). The crest el of the shoreward portions of the piers was +6.0 ft lwd (Figure 120, Sections D, E, and F).
1959	A 375-ft portion of the south pier (Figure 119, Section F1) was re-built. Steel sheetpiling was utilized and backfilled with earth and a stone cap (Figure 120, Section F1). The el of this section of pier was +6.0 ft lwd.
1974	Fill stone replenishment for the north (Figure 114, Sections C and F) and south (Sections C, D, E, and F) piers was performed.
1980	An inspection of the piers revealed cracking, settlement, separation, misalignment, and tilting of the superstructures in various areas on both piers,, Fill stone in most the piers was in need of replenishment also. The structures were in fair to poor condition with the exception of Section F1 (Figures 119 and 120) which was reconstructed in 1959.
1981	Approximately 500 tons of 1- to 8-ton riprap was placed along the west end and lakeside face of the south pier from the pier head to a point 100 ft shoreward. About 115 tons of 3- to 12-in stone fill also was placed under the superstructure at Section B (Figure 119) of the south pier. In addition, sand backfill was placed along 100 ft of Section D of the south pier and 500 ft of Sections E and F of the north pier.
1982	Approximately 300 tons of 6- to 12-in, fill stone was used to replenish the stone fill under the superstructure of the south pier. Additionally, about 500 tons of 50- to 300-lb ballast fill stone was placed into Section C (Figure 119) and along the lakeside of

(Continued)