# CHAPTER 1
# COLUMBIA RIVER CHANNEL NAVIGATION ANALYSIS

## *1.1. Introduction*

The navigation practices of deep-draft vessels on the Columbia River influence the channel design and potential benefits of any channel improvement project. Especially important are the practices of container ships and bulk grain carriers that could take advantage of a deeper channel. The existing navigation practices are the product of the combined effects of river stages, channel depths, size, speed and scheduling of vessels, operating requirements of the pilot groups, and policies of the shippers and government regulators.

To define the navigation practices of container ships and bulk grain carriers on the Columbia River, a detailed study was made of transits that occurred in 1991 through 1993. The goals of the study were to identify the operating limits of ships that might benefit from a deeper Columbia River navigation channel. The study analyzed the number of transits, vessel drafts, departure timing, and underkeel clearances. Additional transit data from 1994 and 1995 was used to supplement the detailed analysis of vessel drafts. The results of the analysis were then presented to shippers and pilots for concurrence and/or refinement.

In the following discussions, the term "draft" will be used to refer to a ship's draft in the fresh water Columbia River channel. For ships with drafts in the range of 36- to 40-ft, the fresh water draft is about one foot deeper than the salt-water draft.

## *1.2. Navigation Database*

To conduct the study of navigation practices, a large database was compiled for Columbia River transits that occurred from 1991 through 1993. Data collected included vessel characteristics, transit information, water surface elevations, and channel depths.

### 1.2.1 Vessel Transit Database

The Port of Portland compiled an extensive array of information on nearly 6,000 Columbia River vessel transits that occurred from 1991-1993. The data included vessel characteristics, routes, local port-of-call, arrival and departure times, freshwater sailing drafts, and cargo types and volumes. Data was obtained from the Columbia River Bar Pilots, Columbia River Pilots, Lloyd's Registry, Merchants Exchange, and PIERS.

1.2.2 Controlling Channel Depths

The controlling depths along the channel were determined from Corps of Engineer's 1991-1993 hydrographic surveys. Each navigation bar (approximately a 3-mile reach) was surveyed 6 to 10 times per year during that time period. The individual surveys along the river were examined to identify the maximum channel elevations a ship would experience as it moved through the channel. A high bottom elevation had to occur over 200-300 ft of the 600-ft wide channel before it was considered a controlling depth. Shoals along the edge of the channel were not considered to be controlling factors in navigation because ships have the ability to sail around them.

1.2.3 Water Surface Elevations

Observed water surface elevations were obtained from a series of six gages operated by the National Weather Service for the Port of Portland as part of a river stage forecasting system. These gages provide real time water surface elevations that are used in a river stage prediction computer model and can be used by Pilots to plan vessel departures. The gage locations and datum are:

| Location | River Mile | Datum Elevation in Feet | |
|---|---|---|---|
| Astoria | 18 | 0.00 MLLW | -3.07 NGVD |
| Skamokawa | 35 | 0.00 CRD | -2.15 NGVD |
| Wauna | 42 | 0.00 CRD | -1.76 NGVD |
| Longview | 67 | 0.00 CRD | -0.34 NGVD |
| St. Helens | 86 | 0.00 CRD | 0.89 NGVD |
| Vancouver | 106 | 0.00 CRD | 1.82 NGVD |

## *1.3 Navigation Practices Analysis*

1.3.1 Vessel Draft Analysis

The first step in the navigation practices analysis was to identify which types of ships might benefit from a deeper navigation channel. The sailing drafts for inbound and outbound transits were reviewed for trends. As Figure 1 shows, outbound drafts are significantly deeper than inbound drafts. The difference between inbound and outbound drafts was expected because export tonnage far exceeds import tonnage on the river. It was determined that the navigation analysis would concentrate on the outbound navigation practices.

The nearly 1000 outbound transits with drafts over 36 ft were then examined to identify the type of cargo and the departure port. This examination identified three groups of ships that might benefit from a deeper channel. The three groups were; the panamax class bulk carriers that loaded corn from the Port of Kalama, bulk carriers that loaded wheat from elevators in Portland and Vancouver, and container ships that called at the Port of Portland. Discussions with shippers and pilots confirmed that those three groups of ships were most likely to benefit from a deeper channel.

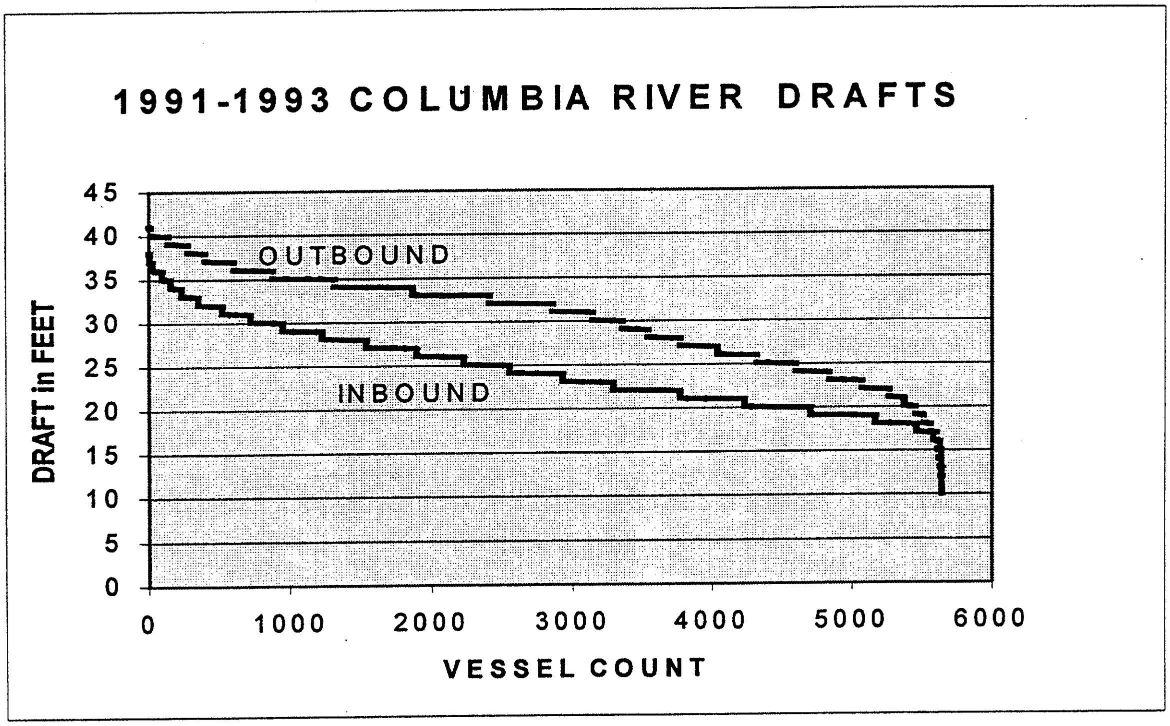


Figure 1. Observed inbound and outbound drafts for all vessel types during 1991-1993. Both data sets have been sorted independently to plot from maximum to minimum.

The panamax class bulk carriers that loaded corn from the Port of Kalama had the deepest drafts. More than 150 of the 487 ships that departed Kalama had design drafts over 40 ft and 107 ships had sailing drafts of 40 ft or more. The deepest draft departing Kalama was 41.6 ft.

There were approximately 1200 bulk carriers that loaded wheat in Portland and Vancouver. Only 25 of those ships had outbound drafts over 39.9 ft, however there were over 460 ships with outbound drafts of 36 ft or more. The deepest outbound draft was 41.3 ft.

The final group was the 650 container ships that called at the Port of Portland. The design drafts for those ships were mostly 38 ft, with some ships having design drafts of 42 ft. Only 62 container ships had outbound drafts over 35.9 ft and only one had a 40-ft draft. Figure 2 shows the design, inbound, and outbound drafts for each container ship transit. The data has been sorted by outbound draft, and shows the corresponding inbound draft and the ship's design draft. As Figure 2 shows, a few container ships enter the river with drafts over 35 ft.

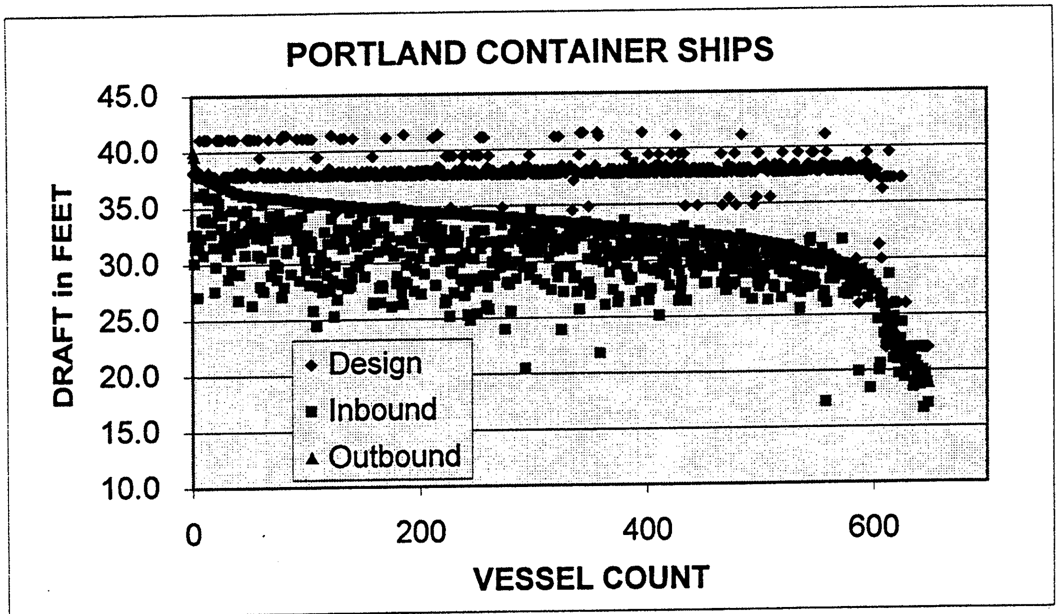


Figure 2. Design, inbound and outbound drafts of container ships transiting the Columbia River in 1991-1993. The data has been sorted to present the outbound drafts in descending order, with the related design and inbound drafts plotted at the same x-axis location.

1.3.2 Transit Modeling

To fully define navigation practices, it was necessary to determine the minimum depth of water and minimum underkeel clearance acceptable to the three groups of ships identified above. To evaluate those parameters, a computer model was developed to reproduce actual transits. The model used actual ship draft and sailing time, channel controlling depths, and observed river stage data to calculate vessel speed and squat, depths of water available and underkeel clearance. A total of 309 transits were reproduced, including 120 bulk carriers from Kalama and 112 bulk carriers from Portland/Vancouver, all the bulk carriers had outbound drafts of 38 ft or more. Ships over 38 ft draft were used because it incorporated most of the panamax class ships and those ships that were making the most use of the water depth available. For container ships, 67 ships with drafts of 35.5 ft or more were analyzed. These were the deepest draft container ships and all had design drafts over 38 ft.

The model used the sailing time from the port of departure to Astoria to computer the average vessel speed. The average speed was then used to compute the ship's squat (the sinkage of the stern of a ship as it moves through the water). Since squat is roughly proportional to the ship's speed squared, the faster container ships experience more squat than the slower bulk carriers.

River stages were interpolated from the hourly gage data and the timing of the transit. At the gage sites the stage during the transit was interpolated from the hourly stages bracketing the transit time. The river stages at locations away from the gage sites were interpolated based on timing and distance to the upstream and downstream gages. The stage was calculated at each navigation bar along the transit to produce a continuous water surface profile.

The total water depth available at each bar was calculated by adding the computed river stage, feet above or below CRD, to the controlling depth, in feet below CRD, taken from the channel surveys. The underkeel clearances were then the differences between the total water depth available at each bar, and the sum of the ship's draft and squat. Figure 3 shows typical results from the transit model. The results for each transit were then sorted to identify the minimum and maximum values for river stage, controlling depth, total water available, and underkeel clearance.

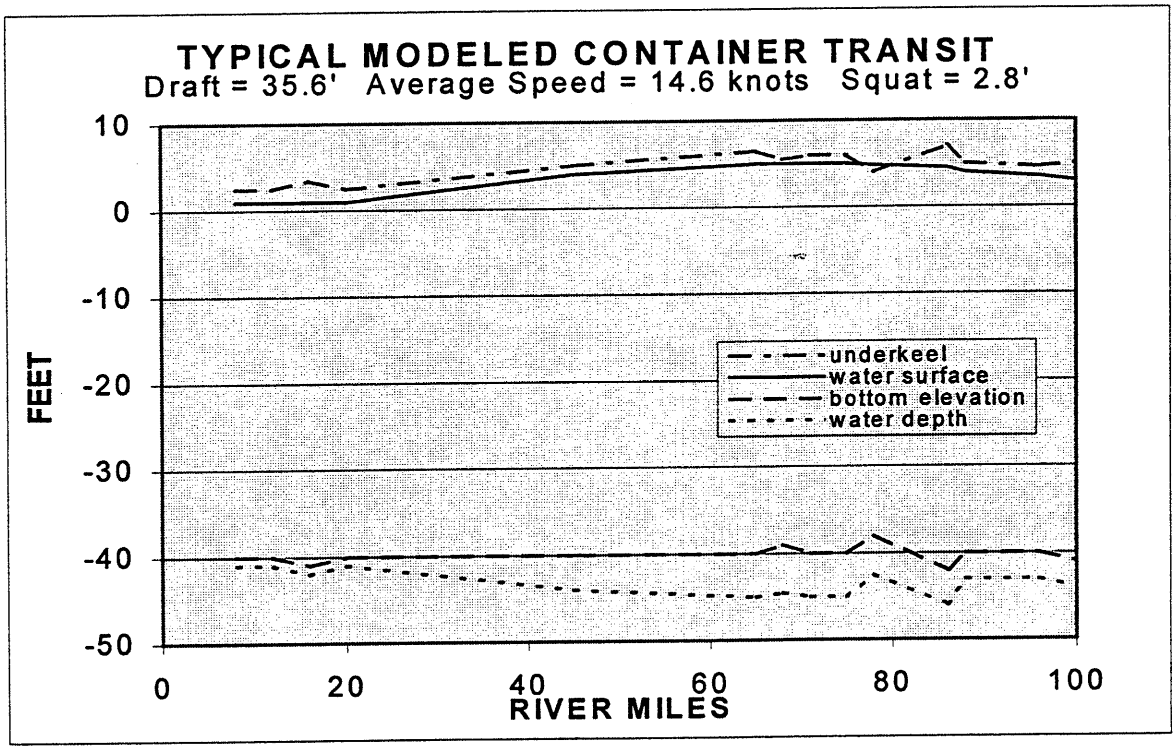


Figure 3. Vessel transit model results showing the reproduced water surface elevation, channel bottom elevation, total depth of water available, and underkeel clearance along the channel.

## 1.4 Operating Practices

A set of operating practices was defined for each of the three groups of ships likely to benefit from a deeper channel. Target values were identified for draft and minimum underkeel clearance. The target values were defined as the limiting values acceptable under normal operations. The values were initially identified from the transit modeling results and then confirmed during discussions with shippers and pilots.

### 1.4.1 Kalama Bulk Carriers

The bulk carrier fleet that calls at Kalama primarily loads corn. The fleet is comprised of two classes of ships, handy size vessels with design drafts of 30-36 ft and panamax class vessels with design drafts of 40-44 ft. Because corn can be purchased and shipped in large lots, panamax class ships comprised about 40 percent fleet, as shown in Figure 4.

The bulk carriers that call at Kalama typically remain in the river for a week or more and attempt to load as much grain as possible before departing. The panamax ships will delay their departure to take advantage of the maximum water depth available to load more grain. However, as Figure 4 shows, nearly all of the panamax vessels left Kalama light loaded, while the handy size ships tended to sail at or over their design drafts.

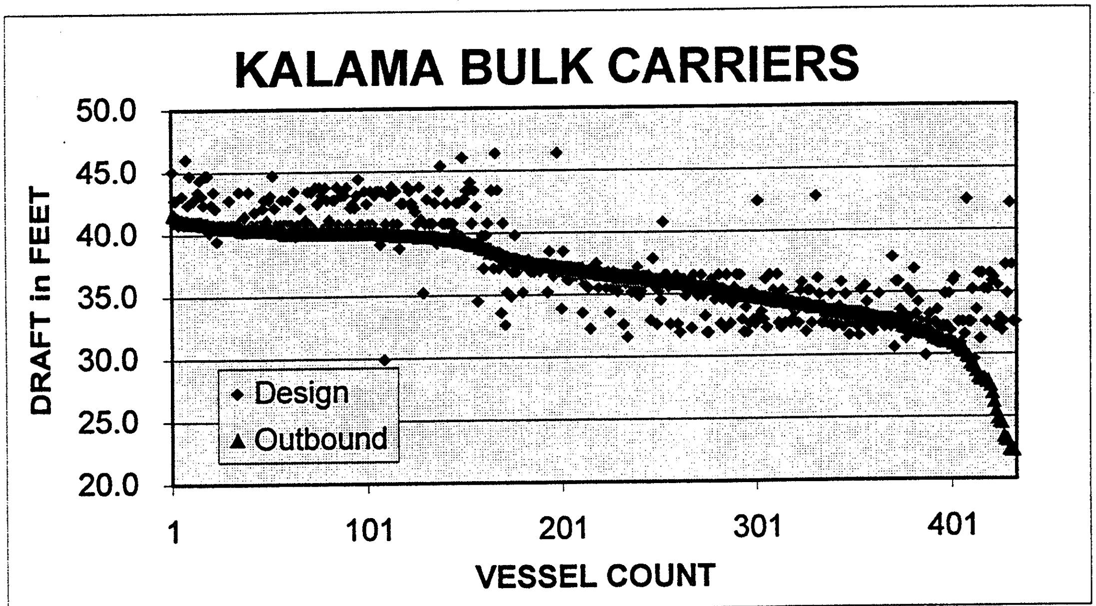


Figure 4. Design and outbound drafts for bulk carriers calling at Kalama in 1991-1993.

Figure 5 shows that from 1991 through 1993, of the 120 ships with sailing drafts of 38 ft or more, 34 sailed with a 40-ft draft and 43 sailed with drafts over 40 ft. Forty-feet was initially selected as the target sailing draft from Kalama because it was the median draft for the panamax ships. Drafts deeper than 40 ft are possible but require better than average channel conditions. The 1994-1995 draft data supported a target draft of 40 ft as there were 46 ships with 40 ft draft and only seven over 40 ft.

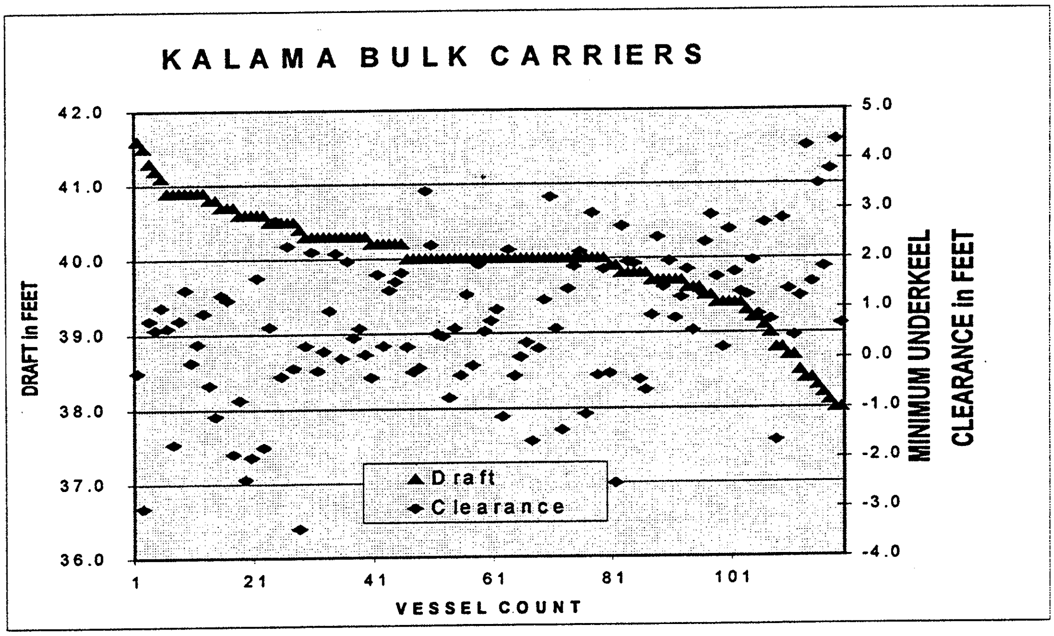


Figure 5. Outbound draft and corresponding minimum underkeel clearance for the 120 ships that departed Kalama with drafts of 38 ft or more, in 1991-1993. The data has been sorted to present outbound drafts in descending order.

As shown in Figure 5, the minimum underkeel clearance was 0.0 ft or less on 33 of the modeled transits. The negative underkeel clearance values probably indicate, a limitation in the modeling method, the ship slowed to reduce squat or maneuvered around the shoal during the transit, or the ship actually touched bottom during the transit. The minimum underkeel clearance typically occurs only at one point along the channel, often just for 100-200 ft as the ship passed across the top of a single sand wave on the bottom of the channel. Because of the frequency of occurrence of 0.0 ft of underkeel clearance, limited potential for cargo damage, and the short duration of the event, 0.0 ft was selected as the target underkeel clearance for the panamax ships sailing from Kalama.

### 1.4.2 Portland/Vancouver Bulk Carriers

Grains, mainly wheat and barley are the main bulk cargoes exported from Portland and Vancouver. The grain fleet is comprised of both handy size and panamax class bulk carriers, as shown in Figure 6. Wheat constitutes the majority of the grain exports and is mainly shipped in handy size vessels. During 1991-1993, almost as many panamax class grain ships called at Portland/Vancouver as called at Kalama, however because of the size of the fleet, Panamax class ships made up only about 10 percent of the fleet.

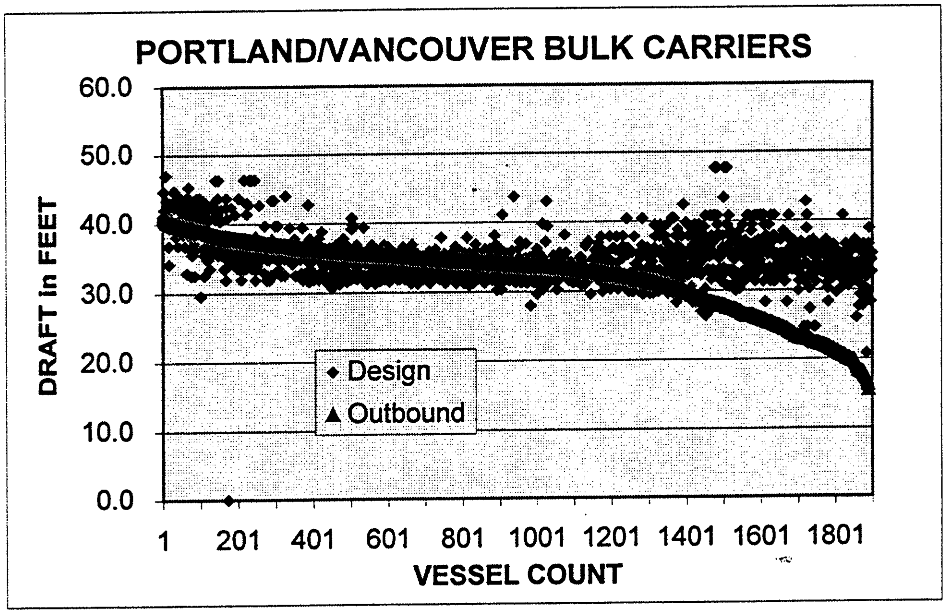


Figure 6. Design and outbound drafts for bulk carriers calling at Portland and Vancouver in 1991-1993.

The bulk carriers that call at Portland and Vancouver typically remain in the river for a week or more and attempt to load as much grain as possible before departing. The handy size ships tended to sail at 33-35 ft drafts, often 2-3 ft over their design drafts. To maximize cargo tonnage, the panamax ships often scheduled their departure to take advantage of the maximum water depth available. However, as Figure 6 shows, nearly all of the panamax vessels sailed light loaded.

A target draft of 39 ft was selected for the Portland/Vancouver panamax size grain ships. Figure 7 shows that in 1991-1993, 39 ft was the median draft of grain ships with drafts over 38 ft. In 1994-1995 there were 139 ships with drafts of 38 ft or more, and the median draft remained 39 ft. This target draft is 1.0 ft less than that identified for Kalama, for the same type of ships. The difference in target drafts is probably due to more limiting channel conditions during the longer transit from Portland/Vancouver. Ships from Portland/Vancouver pass through two low water surface points in the channel, while ships from Kalama only need to pass through one low water point. The longer transit also increases the likelihood of encountering a shoal.

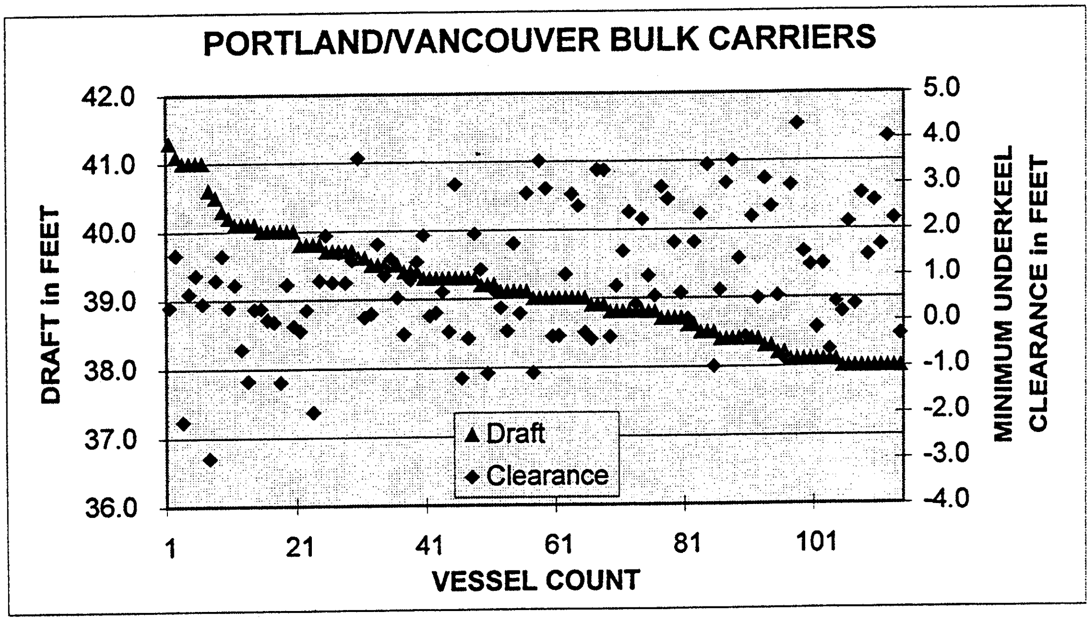


Figure 7. Outbound draft and corresponding minimum underkeel clearance for the 112 ships that departed Portland and Vancouver with drafts of 38 ft or more, in 1991-1993. The data has been sorted to present outbound drafts in descending order.

The minimum underkeel clearance analysis results in Figure 7 show a trend very similar to that of the Kalama analysis, with 24 model runs resulting in zero or negative values. For the reasons given in the above Kalama discussion, 0.0 ft was also selected as the target minimum underkeel clearance for Portland/Vancouver bulk carriers.

### 1.4.3 Portland Container Ships

Container ships operate much differently than the bulk carriers. They are schedule driven and only make short, 1-2 day, calls in the Columbia River as part of an Asia-North America route. Container ships must be able to arrive and depart on set schedules, without delaying for low river stages. Portland is the last North American port-of-call for many container ships. Those ships could be expected to load as much cargo as possible and sail at or near their design drafts. However, the container ships are also concerned about underkeel clearance, because they carry cargo that is fragile and of high value.

As shown on Figure 2, the vast majority of container ships have design drafts around 38 ft, with a few larger 41-42 ft draft ships. The departure drafts show a clear break in slope at 36 ft. This break does not correspond to a change in ship size as it did for the bulk carriers and was interpreted as a change in operating practices by the container ships. The 36-ft draft was therefore selected as the target draft for container ships. In discussions with shippers it was confirmed that 36 ft was their target draft because they could depart at any time without being delayed by a low river stage.

Because of the schedule that container ships are on, few of them try to make full use of the available water depth. In general, the container lines plan to have available on the dock the maximum amount of cargo that can be loaded onto the vessel within the scheduled loading time. However, they do not normally load more than the target draft, even if there are time and cargo available. Only 35 of 649 container ships had departure drafts over 36 ft during the 1991-1993 period. The container traffic increased significantly in 1994-1995 and 157 ships, out of 560, had drafts over 36 ft. In 1994-1995 one container line operated a group of panamax size ships that regularly sailed with drafts in the 38-40 ft range. The container line consulted with the Columbia River Pilots to schedule departure times, sometimes delaying a ship's departure, to take advantage of the maximum water depths available.

As Figure 8 shows, of the 67 container ship transits modeled, only 5 had calculated minimum underkeel clearances of less than zero. There were 17 ships with minimum underkeel clearances of less than 2.0 ft. Two feet was chosen as the target minimum underkeel clearance since that value was exceeded by 75 percent of the 67 deepest container ships. This value fit well with the general container ship guideline of a 4-5 ft allowance for squat and underkeel clearance.

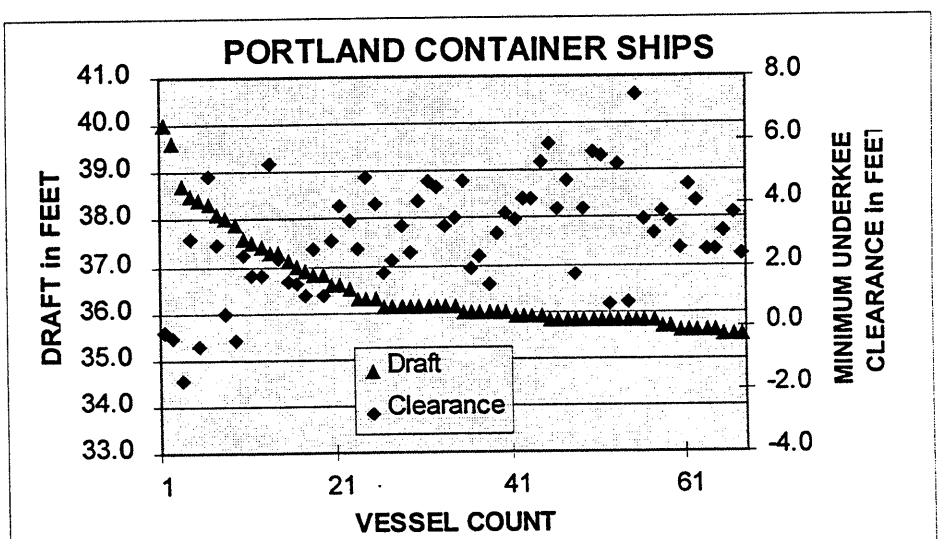


Figure 8. Outbound draft and corresponding minimum underkeel clearance for the 67 container ships that departed Portland with drafts of 35.5 ft or more, in 1991-1993. The data has been sorted to present outbound drafts in descending order.