

APPENDIX A - SHIP SIMULATION STUDY

1 Introduction

Background

The Port of Baltimore was established in 1706. It is one of America's busiest deep-water ports. It is situated in a sheltered harbor and is easily accessed by major American and foreign ports. Its 45-mile shoreline supports many terminals for commercial trade, as well as public and private cargo terminals. It is located approximately 12 miles northwest of the Chesapeake Bay on a 32-square-mile area of the Patapsco River, Figure 1. The Patapsco River originates near Westminster, Maryland, and flows southeasterly for 65 miles to enter the Chesapeake Bay 9 miles south of Fort McHenry.

The port may be reached from the Atlantic Ocean by traveling 113 nautical miles west through the Delaware Bay, Chesapeake and Delaware (C&D) Canal, and the Chesapeake Bay or by traveling 150 nautical miles north through

the Virginia Capes and the Chesapeake Bay. The harbor area includes almost 1600 acres of sheltered waters. Figure 2 shows the Port of Baltimore.

Vessels arrive and depart the Port of Baltimore via the southern Chesapeake Bay (Cape Henry) route or the northern Chesapeake Bay route through the C&D Canal. In October 1990, the main shipping channel from Cape Henry to Fort McHenry was dredged to a depth of 50 feet as part of the Baltimore Harbor and Channels 50-foot project, which gave vessels with drafts up to 47-48 feet, access to the harbor. Ships using the C&D Canal must have a draft no greater than 33 feet.

Ships calling on the Port of Baltimore include containers, bulk carriers, car carriers, tankers, general cargo ships, ro-ro (roll on-roll off) ships, tugs, tug/barge combinations, and naval ships. Container business dominates the port, making it the third largest handler of containerized cargo on the Eastern seaboard.

Navigation Concerns

Increasing growth of the commercial trade in the Port of Baltimore has led to enlargement and improvement of the area. In 1990, the main shipping channel

was deepened to 50 feet, allowing deeper draft vessels to enter the port. In addition, new terminals were constructed, and public and private marine terminals were expanded.

U.S. Army Engineer District, Baltimore (CENAB), proposed a channel improvement project for Baltimore Harbor anchorage and channels in 1997. The proposed improvements involved widening of the East and West Dundalk Channels and the connecting channel, which joins the Seagirt and West Dundalk Channels. The South Locust Point Channel improvements would involve deepening and widening the Fruit Pier Channel. In addition, a proposed improvement involved construction of a 1200-foot square Turning Basin at the head of the Fort McHenry Channel to a depth of 50 feet. The improvements also include deepening and widening portions of Anchorages #3 and #4.

The problems facing pilots in the Dundalk/Seagirt terminal areas result from the narrowness of channel widths in the area. The west branch channel to the Seagirt Marine Terminal is 500 feet wide by 42 feet deep. The west branch channel to the Dundalk Marine Terminal and the connecting channel between Seagirt and Dundalk are 350 feet wide by 42 feet deep. The narrowness of the west branch channel to Dundalk and the connecting channel presents maneuvering problems to vessels, with potential hazards and increased maneuvering times. It was proposed that the west branch channel of Dundalk and the connecting channel

be widened to 500 feet. This modification would allow for safe one-way movement of vessels by creating a consistent loop channel with efficient access to Seagirt and Dundalk terminals. The east branch channel to Dundalk is 300 feet wide and 42 ft deep. Navigational difficulties exist in this area due to the narrowness of the channel. It was proposed that the east branch channel to Dundalk be widened to 400 feet to improve maneuverability.

The existing channel configuration in the South Locust Point Terminal area presents problems to larger ships. To exit the terminal, large vessels must be maneuvered by tugs in the turning basin and depart through the maintained channel section. These conditions are not time or cost efficient. At present, shallow draft vessels exit the terminal via the Fruit Pier Channel, requiring no turning or assistance from tugs. It was proposed that this existing old channel be widened to 400 feet with extra widening at the bends and entrances, and deepened to a uniform depth of 36 feet. This modification would result in a usable loop channel 36 feet deep for all vessels coming to port and eliminate the need for turning exiting larger ships.

The Anchorage #1 (Fort McHenry Anchorage) area at the intersection of the Fort McHenry Channel and the Ferry Bar Channel is often used to turn vessels backing out of the berth at Consolidation Coal Sales Company pier. With a depth

) of 35 feet, the anchorage is too shallow for large ships; therefore, deep draft ships are required to negotiate turns in the main channel outside the anchorage. Due to the restricted area, turning a large vessel requires full tug assistance and takes a significant amount of time. In addition, pilots have reported potentially dangerous conditions exist during these maneuvers, and deep draft vessels have been damaged by backing into the Anchorage. It was proposed that a 1200-foot wide, 50-foot deep turning basin be constructed at the head of the Fort McHenry Channel. The turning basin would include the north section of Anchorage #1. This modification would require deepening of the anchorage area included in the turning basin design. The increased depth within the anchorage would improve the efficiency and safety of turning operations at this location.

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2 Simulation

Simulation Database Generation

Required Data

Data required for a simulation study includes channel layout, bottom topography (bathymetry), channel currents, design ships, and the visual database for each of the Base and Plan conditions. The method for developing each of these is described below.

Visual Scene

The creation of the visual scene database for Baltimore Harbor was mainly derived from navigation charts and from aerial photographs supplied by the District. Modification to these main sources of information was aided by using video and still photos taken during a ship transit and harbor tour with the Association of Maryland Pilots. Employees of the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL) participated in this reconnaissance trip. The reconnaissance trip was also used to document pilot comments on different areas of the channel while in transit. During this trip, a general understanding of the study area was obtained and used along with the data to prepare the simulation prior to validation by the pilots. Revisions were also made based on the pilots' comments during the validation. Bank line configuration, buildings, docks, and other landside features were defined in X, Y, and Z coordinates. These features were then pre-processed for input into the Silicon Graphics Onyx, which generated the visual scene for the harbor. The visual scene was displayed on three large screens per simulator with one-way traffic runs. The simulator setup at the time of this project is shown in Figure 3. Although two-way traffic was not employed for this simulation, both simulators were used for concurrent experimentation.

Radar Scene and Tugboats

The radar file was created from the digitized bank line of Baltimore Harbor created for the visual scene database. The radar database contains information available on a true ship's radar readout, but the database image, Figure 4, is much clearer than a typical ship's radar display to counteract the loss of depth perception from the use of two-dimensional visuals. For this study, four radar ranges were available. A one-quarter-mile-range screen was visible at all times. The other radar screen used was adjustable between 0.75, 1.50, and 3.00 mile ranges.

The quarter mile radar range screen also displayed data about the tugboats being used for maneuvering. A vector on the screen, see Figure 5, showed tug placement, heading, and engine setting. The pilots were asked to use tugs as they would in the harbor. Tugboat settings were verified to act as a typical tugboat available in Baltimore Harbor (a horsepower rating of 3,000). Most pilots used no more than two tugs during an experiment and were allowed to reposition the tug during the run. The time used for repositioning the tug and getting it set up again was based upon the pilots experience and what type of maneuvering was required by the tug.

Channel Database

The channel database was generated from a TABS-MD hydrodynamic study that had been completed at ERDC for the Brewerton Channel Eastern Extension and Tolchester Channels Study in 1996. Currents for an entire Spring Tidal Cycle were calculated. Preliminary analysis showed current magnitudes less than 0.5 ft/sec, so post-project conditions were not calculated separately. The channel database contains the channel bathymetry, current magnitude and direction, and any pertinent environmental data such as wind or waves.

Ship Files

The following two ships were used for the simulation exercise:

1. A bulk carrier - 990' LOA (length overall) x 156' B (beam) x 44' draft
2. A containership - 965' LOA x 106' B x 39' draft

Each of these ships had been previously verified on several other projects performed by the CHL Ship/Tow Simulator, but some changes were made for this study. The most notable changes were the handling characteristics of the ships at slow speeds (less than one knot). The maneuvering performed during this study

used assist tugs and slow speeds because of the docking procedures.

Though a helmsman would normally perform the commands given by the pilot during a transit in the harbor, ship handling was accomplished by the pilot during simulation. This is typically the case in the simulation experiments performed at CHL. The demands placed upon the pilot are considerable, adapting to new and existing channel configurations, rapidly changing ships, and long hours of intense concentration. Having the pilot perform the ship handling eliminates the possibility of the helmsman confusing instructions during the experiment.

Simulation Program

The existing channel and the District supplied plans are shown in Figures 6 - 14.

The simulation program consisted of three stages: 1) validation, 2) testing, and 3) presentation of results. During validation two pilots licensed for Baltimore Harbor came to the CHL Ship/Tow Simulator and simulated transits in the existing harbor for one week. This stage works out any problems with the simulation of the project, such as missing objects in the visual scene, problems with ship handling that would not be experienced in the prototype harbor, bank

effects, wind, currents, etc. After any discrepancies were addressed and/or corrected, the simulated harbor was considered as close to the prototype as CHL, the District, and the pilots felt was possible.

Stage 2 for this project involved six licensed pilots, sent in groups of two for one week at a time. During the testing, the existing channel conditions and proposed design considerations were run in random order (see Table 1 for a full list of runs tested). The existing channel was used as the base to compare with the results of the proposed design runs.

Run	Scenario	Channel	Heading
1	Dundalk 1	Existing	Inbound
2	Dundalk 1	Existing	Outbound
3	Dundalk 1	Proposed	Inbound
4	Dundalk 1	Proposed	Outbound
5	Dundalk 2	Existing	Inbound
6	Dundalk 2	Existing	Outbound
7	Dundalk 2	Proposed	Inbound
8	Dundalk 2	Proposed	Outbound
9	Seagirt 1	Existing	Inbound
10	Seagirt 1	Proposed	Inbound
11	Seagirt 2	Proposed	Inbound
12	South Locust Point	Existing	Inbound
13	South Locust Point	Existing	Outbound

14	South Locust Point	Proposed	Inbound
15	South Locust Point	Proposed	Inbound
16	South Locust Point	Proposed	Outbound
17	South Locust Point	Modified	Outbound
18	Turn in Anchorage	Existing	Outbound
19	Turning Basin	Proposed	Outbound

Both existing and design runs were tested using the spring maximum flood and ebb tides during the first week of testing. However, it was determined with the pilots and the District office that the current magnitude and direction change between the two tidal conditions was insignificant. All remaining experiments were conducted with a flood tide only. Where applicable, inbound and outbound maneuvers were tested.

During the third week of testing, it became apparent that the planned channel at South Locust Point shown in Figure 12, currently known as the Fruit Pier Channel, did not allow ample room for the ship to maneuver into the dock. With input from the pilots and the District office, a modified, slightly widened configuration was designed to be studied (Figure 15).

Stage 3, the results, are presented as track plots in Plates 1-22. Output

from each simulation run (taken at five-second intervals) was collected over the entire schedule of experiments and included the ship's speed, heading, rpm, rudder angle, rate-of-turn, tug usage, and port and starboard clearance to the toe of the channel. The track plots shown in the plates are a representation of the ship's path during the test. Each ship icon indicates the ship's location and heading at approximately one-minute intervals. The rudder displayed on each ship icon is correct for that point in time for the transit; however, it quickly becomes difficult to distinguish between the rudder and the ensuing ship icons. Because of the slow speeds and the tug usage, the rudder angle is not as important for these results as it might be for other projects. Transit time is always a factor for the ships; the difference in time that the plan changes make are also shown in the results.

Simulation Results

The results of the navigation study will be shown by the areas of interest within the Port of Baltimore, which are: 1) Dundalk Channel, 2) Seagirt Channel, 3) South Locust Point, and 4) Fort McHenry Turning Basin. Plates representing the existing channel and suggested plan channels will be discussed for each area, respectively. Since the ebb tide condition was discontinued, those results will be incorporated into the flood tide results, and the two will be discussed as one condition.

Dundalk - Scenario 1

Dundalk Scenario 1 inbound existing and plan tests, Plates 1 and 2, began just inside the Francis Scott Key Bridge, continued up the East Dundalk Channel, and ended at the Dundalk slip. Note the encroachment of the vessel on the channel up from "R 4" in the existing conditions, Plate 1. The vessels went outside of the channel by about 135 feet. As seen in Plate 2, the widening in the plan design alleviated this problem.

The outbound experiments, Plates 3 and 4, reverse the above transit. The vessels start out by backing from the dock and then turning at the head of East Dundalk Channel before continuing outbound to the bridge. Although the existing track-lines in Plate 3 did come closer to the eastern-most channel line than the plan track-lines, there were no significant problems with this outbound scenario.

Figure 16 shows the ending point of the average distance traveled by the vessels during testing for the East Dundalk Channel before docking maneuvers begin. This reference point was selected by picking an area a short distance away from the initiation of docking maneuvers, and examining the output file to see which condition, existing or plan, had an elapsed time shorter than the other. It

was important to select an area outside of docking, because each pilot handles docking differently, and no time constraints are placed upon the pilot that would make the total transit time for each experiment comparable. Once the reference point and the shortest elapsed time were found, (in this case the plan condition), one pilot was chosen to find the corresponding points in the other condition (in this case the existing condition). Only one pilot's trackplot was chosen to minimize the error induced because of the pilot's different approaches to the channel. The figure shows the two transit positions for the vessels. For Figure 16, the distance between the existing and plan vessel is approximately 1600 feet. This translates into a time reduction of about 14 minutes if a comparison speed of 1.5 knots is assumed.

Dundalk - Scenario 2

Dundalk Scenario 2 inbound experiments, Plates 5 and 6, also began just inside the Francis Scott Key Bridge, continued up the East Dundalk Channel, but ended at the western Dundalk slip.

The outbound experiments, Plates 7 and 8, started at the western Dundalk slip, and turned down the West Dundalk Channel. No major problems existed in either of these sets of track plots; however, once again there was a slight decrease in the maneuvering required in the planned channel that created a reduction in transit

time, shown in Figure 17, of about 14 minutes (about the same as Scenario 1).

Seagirt - Scenario 1

Plates 9 - 12 show the inbound and outbound transits for Scenario 1, which started at the Francis Scott Key Bridge and ended alongside Seagirt Marine Terminal. None of these experiments showed any significant navigation problems. Although the ships do cut across part of the anchorage just before "R 2", this area is already deep and therefore not a problem. Figure 18 shows a slight advantage in transit time for the inbound transits in the planned channel, about 6 minutes.

Seagirt - Scenario 2

Plate 13 shows the inbound transits for Scenario 2. There is no existing condition plate, because this widened area does not exist currently. There were no problems encountered in these sets of experiments. No outbound runs were performed for this condition because it so closely resembles the outbound Seagirt – Scenario 1.

South Locust Point

Transits into South Locust Point using existing conditions are shown in Plate

14. Normal operation for this terminal involves turning the ship to port and backing to the dock. This maneuver is time consuming but will allow the vessel to exit the dock more smoothly, Plate 15. Plates 16 and 17 show the inbound transits for the South Locust plan conditions. With the Fruit Pier Channel deepened and marked, the vessel can simply pull into the terminal port side to, Plate 16, or starboard side to, Plate 17.

Plate 18 shows outbound plan condition transits. These track plots exhibit some difficulty in maneuvering the Fruit Pier Channel. After discussions with the pilots and the District office, a modified South Locust Point Channel (Figure 15) was developed. Plates 19 and 20 show the inbound and outbound experiments done with this modified Fruit Pier Channel Plan. One pilot (Plate 20 - bow outside of the channel line) had one incident caused by unfamiliarity with the plan. After that, he had no further problems.

Fort McHenry Turning Basin

Plate 21 shows the experiments conducted for Fort McHenry Channel / Anchorage #1 existing conditions. As shown on the plate, the vessels did not back fully into the anchorage area, since the anchorage is shallow (authorized to 35 feet deep), and the pilots do not depend upon that extra space. The position of the

unnamed buoy directly down from "R - 2NH" (shown in Figure 14, but covered up in Plate 21) forces the pilot to wait as long as he thinks possible before starting his turn. The combination of the shallow area and the buoy severely limit the margin of error for this departure. The buoy was encroached upon several times during experimentation.

Although the location of the unnamed buoy does not change in the plan condition (Plate 22) the assurance of the deepened anchorage allowed the pilots to postpone the start of the turn until the ship cleared this buoy.

3 Recommendations/Conclusions

Dundalk and Seagirt

In Dundalk Scenarios 1 & 2 and Seagirt Scenario 1, the widening of the channel improved the maneuverability of the transit. The degree of improvement is not readily apparent in the track plot plates. It must be remembered that the ships are

under tug assistance. Most of the improvement was seen in the shortened transit time shown in Figures 16 - 18. These plates show a 6 - 14 minute reduction in the transit time from existing to plan using a vessel speed of approximately 1.5 knots. These time reductions are only for comparison. The total time savings may or may not be economically significant. Even though each pilot approaches the channel and utilizes tug assistance differently, the time reduction tends to indicate an easier and safer transit. Since this study was completed, a larger design vessel has been considered for the port, thus increasing the economic benefit of this time reduction. The degree of benefit from this improvement will have to be assessed by the District.

Seagirt Scenario 2 opens up a new slip at Seagirt Terminal. The design for this widening demonstrated no problems during testing.

South Locust Point

The addition of the Fruit Pier Channel as a navigable channel reduces the transit time by more than half from buoy "R-2" at South Locust, when the vessel needs to be starboard side to the terminal. This reduction is simply because the vessel no longer has to turn 180 degrees before beginning docking maneuvering. This translates into about an hour difference once the vessel gets to this point in the channel. The only problems with this plan were addressed in the modified plan (Figure 15). Once this modification to the Fruit Pier Channel at South Locust

Point was put in place, the full potential of this improvement was realized.

Fort McHenry Turning Basin

Ship maneuverability improved with the provision of a 50-foot deep and 1200-foot wide turning basin at the head of the Fort McHenry Channel. However, the pilots were able to utilize very little of the deepened and widened turning basin because the vessel was so constricted backing out of the coal dock. Therefore, the Turning Basin improvement needs to be reconsidered. Figure 19 shows a section marked "Area most used for turning". A widening and deepening in this area would better help the vessels turning out of the coal dock and give them some amount of flexibility that they do not now have with the shoaling in that area. A design for widening in that area should be further looked at by the District.

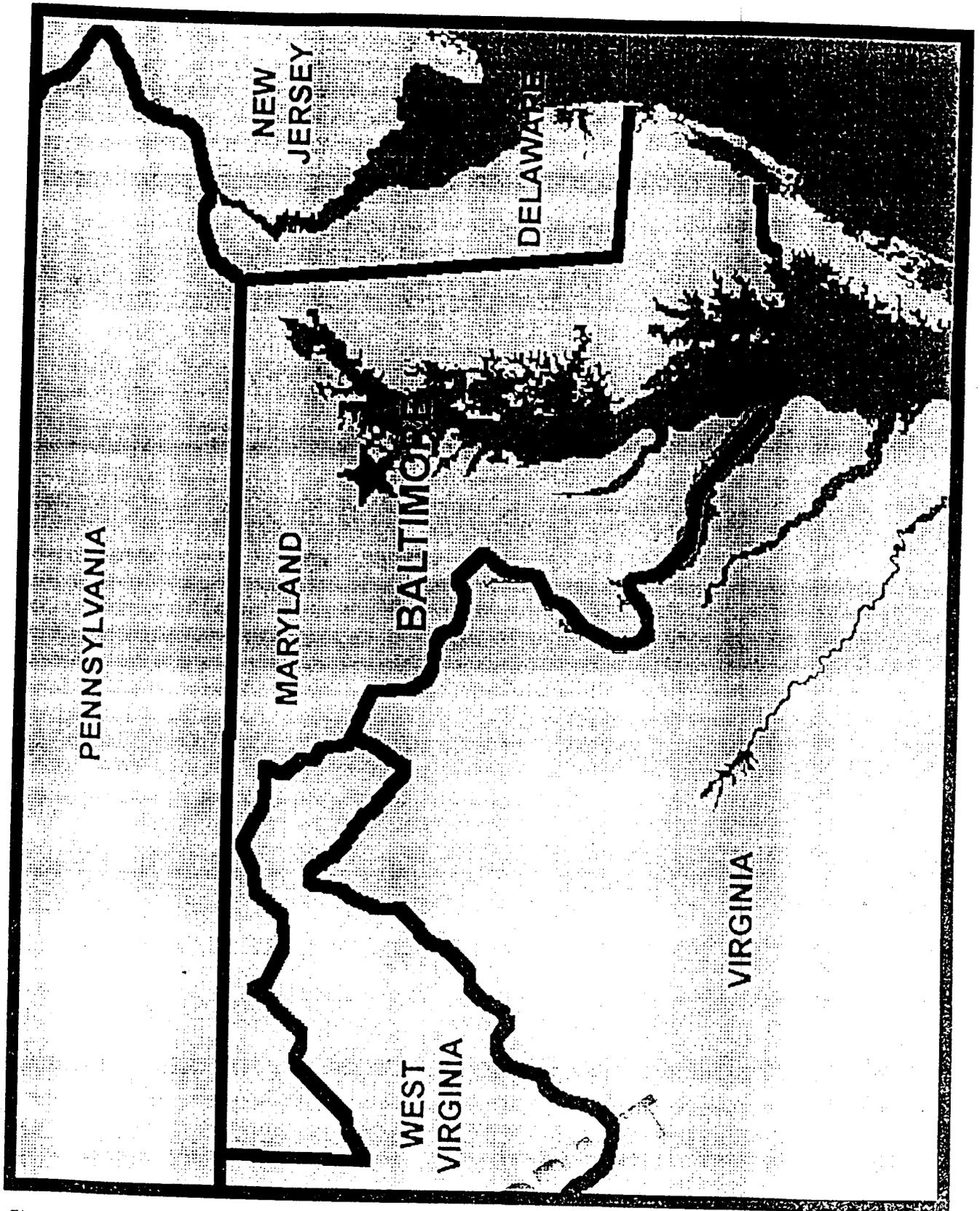


Figure 1 Project Location Map.

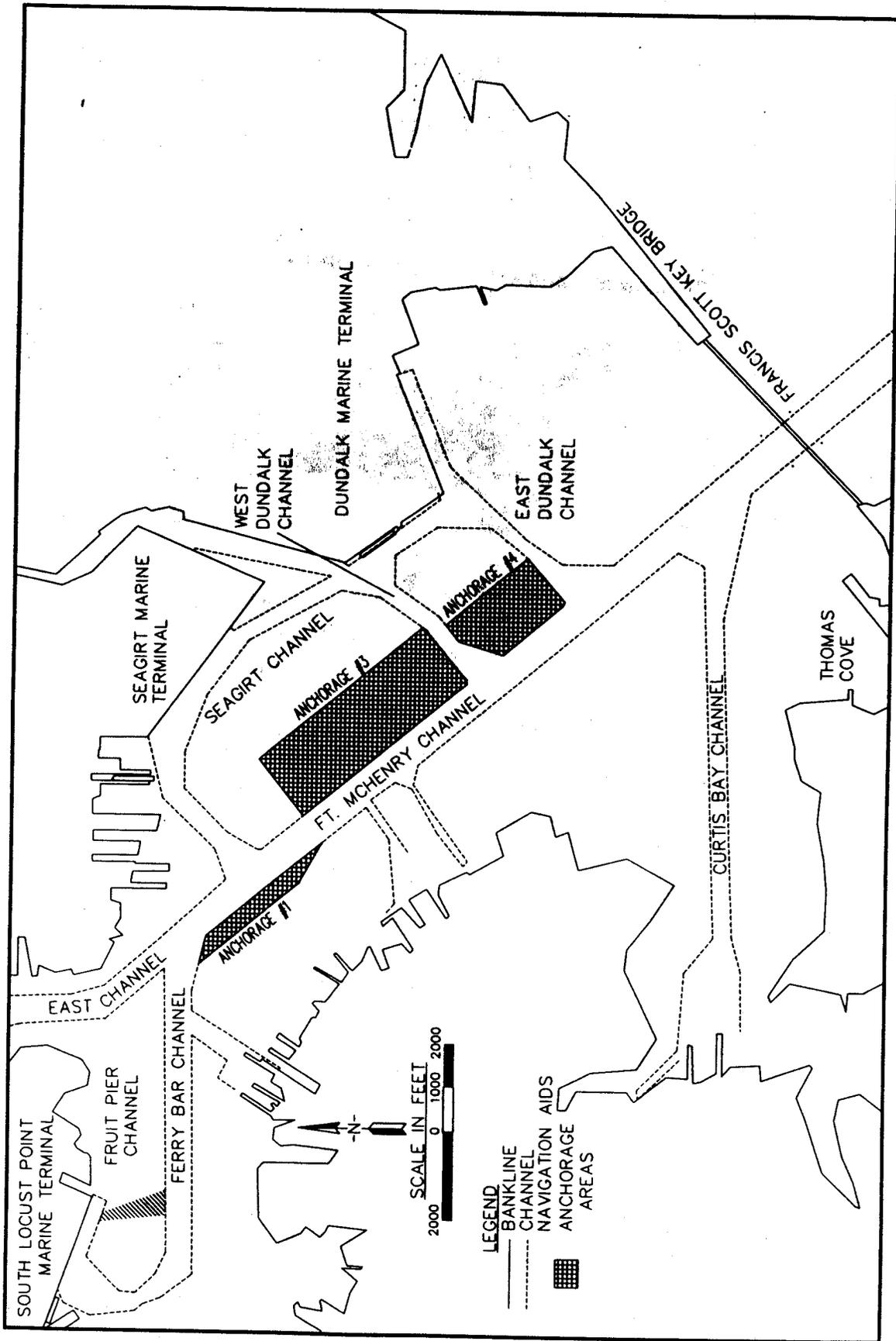


Figure 2. Port of Baltimore

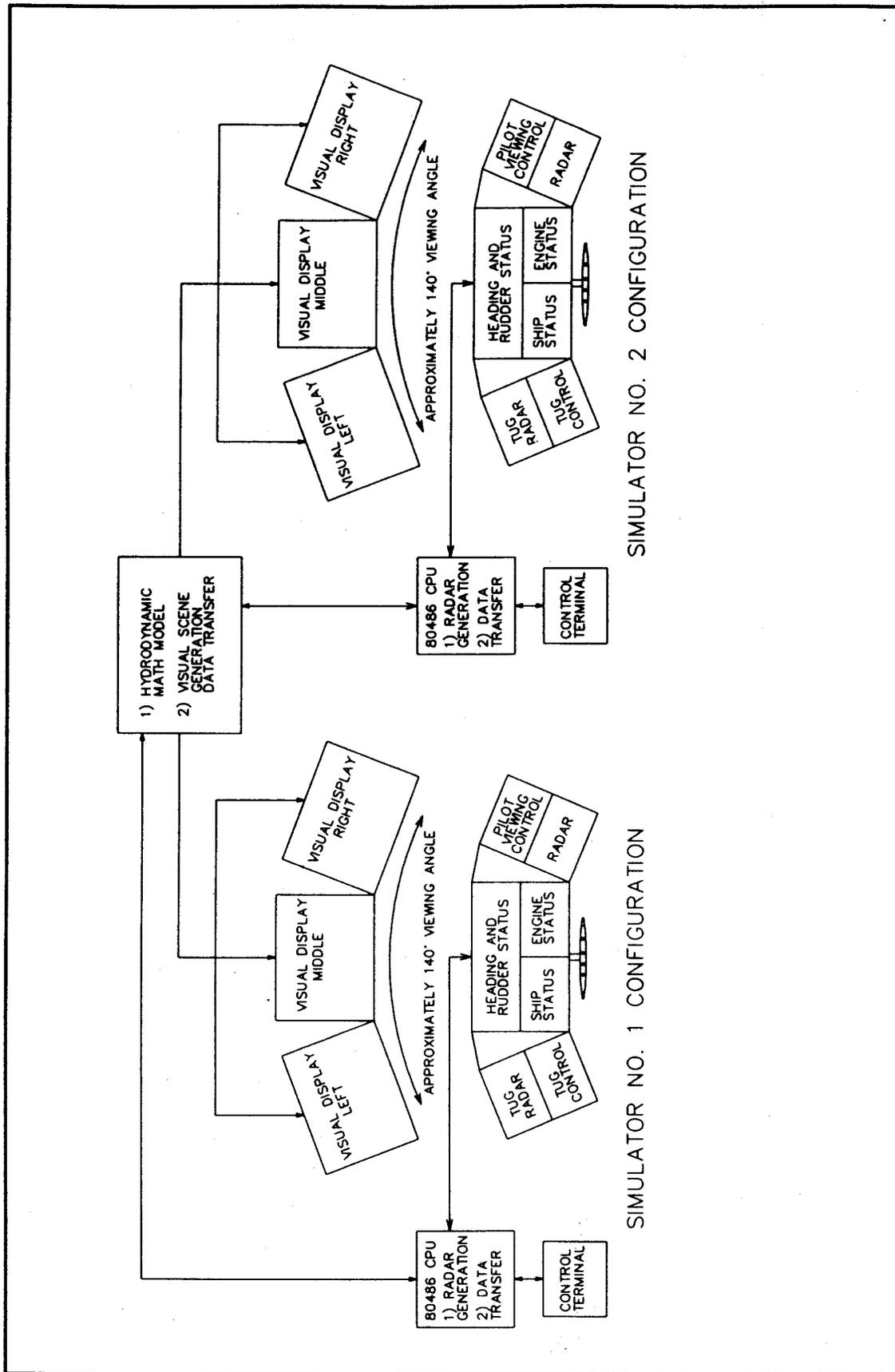


Figure 3. Ship/Tow Simulator configuration

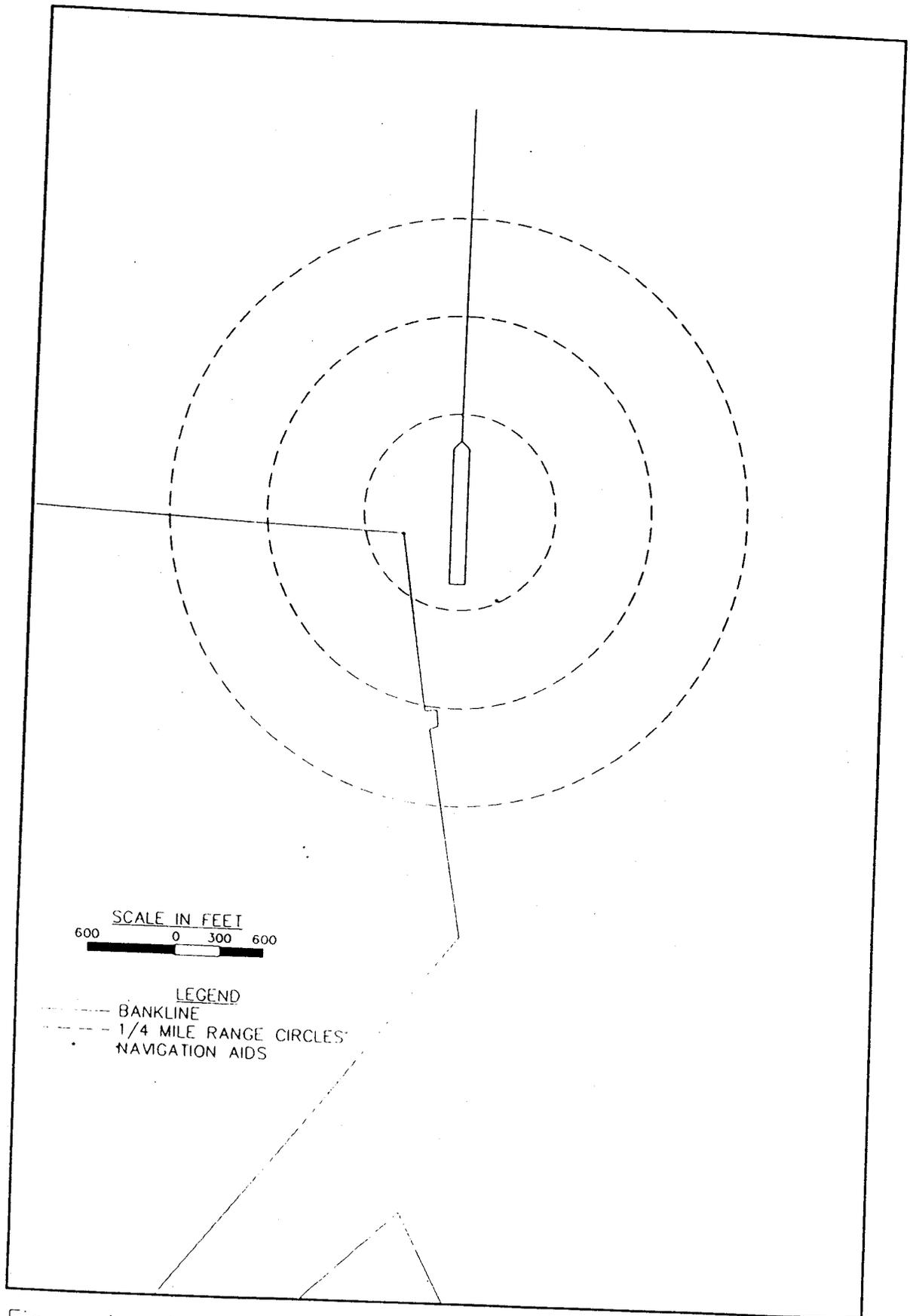


Figure 4. Variable Range Radar Image

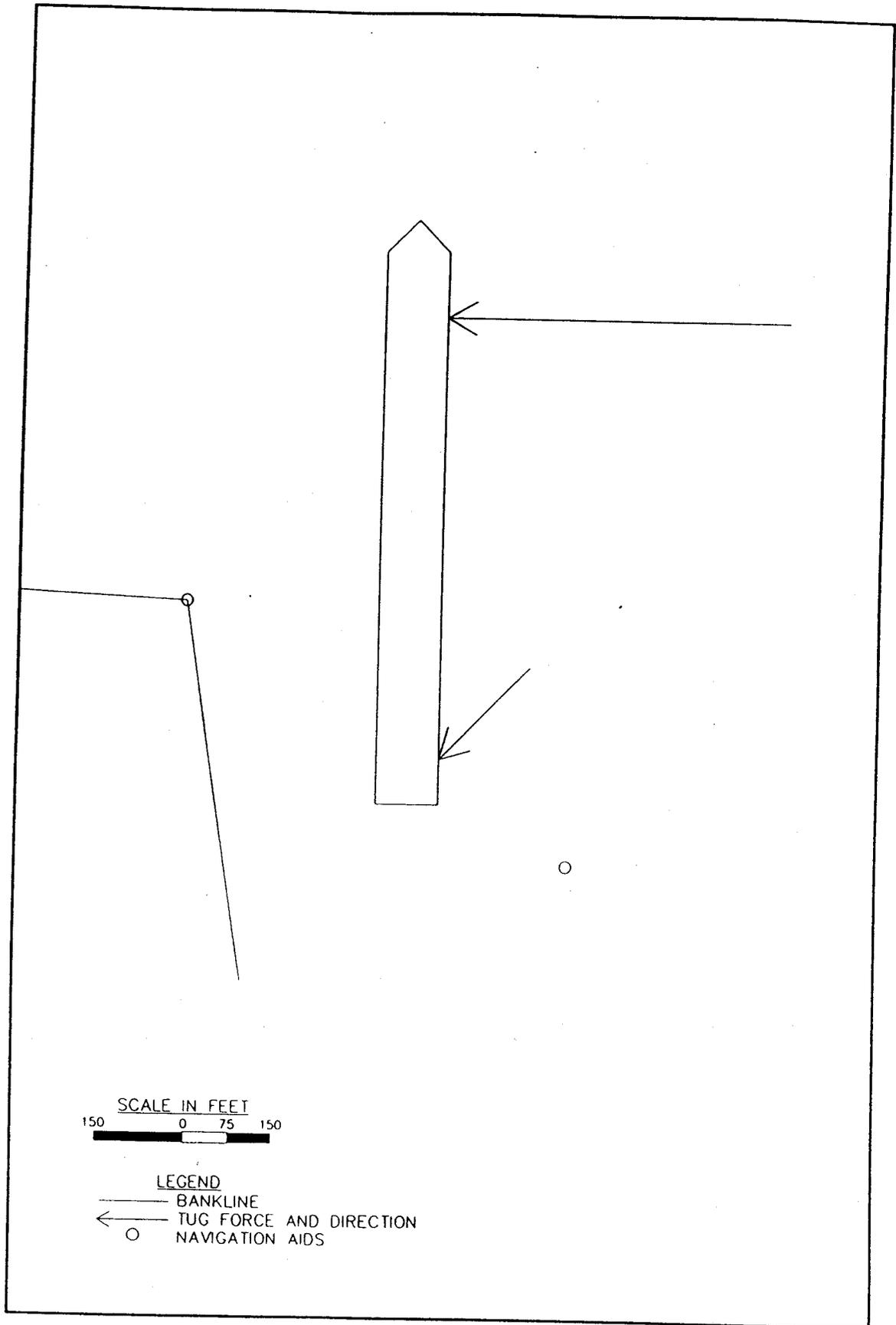


Figure 5. One quarter mile radar screen with tug visual.

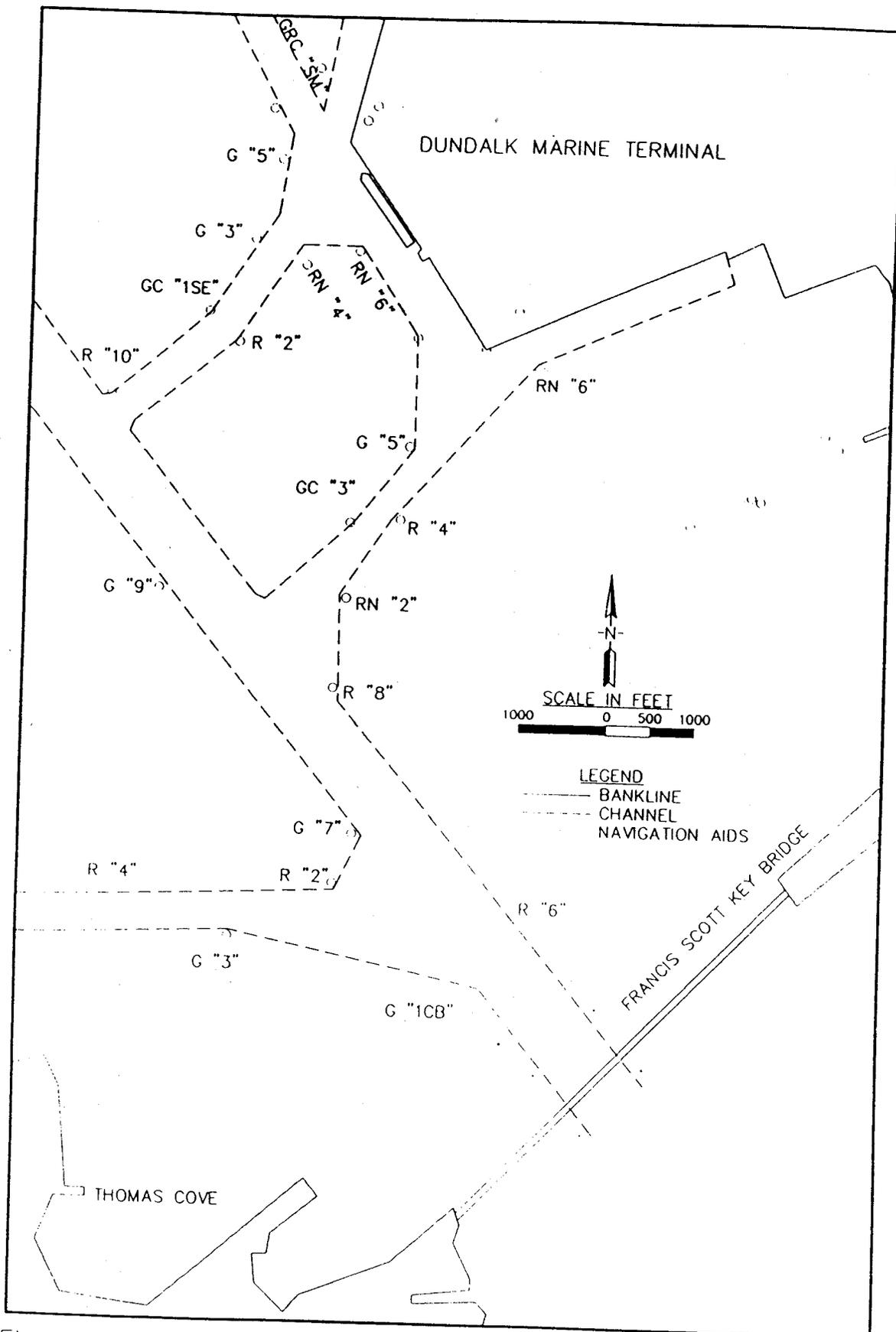


Figure 6. DUNDALK TERMINAL – EXISTING CONDITIONS

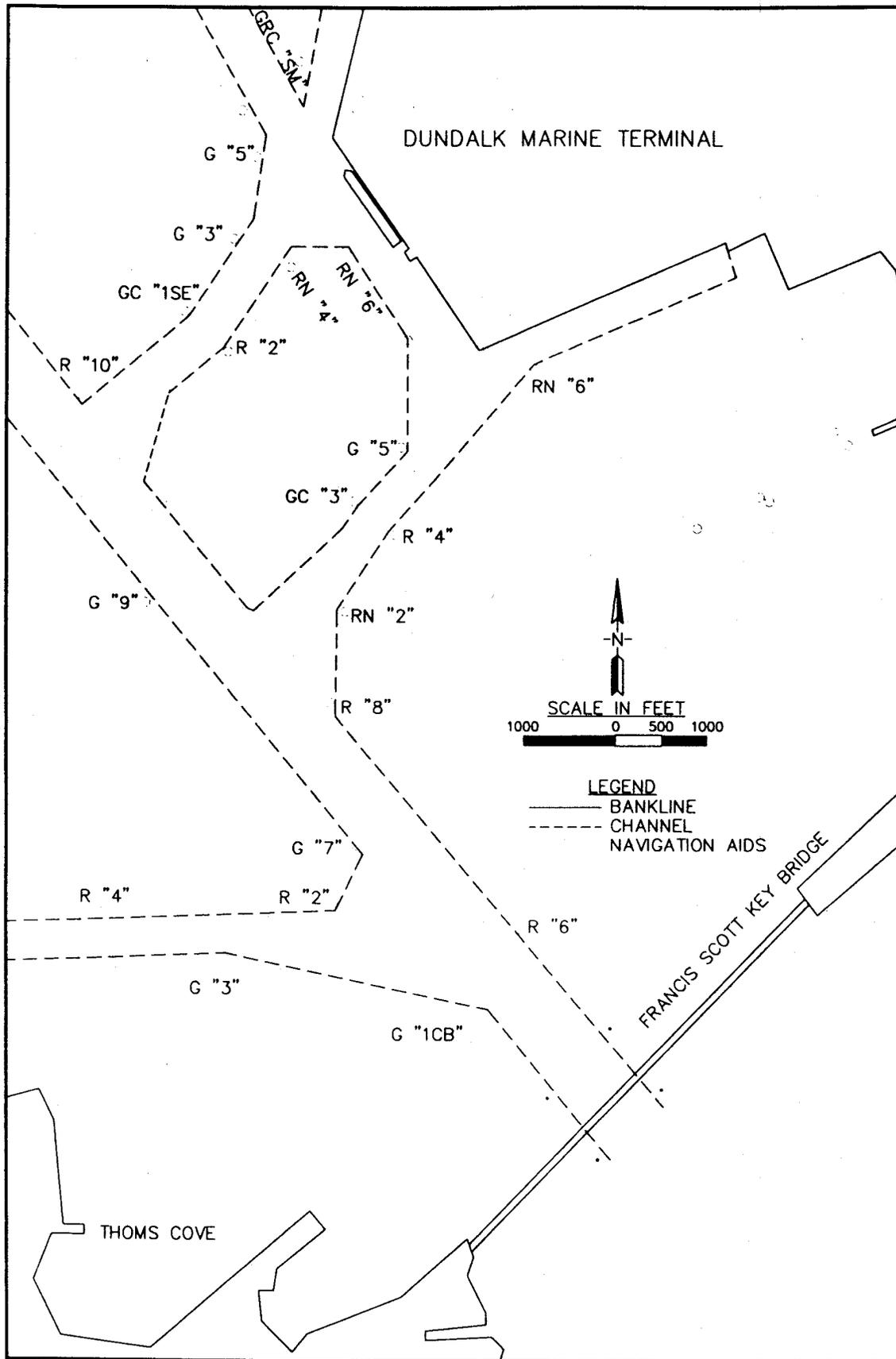


Figure 7. Dundalk Terminal – plan conditions

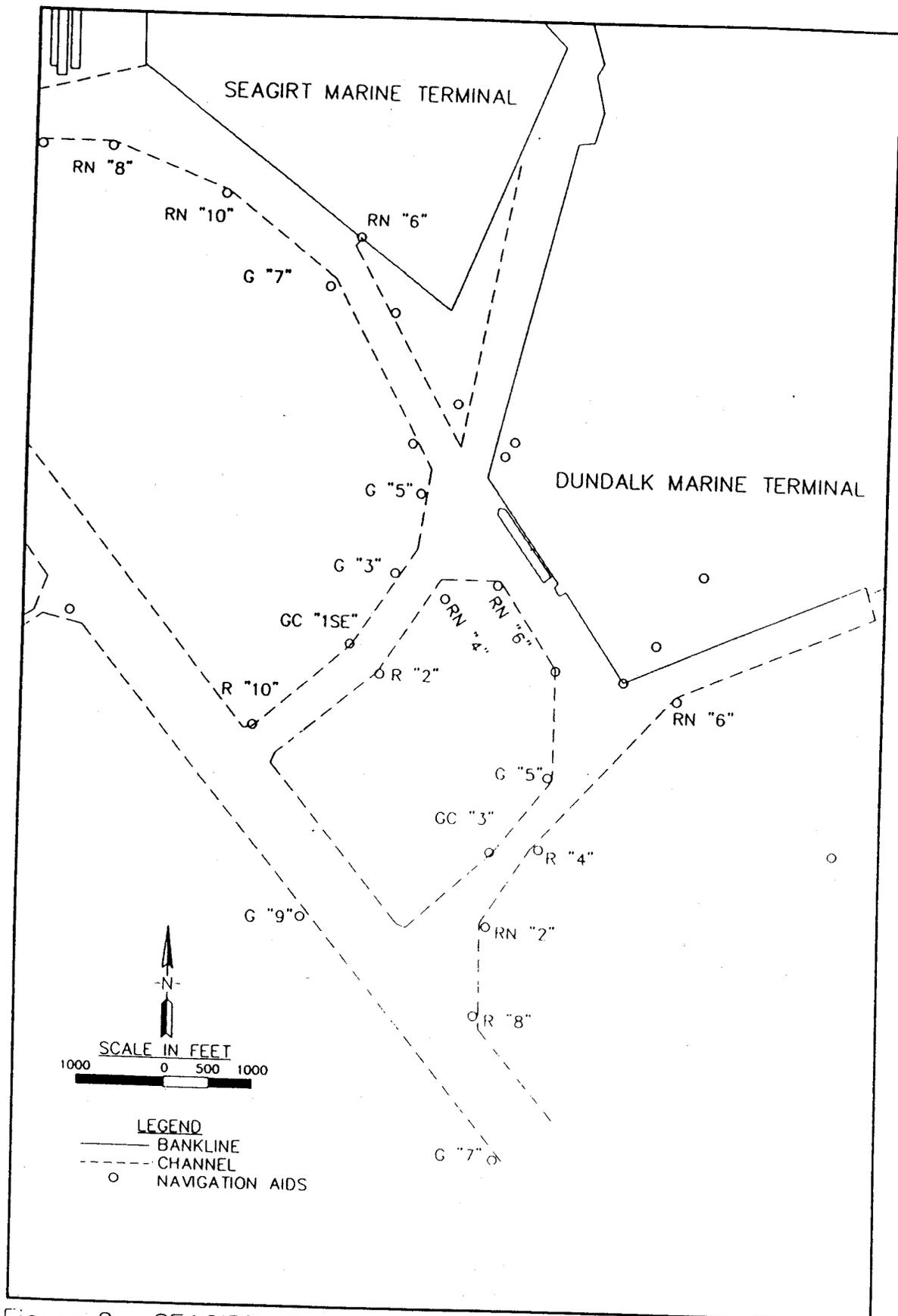


Figure 8. SEAGIRT TERMINAL – EXISTING CONDITIONS

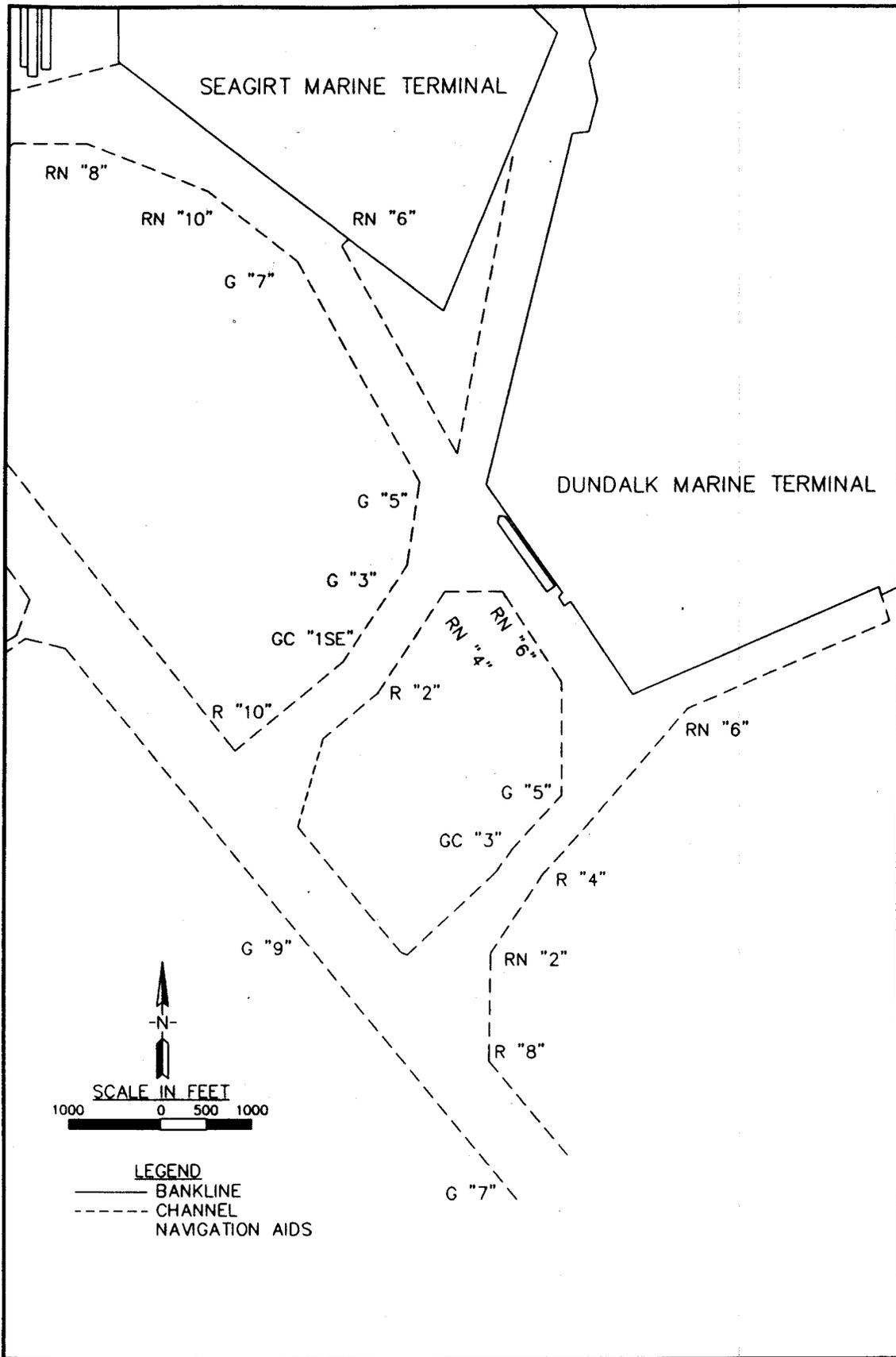


Figure 9. Seagirt Terminal plan conditions (Scenario 1)

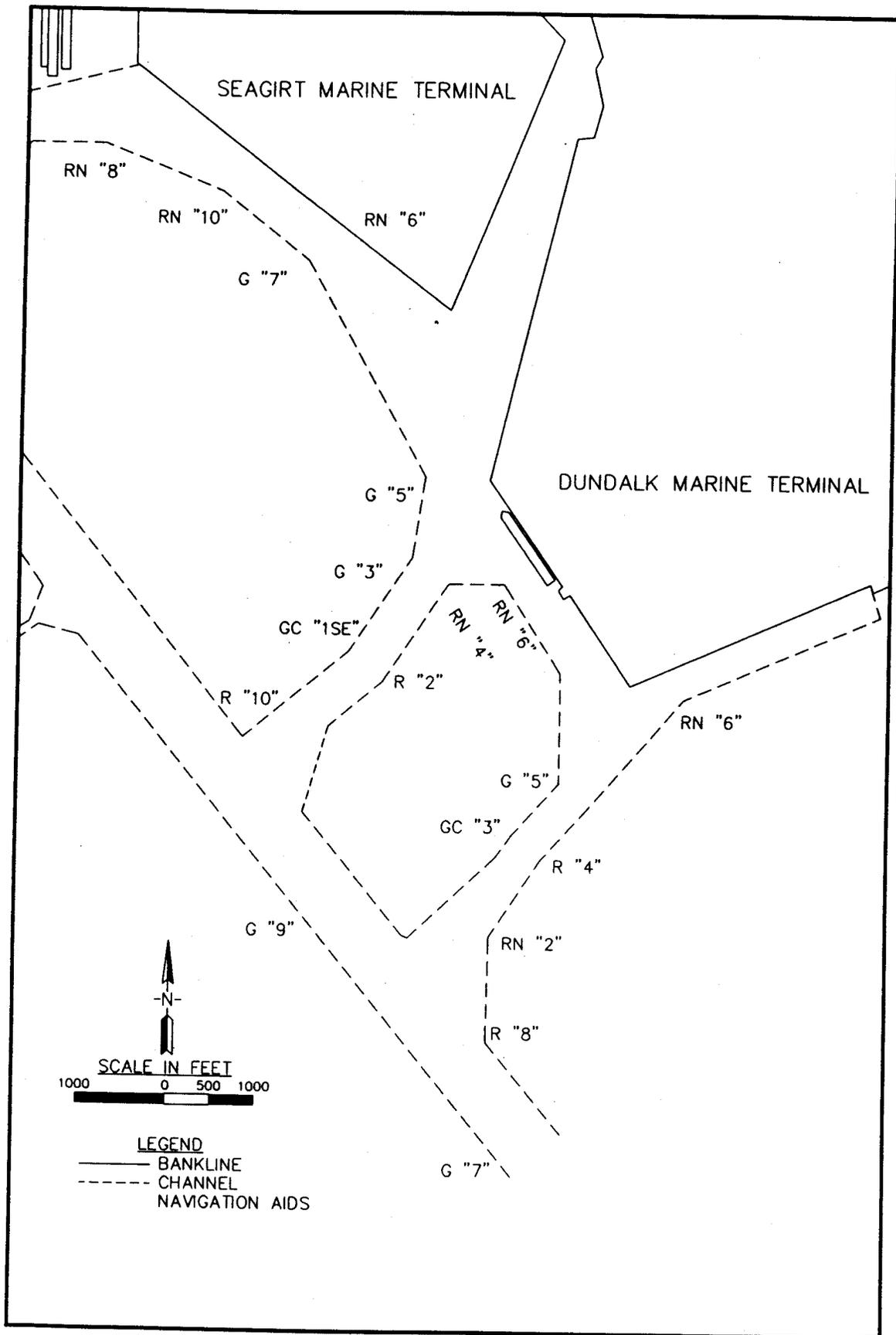


Figure 10. Seagirt Terminal plan conditions (Scenario 2)

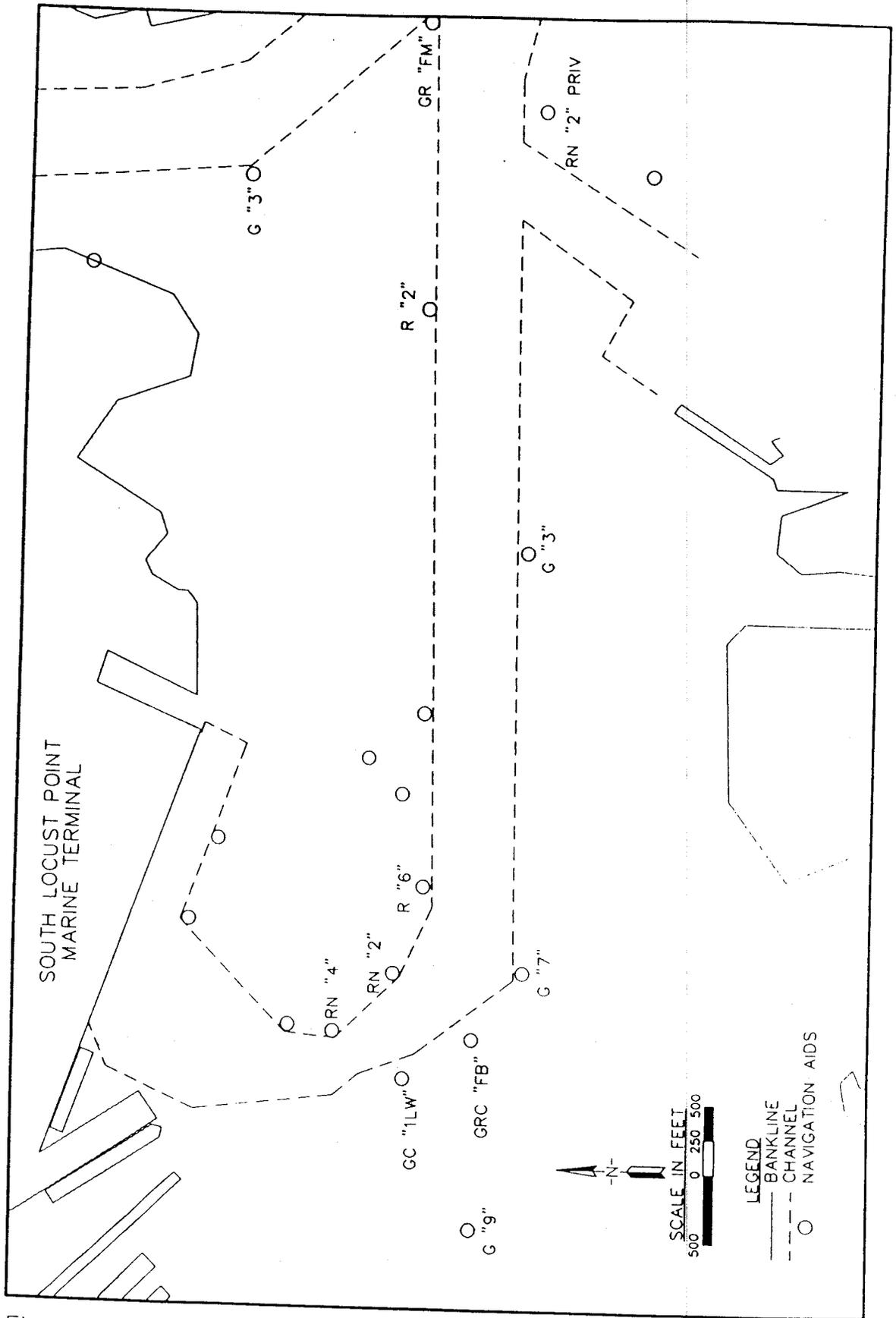


Figure 11. SOUTH LOCUST POINT - EXISTING CONDITIONS

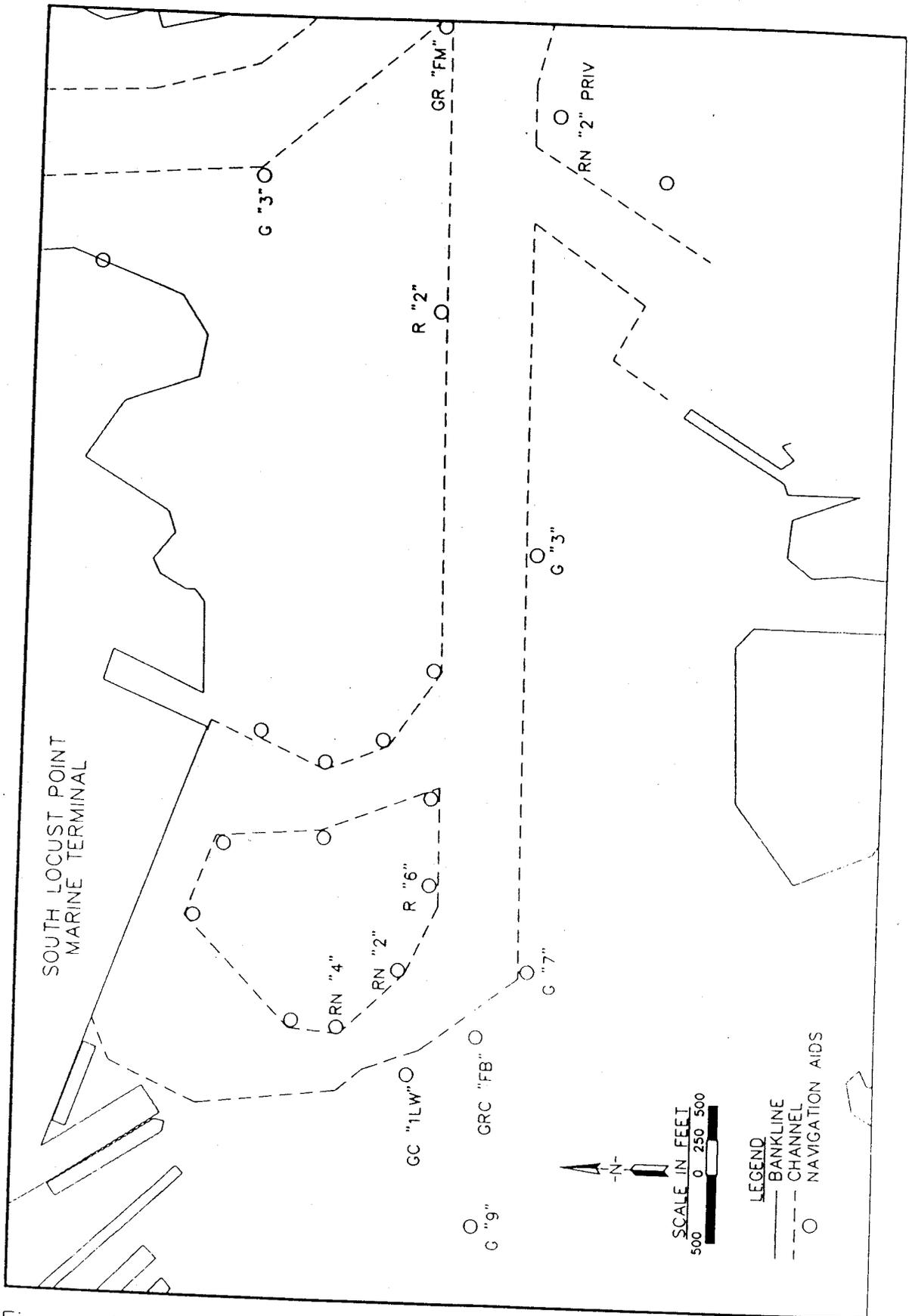


Figure 12. SOUTH LOCUST POINT - PLAN CONDITIONS

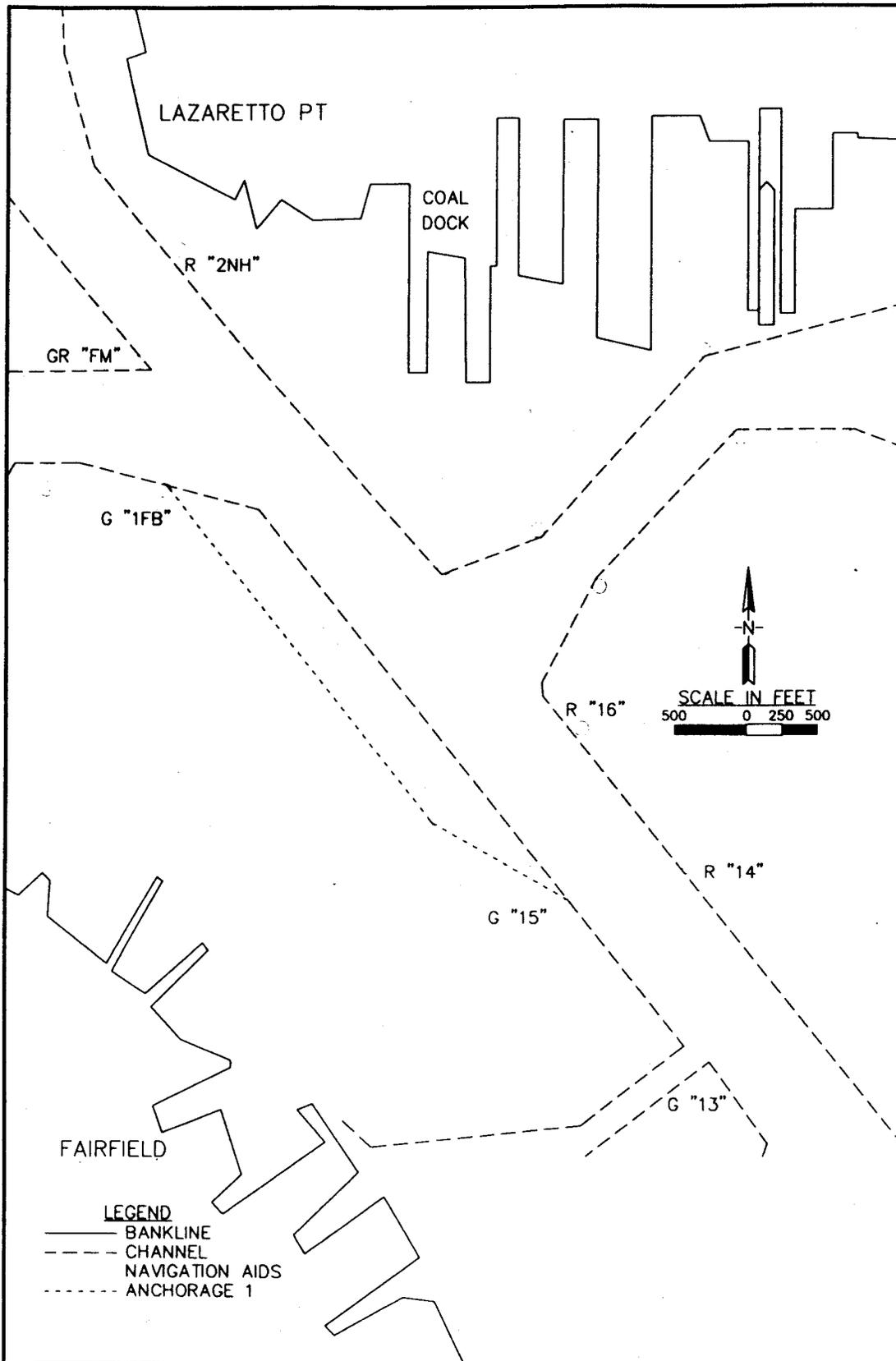


Figure 13. Ft. McHenry Channel and Anchorage #1 existing conditions

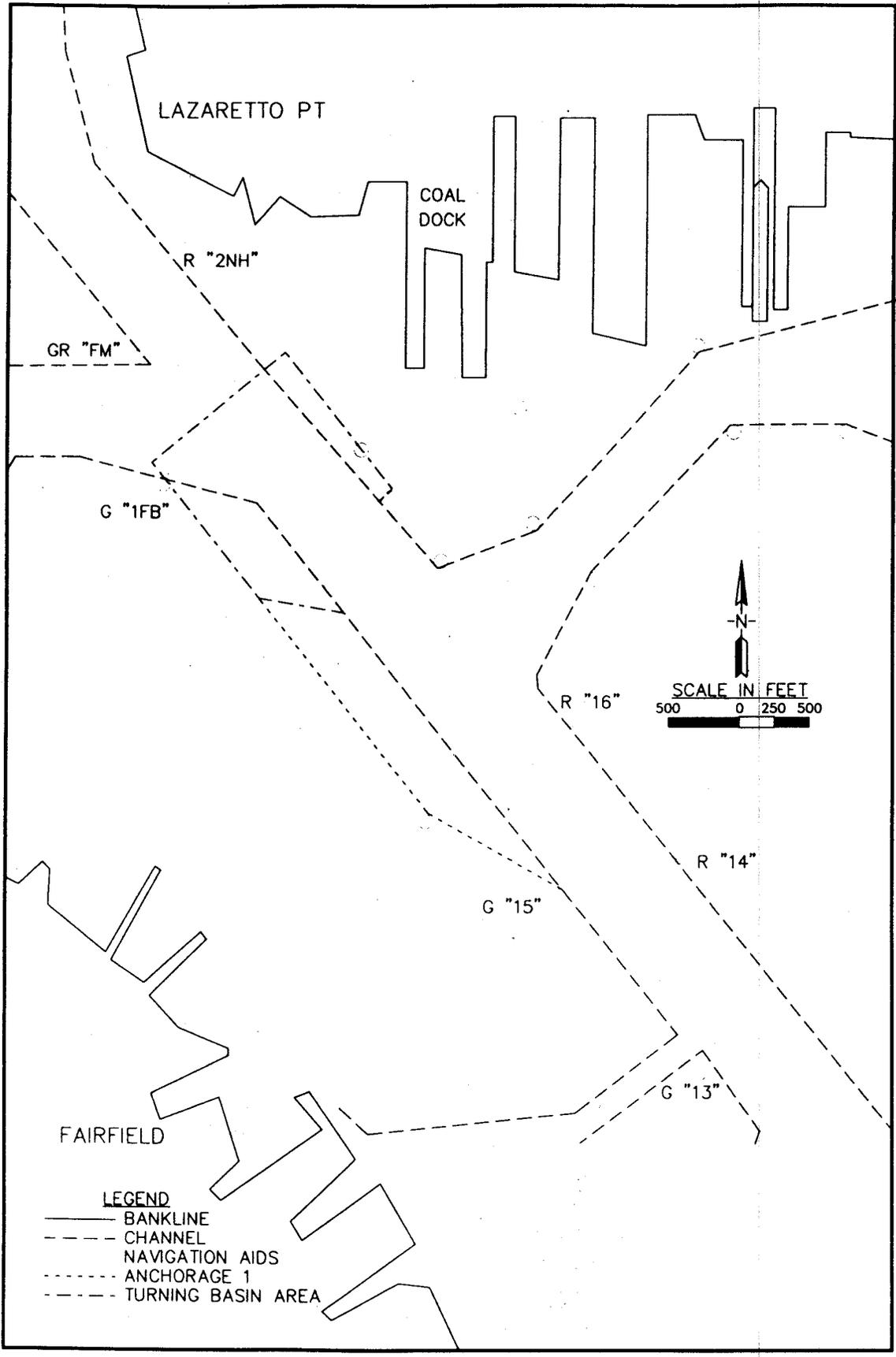


Figure 14. Ft. McHenry Turning Basin plan conditions

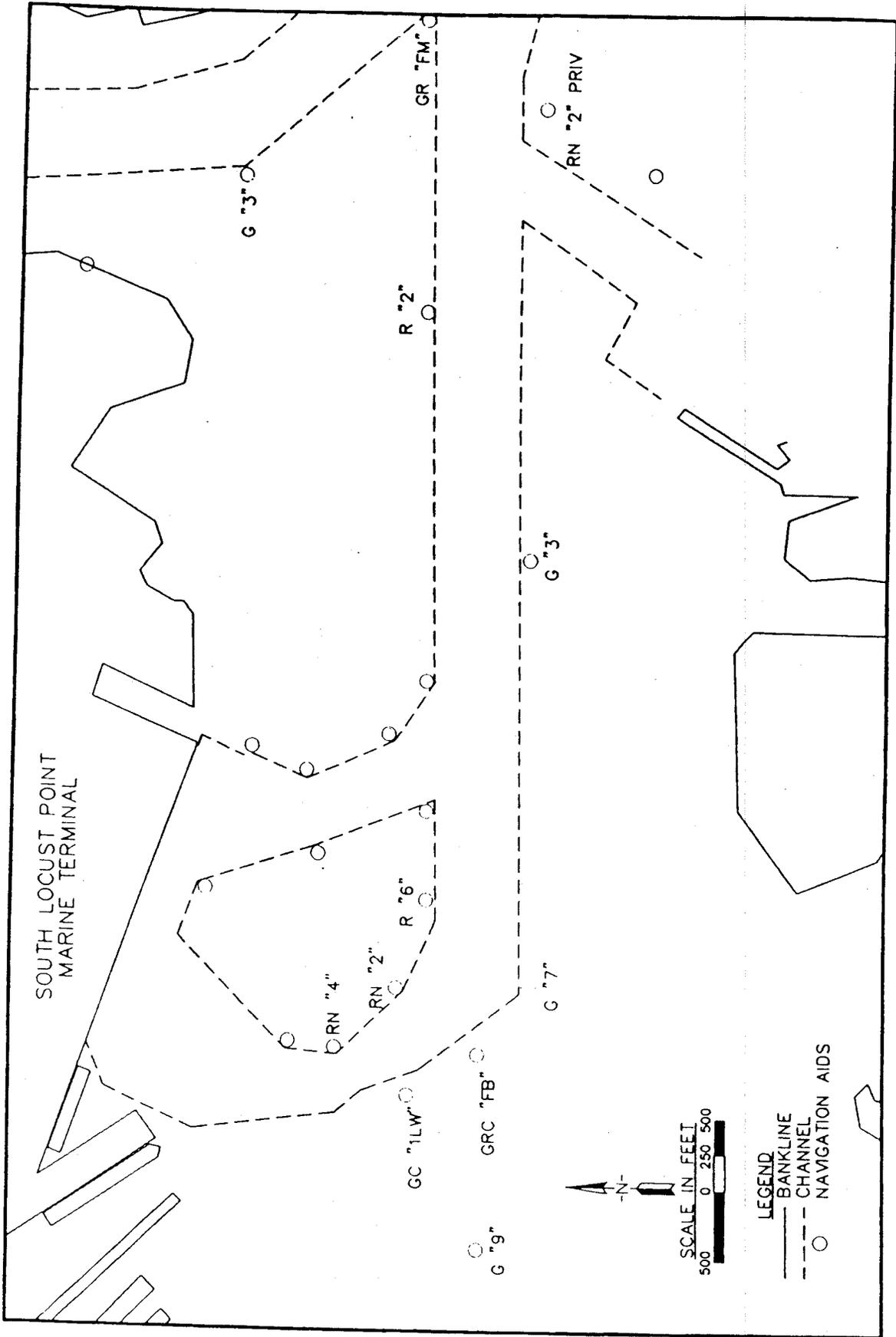


Figure 15. SOUTH LOCUST POINT - MODIFIED PLAN

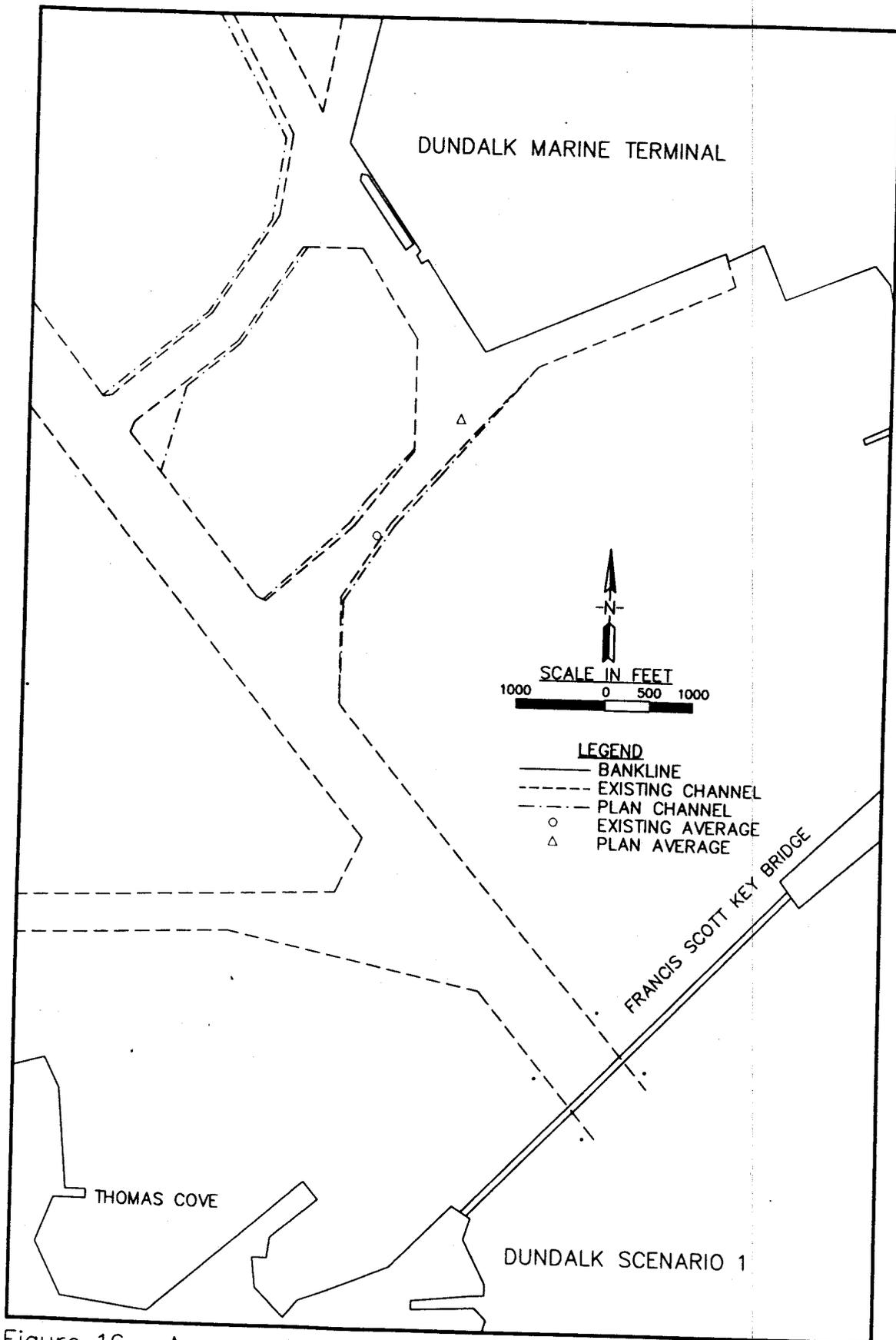


Figure 16. Average traveled distance, Dundalk Scenario 1

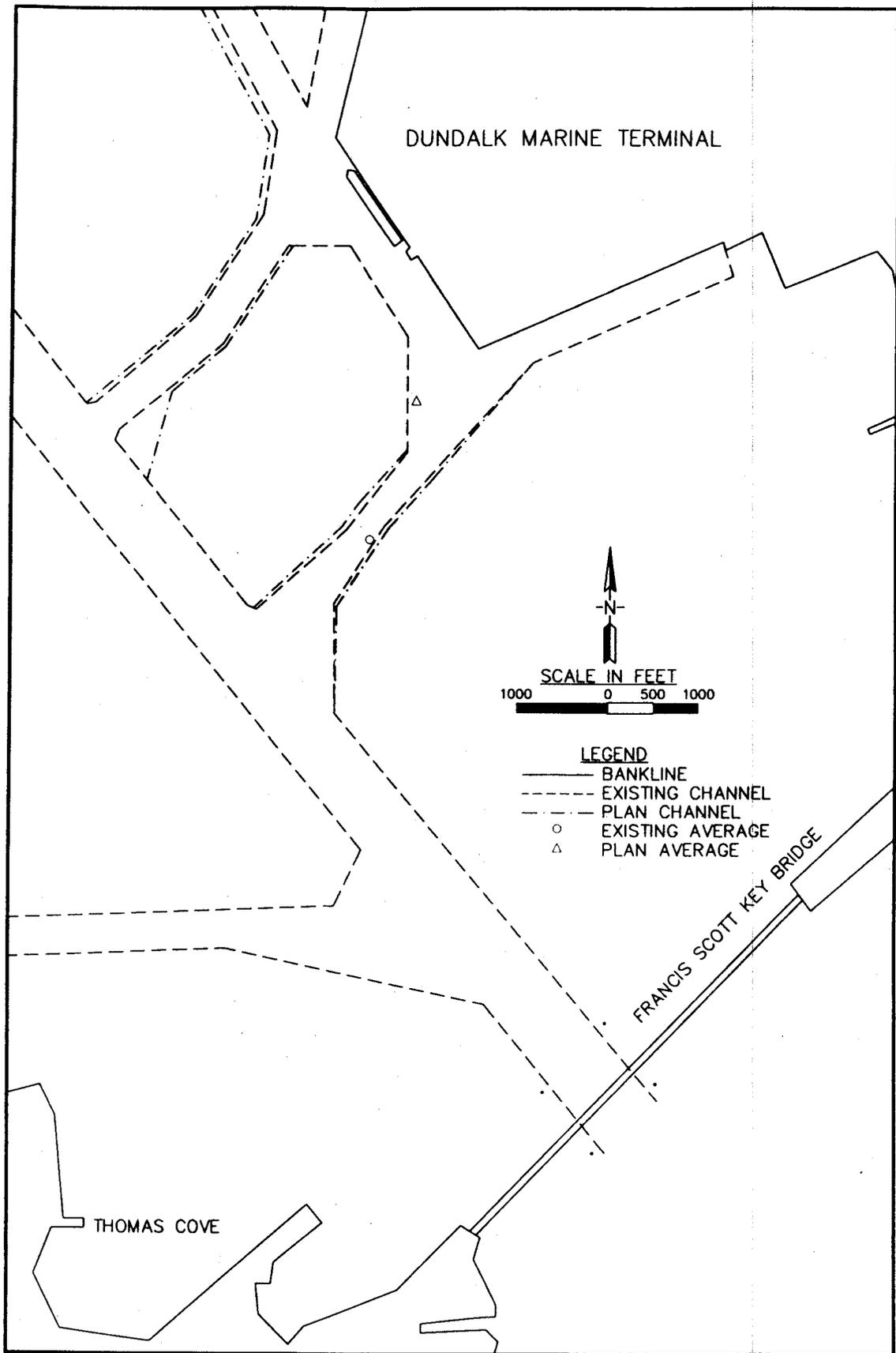


Figure 17. Average traveled distance, Dundalk Scenario 2

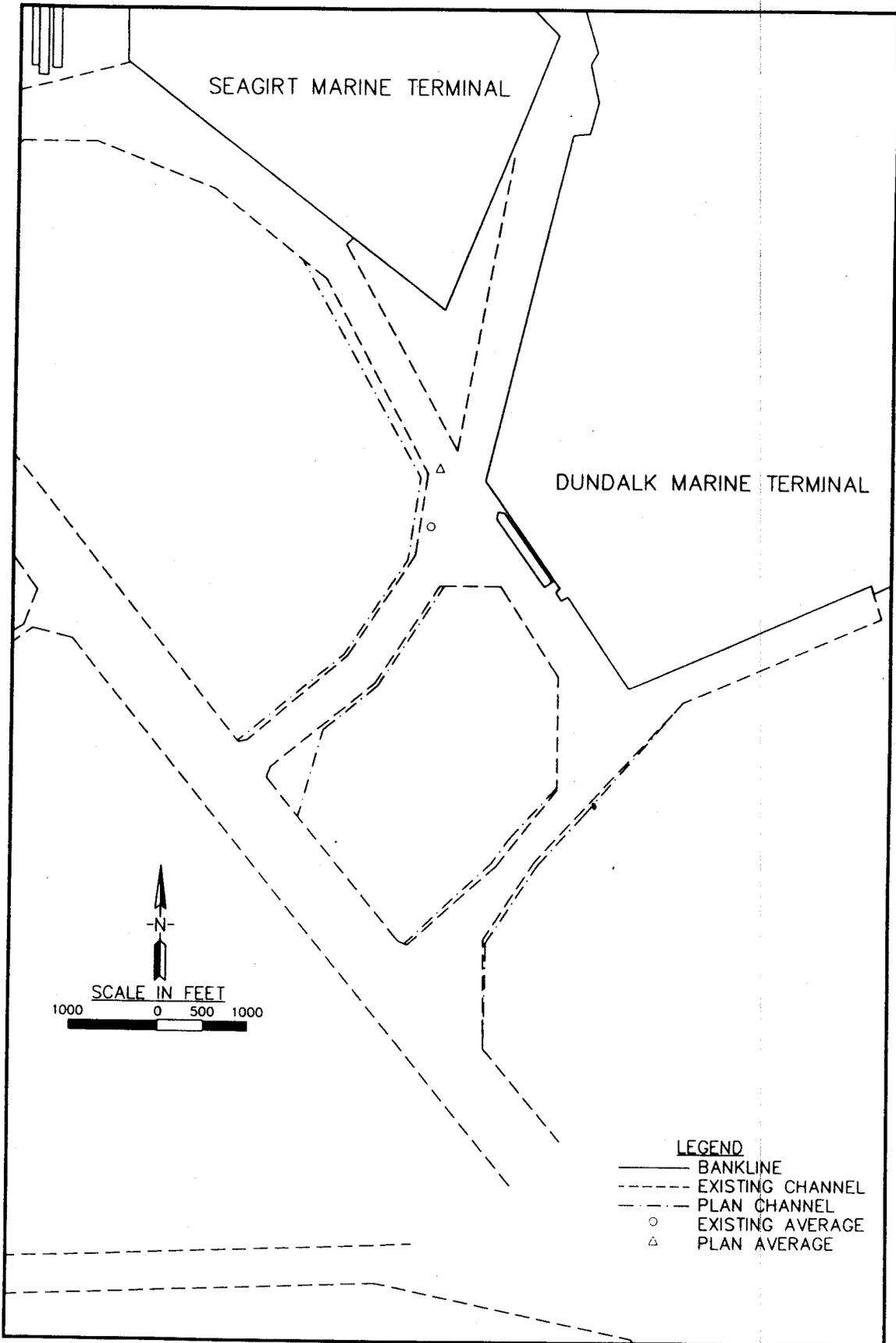


Figure 18. Average traveled distance, Seagirt Scenario 1

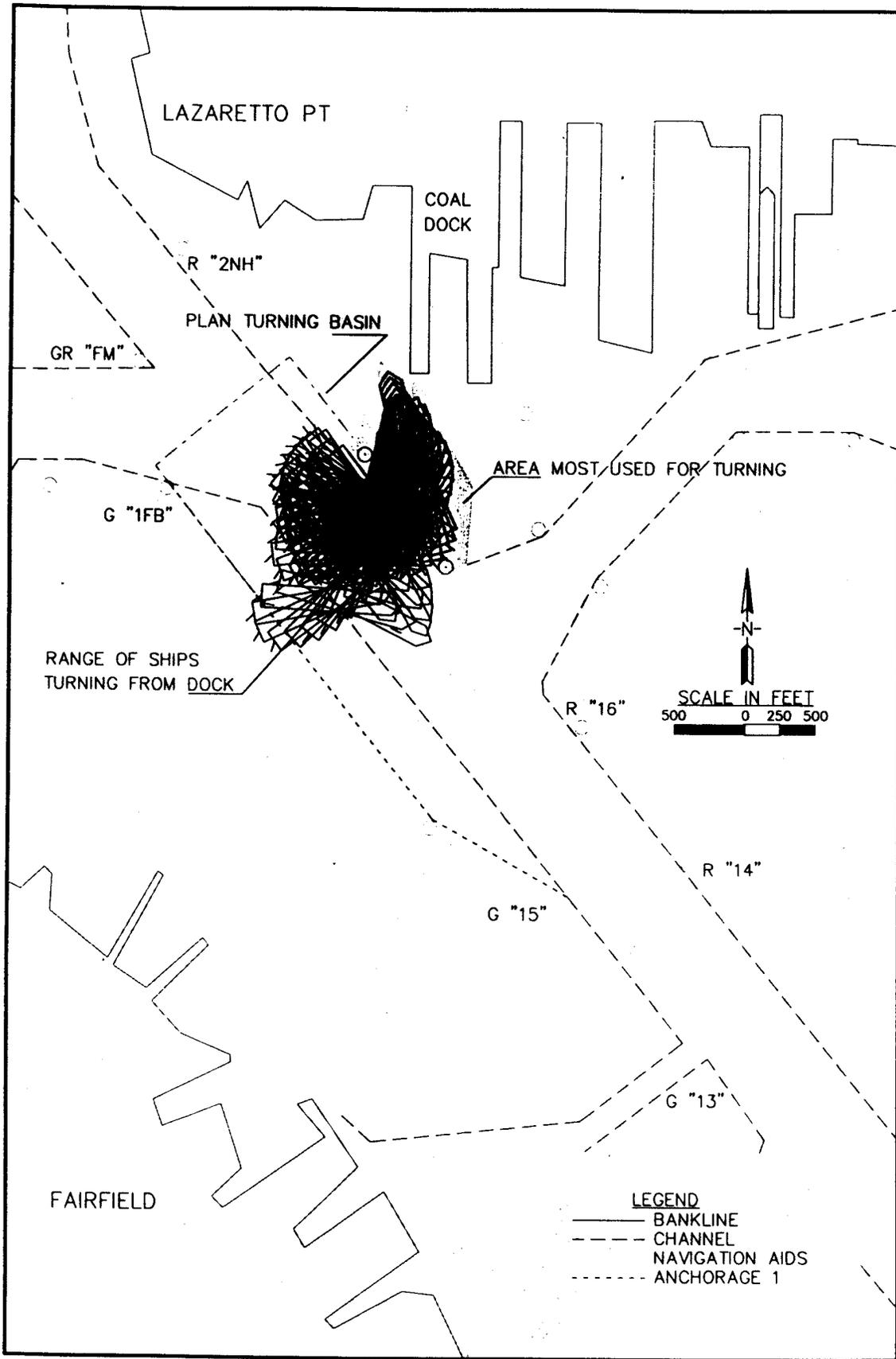


Figure 19. New turning basin considerations

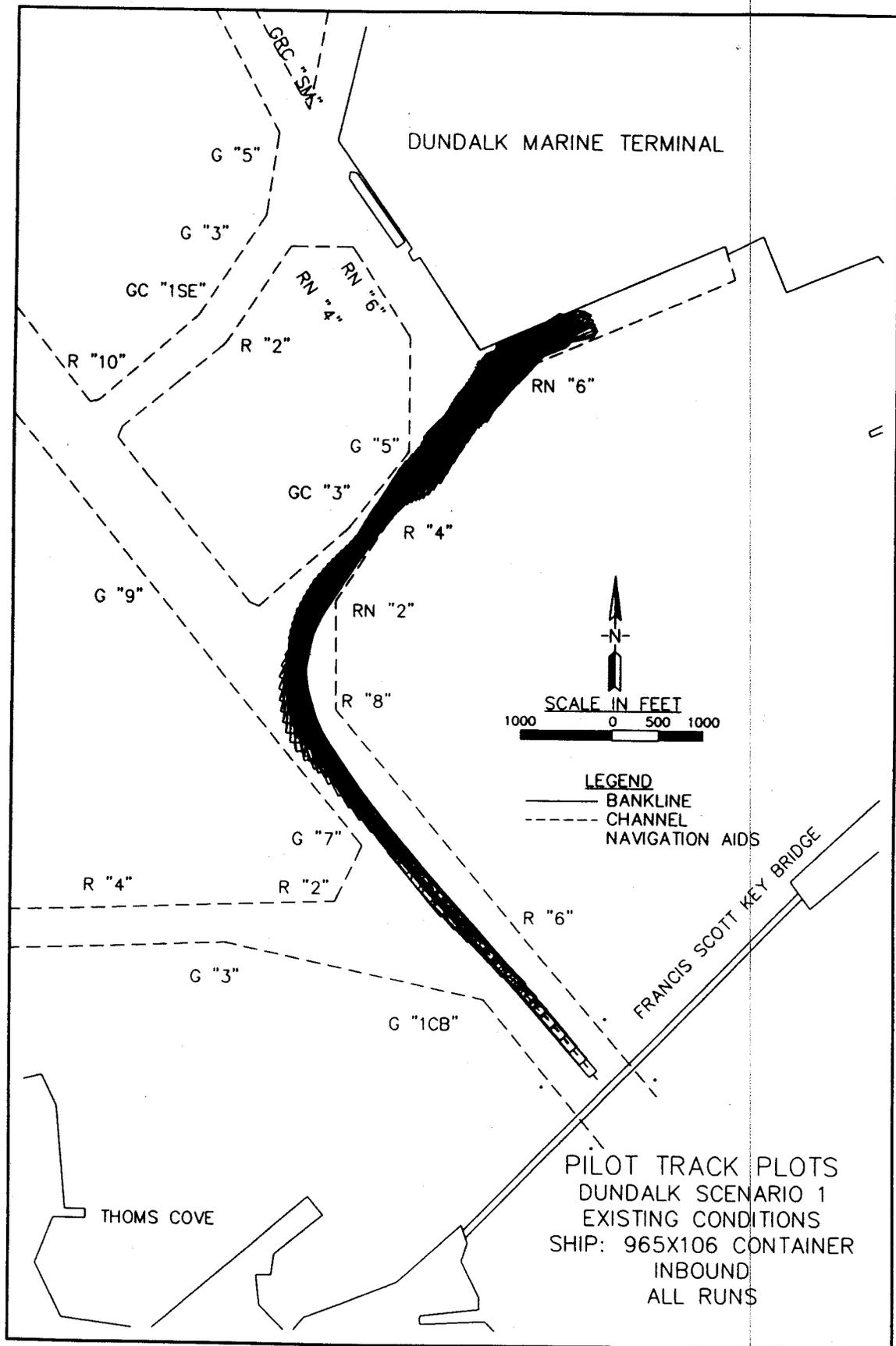
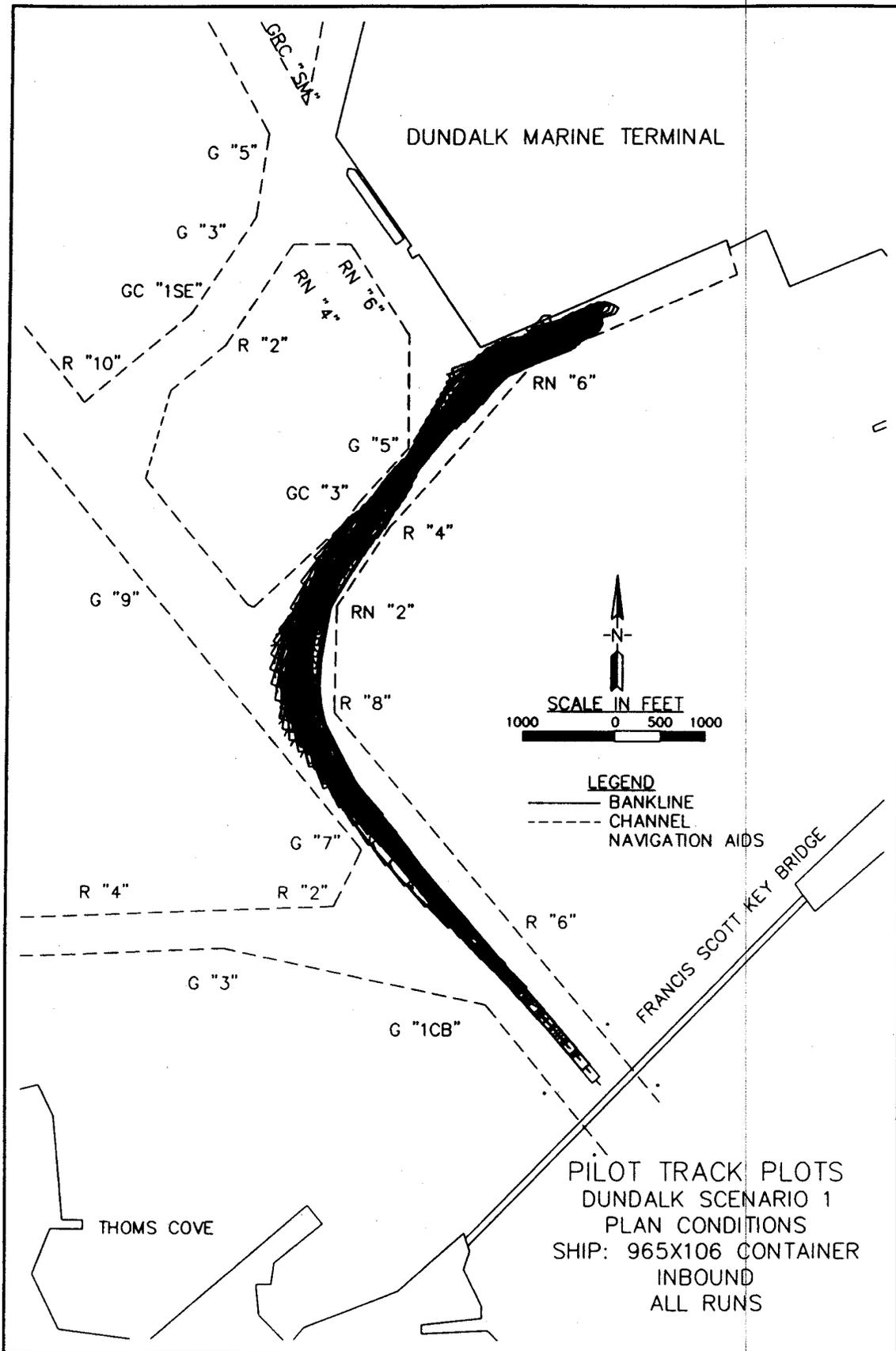
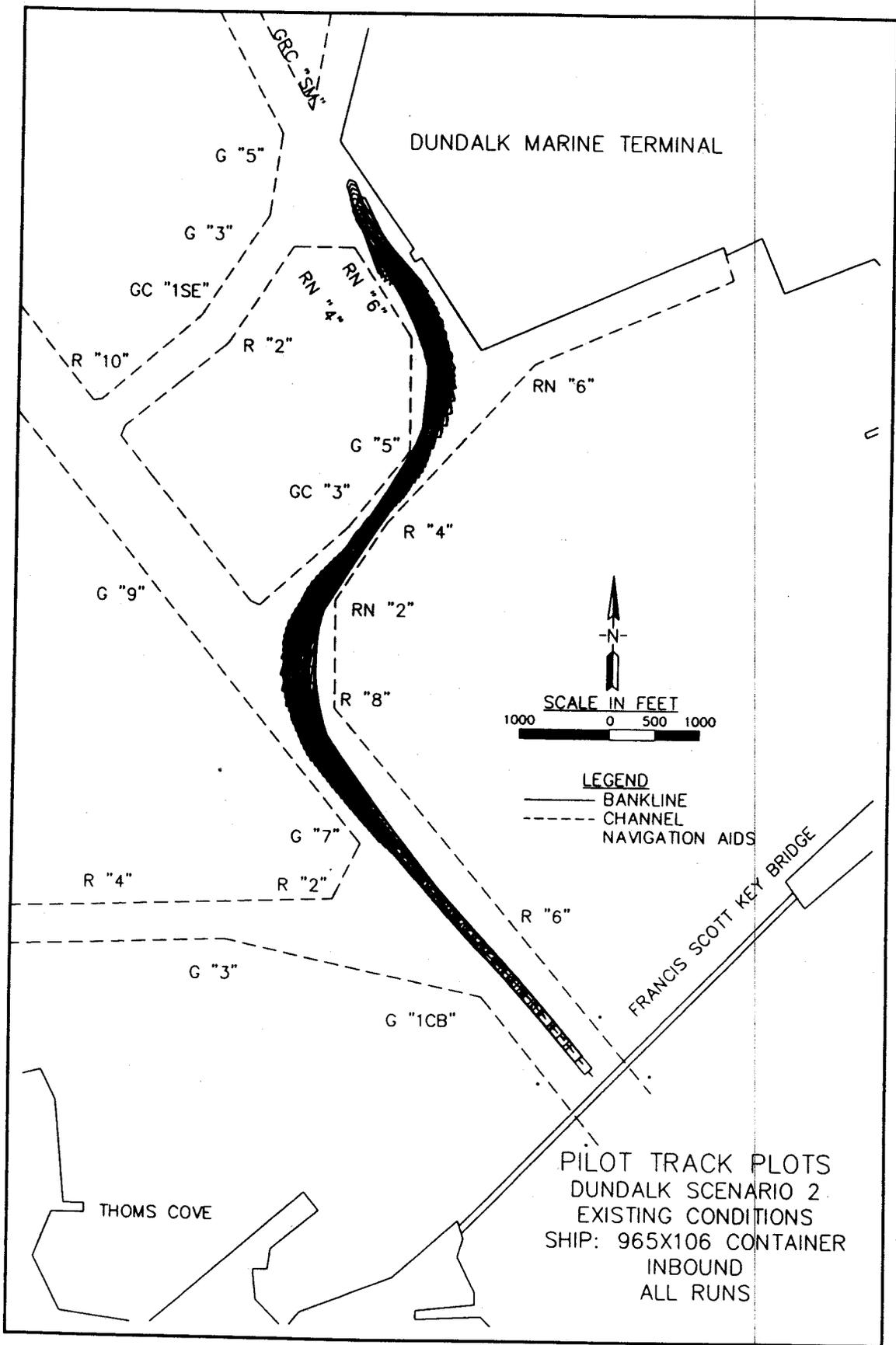
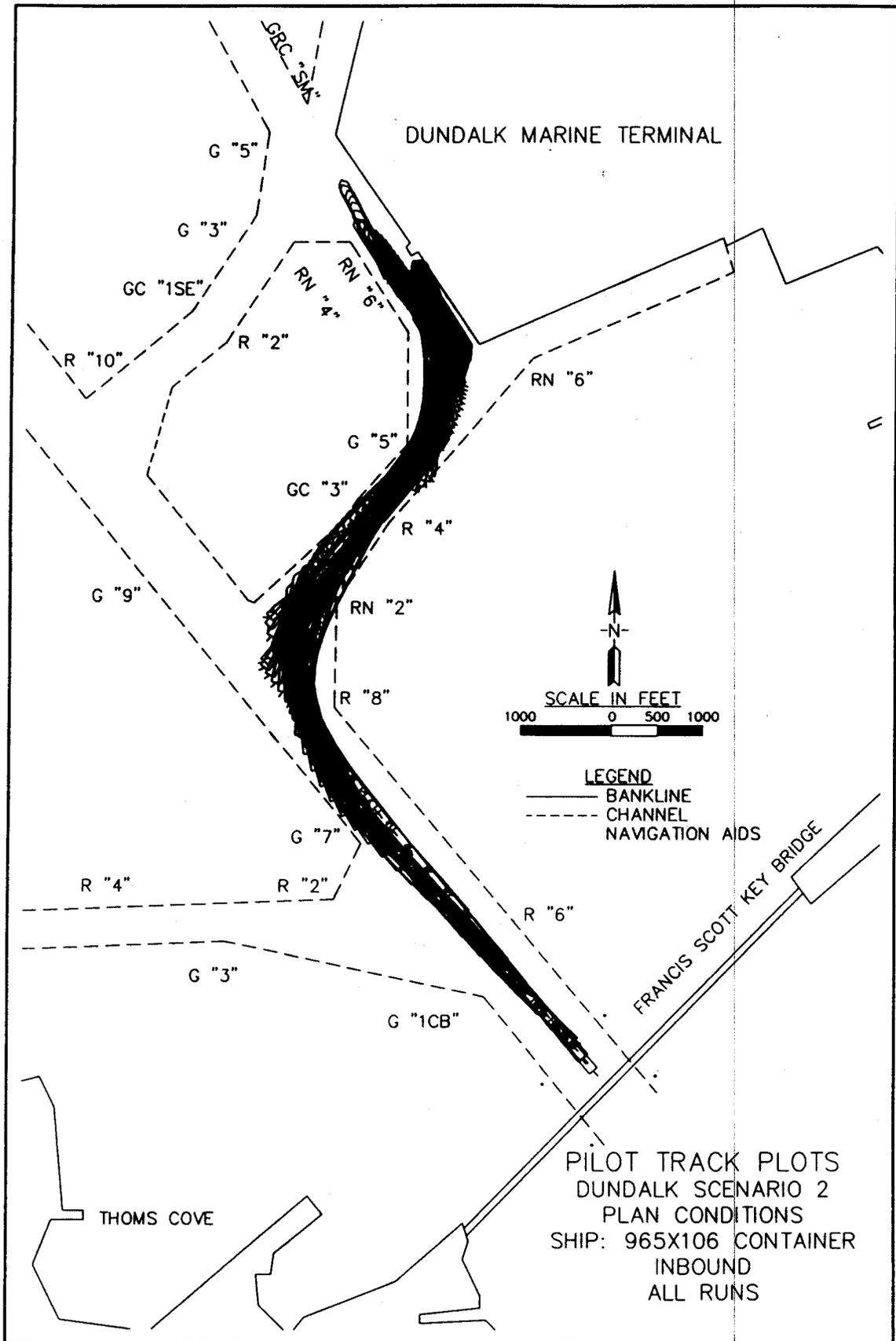
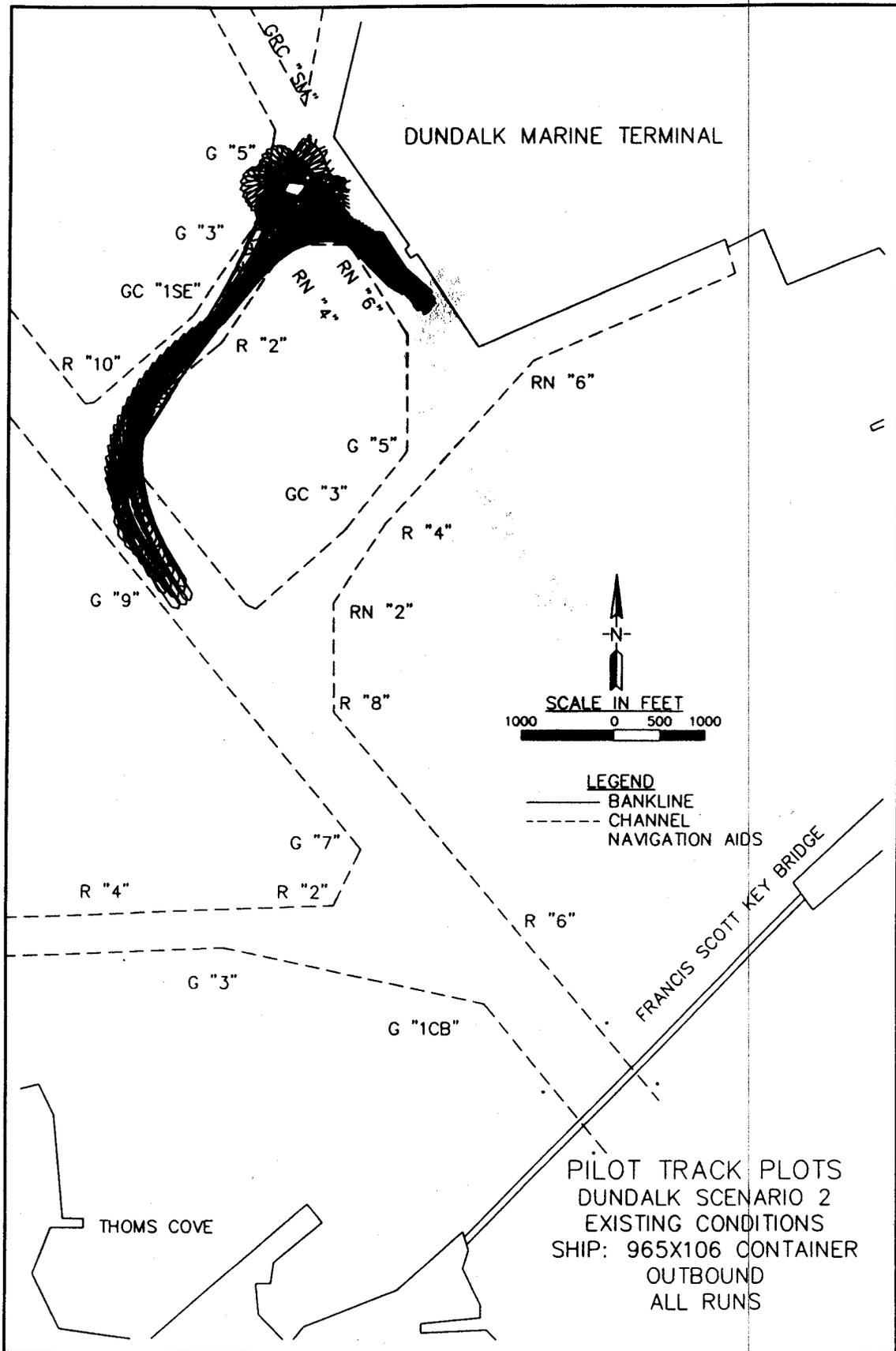


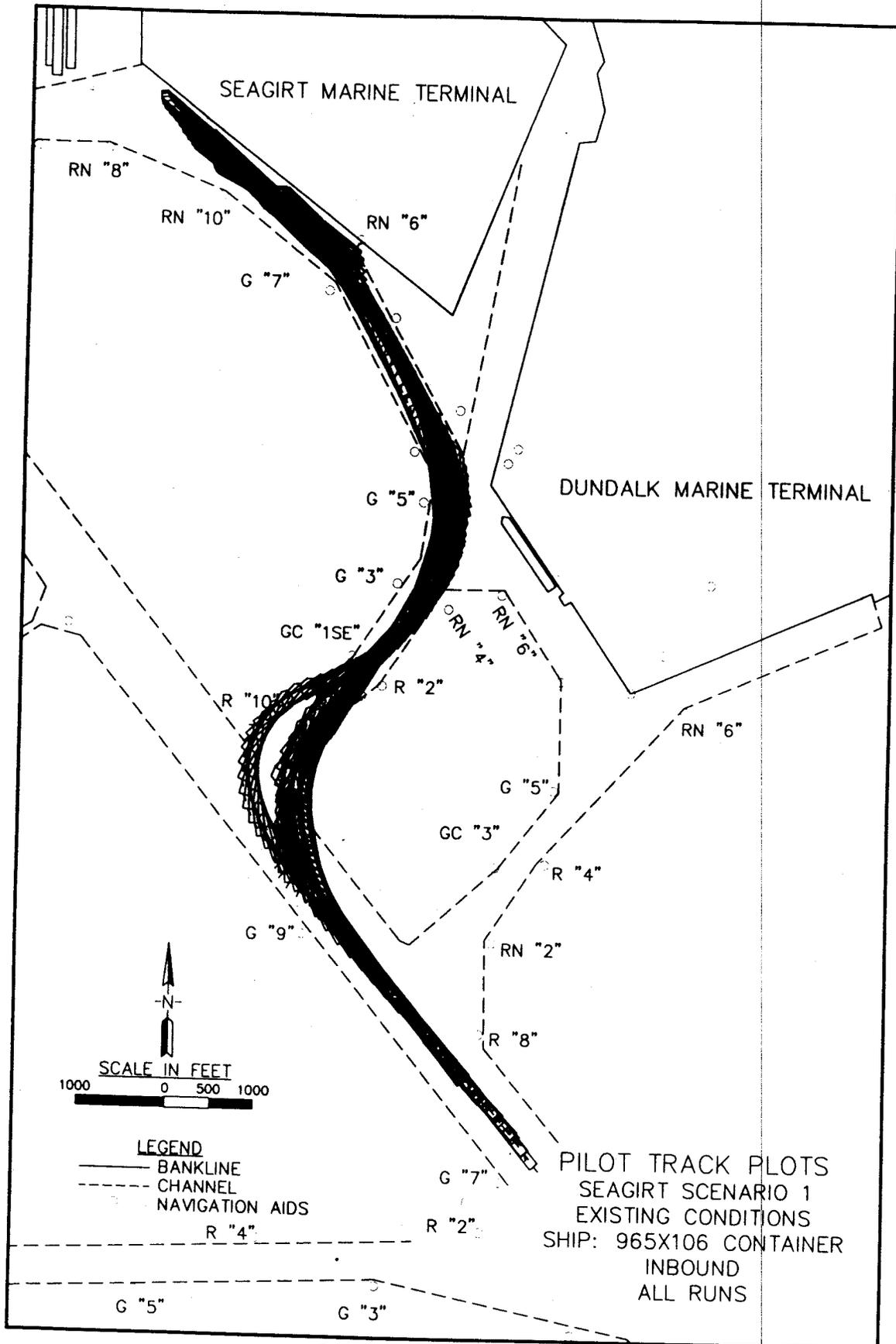
Plate 1

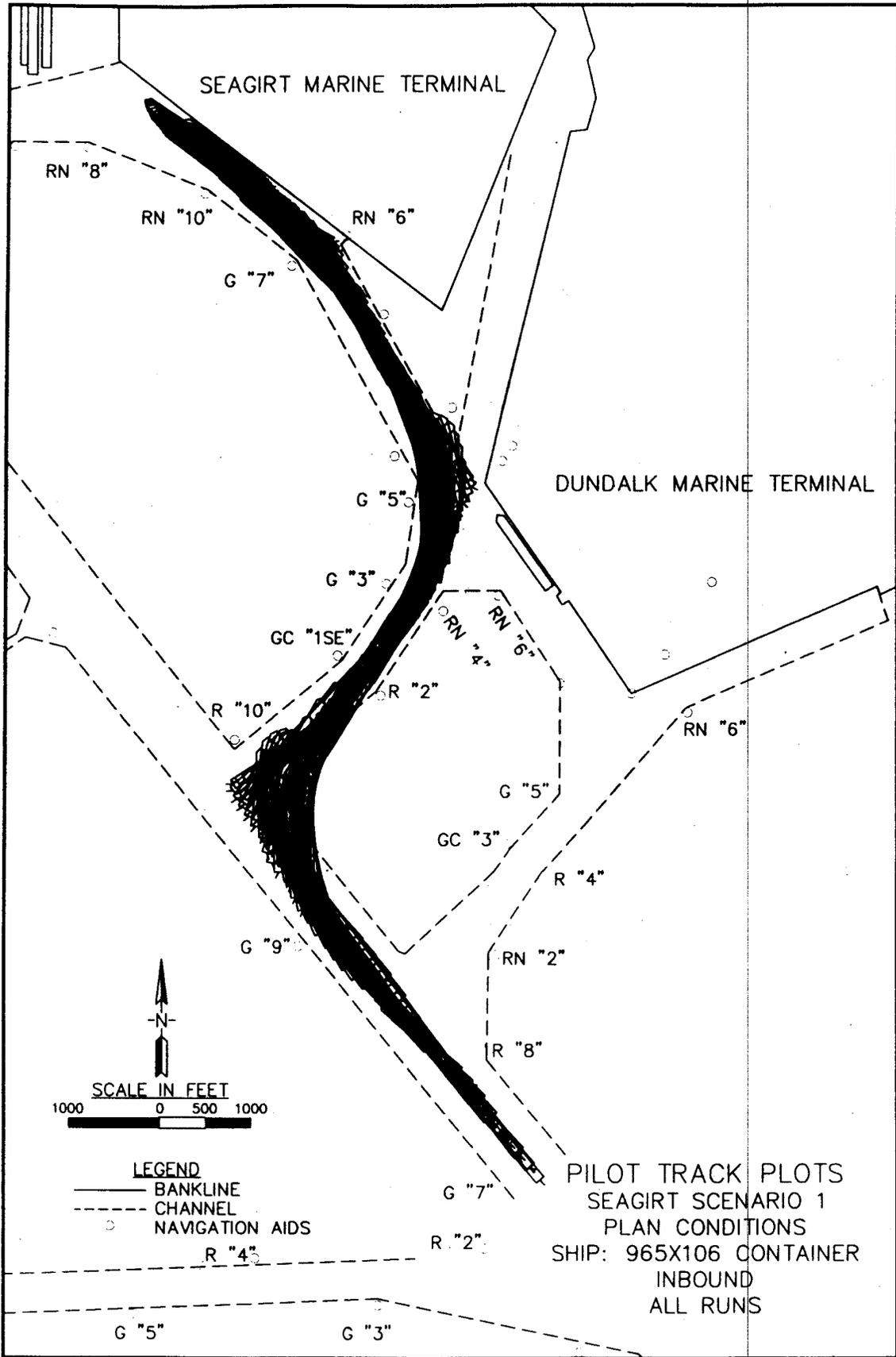


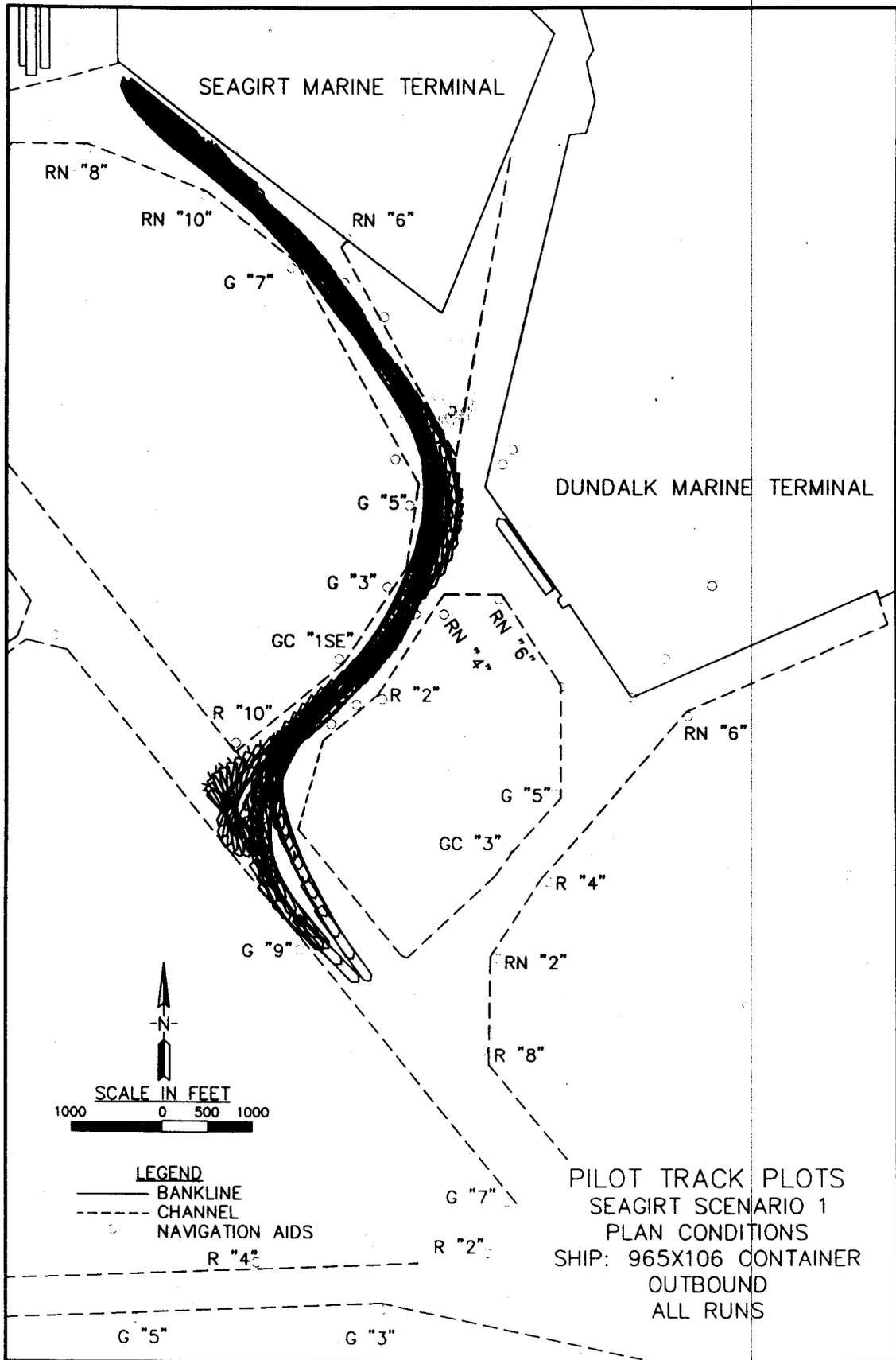


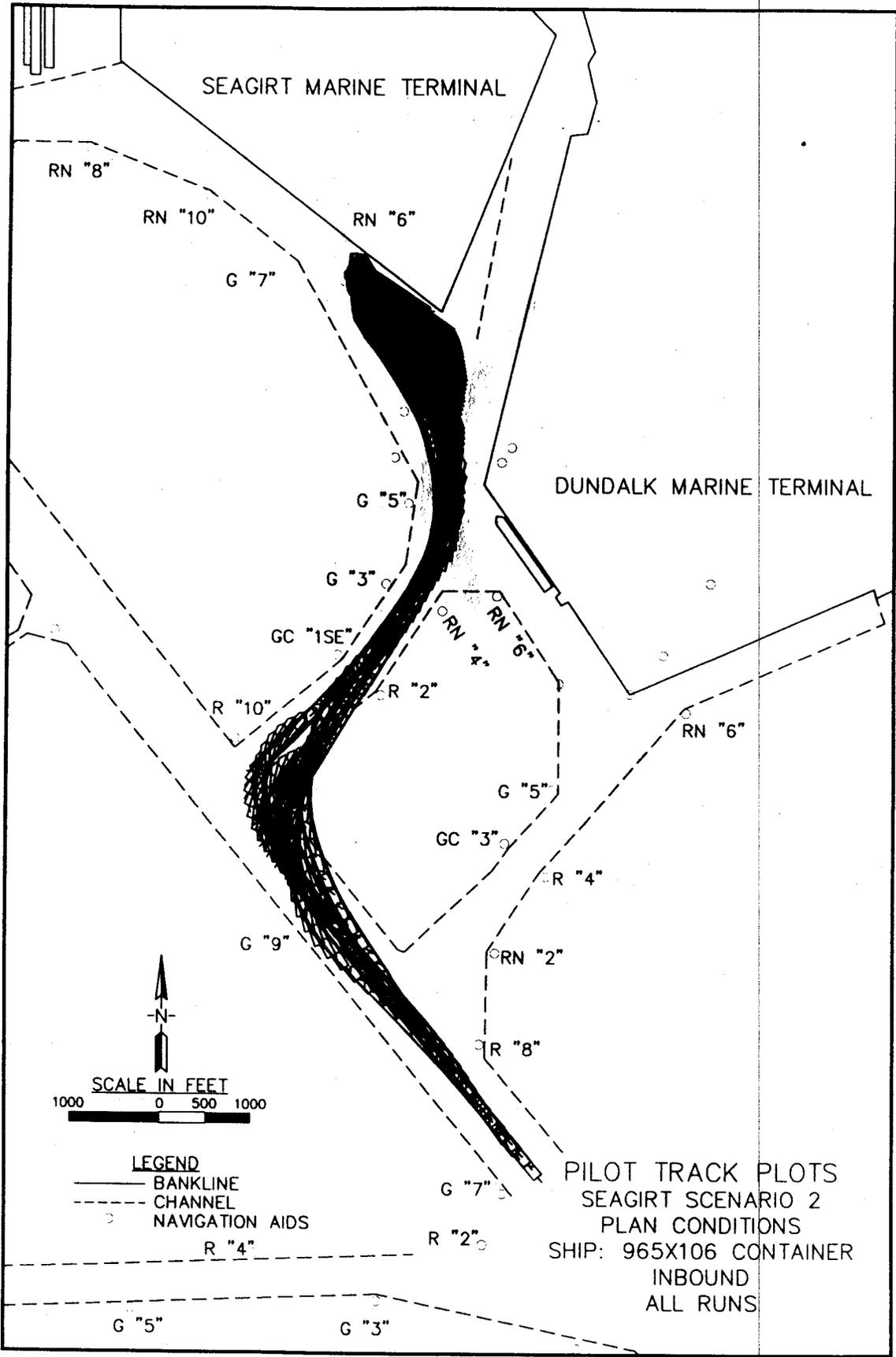












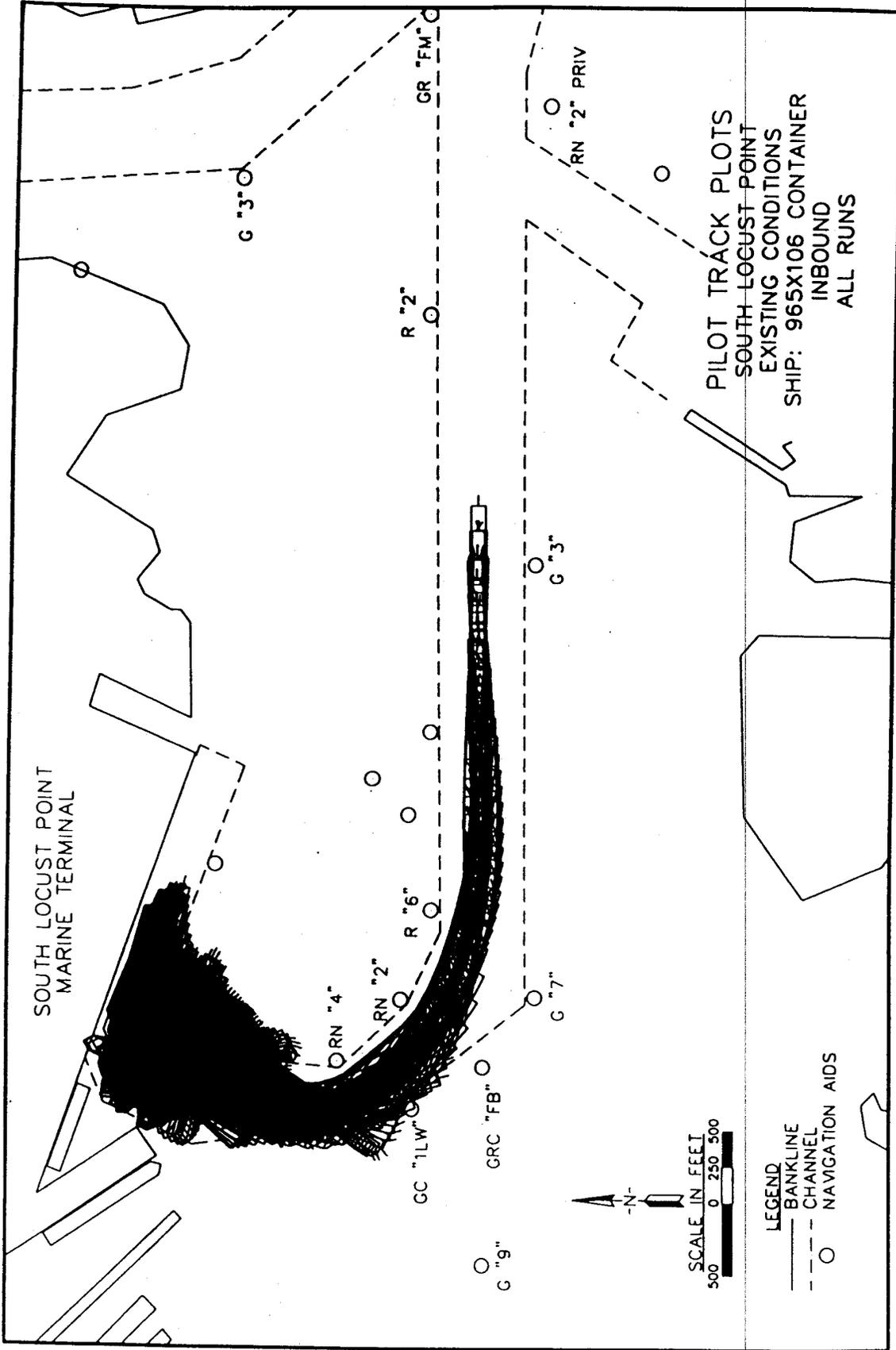
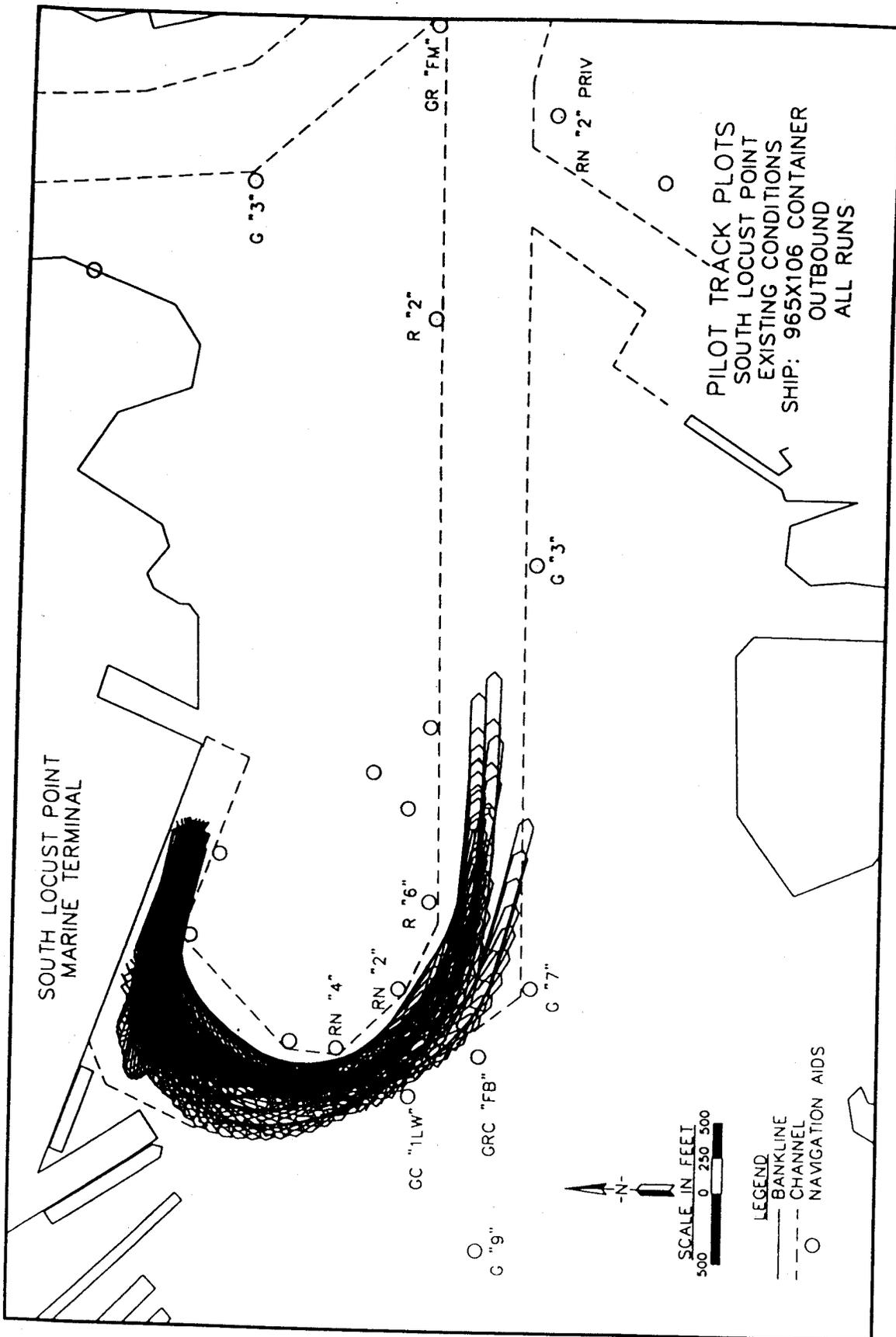


Plate 14



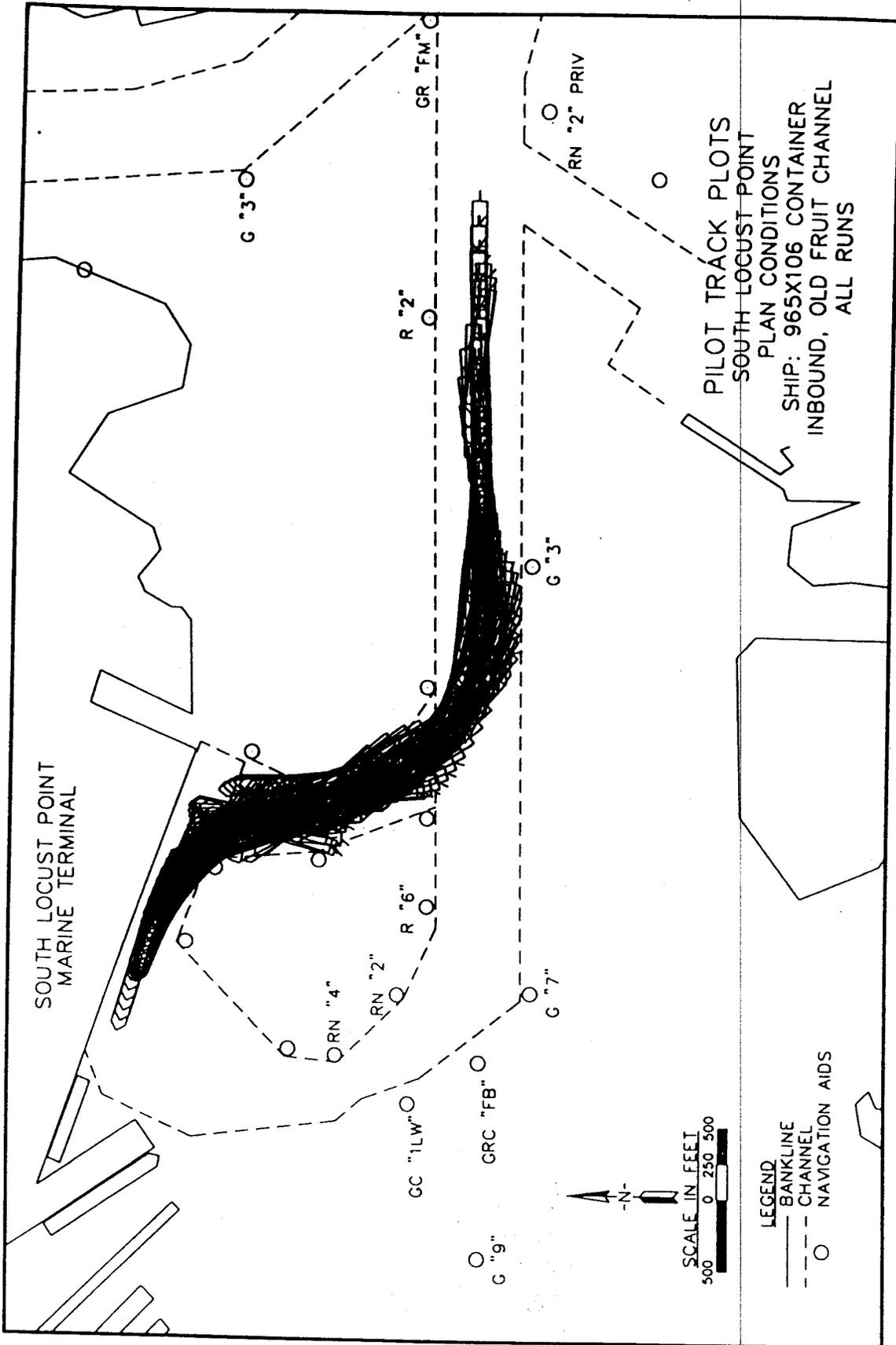
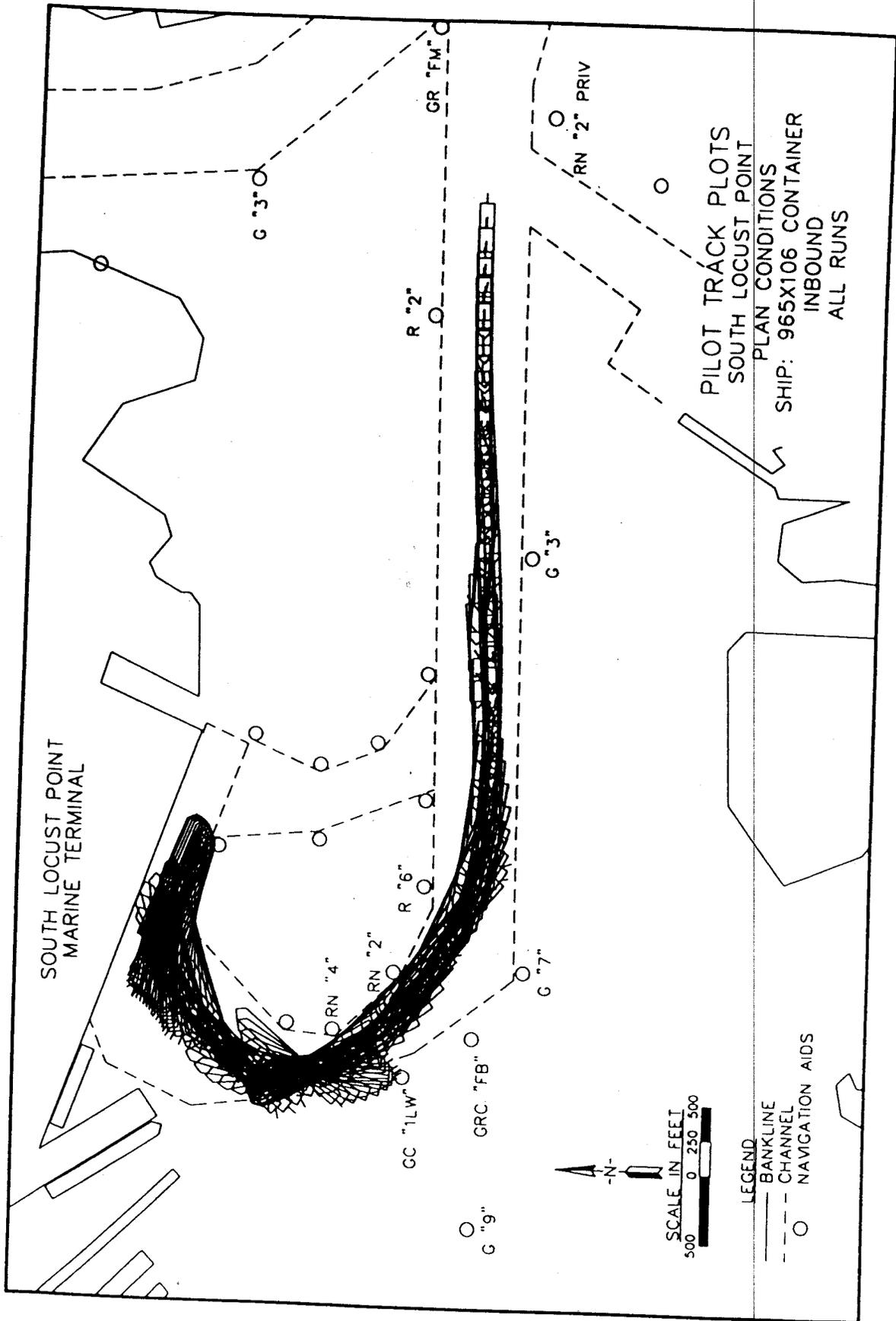


Plate 16



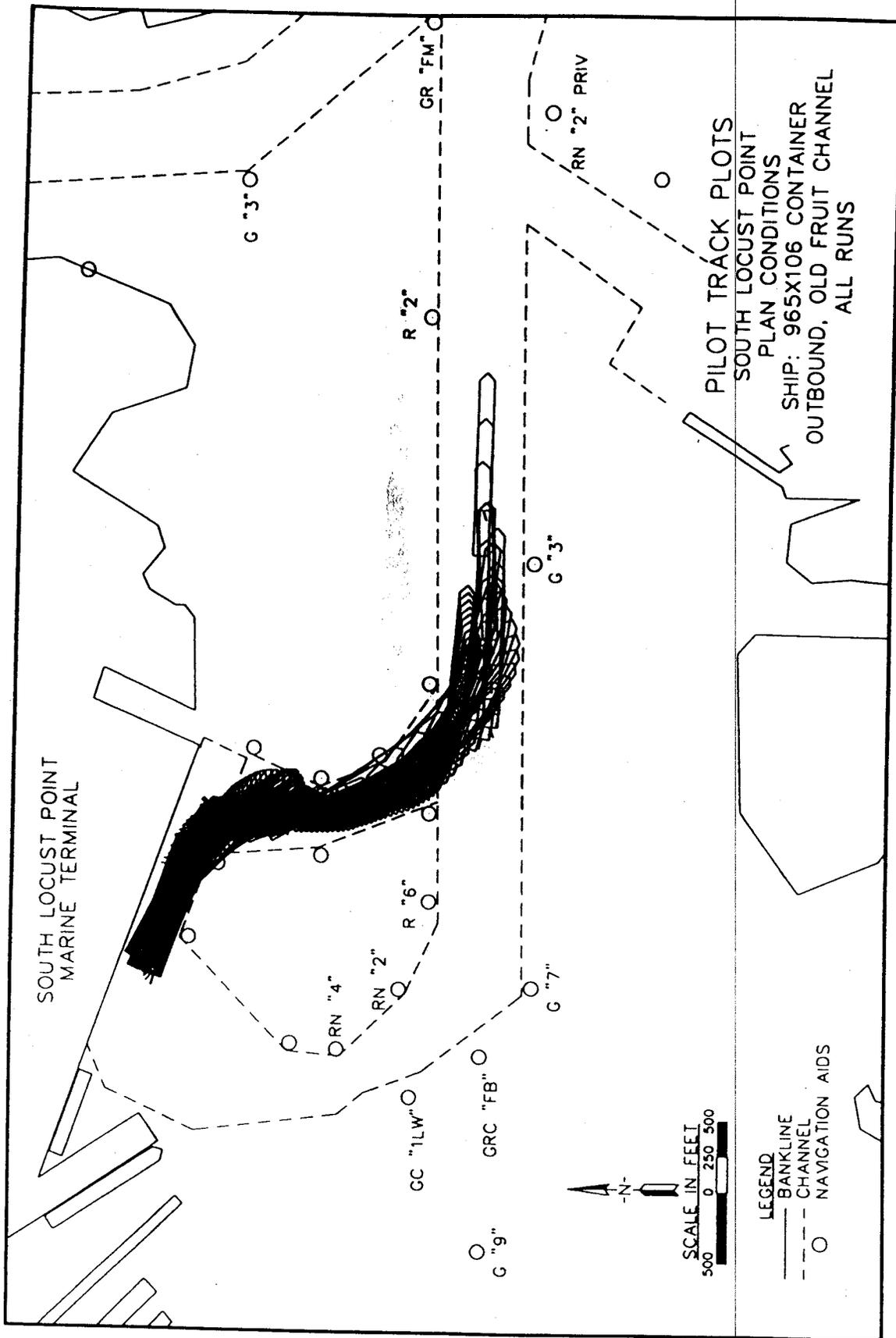


Plate 18

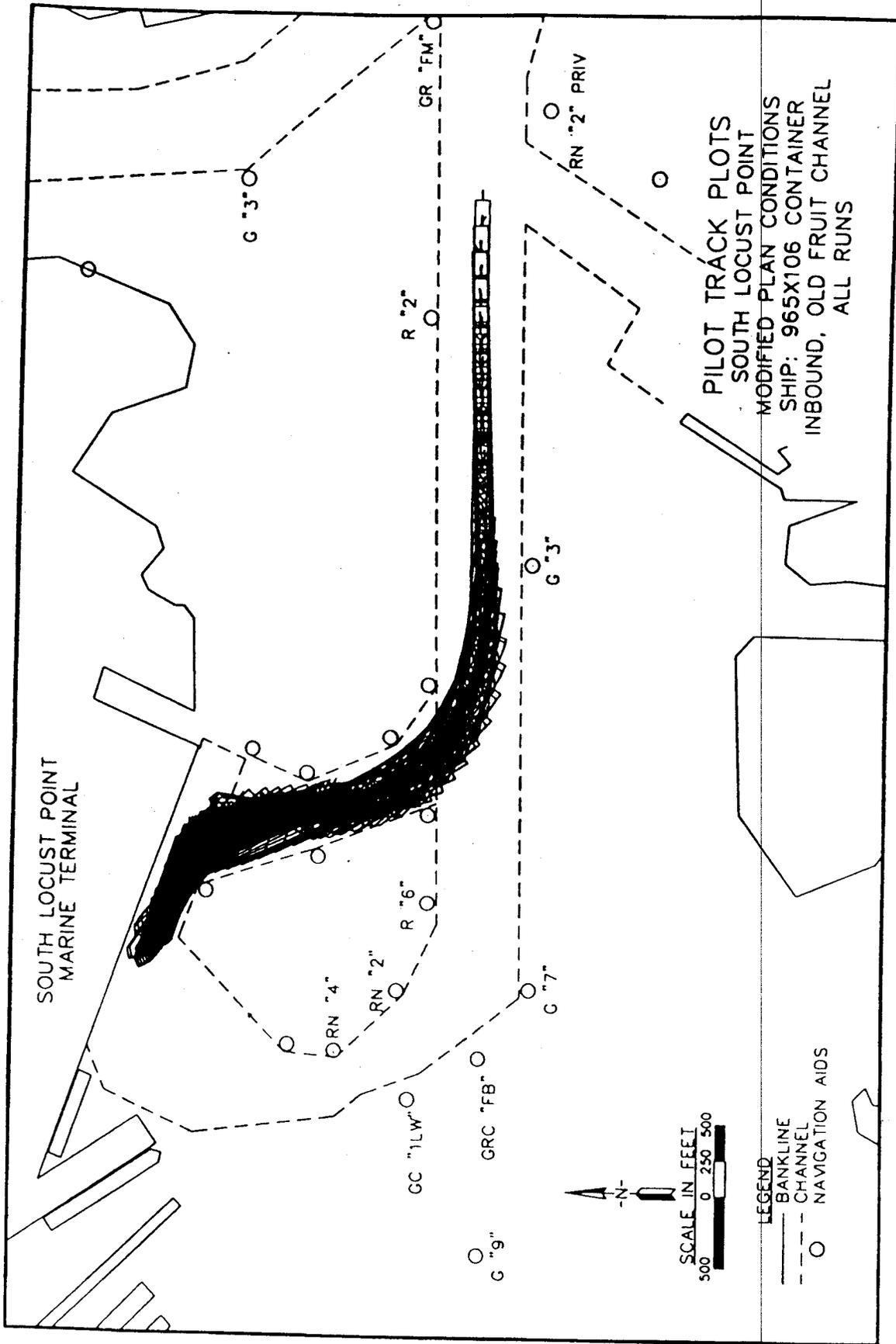


Plate 19

