FILE COPY

DESIGN MEMORANDUM

ON

HYANNIS HARBOR, MASSACHUSETTS

(MINOR REHABILITATION BREAKWATER)

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM 54, MASSACHUSETTS

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDGW

10 February 1961

SUBJECT: Design Memorandum on Hyannis Harbor, Massachusetts (Minor Rehabilitation - Breakwater)

TO: Chief of Engineers
Department of the Army
Washington, D. C.
ATTN: ENGCW-E

1. Reference is made to letter ENGCW-E, dated 24 August 1960, subject "Rehabilitation Projects - Definite Project Studies," which stated that a design memorandum on Hyannis Harbor should be submitted for approval.

2. A design memorandum has been prepared for the subject project in accordance with Engineer Manuals EM 1110-2-1150, EM 1110-2-1151, and EM 1110-2-2904. Ten copies of the design memorandum are hereby submitted for review and approval.

3. Funds in the amount of $45,000 have been allocated for rehabilitation of the Hyannis Harbor breakwater. Additional funds in the amount of $130,000 are required to complete the rehabilitation currently estimated to cost $175,000. The additional funds required were requested in letter NEDVN, Attention ENGCW-O (Mr. Armstrong, Room G 419), dated 30 January 1961, subject: "Hyannis Harbor, Massachusetts - Rehabilitation Project."

1 Incl
Design Memorandum
(10 cys)

SEYMOUR A. POTTER, JR.
Brigadier General, USA
Division Engineer

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 Trapelo Road
Waltham, Massachusetts

NEDGW

10 February 1961

DESIGN MEMORANDUM ON HYANNIS HARBOR,
MASSACHUSETTS (MINOR REHABILITATION - BREAKWATER)

PERTINENT DATA

1. A summary of physical features and costs of the repairs to the existing Federal breakwater at Hyannis Harbor, Massachusetts is as follows:

Features	Present Estimate (1960)
Repairs to existing breakwater to restore structure to project dimensions	$175,000

PROJECT AUTHORIZATION

2. The existing project, authorized by the River and Harbor Acts of 1827, 1871, 1886 and 1945, provides for a stone breakwater 1,170 feet long lying about 0.7 mile offshore; a 15.5-foot protected anchorage behind the breakwater; a 12-foot channel with widths of 150 and 100 feet in the outer and inner harbors, respectively; a 12-foot anchorage of about 5 acres in area adjacent to the inner harbor channel north of Harbor Bluff; a riprap jetty 1,000 feet long extending south from Dunbar Point. The existing project was completed in November 1959.

3. The breakwater was completed in 1882 and the dredging behind the breakwater in 1906. Construction of the 12-foot channel and anchorage was accomplished in 1959. The existing project costs to 30 June 1960 were $587,500 for construction, including non-Federal costs of $103,000, and $56,300 for maintenance.

INVESTIGATIONS

4. History of the Breakwater. - Hyannis Harbor was established as a harbor of refuge in 1827 by the authorization of a breakwater 1,170 feet long to protect an area of about 175 acres from southerly storms. The depth of entrance was 15.5 feet. The breakwater construction consisted of a

stone mound topped by a wall of stone masonry laid dry. This wall was completed for about 375 feet in 1838. The cost for the completed work was about $70,900.

5. In 1853 additional stone was placed to strengthen the then undamaged section of the previously completed work at a cost of $5,000. In 1873 the design of the structure was modified to strengthen it, and the breakwater was completed in 1881. The cost of the work between 1873 and 1881 was $47,500, making the total cost for the finally completed breakwater $123,400.

6. The original design provided for a stone mound with 1 to 1 side slopes to mean low water with a cut stone parapet wall 16 feet wide at MLW and 10 feet wide at elevation 10. The western 375 feet of the structure was completed to this design between 1828 and 1837. In 1853 the western 215 feet was strengthened by addition of stone to bring the sea side slope of the stone mound to 1 on 2 and widen it to 22 feet at MLW. The remainder of the previously completed work had been damaged too much to be strengthened.

7. In 1873 the design was modified to provide a stronger structure. The cross section between stations 2 + 15 and 7 + 65 (Station 0 + 00 is at the west end of the structure) was built with the stone mound 20' wide at MLW with side slopes of 1 on 1 on the harbor side and 1 on 2 on the sea side. The parapet wall varied from 14 feet wide at elevation 8.5 to 20 feet wide at MLW, with a layer of stone 12 feet wide at elevation 10 and a top layer 10 feet wide at elevation 11.5.

8. Between stations 7 + 65 and 8 + 60 the stone mound was the same but the parapet wall was built tapered from 20 feet wide at MLW to 16 feet wide at elevation 7 and the two top courses of stone, which completed the wall to elevation 10, were laid parallel to the breakwater instead of perpendicular as in the rest of the structure. From station 8 + 60 to the end, the cross section was much heavier, the stone mound being 30 feet wide at MLW with the same 1 on 1 harbor side slope and 1 on 2 sea side slope. The wall as built varied from 28 feet wide at elevation 7 to 30 feet at MLW with two layers of stone 10 feet and 12 feet long on the top to complete the wall to elevation 10.

9. The stone specified for the work completed in 1881 included blocks and rubble stone to average 1.5 tons with none less than 0.25 tons for the stone mound below MLW. The parapet wall was to be laid up masonry blocks averaging 1 ton with none less than 0.25 tons. The top layer stones still on the eastern end of the structure are 10 feet or 12 feet long, 1.5 feet thick and about 1.5 feet wide, and are estimated to weigh about 1.8 tons.

10. Maintenance of the work completed in 1881 was first required in 1937, when the breakwater tip was restored and reinforced at a cost of $2,700. The only maintenance since then was done in 1950 when 3,200 tons of stone riprap were placed to repair the parapet wall from station 0 + 00 to 5 + 15, between 6 + 24 and 7 + 28, and at the tip at a cost of $29,200. Because it was economically impossible to duplicate the original construction of the parapet wall in 1950, the wall was repaired by placing stone riprap with 1 on 1 side slopes to a top width of 10 feet at elevation 10. The stone specifications required 95% to be over 1 ton, from 10% to 20% to be between 1 and 2 ton, and 3 to 6 ton stone for the top and slopes with the heaviest stone to be placed along the toes of the slopes. The navigation beacon at the breakwater tip was re-installed after the tip was repaired. Surveys made in 1956 showed that the most of the areas repaired in 1950 required maintenance again.

11. Surveys to determine present conditions were made in September and October 1960. The plotted cross sections show that the top of the breakwater is almost completely broken down between stations 0 + 00 and 8 + 00 to an average height of about elevation 7, and at one point (station 1 + 50) almost to elevation 3.1, which is mean high tide level. No maintenance is required between stations 8 + 00 and the tip, except for a short section between stations 10 + 75 and 11 + 10.

12. Suitability of Design as Constructed. - The breakwater was originally authorized and constructed to provide a harbor of refuge and shelter an anchorage for small coastal sailing vessels. The protected anchorage has been used for refuge since the breakwater was completed and is still necessary to protect present vessel traffic. The breakwater is required to protect the anchorage and its design as a harbor facility, that is its location and height, is considered adequate and necessary to serve this purpose.

13. The structural design of the breakwater as constructed is considered to be adequate, in view of the fact that no major repairs or maintenance was required from 1881 to 1950, well over the 50-year project life normally considered reasonable. However, it is not considered economically possible to duplicate the construction method and design used when the breakwater was built.

14. Data and Criteria Used in the Design Developed for Repair of the Structure.--Wave refraction studies were made to select a design wave for the breakwater location but the results were inconclusive because of extreme irregularity of the bottom of Nantucket Sound. Although the

fetch to Marthas Vineyard is 17 miles, to Nantucket is 21 miles, and is unlimited between the two; there are many intervening shoals of 0 to 12 feet that would break up and refract large or long period waves.

15. It is considered that the best evidence of the size of waves at the breakwater is the breakwater itself. The structure was constructed with four different sections in 1881, repaired in another manner in 1950, and each section shows differing degrees of damage from wave attack. The stronger eastern part has effectively resisted wave attack for 80 years with no major damage, while a weaker section built in 1881 lasted at least until 1936 without major damage and was first repaired in 1950. The repair section constructed in 1950 had been badly damaged by 1956.

16. Analysis of the stronger eastern section using the WES - Hudson formula for stable cover stone weight (with a K_Δ of 10 in view of the tight interlocking of the laid up masonry in the wall above MLW) indicates this section would be stable under a design wave of 9.4 feet. In the same manner the design of the central section was found to be adequate for a design wave of 7.5 feet, and the 1950 repair section (with a K_Δ of 2.5) satisfactory for a design wave of 7 feet.

17. It was concluded that a design wave of less than 7.5 feet would be too small, that a design wave between 7.5 and 9.4 feet would be reasonable, and that a design wave of 9.4 feet would be conservative. The design wave was therefore selected as 9.5 feet.

18. Riprap stone up to about 7 tons is commonly available, and contractors are skilled in constructing stone riprap breakwaters and jetties, so that this type of structure is economical in this area. The weight of cover stone for various side slopes was investigated using the WES - Hudson formula

$$Wr = \frac{Wsr\ H^3}{K_\Delta\ (Sr - 1)^3\ \cot a}$$

for stone weighing 165 pounds per cubic foot using a K_Δ of 2.5. It was determined that a cover stone layer 8 feet thick of 5 ton stone placed on a 1 on 1.5 slope would be required. The required crest width, 2 stones wide, would be 8 feet.

19. In general the existing structure has a sea side slope of 1 on 2 below MLW and varying slopes from 1 on 1 to 1 on 1.5 above MLW. The width at MLW varys from 20 to 28 feet. The thickness of the cover layer required to permit adequate interlocking is greater than the difference in elevation between the existing top of the structure and the required crest elevation. Building up the structure to the required elevation would therefore require removal of the top of the existing structure down to elevation 2, or placing cover stone of the required thickness on

the inner or outer face. Because less material would be required, and any necessary rehandling to interlock new stone would be above MLW, it is considered that the repair stone should be placed on the harbor side of the existing breakwater centerline.

20. Proposed Design for Rehabilitation of the Breakwater. - The selected design for rehabilitation is a riprap mound with a crest width of 8 feet at elevation 10 and side slopes of 1 on 1.5, constructed with 5 ton stones placed on the top and harbor side of the existing structure. This design is considered equivalent in stability to the design originally constructed, which is too costly to duplicate. The proposed design will be far easier to repair when maintenance is required.

21. Necessity for Repairs or Replacements. -There is no indication that the need for a breakwater in this location will change in the foreseeable future. There was no maintenance cost for the original structure during the first 50 years that would be considered a normal project life. Because it would be unreasonable to predict that no future maintenance would be required for a 50-year project life it is estimated after rehabilitation the top 4 feet of the structure will require replacement during a 50-year project life. This amounts to about 3,500 tons of stone in 50 years or 70 tons/year. On this basis the average annual maintenance cost is estimated at $1,000.

LOCAL COOPERATION

22. All requirements of local cooperation for the existing project have been fully complied with. Total costs for all requirements of local cooperation under terms of the project authorization amounted to $103,001. In addition, the Commonwealth of Massachusetts and local interests have expended nearly $235,000 in extending the breakwater to shore, and in dredging channels in the outer and inner harbors, and $52,000 have been expended by local interests for construction of a riprap jetty 1,000 feet long extending south from Dunbar Point.

23. No requirements of local cooperation were prescribed when the breakwater was authorized.

LOCATION AND TRIBUTARY AREA

24. The area tributary to Hyannis Harbor consists of parts of the towns of Barnstable and Yarmouth. Hyannis, a village within the town of Barnstable, is the principal business center on Cape Cod. The area is primarily a resort area and is extensively developed with summer residences. Many of the summer residents have pleasure craft and ply the adjacent waters of Lewis Bay and Nantucket Sound. The major industries are the service of the summer residents and fishing. Regularly scheduled ferries to Nantucket and Marthas Vineyard are based at Hyannis.

PROJECT PLAN

25. The project plan consists of rehabilitation of the existing breakwater to the authorized height by placing a stone riprap mound along the damaged portion. The stone mound is to have a crest width of 8 feet at elevation 10, side slopes of 1 on 1.5, and be constructed with 5-ton stones placed on the top and harbor side of the existing structure. Rehabilitation is required from station 0 + 00 (at the west end) to 7 + 75 and from 10 + 75 to 11 + 10.

COST ESTIMATES

26. The current estimate of cost is based on the volume of material required to achieve the design dimensions as determined from cross section surveys made in September and October 1960, and unit prices prevailing in January 1960.

Breakwater (Rehabilitation)	
Stone riprap 14,000 tons at $10 per ton	$140,000
Contingency allowance @ 10%	14,000
Engineering and Design	4,500
Supervision and Administration	16,500
Total	$175,000

27. The current cost estimate is greater than the $45,000 allocated and available for rehabilitation of the breakwater. The increase is partly due to additional damage to the structure subsequent to the investigation on which the budget estimate was based. However, a factor of greater importance is the change in the design for rehabilitation. Careful consideration was given to rehabilitation within the limitation of the available funds, and the possibilities of partial rehabilitation to lower design standards. Rehabilitation to lower standards would increase future

maintenance costs substantially and result in a higher project annual cost. Partial rehabilitation would only reduce the future maintenance in proportion to the length of structure rebuilt.

28. It is therefore considered that the breakwater should be rebuilt to the new design cross section insofar as possible with the presently available funds and the remaining work done when additional funds become available. Breaking the rehabilitation work into two separate units done at different times would increase the rehabilitaion cost as shown below:

Breakwater Rehabilitation	Partial	Completion	Sum
Stone volume (tons)	2,600	11,400	14,000
Contract unit price	$12.00	$10.10	-*-
Contract cost	$31,000	$115,000	$146,000
Contingency allowance @ 10%	3,000	11,000	14,000
Engineering and Design	4,500	2,500	7,000
Supervision and Administration	6,500	11,500	18,000
Total	$45,000	$140,000	$185,000

29. Rehabilitation to the extent possible with the presently available funds would permit rebuilding 140 feet to design height between stations 6 + 35 and 7 + 75, and thus extend the longest portion of the breakwater that is in good condition from 300 feet to 440. Doing this partial work is considered justified even if the remaining rehabilitation is indefinitely postponed, as it is expected that it will prevent additional damage which would increase future repair costs.

SCHEDULES FOR DESIGN AND CONSTRUCTION

30. Field investigations consisting of profiles and cross sections were completed in October 1960. Design studies are complete and preparation of standard plans and specifications are about 30 percent complete. Invitation for bids will be issued in April and construction is scheduled to start in May 1961. Construction to the limit of presently available funds would be completed in June 1961. If additional funds are made available this fiscal year to permit completion of the rehabilitation under a single contract, construction could be completed in July 1961.

Fund Requirements:

Allocated to date	$ 45,000
Additional funds required to complete full rehabilitation	130,000
Total (Jan 1961)	$175,000

BENEFITS

31. Benefits were not evaluated at the time the breakwater was authorized (in 1827). The breakwater, and the anchorage behind it that was dredged in 1906, was justified on the need for a harbor of refuge for coastal sailing vessels. Although commercial sailing vessels are gone now, the anchorage and the breakwater which shelters it are still necessary for present and prospective vessel traffic.

32. The harbor is used by an estimated 50 fishing boats that take shelter during fog and adverse weather conditions. This fleet is made up of menhaden boats from as far as New Jersey and menhaden purse seiners from Norfolk, Virginia and Lewes, Delaware. These boats, which follow the fish up the coast, use Hyannis Harbor for refuge.

33. In addition the anchorage is used for refuge by a large number of recreational craft that operate in Nantucket Sound, and it is the only refuge available under certain conditions. The breakwater also provides shelter when the entrance to the 12-foot channel into the inner harbor is hazardous to navigate because of storm waves. The anchorage behind the breakwater is also used by a local fleet of yachts, sail boats, inboards and outboards.

34. In view of the large number of boats that use the protected anchorage for refuge it is considered that the breakwater should be rehabilitated and the anchorage maintained as a harbor of refuge.

RECOMMENDATION

35. It is recommended that funds in the amount of $130,000 be allocated to permit complete rehabilitation of the breakwater structure in one contract.

3 Incl
1. Appendix - Breakwater Design
2. Map - Hyannis Harbor, Project Plan
3. Survey Drawings - Hyannis Harbor - Breakwater Profile and Cross Sections (HY 134 - 3 Sheets)

DESIGN MEMORANDUM

on

HYANNIS HARBOR, MASSACHUSETTS

(MINOR REHABILITATION - BREAKWATER)

APPENDIX

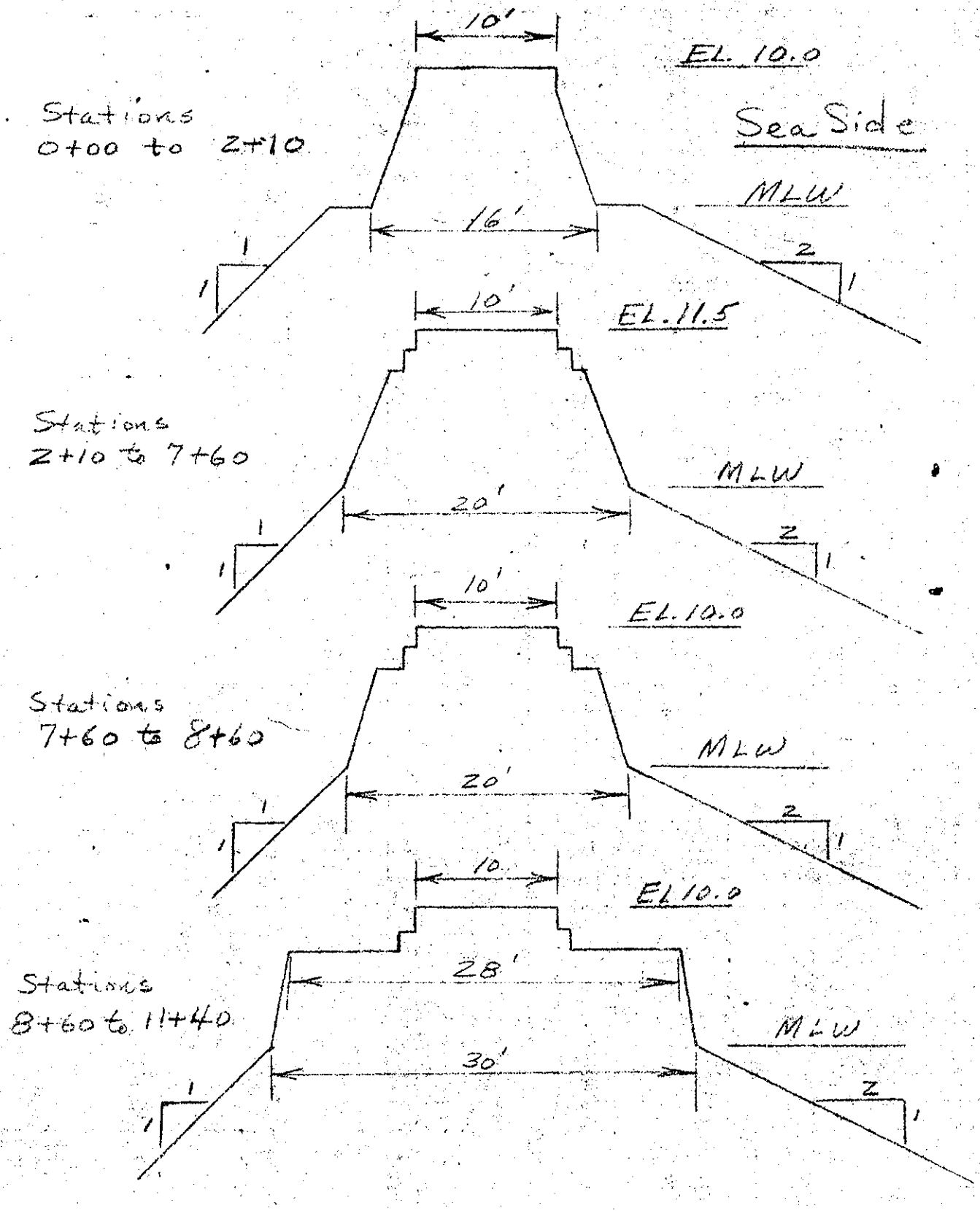
BREAKWATER DESIGN

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

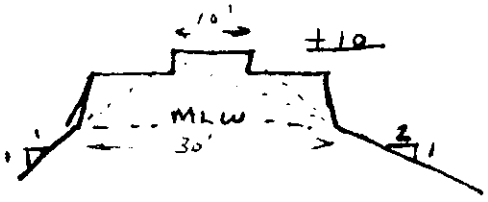
Appendix

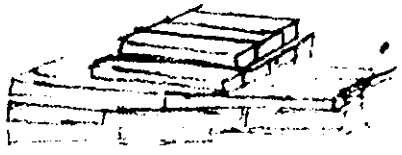
SUBJECT: Design Memo – Hyannis Harbor Breakwater
COMPUTATION: As built Cross Sections 1873 Design
COMPUTED BY: A R Chandler CHECKED BY: DATE: 13 Jan 61



SUBJECT Design Memo - Hyannis Harbor Breakwater
COMPUTATION Design of Existing Structure
COMPUTED BY A. R. Chandler CHECKED BY DATE 16 Jan '61

East End - Completed ~~1873~~ 1881 - Still in good condition



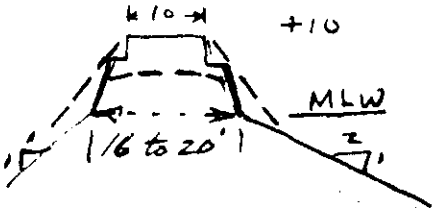


Granite Blocks
10' to 12' long
about 1½' square

1.5 x 1.5 x 10' = 22.5 ft³
@ 165/2000 = 1.8 Tons

Interlocked in layers

West End - Completed ~~1873~~ 1881 - Repaired in 1950



Top 3 to 5' knocked off
Replaced with riprap 3-6 Ton
Stone on 1:1 slopes.
Much of repaired work damaged by 1956

Therefore: Design of east end is adequate.

Original design of west end fair (lasted 1881-1936 ok 53 years)
(Breakwater tip repaired in 1936 - no other work needed then)

Repair design inadequate - But should be ok for waves of about $H_{1/3}$ = 7' to 9' (3 to 6 tons)
(top stones probably were as small as 3 tons).

Original east end design is difficult to evaluate but is estimated to be equal to rubble on 1:1 slope weighing 4 times actual weight of interlocked stone (7.2 tons) which would be ok for $H_{1/3}$ = 9.4 feet.

Original west end design same weight on 0.5:1 slope which would be ok for $H_{1/3}$ = 7.5 feet

SUBJECT Design Memo - Hyannis Harbor Breakwater
COMPUTATION Design of Rehabilitation
COMPUTED BY A.R. Chandler CHECKED BY DATE 16 Jan 61

Study of present cross-sections indicates almost all have slopes below mean low water of 1:2 and slopes of about 1:1.5 above m.l.w. Structure appears to be stable on 1:2 slope below m.l.w.

Design Wave use $H_{1/3} = 9.5$ feet

Cover Stone WES formula

$$W_r = \frac{W_{sr} H^3}{K_a (S_r - 1)^3 \cot a}$$

$W_{sr} = 165$ #/cuft

$S_r = \frac{S_s}{S_w} = \frac{2.65}{1.03} = 2.57$

$K_a = 2.5$ breaking waves

$H_{1/3} = 9.5$

1:1 side slope $\frac{165(9.5)^3}{2.5(1.57)^3\ 1} = 17.05 \frac{(9.5)^3}{1} = 14,600$ (857.4) 7.3 tons

1:1.5 " ÷1.5 9,740 4.86 tons

$\boxed{\text{USE } \underline{5 \text{ ton stone}} \text{ on } \underline{1:1.5 \text{ slope}}}$

Cover thickness

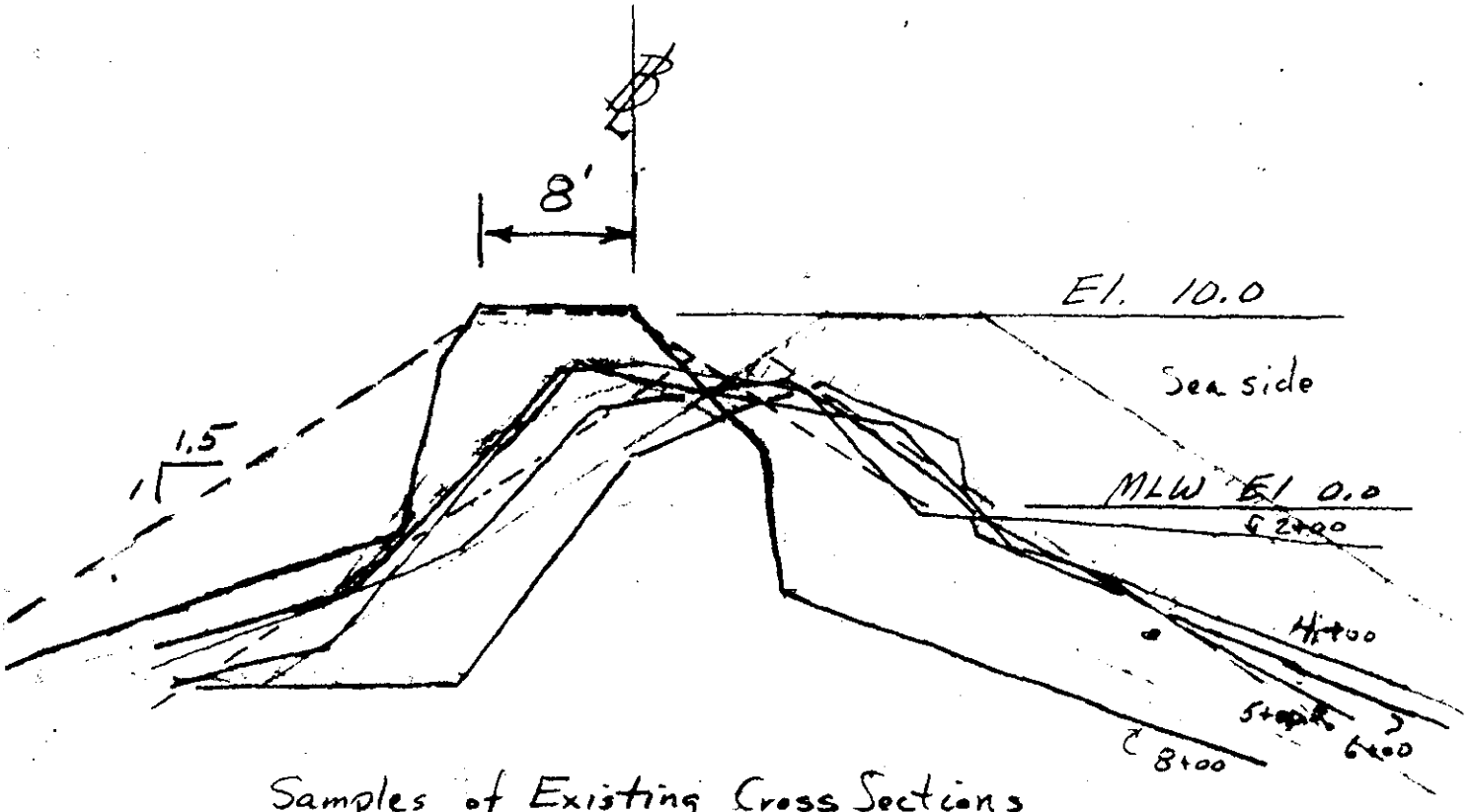
Nominal cube $\sqrt[3]{5^T \times 2{,}000^{\#}/165^{\#}/ft^3} = 3.9'$

$\boxed{\text{USE minimum 2 stones} \quad 8' \text{ cover layer}}$

Crest Width

$\boxed{\text{USE minimum - 2 stones} \quad 8' \text{ crest width}}$

SUBJECT Design Memo - Hyannis Harbor Breakwater
COMPUTATION Design of Rehabilitation Section
COMPUTED BY A. R. Chandler CHECKED BY DATE 16 Jan 1961



Samples of Existing Cross Sections

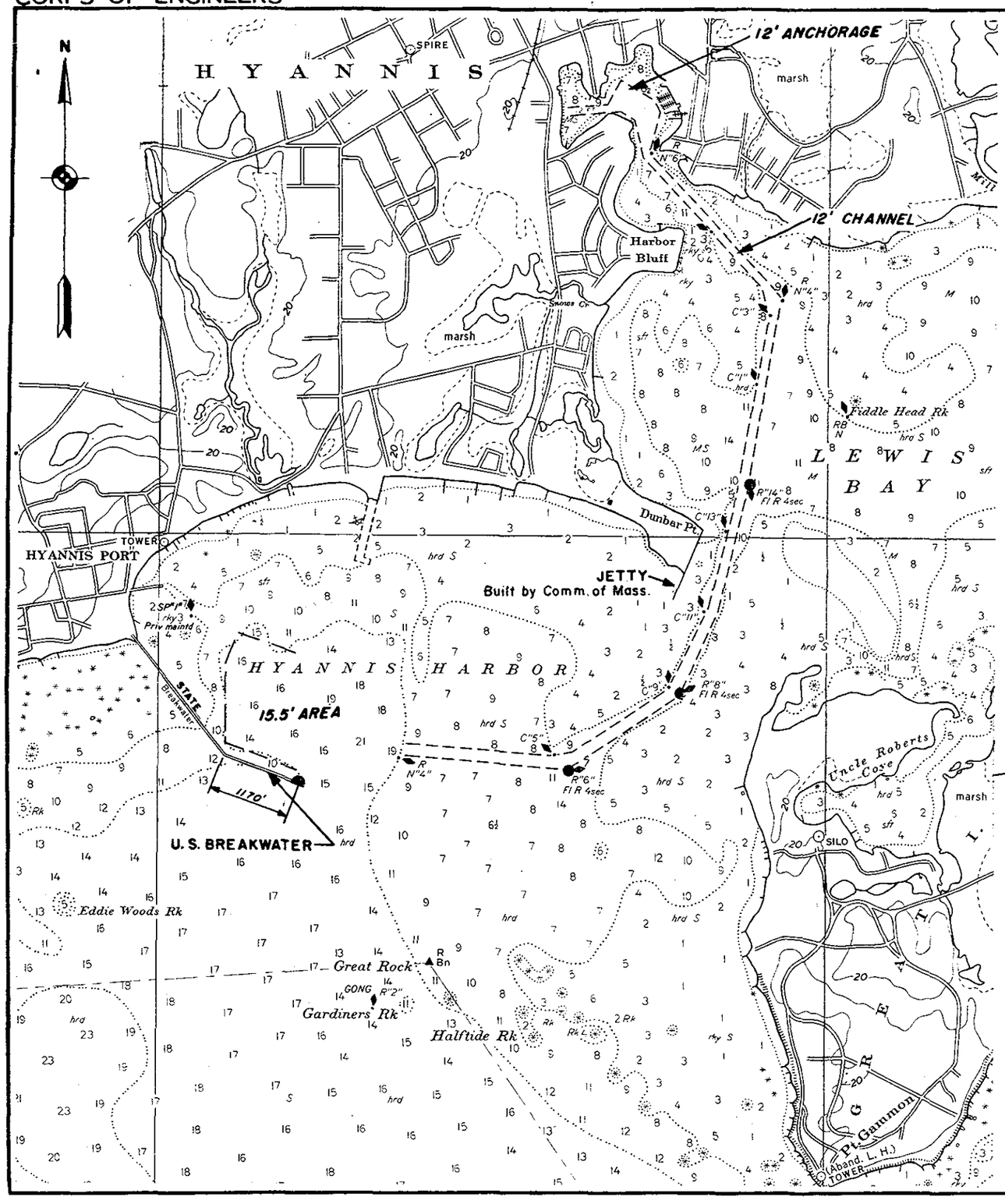
Repair Cross Section fitted to Base line to

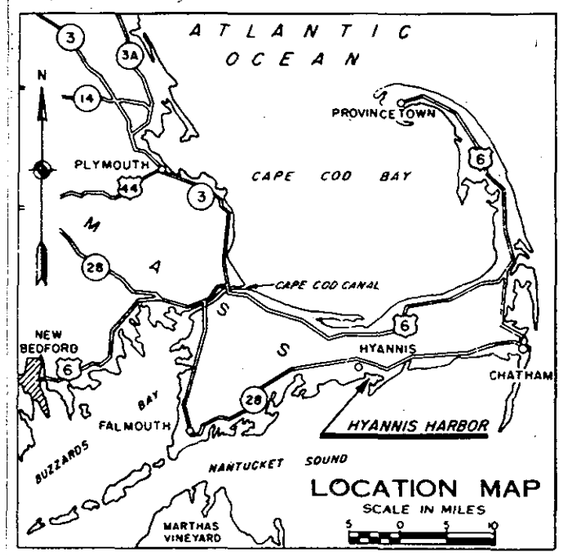
a) Keep crest behind 1:1.5 Slope from M.L.W.

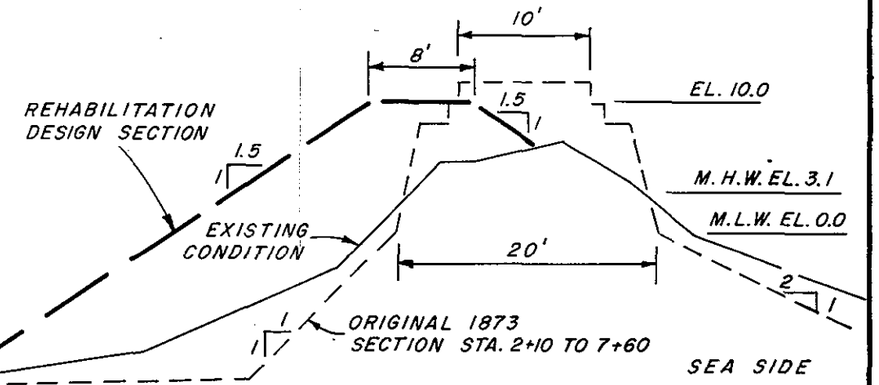
b) Ensure Repair thickness of about 8'.

c) Meet good existing work on east end.

Note: This places all repair stone on top and harbor side of existing structure, but requires less stone than would be needed if the repair stone were placed on the sea side, and will not require rehandling existing outer slope riprap 10 feet below mlw to toe new stone in.







TYPICAL SECTION
BREAKWATER REHABILITATION

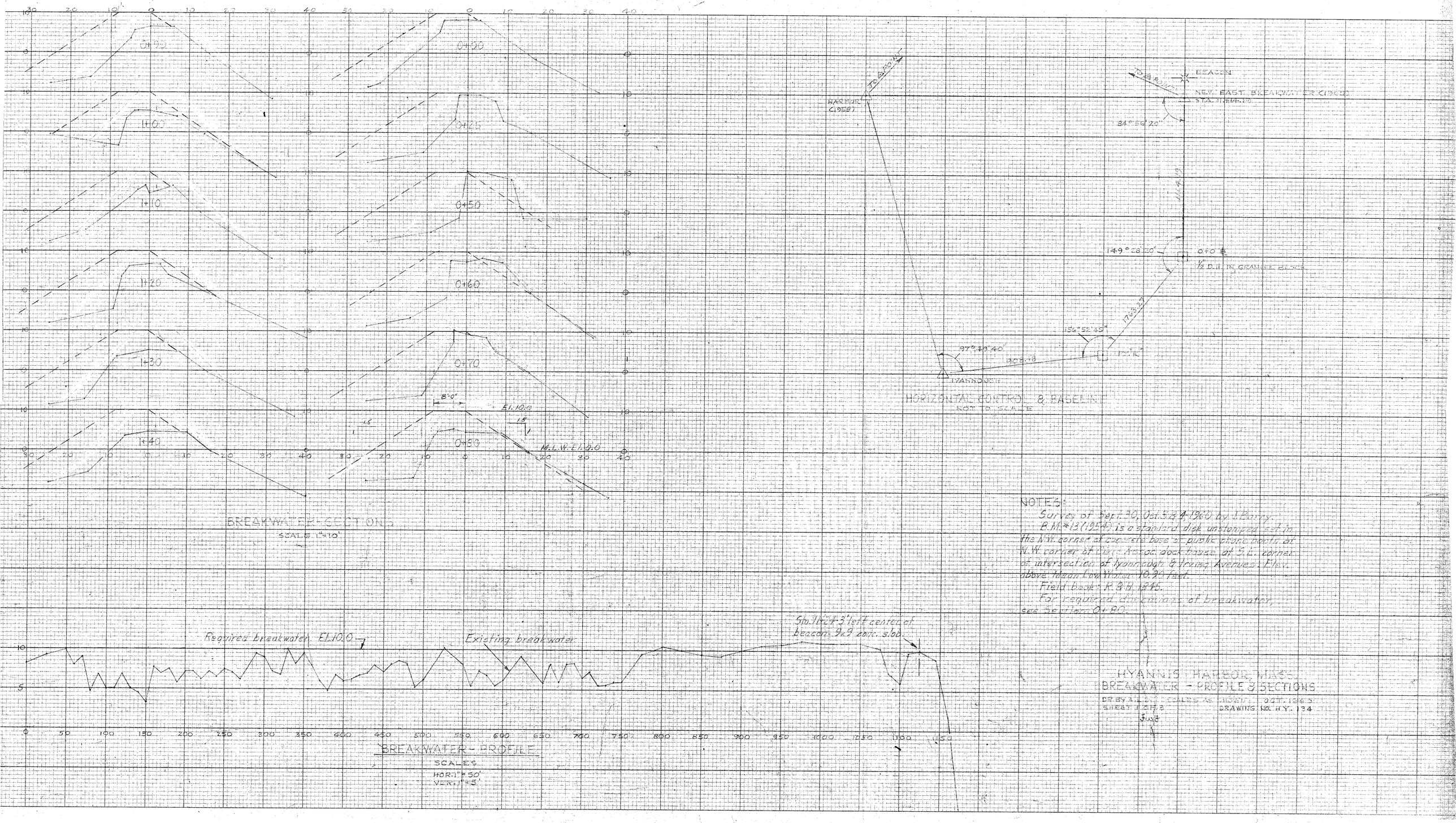
SCALE IN FEET
5 0 5 10 15

TO ACCOMPANY
DESIGN MEMORANDUM
DATED FEBRUARY 10, 196

HYANNIS HARBOR, MASS.
PROJECT PLAN

SCALE IN FEET
1000 0 1000 2000

U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.



NOTES:

Survey of Sept. 30, Oct. 3 & 4, 1960 by J. Barry.

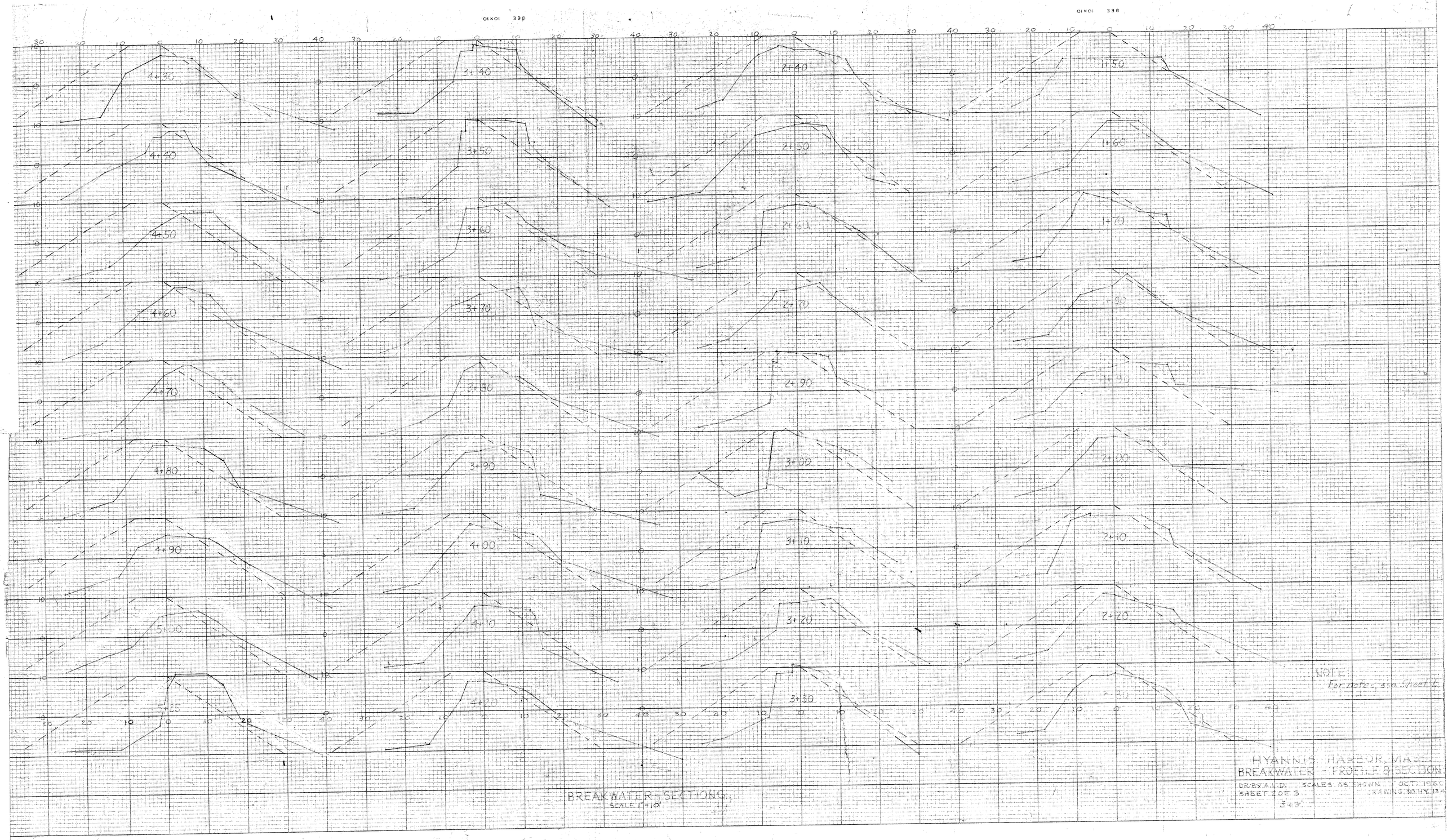
B.M. #13 (1954) is a standard disk unstamped set in the N.W. corner of concrete base of public phone booth at N.W. corner of Cape Assoc. dock house at S.E. corner of intersection of Iyannough & Irving Avenues. Elev. above Mean Low Water 10.90 feet.

Field Book: R.&H. 1845.

For required dimensions of breakwater, see Section 0+80.

HYANNIS HARBOR, MASS.
BREAKWATER - PROFILE & SECTIONS

DR. BY A.L.B. SCALES AS SHOWN OCT. 1963
SHEET 1 OF 3 DRAWING NO. HY. 134


4+30
4+40
4+50
4+60
4+70
4+80
4+90
5+00
5+25
2+40
3+50
3+60
3+70
3+80
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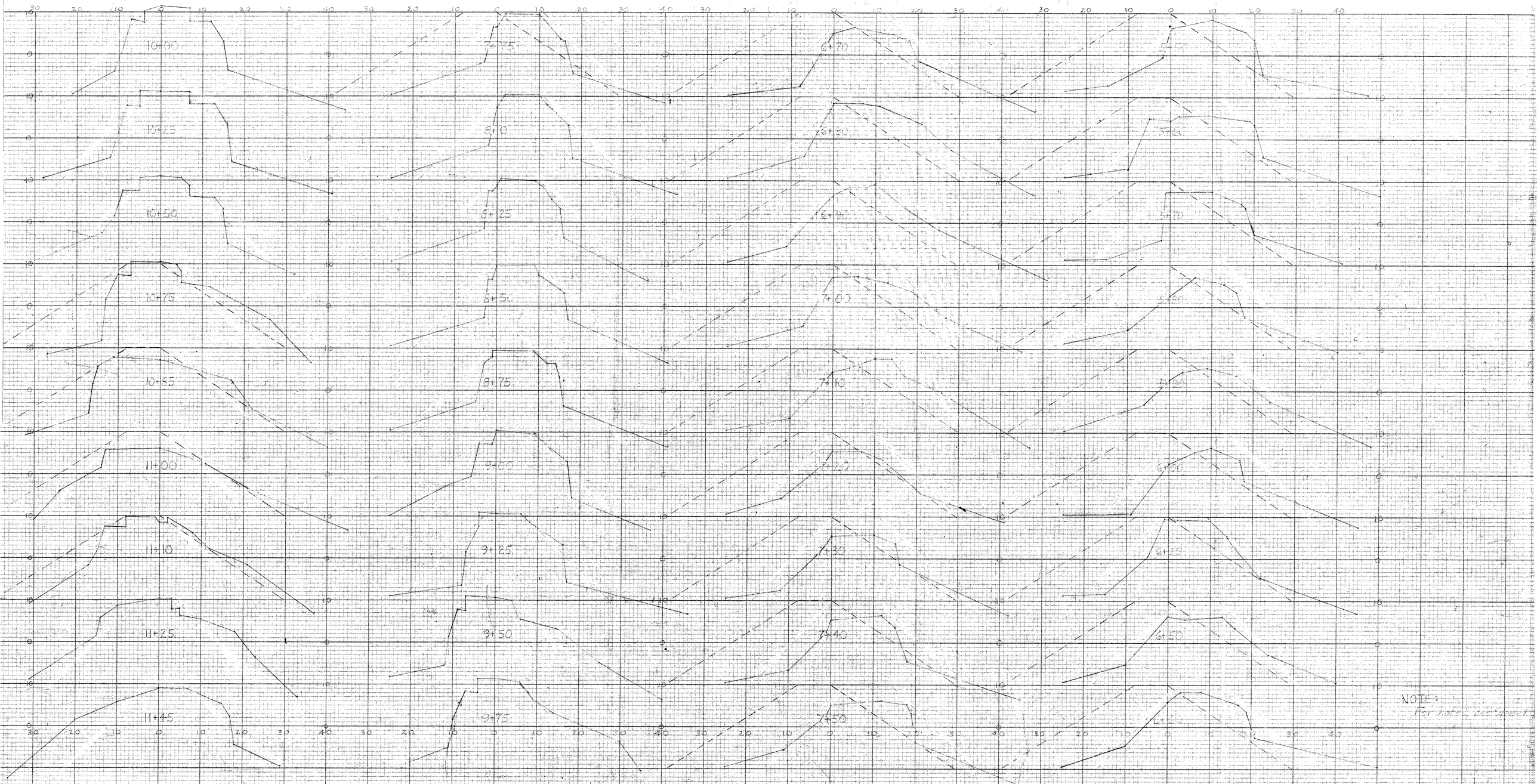
3+10
3+20
3+30
1+50
1+60
1+70
1+80
1+90
2+10
2+20
2+30
NOTE:
For notes, see Sheet 4.
BREAKWATER SECTIONS
SCALE 1"=10'
HYANNIS HARBOR, MASS.
BREAKWATER - PROFILE & SECTION
DR. BY A.L.D. SCALES AS SHOWN OCT. 1962
SHEET 2 OF 3 DRAWING NO. HY 13



BREAKWATER SECTIONS
SCALE 1"=10'

HYANNIS HARBOR, MASS.
BREAKWATER - PROFILE & SECTION
DR. BY A.L.D. SCALES AS SHOWN OCT. 19
SHEET 3 OF 3 DRAWING NO. H.Y. 13