HISTORIC AMERICAN ENGINEERING RECORD

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Cleveland Breakwater
Cleveland Harbor
Cleveland
Cuyahoga County
Ohio

OH-1

HAER
OH,
18-CLEV,
17-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
Heritage Conservation and Recreation Service
Department of Interior
Washington, DC 20243

HISTORIC AMERICAN ENGINEERING RECORD

CLEVELAND BREAKWATER

HAER-OH-1

Location: Waterfront Lake Erie, Cleveland Ohio
Cleveland, Ohio
Cuyahoga County

Date of Construction: 1875-1915

Present owners: U.S. Army Corps of Engineers

Present Use: Breakwater

Significance: The Cleveland Breakwater is a significant example of engineering technology. the construction of the breakwater is relatively simple in concept, but demonstrated several innovative engineering advances. The breakwater created the Cleveland Harbor and thus allowed for significant commerical developmment on the waterfront of Cleveland.

Historian: Edward Pershey, 1978

Cleveland Harbor

"Cleveland is growing so rapidly, and its trade and commerce are increasing at such a rate, that it will soon demand the construction of an outer harbor."

Major Walter McFarland

In charge of Cleveland Harbor, 1870

"If the private enterprise of many of our citizens could be supplemented by a little more disinterested public enterprise and spirit we might soon become a more respectable second to Chicago than we are."

John H. Sargent

Western Reserve Historical Society (Cleveland)

1892

"This breakwater will add to the harbor a magnificent sheltered area. Is this all that is necessary? Will this suffice of itself to restore to Cleveland its lost commerce, or even insure it of its fair share of the future increase of business? No, most emphatically no. The general government is simply building a fence around your farm; it is for you to cultivate it with skill and diligence if you desire a valuable crop."

General Dan C. Kingman

Chief of Engineers, U.S. Army

In charge of Cleveland Harbor, 1901-05

Cleveland Harbor

INTRODUCTION

Cleveland, Ohio, has an artificial harbor created out of Lake Erie and protected from the lake by a man-made structure called a breakwater. U.S. Army engineers constructed this wood, stone and concrete rebuke to the lake between 1875 and 1915. It stands in 1978, with various repairs made during the intervening years, essentially as it stood in 1915, a physical symbol of the commercial and industrial development of Cleveland, which it parallels.

The technology of breakwater construction is simple when compared to the complexities of urban development, but the two have a shared entropic character which obviates their differences. The breakwater dissipates the force of natural wave action. This continual fight against the second law of thermodynamics reflects the essence of the city. Further, the two sites are mutually dependent for their functional existence. Although the city could conceivably stand alone, without the breakwater Cleveland would be more town than city, and the breakwater cannot exist but as the physical and economic boundary for a large commercial and industrial center. Their histories, likewise, are coincidental.

This study of the history of Cleveland harbor's breakwater rests primarily on the resources of the U.S. Army Corps of Engineers which built and maintains it. The valuable assistance of the Corps, in funding the project and providing access to the records, must be acknowledged. Ellen Cummings of the Environmental Section of the Corps' Buffalo District served as liason and a source of information. At the Corps' Cleveland office Captain William Lucas was most patient and agreeable during the ever changing requests for trans-

portation out to the breakwater. John Wolfs, Director of the Cuyahoga County Port Authority, provided insight into the role of the breakwater and harbor, as well as important documentary sources. The photographs included in this report were copied from the Cleveland Picture Collection, History and Biography Section, Cleveland Public Library, through the help and cooperation of Ms. Margaret Warden.

I. SETTING THE GEOLOGIC STAGE

In the latter half of the eighteenth century the Cuyahoga, a meandering river in what was to become the Western Reserve Territory of the future United States of American, cut across a sand bar and formed a new mouth into Lake Erie about 1 1/2 miles to the west. The old mouth soon silted closed, and the eastern opening into the old river bed, which ran parallel to the shoreline for the mile and a half, was also closed by the freshets of material carried by the swiftly moving river as it now took this new and shorter route to the lake. The Old River Bed was turned into a low, marshy lagoon. The land just north of the lagoon, once contiguous with the east bank of the river, was now a peninsual joined only to the west bank by the new sand bar across the old mouth.[1] (FIG 1, BRW-2) These natural occurances of a rather crooked river set the natural parameters for the development of Cleveland Harbor, Ohio, for the next 200 years.[2]

Moses Cleveland, the city's mis-namesake, arrived in 1796 to find the river already settled with its new mouth and marshy, abandoned lagoon. Apart from the river, the early inhabitants found no natural harbor of any sort along Cleveland's shore. From its beginning the city had looked upon the river as its central, most important natural feature providing navigable inland passage and sheltered docks for lake-born commerce. In a real sense, the development of Cleveland Harbor arose from a conscious response to make maximum use of the river for commerce and industry.

Although the river, with its many bends, afforded several miles of riverfront dock space, the lack of a natural lake harbor plagued Cleveland's commercial development. The yearly freshets on the river threatened to silt up the mouth to unusably low depths. Rough weather amplified the effect of the freshets, the prevailing northwesterly and northerly winds prevented the sandy material from being carried out into the lake, as well as making entrance into the river's mouth a hazardous experience for lake pilots.

The original idea for an artificial lake harbor at Cleveland cannot be pinpointed,but developed from the work done by U.S. Army engineers to artificially protect the mouth of the Cuyahoga, beginning in 1826. The idea for an artificial harbor persisted as Cleveland grew into a city, and it became a necessity by the 1870's. For the first 70 years of urban habitation, however, the river, the Old River Bed, and the Ohio Canal, which terminated at the river,were the focus of harbor development.

II. THE CUYAHOGA RIVER AS HARBOR IN EARLY CLEVELAND

The Ohio Canal opened in 1826, and Cleveland began its hectic history as a major commercial town. The canal entered the Cuyahoga River just south of its mouth, on the first bend. Cleveland, on the east bank, and Ohio City, a separate municipality on the west bank, passed ordinances relating to harbor master duties, dockage and river use. The latter municipality also attempted to use the marshy lagoon of the Old River Bed by cutting a ship channel through to the river proper, and by unsuccessfully opening up the old mouth of the river at the western end of the old bed.[3] The city of Cleveland passed ordinances in the 1840's to regulate public landings and impose a tariff on goods landed at public docks along the river.[4]

The regulation of the river and its improvement, including dredging, was the work of the city for many years. Straightening the Cuyahoga River to eliminate the many surves and bends has been a favorite topic in Cleveland business circles since the city was founded. No major channel cutting across any of the various loops has ever been constructed, though sections have been widened.

Early suggestions for a harbor in the lake came from various sources. In 1837, a map proposing two plans for enlarging Cleveland Harbor showed not only the use of the Old River Bed mouth, but also the construction of a 3,000-foot breakwater beginning just east of the river's mouth, about 1500 feet from shore and running parallel to the shoreline.(C7HB) Neither proposal was enacted. In 1855, a citizen of Cleveland suggested a breakwater plan approved by city council. The plan of J.D. Garrett called for wooden cribwork filled with stone, resting in 15 feet of water out in the lake a distance of 1000 feet. The superstructure of the breakwater was to have reached six feet above water level and the whole breakwater was to have stretched from a point opposite the east bank of the river mouth to a point opposite Wood Street, on the city's eastern limit, or just a little over 3500 feet. The plan was hailed as a "visionary scheme," but as with many such visions nothing was done about it.[5] In 1870 the Cleveland City Council again considered an artificial harbor with breakwater, but found the estimated cost of $3,000,000 beyond the resources of the city.[6] The magnitude of such an undertaking surpassed the scope of municipal government or private enterprise in Cleveland. Four years later the federal government surveyed the lake for just such a plan and a year later construction began on the west breakwater of Cleveland Harbor.[7]

III. THE U.S. ARMY CORPS OF ENGINEERS & CLEVELAND HARBOR

Although harbor and dock development were a major concern of Cleveland's business sector, the real story of the breakwater at Cleveland Harbor lies with the United States Army Corps of Engineers. An act of Congress in 1825 provided $5,000 for the construction of two parallel piers, one on each side of the mouth of the Cuyahoga, and for the divergence of the river into a more direct line into the lake perpendicular to the shoreline. Corps engineer Captain T.W. Maurice drew up the plans for the work, but the funds were insufficient and work was done.[8]

Congress passed a larger appropriation of $10,000 in 1827 and the work began. Figure 2 (map 91-c-10, Buffalo District c2HB) shows the plan for the actual construction. A 255-foot dam was built across the channel of the river immediately above the mouth, and the current of the river was used to breach a low sand bar that ran across the proposed new mouth. By 1828 the river had done its part and formed the new opening into the lake, the third mouth for the Cuyahoga in a period of about 75 years.[9]

The divergence of the river bed had a long-lasting effect on municipal growth in the area. By moving the mouth 700 feet east, the Corps effectively transferred a plot of ground from the east to the west bank, allowing Ohio City to annex a portion of what was formerly Cleveland. Some local historians credit this act with providing the "bait" by which Cleveland annexed all of Ohio City in 1854 creating the east-west polarized municipality which lingers to this day.[10]

The mouths of the river, old and new, offered a depth of only 3 to 4 feet, while the river channel and lake bed were approximately 15 feet deep on either side. To increase the action of the river current, the mouth was narrowed by the building of the two pile piers along the banks of the mouth. By 1828 the depth across the mouth had reached 6 to 8 feet.[11] The depth increased from 10 to 11 feet by 1833, and by 1839 the opening allowed the largest lake vessles of the time to use the river channel.[12]

The piers at the new river entrance were initially wooden pile structures and were completed in 1831. They stretched about 1500 feet into the lake, and cost a little over $28,000 to build. From 1837 to 1840 the piers were made permanent structures by reinforcing them with outer rows of piles, inclined planes of loose stone, and topped with masonry stone. Total appropriations by 1840 amounted to over $124,000 and another $67,000 was the estimate for completion of the masonry work. However, since the piers had already functioned as planned, i.e. the river current flowing through the narrower man-made mouth, which widened out into the lake, had acted as a natural dredge, no further work was authorized for the next four years.

Between 1844 and 1875 the west and east government piers (P118, 119, HB) at the river (c6HB) entrance went through a series of repairs. In the years 1846 to 1851 and again 1855 to 1864 no appropriations were enacted by Congress, and at the end of each period the piers were found to be in terrible shape from the action of the lake waves and collision with ships entering the river, though the real cause lay in the lack of maintenance over these years. During the Civil War the east pier had been wholly appropriated by the Cleveland and Pittsburgh (later Pennsylvania) Railroad for warehouses. This was a legal question of uncertain proportions, only haphazardly solved in 1877 with the transfer of the portion of the occupied pier to the railroad.[14] (S26HB)

In 1866, under the direction of Colonel Thomas Jefferson Cram, the Corps elongated the west and east piers by approximately 500 feet, using a pile pier construction. Cram's successor, Major Walter McFarland, severely criticized the stability of the construction as compared to stone-filled lattice cribwork, and introduced the use of iron tie-rods to reinforce and strengthen the piers.[15]

McFarland's successors, Colonel Franklin Harwood and Lieutenant Colonel Charles E. Blunt, finished the reinforcement of the piers. Work continued until the turn of the century, with an important point was reached in 1873. In his annual report for that year Harwood stated:

> It is probable that owing to the pile-pier construction, so difficult of repair when once damaged, it will be necessary to expend, at undetermined intervals, large sums in keeping the pier in order. As the damage is, however, due in great measure to vessels breaking the pier while endeavoring to enter in stormy weather, and as the item of damage would be almost entirely eliminated should a harbor of refuge be constructed backward, as now proposed, no definite estimate can be made to meet this contingency.[16]

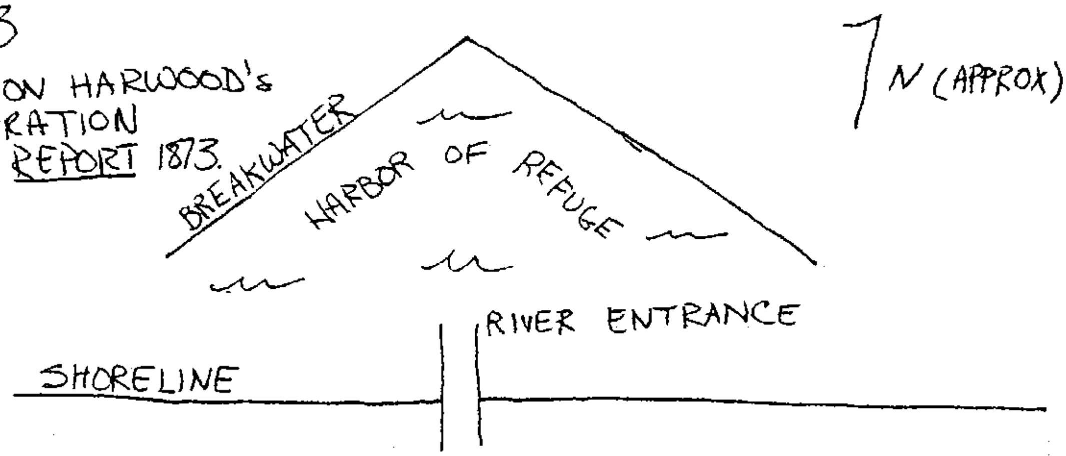
The proposed breakwater of 1873 was first and foremost intended as a shield for the river entrance, (s18HB) to protect the pile piers from the collision with boats running before high winds and choppy lake conditions. In 1874 and 1875 the breakwater itself became important in the creation of a lake harbor and Cleveland Harbor began to take the shape it has retained to this day.

IV. "HARBOR OF REFUGE" AT CLEVELAND

"To construct a harbor of refuge at Cleveland, a breakwater or system of breakwaters would evidently be needed." This is the first statement in the report of Major Franklin Harwood on the survey made at Cleveland, as directed by an Act of Congress passed March 3, 1873.[17] Harwood's report, dated December 31, 1873, predated by almost two years the start of actual construction on November 30, 1875. The construction project resembled Harwood's proposal only in that the two were breakwaters. In the intervening time major changes were made based on the view of the role that the breakwater was to play in the local industrial and commercial economy.

In 1873 the U.S. Board of Trade had requested that Congress improve the harbors in Lake Erie, especially at Cleveland, and this resulted in the Harwood survey work. The survey approached the problem as one of harbor improvement for existing facilities, and at Cleveland this meant a refuge harbor opposite the mouth of the Cuyahoga to allow ships calm waters near the mouth and to protect the piers at the mouth from rough weather.[18] Basic breakwater designs were outlined including the Cleveland Board of Trade's own sketch for a completely closed harbor.[19] All the various proposals had taken the form of two or more arms, east and west, separated by a gap of about 300 feet opposite the entrance to the river. Harwood objected to this form because ships coming into the harbor would necessarily be attempting to navigate a narrow channel while fighting strong prevailing cross winds, a situation not very different from the existing case with the river entrance piers. Also, such a design in any form, he argued, would be "nearly useless until completed, and constantly more endangered while in process of construction than a continuous work, starting at a point 3,000 feet perpendicularly opposite the east pierhead, with two arms extending at an angle shoreward, to a maximum length of 4,000 feet (see figure 3, below). The design allowed the work to form a lee quickly, and the arms could be built to any length, in sections, as the commerce ofthe port grew. The angle of the arms was determined by selecting an end point for the maximum length based on the "prevailing incoming wave," and working towards that point. The average depth along the arms would have been 34 feet.

Fig. 3
BASED ON HARWOOD'S ILLUSTRATION ANNUAL REPORT 1873.



For the breakwater itself Harwood proposed wooden cribwork, although beyond projecting a cross-section of 40 feet, he specified a design only by referring to work in progress at Buffalo harbor. The total cost he estimated at $4,000,000.[21]

Harwood's major contribution, however, was not his design but his study of the nature of the lake bed on which the breakwater was to rest:

> ". . . the bottom of the lake, all along the water-front, consists of a loose deposit of soft blue clay, silt, and sand, no rock or firm foundation of any character being found within 25 feet of the upper surface at any point

> . . . This fact will seriously affect the cost of any structure which may be determined upon, no matter where located . . ."[22]

In determining the character of the lake bed Harwood had used an "ingenious machine" of his own design which drove a hollow rod into the lake bottom to obtain core samples.[23] This core sampler had been used at Buffalo, and was used a second time at Cleveland for a survey under the direction of Lt. Col. Charles Blunt in 1874. Blunt's report confirmed the loose, silty nature of the lake bottom, and concluded that the "cost of foundation for this breakwater cannot, therefore, be forseen with certainty."[24]

The 1874 survey for a Cleveland breakwater was a congressional reaction to Harwood's extensive and expensive plan. Two alternatives were requested, both of smaller scale, in four and five fathoms of water. The basic concept and shape of the breakwater remained identical with that of Harwood's plan, but the total costs were considerably less. At four fathoms, with the uncertainty of the bottom foundation as an unknown factor, Blunt estimated that $434,000 to $564,000 would be needed to complete the breakwater. At five fathoms the cost rose to a total of between $1,200,000 and $1,300,000.[25]

The Blunt survey went back to Congress late in 1874, and early in 1875 an initial appropriation of $50,000 was made toward the construction of a breakwater in five fathoms. Blunt's proposed rentention of Harwood's design, however, was referred to a Board of Engineers who were to meet in Cleveland to make a final design selection.[26]

The Board of Engineers convened in Cleveland on April 21, 1875 and by June 9 had approved a plan. The new plan revereted in part to the original idea as suggested by the Cleveland Board of Trade: the breakwater to start at the shore, about 700 feet west of the end of the Old River Bed, and extend at a 68° angle into the lake to a length of 2,400 feet, thence parallel to the shore for another 4,700 feet, to a point perpendicularly opposite the west pierhead. The west pier was to be extended 600 feet out into the lake, leaving an opening of approximately 300 feet between it and the end of the breakwater to form a closed harbor west of the river entrance.[27]

This breakwater no longer served as a protection structure for the river entrance, which stood outside the harbor in this plan, but rather formed an alternate dock area to the riverfront. The Engineering Board adopted this plan based on the cost estimate of $1,373,000 which compared favorably with Blunt's five-fathom project, but which offered a protected harbor area of over twice the size.[28] Also, Blunt's plan, as with Harwood's earlier design, left the harbor open on both sides, while the Engineering Board's breakwater was essentially a closed figure with a small entrance facing east. The west side of the river was chosen over the east shoreline because of the "now much used" Old River Bed and the fact that the river emptied into the lake with a current that flowed "mainly to the eastward" and would have possibly silted closed any similar 300-foot entrance in an eastern harbor. The plan also assumed that of the 200 acres of protected harbor, 10 acres along the shore would be suitable for wharves and slips, leaving almost 190 acres of navigable harbor.[29]

The Engineering Board's project offered new possibilities for Cleveland and lake commerce, and was accepted by the Chief of Engineers, A.A. Humphreys, who communicated the proposal to the Secretary of War with one modification. Since the original Congressional appropriation had been for a breakwater in five fathoms (30 feet), and the Engineering Board had planned for an depth of only 27 feet, Humphreys extended the shore arm another 730 feet, and the west pier 1,000 feet into the lake instead of 600. With this modification the breakwater would sit in five fathoms of water and conform to the legal appropriation.[30]

The shore-arm and lake-arm of the modified Board of Engineers' plan of 1875 became what can now be walked on as the Cleveland west breakwater, and formed the initial branch from which the whole breakwater system grew. In 1884, before the west pier had been extended, the plans were modified again by the Board of Engineers to continue the breakwater segment parallel to the shore eastward, after a gap opposite the river entrance, to form a mirror image harbor east of the river.[31] By that time, however, the construction of the west breakwater had been completed, and these modifications can best be discussed within the context of breakwater design and construction.

V. CLEVELAND'S BREAKWATER: FUNCTION, CONSTRUCTION TYPES & SCALE

The function of a breakwater, such as Cleveland Harbor, may seem simple and obvious. (c4HB) It exists to dissipate the kinetic energy of the waves into a random splash, creating on its harbor side a body of water whose motions are independent of the movement of the larger free body on the lake side. The effect of a breakwater, even on a calm day, is noticeable. The line separating the protected water from the open lake, the shadow edge of the breakwater wall, is abruptly demarcated. Cruising along the harbor side and watching the waves break and spill over the top, one is not aware of the total effect until the end of the structure is reached, when quite suddenly the surface of the water becomes comparatively rolling and quite rough. Experiencing this effect emphasizes the importance of the breakwater in relation to the city shoreline which, in the shadow of the structure, grows outward toward, instead of away from, the on-rushing waves of the lake, which would otherwise pound and erode the shoreline.

The breakwater is essentially two structures. The foundation, or base, rises to within three or four feet of the surface of the water. The base is protected from decay and destruction by the envelope of water surrounding it. The top portion breaks the water and rises 10 to 12 feet above its surface. The top, exposed to the air, takes the brunt of the wave action and major structural changes and repairs have been made to the Cleveland breakwater's top segments. The two portions may be two different constructions, similar structures or two may be contiguous. The submerged foundation at Cleveland is the original.[32]

Cleveland Harbor breakwater has four distinct segments with three different construction types: stone-filled wooden crib substructure with concrete superstructure; stone-filled wooden crib with stone superstructure, and "rubble mound" construction built entirely of gravel and quarry stone. There are two forms of rubble mound breakwater: gravel and stone pile with laid masonry at the top, and a simpler gravel and stone pile with no organized superstructure. The breakwater proper is of the first type of rubble mound construction. The simpler construction was used in Cleveland in dikes built around landfill areas.[33]

Each part of the various segments beginning with the west breakwater in 1875 were built using the type of construction which was then standard for breakwaters, with modifications based on the market price of materials and labor. The various types of discernible from water level, although only the superstructures are visible. Construction methods observable in Cleveland in 1978 differ only slightly from the original work. The laying of a quarry stone (P98, 101, 102, 104 HB) (S1, 3, 4, 5, 8-12, HB) is currently being done on repairs to the east breakwater, and the building up of rubble mound (S12 HB) dikes is occurring east of the breakwater's eastern terminus at the shoreline of a newly created Ohio state park. Pouring of concrete caps to repair the west breakwater is scheduled but was not in progress at the time of the HAER team's inspection of the harbor. No work has ever been done on the substructure foundations of the breakwater, except for the removal of segments in 1895, 1909, and 1934 and the removal of the incomplete east shore arm, 1911-15.

The scale of the breakwater cannot be appreciated, nor even easily observed, from the shore. The visible structure from the western shore terminus to the eastern lake terminus extends over five miles, with gaps of 201 feet along the west shore arm, and 750 feet at the harbor entrance. The eastern end is open to the lake. Two 1,250-foot arms protect the harbor's entrance opposite the mouth of the Cuyahoga. The structure at water level varies in width from 30 to 40 feet. A cursory examination by boat takes slightly over two hours. An everchanging sequence of missing, delapidated, original and repaired segments passes alongside the observer. The breakwater, somewhat unimpressive from shore, commands attention at close range. The lake waves occasionally breaking over the top attest to the dynamic function of this deceivingly static structure.

VI. BUILDING CLEVELAND HARBOR BREAKWATER

In 1881 Major John Wilson of the Corps of Engineers, in charge of Cleveland Harbor, described the construction of the new breakwater, which had been underway since 1875:

> The method of construction of the work which is now being built in water from 27 to 30 feet deep, upon a soft bottom, is to first prepare a foundation of rubble-stone 50 feet wide on top and 5 feet deep, with natural slopes; upon this, cribs 50 feet long and 32 feet wide are sunk and connected by a superstructure 8 feet high. The work is heavily riprapped with stone weighing not less than one ton each, timber 12 inches square is used--hemlock under the water and Michigan white pine above.[34]

The method of construction and the size of the cribwork differ substantially from an extant drawing made by Captain M.B. Adams, assistant at Cleveland Harbor during the initial year of construction, 1875 (fig. 4 Cl HB). The cribwork in Adams' drawing measures 18 feet high on a base 30 feet wide narrowing to a top section of only 14 feet. The mechanism pictured appears to have a chain pully device for lowering the crib onto an extensive base of rock foundation. No verbal description of this proposed method exists. The method actually used more nearly coincides with a description of the sinking of cribwork for the east breakwater in 1898:

> . . . the crib when towed to position, will be held firmly against the end of the previous crib and may sunk by filling or partly filling the compartments . . . When the crib has been sufficiently loaded to rest lightly upon the bottom, its position will be adjusted . . .and the crib will then be filled, distributing stone as nearly uniformly as possible to insure even settlement.[35]

The method described was for that of cribwork of much larger dimensions, but the process was essentially the same.[36] The work was performed entirely under contract to a local, civilian company, Sherwood & Geissendorfer of Cleveland, with three other Cleveland contractors supplying material, and one Philadelphia company supplying timber and labor for construction of cribwork on shore.[37]

Once all the cribwork had been sunk, additional stone (rip rap) was placed on the lake side to a ehight of eight feet from a base of 16 feet, and on the harbor side to a height of 5 feet from a base of ten feet. A severe storm in November of 1884 caused appreciable settling, about four feet, along a large segment of the newly built breakwater, and additional rip rap stone (See S34 HB) and foundation stone was added.[38]

The harsh storms and winter weather experienced in 1884 prompted the corps engineers to make two modifications to the breakwater. First, quarter-inch plates of boiler-iron, 36" x 72", were bolted over the junction of the crib and superstructure, extending well below low-water level, to protect the wood from the scraping action of ice flows.[39] In 1885, a timber parapet, 4' x 16', running the length of the completed breakwall, was affixed to the top lake-side edge, to provide additional height against the waves (C9HB, top). This gave the cribowrk a total height of 39 feet, lakeside, and 35 feet harborside (27-foot crib, 8-foot superstructure, and 4-foot parapet running along the whole length but covering only half of the superstructure in width). The parapet addition was finished in 1888.[40]

The first 1,000 feet of the breakwater, the arm connected to the shore, was built up first of pile-pier rip-rapped with stone. The shallower water allowed this type of construction. In 1934 this section was abandoned in connection with a public works project involving landfill and the development of a recreational marina for the city just outside the breakwater along the west shore of the lake.

At the same time that the parapet was being added to the west breakwater and plans for the extension of the west pier were being formed, the Board of Engineers made the decision to enlarge the protected harbor. Rather than confine the harbor to the west shore, with an entrance between the eastern terminus and the extended pier, the new harbor would cover areas on both sides of the river entrance, with a harbor entrance from the lake directly opposite the river mouth.[41] In 1887 construction began on the modified plans to build an east breakwater similar in shape to that of the west. The 1885 modification was a move back towards the Cleveland Board of Trade 1870 proposal for a completely enclosed harbor, symmetrical about the Cuyahoga River mouth. However, between 1887 and 1915, when the breakwater was essentially completed as it stands today, several additional modifications were made which unbalanced this symmetry and created an open-ended harbor to the east.

Construction of the initial east breakwater lasted from 1887 to 1893. Stone-filled wooden crib substructure and wooden crib superstructure, similar to the west breakwater, was set in place using methods described above. The gap left between the eastern end of the west wall and the western end of the new east portion was 500 feet. The completed east breakwater stretched 2494.5 feet from the entrance, parallel to the shoreline.

As the new east breakwater was being finished, the pollution pouring out of the Cuyahoga, a problem since antebellum days, tended to flow easterly into the newly created harbor area, as had been predicted by the 1875 Board of Engineers who had selected the western harbor site. To partially alleviate this condition, a 201-foot gap in the shore arm of the old west breakwater (P115 HB) (S35 HB), approximately 700 feet from shore, was opened by removing a section of the structure. This work was completed in 1896 and remains open today, protected by a stone-mound spur constructed in the 1930's by public works crews.

The deteriorating condition of the wooden crib superstructure of the original west breakwater indicated in the late 1890's that future repairs of rotting wood sections would be expensive and recurring. In 1897 the Corps proposed to modify the superstructure by removing the superstructure to a level three feet below water and replacing it with poured concrete masonry.[42] Except for pierheads for the support of terminal lights and fog whistles, this is the only section of the whole breakwater system in Cleveland to have a concrete cap (P112,113,114 HB) (S29 HB to S33 HB), although both east and west piers at the river entrance also received such superstructures. The concrete, of American Portland Cement, was poured on shore into a whole section form, and, when set, was carried out to the breakwater and set in place in the same manner as solid quarry stone. The superstructure consisted of two segments: stone or concrete blocks as a base, and a solid concrete parapet which resembled the cross section of the wooden parapet and superstructure it replaced (C9HB, bottom).

In 1898-99 the east breakwater was extended 864 feet, just about to the point where it was to break in at an angle toward shore. From 1899-1902 this shore arm was partially completed. Cribs of 216-foot lengths, instead of the 50-foot lengths previously used, were sunk in much the same manner.[44] Even as this extension was being started and continued, two events drastically changed the scope and nature of the breakwater. (C3 HB shows harbor as of 1900.)

A storm in November of 1898 broke through a 450-foot section of the west breakwater (just west of the harbor entrance) before the new concrete superstructure had been installed. The break was repaired immediately using rip rap stone of large sandstone blocks, dropped into position "without special care." A year later, when the new superstructure was ready for replacement at that spot, the temporary jumbled rip rap patch was found to have survived weathering very well. Coincidentally, a Board of Engineers, in a report on Ashtablula Harbor, Ohio (east of Cleveland on Lake Erie) had recommended the use of stone-mound breakwaters as a less complex and more durable form for breakwaters than stone-filled wooden cribwork. The experience at Cleveland with this repaired section indicated that such a construction type would be "fairly stable, even though the top and slopes be covered with stone of smaller size and less carefully laid, than has heretofore been considered essential."[45]

The west breakwater received a completed concrete superstructure by 1904 although only a small portion had been replaced prior to the storm, and the east breakwater extension, employing cribwork, continued to 1902. After this date, the Corps of Engineers abandoned the use of wooden crib breakwaters and piers at Cleveland and began using the type of construction called "rubble-mound" with a laid masonry stone cap.

The development of the all-quarry-stone breakwater at Cleveland served as an experiment in such design for the Corps. When the rubble mound type was first proposed in 1903, only two other such stone breakwaters existed on the Great Lakes, and there was little criteria to judge the effect of the waves on various sized stones. The cross section of the new breakwater construction consisted of a core of sand, a layer of coarse gravel, then a layer of small stones, covered finally with large paving blocks.[46] The base measured 144 feet, and rose on the slant to a mound above the water level with a profile of 10 feet on top by about 30 feet at the water. (Map 6B, U.S.A.C.E.)

In 1902 an Act of Congress authorized the construction of a new entrance to Cleveland Harbor, and the extension of the east breakwater to the city's eastern limits. The new rubble mound construction method was selected for the two new breakwaters: a double arrowhead breakwater (S19-23 HB) (P107, 108 HB) to protect the harbor entrance on the lake side; and a separate breakwater, beginning 550 feet east of the eastern end of the original cribwork east breakwater. Since both of these projects were experimental, changes were needed in the rubble mound design during the early construction period 1903-1907.

Construction began on the new east breakwater late in 1903 using the rubble mound design with a core of sand (C5 HB) at depths below 20 feet. It was soon realized that 20 per cent of this core sand was being washed out of the interior of the mound, allowing the upper layers of heavy stone to settle appreciably. The design was changed to increase the coarseness of the layer of stone and decrease the amount of sand core. Furnace slag from the steel mills was suggested for use in the larger secondary layer, but that material was being used by the railroads for track ballast and was not readily available, so shale stone was selected. Also, the cross section was skewed towards the lake side so that ". . . the center of pressure, due to the weight of the structure and force of the seas striking it, is better distributed over the base, and the resulting slopes provide greater stability and can be more certainly and easily constructed." The cost factor increased also, but only by about 1%.[47]

A storm during October, 1906, caused major settling in the first sections of the east breakwater extension, so much so that the Corps eliminated entirely the use of sand for the core filling, and substituted quarry stones. The new design called for a minimum of 25% of the core stones to be not smaller than one ton. The Corps, experiencing similar settling problems at other rubble mound breakwaters under construction, notably at Buffalo, applied this Cleveland modification to all similar work being done in the district, even though the protracted stability of the quarry-stone core design had not been proven.[48]

The new breakwaters were completed using the modified rubble mound type (S13 HB). (See Corps of Engineers Drawing 6B for Cross Sections.)

Further changes involved removing 200 feet of the west terminus of the original east breakwater to enlarge the harbor entrance in 1909, and a 150-foot section of the east terminus of the west breakwater was similarly removed in 1934 (P111 HB). The wooden superstructure of the original east breakwater was replaced with a stone cap in 1917-8 and 1926. (P99, 100 HB) (S2 HB) Between 1911 and 1915 the shore arm of the original east breakwater, a portion never completed as projected, was entirely removed, and the 550-foot gap between the two east breakwaters was bridges, unifying the whole east section. (P105 HB) The same year, 1915, the extension was completed to a length of 17,970 feet, the present length of the breakwater, and in 1918 a concrete pierhead at the easterly end was installed as a foundation for a market light. (S7 HB) Except for the placement of rip rap along the west breakwater and annual maintenance repairs, the Corps of Engineers has made no major changes to the breakwater proper, although extensive landfill areas along the shoreline (S6 HB) (P103 HB) opposite the east breakwater have significantly changed the lakefront at Cleveland.[49]

VII. THE BREAKWATER AND COMMERCIAL DEVELOPMENT IN CLEVELAND

The intriguing aspect of Cleveland's breakwater, constructed and maintained by the federal government through the U.S. Army Corps of Engineers for the city, is the apparent lack of harbor development as envisioned during the time of its construction. What is even more puzzling is the fact that the non-development of the harbor by private enterprise was considered a critical factor in the initial consideration to enlarge the harbor easterly as early as 1896. In 1902 Act of Congress that provided for the enlargement appears to have been made in order to stimulate the use of the eastern shoreline in Cleveland for commercial docks.[50] The only area which has been so developed, however, has been the shore opposite the original east breakwater which was completed, as it now stands, in 1900. The Cuyahoga River continues to serve as a major docking area, limited though to its use by ships short enough to navigate its curves. (P118,119 HB) (S16 HB) (C8 HB) The west harbor has only one ore dock in operation, a vintage Hulett unloader which handles those ships not equipped with self-unloading mechanisms. (P117 HB) (S38 HB) (S37 HB) The east harbor, beyond East Ninth Street, opposite the rubble mound extension of 1903-1915, has been the site of major landfills, recreational boat marinas, one commercial dock, and the Burke Lakefront Airport of the city of Cleveland, which yearly has expanded onto landfill created by the Corps. The newest landfill dike at Gordon Park lies to the east beyond the breakwater extension entirely. The east breakwater serves now, not so much as a harbor structure, but as a protection against shore erosion of the eastern lakefront--a shoreline created in large measure as a reflection of the breakwater itself.

In 1897 such a plan of development could, or would, not be seen. Correspondence between the Corps and the Cleveland Chamber of Commerce during that year reveals the important role the breakwater was to play in Cleveland's future, as seen by the city's leading capitalists. Colonel Jared Smith, in charge of Cleveland Harbor 1892-1900, sent a letter of inquiry to the Chamber of Commerce in conjunction with the passage of the 1896 Rivers & Harbors Act in Congress. The act questioned the advisability of abandoning the projected shore arm of the Cleveland east breakwater instead of extending the work parallel to the shoreline for the equivalent distance. Smith served to present Congress's inquest to the Cleveland community.[51]

Smith posed two limiting criteria. First, the west breakwater protected a harbor within which "Up to the present time no wharf or pier for business purposes has been constructed . . ." (the Hulett ore unloaders were not installed until 1912). Second, the real question was not whether to re-orient the authorized construction from a deflecting arm to a parallel arm, but whether that re-orientation should not justify, in the end, the extension of the breakwater beyond the authorized length, possibly to the city limits.[52]

In light of these two remarks, Smith asked five distinct questions. First, what businesses were in existence along the land opposite the proposed extension which would directly benefit from the new breakwater?

Second, what new businesses would be encouraged by a new east breakwater?

Third, would all possible benefits, added together, justify the expenditure of public money in terms of investment and future growth?

Fourth, could the expenditure be justified on the basis of future growth when existing west harbor development had not resulted in an influx of private enterprise and capital expenditure in that area?

Fifth, if the expenditure could be justified, either in 1897 or at any later date in the foreseeable future, should the extension be an addition to the existing breakwater, creating a contiguous west-east harbor, or should a separate and independent breakwater create a harbor free from the existing west harbor? (This option would have left the development and maintenance of existing facilities, especially the west harbor, as a distinctly separate problem with variables peculiar to the economics of the west harbor region.)[53]

Smith's letter to the Chamber of Commerce remains as the most thoughtful and insightful assessment of the potential of the Cleveland breakwater ever written, especially considering the critical point as which it appeared.[54] Cleveland in 1897 was in the midst of its prime expansion era, with the period of heavy industrial and manufacturing expansion in the first decade of the twentieth century still to come. The lengthy reply to Smith's inquiries by the Chamber of Commer's Rivers and Harbors Committee reflected the optimism felt by the city at the time.

The Chamber of Commerce heavily endorsed the extension of the east breakwater along a line parallel to the shore.[55] Its reasons were quite specific, and separated in context, though not in detail or spirit, from the direct replies to Smith's five questions.

The growth of shipbuilding on the Great Lakes, and the enlargement of ship channels by the federal government had severely taxed the inner harbor, as it existed in 1896 at Cleveland. The growth of Cleveland beyond service as a transshipment port to that of a manufacturing center requiring transportation facilities for the inlet of raw materials and the outlet of produced goods demanded growth space along the shore. The Chamber of Commerce found that space could only be located <u>east</u> of the river.

The lack of a protected harbor east of the Cuyahoga had lost Cleveland ". . . several very important enterprises, the shipments and receipts of which by lake would be measured by hundreds of thousands of tons annually . . . " and one east shore manufacturer, in particular, was facing limited growth since it could not construct docks in the unprotected lakefront. The Chamber of Commerce letter did not specify either of these by type of industry or by name.[56] The non-development of the west harbor was blamed on the location, suitable only for transfer docks of iron ore and coal, and the problem of riparian land ownership, a problem generated by the railroad companies, and one with which the Corps was fully aware because of its difficulties with the east pier and the Pittsburg and Cleveland Railroad. The Chamber of Commerce was adamant about the inadaptability of the west harbor, and stated emphatically that ". . . as a lake receiving and shipping port, Cleveland has reached a point at which enlargement is absolutely required for the accommodation of existing business, which can only be obtained by the extension of the east breakwater."[57] The extension requested by the Chamber of Commerce was an addition to the existing structure so as not to "prevent its extension as a continuous whole a considerable distance farther than is provided for."[58]

The replies to Smith's five point inquiry substantially repeated the foregone reasoning, only further emphasizing Cleveland as the ideal transshipment facility and the new east breakwater harbor area as the optimum place within which manufacturing establishments could build. The tone of this part of the letter resounds with the public relations work of the Cleveland Growth Association in the late 1860's--"Cleveland. The best location in the nation."

The report of Colonel Smith in 1898, in which this correspondence is included, concluded with a rejection of the proposed extension beyond the authorized limit, and a recommendation that the deflecting arm be retained to protect the harbor and wharves from northeasterly winds. Within three years, however, the increasing flow of freight, principally into Cleveland in the form of iron ore and coal, caused a reversal of the 1898 decision by Smith, and in 1902 Congress authorized the final extension of the east breakwater to the city's eastern limit.[59]

Initially, an independent breakwater was constructed, leaving the shore arm in place until the new extension was completed. In his report for 1902, Major Dan Kingman, successor to Smith, expressed the new attitude toward the east harbor:

> I believe that as the east breakwater is extended to its full length advantage will be taken of the fine facilities that it will offer, and that docks will be built under its shelter, the land approaches changed to conform to the new conditions, and the lake business of Cleveland will be done to a very large extent in the new harbor . . .[60]

Kingman's only correct prophesy was the rearrangement of "land approaches" for the east breakwater protects basically only landfill and the docks of the Corps itself at the extreme western edge of the east harbor extension. (P120 HB)

NOTES

Opening quotes:

General Dan Kingman, as quoted in E.B. Thomas, "Cleveland Harbor Problems," Journal of the Cleveland Engineering Society 8(1915): 11.

Major Walter McFalrland, "Annual Report Upon the Improvement of Cleveland Harbor, Ohio, for the Year Ending June 30, 1870," Annual Report of the Chief Engineer of the United States Army 1870, p. 178.

John H. Sargent, The Development of Cleveland's Harbor, Western Reserve Historical Society Tract 82 (Cleveland: Western Reserve Historical Society, 1892), p. 298

1. Sargent, pp. 287-88; HAER photo-copy BRW-2 (Fig. 1).

2. "Cleveland Harbor, OHio" is the name used by the Corps of Egnineers to designate the location of their work in Cleveland. This report will adhere to that use. "Old River Bed", an unofficial but long used and accepted name for the 18th century river channel, will be retained also.

3. Sargent, p. 289; "An Ordinance to provide for the opening and excavation of the Ship Channel, and for the improvement of the Old River Bed, and the streets and public landings abutting thereupon and parallel therewith," passed May 18, 1854 in the City Council of Ohio City, Ohio.

4. The follwoing city ordinances were passed by the city council of Cleveland:

   "To prohibit certain Nuisances, Section A, Harbor Master to grant permission to land certain article s herein named," May 8, 1844. This ordinance listed wood, timber, lumber, stone, stone coal, brick and sand and clay.

   "To Regulate Carriages, Vessels, and Steamboats, at the Pier in front of Bath Street in the City of Cleveland," March 10, 1846.

   "To Establish Rate of Charges on the Public Docks and to Procure for the Collection of the same," July 10, 1847.

5. William G. Rose, Cleveland: The Making of a City (Cleveland: World Publishing, 1950), p. 273.

6. James Kennedy, <u>History of Cleveland</u> (Cleveland: Imperial Press, 1896), p. 412.
7. Ibid., p. 413.
8. "Improvement of Cleveland Harbor Ohio: History of the Work," <u>Annual Report of the Chief Engineer of the United States Army 1880</u>, p. 2135. These annual reports, in the 19th and early 20th century, are invaluable sources of information, composed primarily of the individual reports of the harbor officers and ~~xxx~~ district commanders. The reports are often detailed and lively, with correspondence, maps and photographs. There are indices for the reports, which were first issued in 1866. Hereafter simply <u>Annual Report (date)</u>.
9. Ibid.
10. Sargent, p. 288.
11. <u>Annual Report 1880</u>, p. 2135.
12. Ibid., pp. 2136-7.
13. Ibid., p. 2137.
14. Ibid., pp. 2139, 2141; also Charles E. Blunt, "Repairs of the East Pier, Cleveland Harbor, Ohio," <u>Annual Report 1877</u>, ii, p. 965.
15. <u>Annual Report 1869</u>, pp. 155-177.
16. <u>Annual Report 1873</u>, p. 338.
17. Major Franklin Harwood, "Harbor of Refuge at Cleveland, Ohio," <u>Annual Report 1874</u> p. 233.
18. Ibid. The whole report runs six pages plus a map.
19. Ibid., p. 234.
20. Ibid., p. 236.
21. Ibid., p. 238. Harwood estimated a cost of $273 per lineal foot, but enlarged that figure to $500 per lineal foot for "contingencies."
22. Ibid., p. 233.
23. Ibid.; Charles E. Blunt, "Examination for Breakwater at Cleveland, Ohio," <u>Annual Report 1875</u>, p. 304.

24. Blunt, Annual Report 1875, p. 304.

25. Ibid., pp. 305-306.

26. "Letter of the Chief of Engineers Brig. General A.A. Humphreys to Hon. W.W. Belknap, Secretary of War, June 23, 1875," Annual Report 1875, pp. 307-308.

27. "Report of the Board of Engineers [Convened at Cleveland]," Annual Report 1875, p.

28. Blunt's five-fathom plan produced a harbor of 92 acres, while the Board of Engineers' plan offered a harbor of 200 acres. "Letter," Annual Report 1875, pp. 307-308.

29. "Report of the Board," Annual Report 1875, p. 309.

30. "Letter," Annual Report 1875, pp. 307-308; and Annual Report 1880, p. 2141.

31. Annual Report 1885, p. 2235.

32. Drilling samples taken in 1977 along the west breakwater indicated an extant wood & stome crib of 27 feet in height, and a total structure from the leveling course x to the level of the concrete cap of about 38 feet. Drilling logs, Herbert & Associates for the Corps of Engineers, November, 1977, hole nos. CDU77-5 and CDU77-6; also "Plan of Exploration and Geologic Profile," Sheet 16, Rehabilitation of West Breakwater, U.S. Army Corps of Engineers, Buffalo District, 1978.

33. The breakwater (see map 6 by the Corps, dated 1971) west of the Cuyahoga has a concrete cap over wooden cribwork; the first portion of the east breakwater, to xx about East Ninth Street, has a stone cap over wooden cribwork. The east breakwater from East Ninth Street out to the eastern terminus, and the arrowhead breakwaters at the harbor entrance are rubble mound with stone masonry cap. The term rubble mound was used originally to designate any type of breakwater construction using a pile of stone and gravel for the substructure in place of wooden cribwork. The term now is used only for those breakwaters and x dikes which lack the laid masonry top and look, therefore, like a "mound of rubble stone."

34. Major John Wilson,"Improvement of Cleveland Harbor, OHio," Annual Report 1881, p. 2312.

35. "Advertisement, Instructions for Bidders, Specifications and Form of Proposal for Constructing Part of West Pier, Removing Part of Old West Pier, Dredging, and Completing East Breakwater at Cleveland Harbor, Ohio," U.S. Army Corps of Engineers, June 23, 1898, p. 10.

36. No photographic record, sketches or engineering drawings have yet to appear illustrating there early stages of construction, 1875-1884.

37. Annual Report 1880, pp. 2145-2146.

38. "History of Cleveland Harbor," U.S. Army Corps of Engineers, Buffalo District (1945), p. 6. (Mimeograp hed.)

39. Lewis C. Overman,"Improvement of Cleveland Harbor, Ohio," Annual Report 1885, p. 22

40. "History," (1945), p. 7.

41. Ibid.; Annual Report 1885, p. 2235.

42. Photographs of the work appear in Annual Report 1899, p. 3057 and 1900, p. 4064. The design of the concrete work was that of Colonel Jared Smith, in charge of the harbor. George Cushing, "The Stone Breakwater at Cleveland, OHio," Engineering News 57(1907): 565.

43. Annual Report 1900, pp. 4063-4067. This report, with photographs and maps is the best description of breakwater construction at Cleveland. "Advertisement...," 1898, Sections 46-58 and 61-70, gives the details for contractor's specificati including concrete mixtures and tensil strengths.

44. "Advertisement...," 1898, Sections 61-63.

45. Annual Report 1900. p. 4065, and accompanying map; BRW-5 is a photo-copy of that map from this report.

46. "Cross Section of Rubble Mound Breakwater," engineering drawing 91-C-40, U.S. Army Corps of Engineers, Buffalo District (1904) is a good schematic of an intermediate design, but not yet the final form.

47. Ibid.; Annual Report 1904, pp. 3176, 3184-5; also Cushing, p. 566.

48. Curtis Townsend, "Improvement of Cleveland Harbor, Ohio," Annual Report 1907, pp. 2080-2081. The use of stone to build breakwaters was prompted by the increasing cost of wood timber and concrete. Stone is preferable to concrete since it will weather better against dissolution and mechanical breakdown by pounding waves. However, a relatively close source of quarry stone is needed, or transportation costs enter as a significant factor. In water over 30 feet deep, the use of concrete which can be poured into consistently uniform shapes and sizes proves to be slightly less expensive than stone, which works well in water shallower than 16 feet. For depths in between, the two materials are comparable. The laying of masonry stone is increasingly being lost as an art to the passing generations. See "Experiances with Breakwater Design on the Great Lakes," Engineering News-Record 89(1922): cover, 684-688 for state-fo-the art construction methods and types. Also, Cushing, passim. The stone for Cleveland's breakwaters came from inland quarries at Berea and Amherst, and on the Lake Erie islands at Sandusky, Ohio.

49. "History" (1945), pp. 12-26; and "Preliminary Report on Section III Study of Cleveland Harbor, Ohio," U.S. Army Corps of Engineers, Buffalo District, March 28, 1977, pp. 2-4, 8-9. (Mimeographed.)

50. House Doc. 118, 56th Congress, 2nd Session. (Citation only, I have not used the do

51. Annual Report 1898, pp. 2727-30.

52. Ibid., p. 2727.

53. Ibid., pp. 2727-2728.

54. A later article by E.B. Thomas (Rivers & Harbors Engineer for the City of Cleveland), "Cleveland Harbor Problems," Journsl of the Cleveland Engineering Society 8(1915): 5-30 presents a very good summary of harbor development, but

coming as it did in 1915, it was a <u>de facto</u> assessment in many ways.

55. <u>Annual Report 1898</u>, pp. 2728-2730.

56. Ibid., p. 2729.

57. Ibid.

58. Ibid.

59. <u>Annual Report 1901</u>, pp. 277-299, contains a full description of the extension plans

60. <u>Annual Report 1902</u>, p. 2270.

BIBLIOGRAPHY

"Advertisement, Instructions for Bidders, Specifications and Form of Proposal for Constructing Part of West Pier, Removing Part of Old West Pier, Dredging, and Completing East Breakwater at Cleveland Harbor, Ohio." U.S. Army Corps of Engineers, ~~Buffalo District~~ Cleveland Harbor. June 23, 1898.

Annual Report of the Chief Engineer of the United States Army. Washington, D.C., 1866--. Contains the yearly reports by the office in charge of Cleveland Harbor, which will not ~~xxx~~ be listed separately in this bibliography. The principal years used were 1869, 1874, 1875, 1880, 1898, 1900, 1901, 1904, 1905 and 1911, with shorter extracts from other years as well. Reports other than normal annual reports about Cleveland Harbor in the Annual Report are listed separately below.

Blunt, Charles E. The Breakwater at Cleveland Harbor. 43rd Congress, 2nd Session, House of Rep. Ex. Doc. 75, Part 4; also as "Examination for Breakwater at Cleveland, Ohio." Annual Report 1875, pp. 304-306.

_______________. "Repairs of East Pier, Cleveland Harbor, Ohio." Annual Report 1877, ii, p. 965.

Cullum, George W. Biographical Register of the Officers and Graduates of the U.S. Military Academy at West Point, New York, With Its Establishment in 1802 to 1890..., 3rd ed. 3 vols. New York, Boston: Houghton, Mifflin & Co., 1891. Vol. 4, 1890-1900. Cambridge, Mass.: University Press, 1901. Vol. 5, 1900-1910. Saginaw, Michigan, 1910. Vol. 6A and 6B, 1910-20. Saginaw, Michigan, 1920. Vol. 7, 1920-30. Chicago: Lakeside Press, 1930.

Cushing, George. "The Stone Breakwater at Cleveland, Ohio." Engineering News 57(1907): 565-566.

"Experience with Breakwater Design on the Great Lakes." Engineering News-Record 89(1922): cover, 684-88.

Harwood, Franklin. "Harbor of Refuge at Cleveland, Ohio." Annual Report 1874, i, pp. 232-238.

"History of Cleveland Harbor." U.S. Army Corps of Engineers, Buffalo District, 1945. (Mimeographed.)

Hood, Cliffor d. Easing the Cuyahoga: A 100-Year Program. Cleveland: Chamber of Commerce, 1947.

"Improvement of Cleveland Harbor, Ohio: History of the Work." Annual Report 1880, pp. 2135-2142.

Kennedy, James. History of Cleveland. Cleveland: Imperial Press, 1896.

"Letter of the Chief of Engineers Brig. General A.A. Humphreys to Hon. W.W. Belknap, Secretary of War, June 23, 1875." Annual Report 1875, pp. 307-308.

Preliminary Feasibility Study of Cleveland Harbor, Ohio. U.S. Army Corps of Engineers, Buffalo District, 1875. Especially Sections A and B.

"Report of the Board of Engineers [Convened at Cleveland] ." Annual Report 1875, pp. 308-310.

Rowe, Robert S. Bibliography of Rivers and Harbors and Related Fields in Hydraulic Engineering. Princeton, N.J.: Rivers and Harbors Section, Department of Civil Engineering, Princeton University, 1953.

Sargent, John H. The Development of Cleveland's Harbor. Western Reserve Historical Society Tract 82. Cleveland: Western Reserve Historical Society, 1892.

Thomas, E. B. "Cleveland Harbor Problems." Journal of the Cleveland Engineering Society 8(1915): 5-30.