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VESSEL CHARACTERISTICS FOR INLAND WATERWAYS TRANSPORT

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ABSTRACT

Inland waterways transport has a potential to be exploited in order to reduce the congestion at the seaport, the road to other destination, subtracting the cost for road construction, to decrease the use of energy resources, and environmental degradation. The inland waterways port is not new, however the references of inland port are still limited, therefore the studies of these issues are encouraged. This study looks at the benefit of such a inland waterways ports; then using the design parameter of ships pass through to port will be made base on the data gathered from containership's companies and the basic equation from the literature referred. The size of vessels that passed through the waterways depend on the depth and width of channel, so also when the vessel will be berthed at the port, these depend on the size of turning basin diameter and depth of wharfs. These equations for determining the size of vessels that pass through particular waterways are formulated. The proposed of these models are implemented by a case study at existing and the port website information from many countries, the results indicate that these equations achieve a good result.

Keywords : *Inland waterways, channel, containership, transport, squat.*

1.0 INTRODUCTION

The inland waterways system is vital for the transport resources and agricultural products. The coal generates a large portion of the country's electricity, and the majority of agricultural products such as corn, soybeans are served by ship and barge. Traffic congestion restricts the movement of goods and people, increases the use of energy resources, increases trip time, contributes towards poor air quality, and decreases the productivity of the region. As congestion along the channel increases, the frequency of accidents increases and environmental degradation will continue. Transportation of goods by vessels can have advantages; ships use less fuel to move goods compared to other methods of transportation and, therefore, cause less air pollution. The noise generated by

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vessels and the visual intrusion of the ships on is less than other modes of transport. It is generally safer to transport goods by vessel than by trucks or rail. Trucks travel is mixed traffic with automobiles and other trucks. When truck-involved accidents occur, they usually in injuries, loss of cargo and substantial delays will occur.Rail transport generally involves a large number of rail cars in a straight line moving at high speeds. If an accident occurs, usually multiple rail cars are involved resulting in a loss of cargo and the temporary shutdown of the rail line.Vessels traveling on the sound are generally traveling well away from other vessel and, therefore, the chances of an accident or loss if goods are loaded relatively limited.

Marine civil engineering is often called upon to prepare designs for shipping channels. The task generally involves selecting the appropriate channel depth and width, although it also involves selecting geometry of channel bends and areas for vessel turning (i.e., turning basins). Navigation channel design is complicated by the fact that the design engineer must provide channel dimensions that can safely accommodate large vessels can be quantified using mathematical model.

The approach channels can also have a significant effect on port operation due to the limitation to ships sailing through its bends or passing each other in two-way channels. Sometime limitations in turning circles or in the area around the berth can result in reduced port efficiency. The landside transportation link (e. g., railway, highway, pipeline, etc) may also be a factor affecting port operations. The port is an important link of a total transportation chain. It is built to serve water transportation in coordination with the inland transportation system. In this paper provides the mathematical model with focus on of depth of channel, width of channel, and turning basin for container vessels.

2.0 CHANNEL LAYOUT

When choosing a channel layout from several alternatives, the one which offers the more economical solution and allows the easiest navigation under most stable and clearly defined conditions should be selected. This, typically, is a compromise between navigation and hydraulic aspects with regard to tide, waves, current, winds, siltation, visibility, and geotechnical condition of the seafloor.

In some cases, depending on the design conditions, the individual legs and curves may have different width and depth, and be navigated at different speeds. In all cases, a single curve is better (and preferred) than a sequence of smaller curves at close intervals. At bends, a channel should be widened to account for the fact that the path of a ship in a bend is wider than a straight section. [1] suggest that the increase in channel width at bends (ΔW) should not be less than $L_s^2/8R$, where L_s is length of designed ship and R is bend radius.

An inland waterway channel will usually follow natural river course with cutoff, as necessary, to eliminate sharp bends. Adequate straight segments between bends are required to allow a large ship or tows sufficient time to obtain proper alignment for passing through the next bend. A recommendation that a straight leg between two bends should not be shorter than 5 lengths of a ship designed [2]. River training structures are usually needed in erodible rivers to maintain channel dimensions and alignment.

2.1 Channel Depth

The channel is the minimum depth of water in the channel which should satisfy the following safety criteria with respect to ship under keel clearance [3]. The required depth of the channel depends on different factors related to the ship, to the bottom, and to the water level. The minimal requirement in the determination of the channel depth is that it is passable by the design of ship with the largest draft during high tide.

Minimum Waterways Depth for safe navigation is calculated from the sum of the drought of the design vessel as well as a number of allowance and requirements as seen in the following formula (see Figure 1):

Actual waterways depth = Target Vessel Static Drought + Trim + Squat + Exposure Allowance + Fresh Water Adjustment + Depth Transition Tidal Allowance (see Figure 1. Components of Waterway Depth)

Project (advertised) Water Depth = Water Depth – Overdepth Allowance

In addition the factors affecting Waterway Depth included in this section, other that should also be taken into account include [5]:

- The effect of currents in the waterways;
- The effect of water levels in the waterway and adjoining water bodies, by such changes as river flow and wind set up;
- Environmental effects; and
- Limiting depths elsewhere in the waterway.

Allowances refer to additional width increases to compensate for bank slumping and erosion, sediment transport and deposition, as well as the type of bank material [9].

The equation, one of the more recent series of physical model tests and field measurements was conducted by [5] for cargo ships and bulk carriers with bulbous bows in restricted and unrestricted channels. Many of the early formulas did not have ships with bulbous bows. The range of ship parameters was somewhat limited with R_{LB} from 6.7 to 6.8 and B/T from 2.4 to 2.9. They conducted some supplemental physical model tests with an h_T/h = 0.5 and n=2 to investigate the effect of channel width in restricted channels. Their formula bow squat S_{bE2} is defined as :

$$S\left(d/D^2\right) = a\left[V_S/\sqrt{gd}\right]^b \left[D/d\right]^C F_W \qquad (1)$$

Where: S = squat (m); d = vessel drought (m); D = channel depth (m); Vs = vessel speed (m/s); g = gravity acceleration (m/s); W = channel width (m); B = vessel beam (m); F_w = channel width factor. With F_w = 1, where W > 9.61 B; a, b, c are common coefficients are 0.298, 2,289, and -2.972 respectively.

$$F_W = \frac{3.1}{\sqrt{W/B}}, \qquad where \qquad W \quad \langle \quad 9.61B\,; \qquad (2)$$

and, these equation is non dimensional and therefore can be used universally with any system of measurement units.

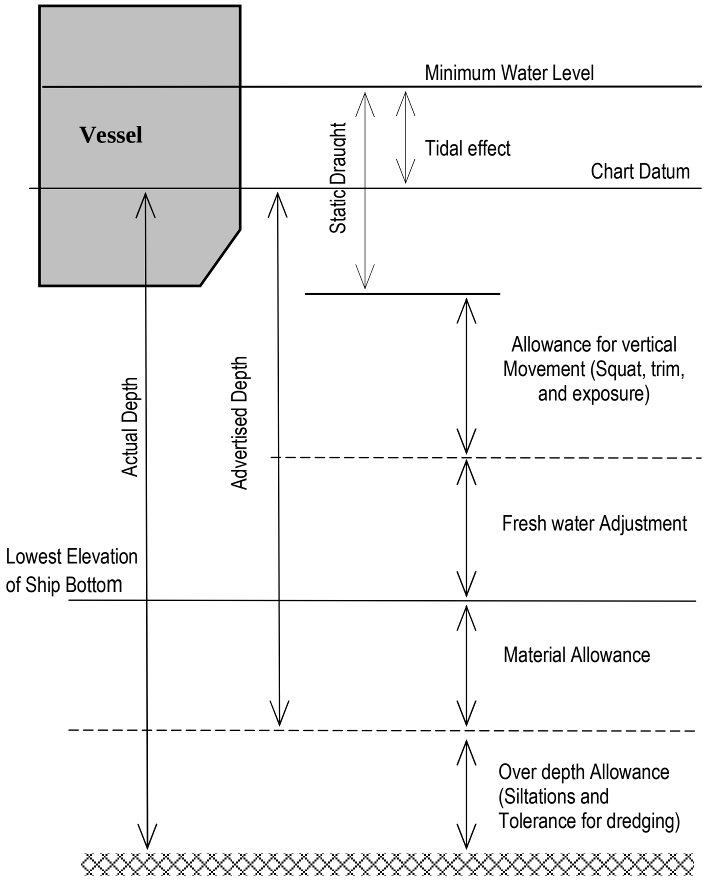

Figure 1: Components of Waterway Depth

2.2 Channel Width.

This is the nominal width at the bed of the channel over which the nominal channel depth is ascertained. The width of a channel is determined from maximum beam and maneuvering characteristics of the design ship, the volume and nature of traffic (e.g. regular or involving dangerous cargos, one or two ways) channel cross section geometry (e.g., fully restricted or semi restricted), current and wave action, and winds that will cause the vessel to yaw. Furthermore, a safety margin is usually added to ensure a ship safe travel through the channel [2].

The basis for the variables included in the equation is the waterway target vessel. The total channel width refers to the horizontal distance measured from the toe-to-toe side slopes at design depth. Total width is expressed as:

Total Width = Design Width + Allowance

Design Width refers to the summation of width requirements for [7]:

i. Ship maneuvering
ii. Hydrodynamic interactions between meeting and passing vessels in two-way traffic

iii. Counteracting cross-winds and cross-current
iv. Counteracting bank suction
v. Navigational aids

2.3 Two-Way Channel

For better control of a ship passing another ship in a two-way channel, adequate clearance between maneuvering lanes is required. Passing problems are particularly pronounced in restricted channels, where two-way traffic is faced with decreased controllability during meeting situations, combined with bank suction. When two ships meet in channel, asymmetric pressure is develop on both sides of both ships with a tendency of diverting these ships from the path they followed before meeting. [5-9] described this situation as follows (Figure 2).

$$B = 2\,B_m + B_c + 2(B_{bc} + \Delta B_{bc}) \tag{3}$$

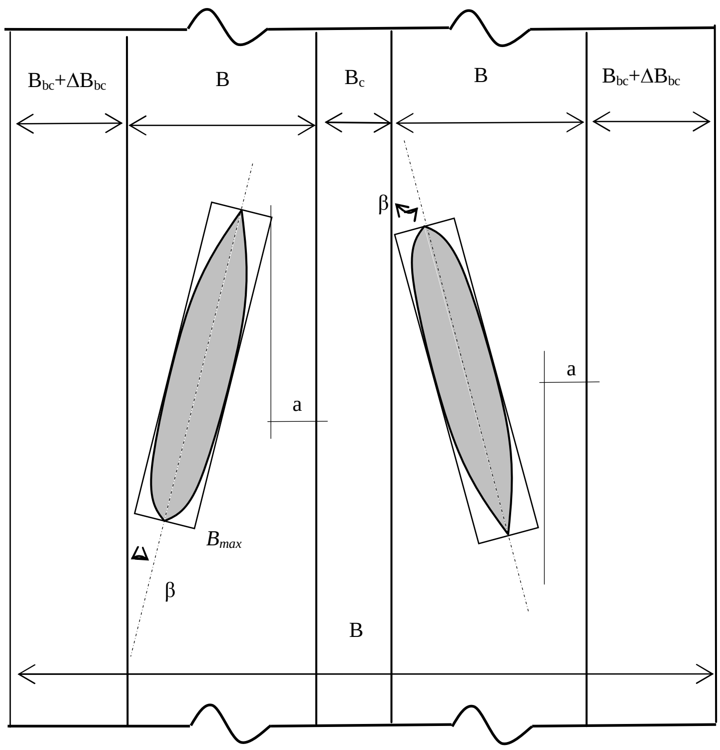

Figure 2 : Plan for Passing Ship in Two-Ways Navigation Channel

[7] recommends value of *Bc* as a function of vessel's speed, traffic density and ship sailing condition, e.g., is she navigation the outer channel exposed to open water, or is sailing in inner channel, located in protected water. For this matter in the case of a fast sailing ship (V_{max} = 12 knots), in outer channel Bc = $2B_{max}$, when speed is moderate (V_{max} = 8-12 knots) Bc = 1.6 B_{max}, and for low sailing ship (V_{max} = 5-8 knots) Bc = 1.2 B_{max}. When a ship is sailing in the inner channel at moderate speed Bc = 1.4 B_{max}, and for slow moving ship Bc = B_{max}

3.0 TONNAGE OF SHIPS VS WIDTH AND DEPTH OF CHANNEL

Equation of tonnage of ship related to width and depth of channel are achieved. The range of ships tonnage is from 2000 until 60000 dwt, those will be assumed to serve in channel, with ships speed 5 m/s. The listing of containership is as shown in Appendix 1. Figure 3 and 4 indicate that the graph was achieved with good result R = 0.873 and 0.878. W_C is width of channel and D_C is depth of channel, T_S is the tonnage of ships divided 1000, the equation are presented as follows;

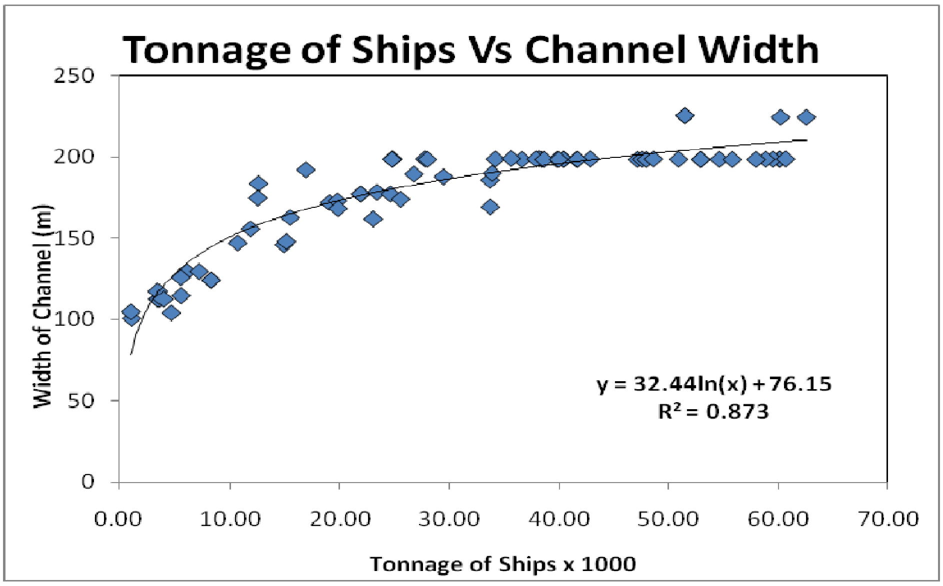

Figure 3 : Tonnage of Ships Vs Width of Channel

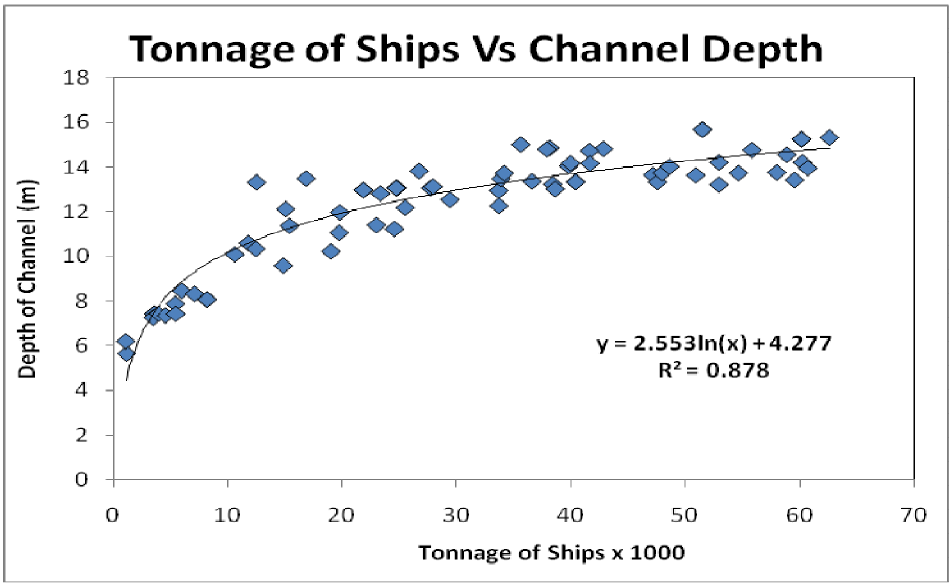

Figure 4 : Tonnage of Ships Vs Depth of Channel

$$W_C = 32.44 \ln (T_S/1000) + 76.15 \quad (4)$$

$$D_C = 2.553 \ln (T_S/1000) + 4.277 \quad (5)$$

Where ; W_c is width of channel, D_c is Depth of Channel. There is correlation between the tonnage (T_S) and length of ships (L_S), Tonnage of ships divided by 1000, L_S is the length of ships in meter. This equation is always used to take account a bends of channel and length of berth at port. The equation is as follows:

$$L_S = 67.402 T_S^{0.3423} \quad (6)$$

Bends in channel should only be employed where absolutely necessary because of the difficult navigation condition that results from imbalance in flow and velocity with changes in the channel direction. The following equation for determining the increase in channel width in bends was developed from the Dave Taylor Model Basin studies:

$$\Delta W = \frac{0.9144 \phi V_S^2 L_S F}{R_t C_c S} \quad (7)$$

Where;

ΔW = increase in the ship lane width, (m)

Φ = angle of turn, degrees

V_s = speed of ship in channel relative to the bottom, (knots)

L_s = ship length, (m)

C_c = coefficient of vessel maneuverability (poor =1, good = 2, very good = 3)

S = unobstructed sight distance from the bridge of the ship, (m)

F = 1.0 for one ways traffic; 2.0 for two ways traffic.

As mentioned above, the equations 2 and 3 are the results of ships tonnage with a capacity of 2000 to 60,000 dwt, the equation are also checked by tonnage of vessels up 60,000 dwt, the Table 1 shows that these equation has to increase consistently. These equations also compare with the existing channel port, depth of these channels base on the maximum containership pass through their port, the results indicate that the values of theoretical is lower than the existing of channel port. The results are illustrated in Figure 5 and 6 that width and depth of existing channel such as Laem Chabang, Thailand, Port of Oakland, etc were explored by internet website in comparison with theoretical calculation [10-13]

Table 1: Tonnage of Ships Vs Depth and Width of Channel

Tonnage of Ships (ton)	Depth of Channel[4] (m)	Width of Channel[5] (m)
5,000	7.89	104.62
10,000	10.10	139.58
15,000	12.13	160.03
20,000	11.98	174.53
25,000	13.08	185.79
30,000	13.13	194.98
35,000	13.74	202.76
40,000	14.73	209.49
45,000	14.83	215.43
50,000	15.03	220.74
55,000	15.22	225.55
60,000	15.33	229.94
100,000	16.19	255.70

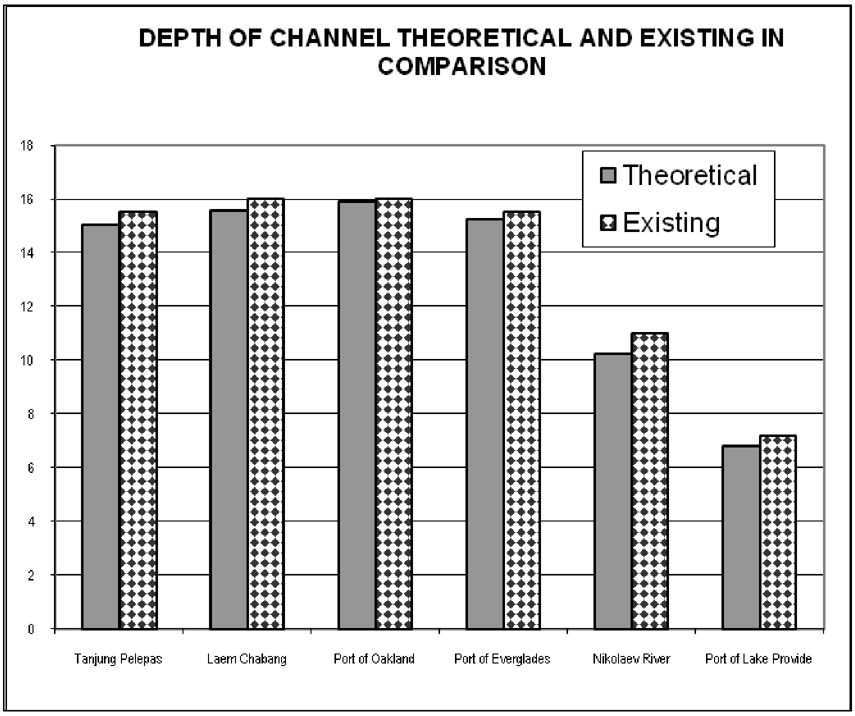

Figure 5. Depth of Channel Theoretical vs Channel Depth Existing

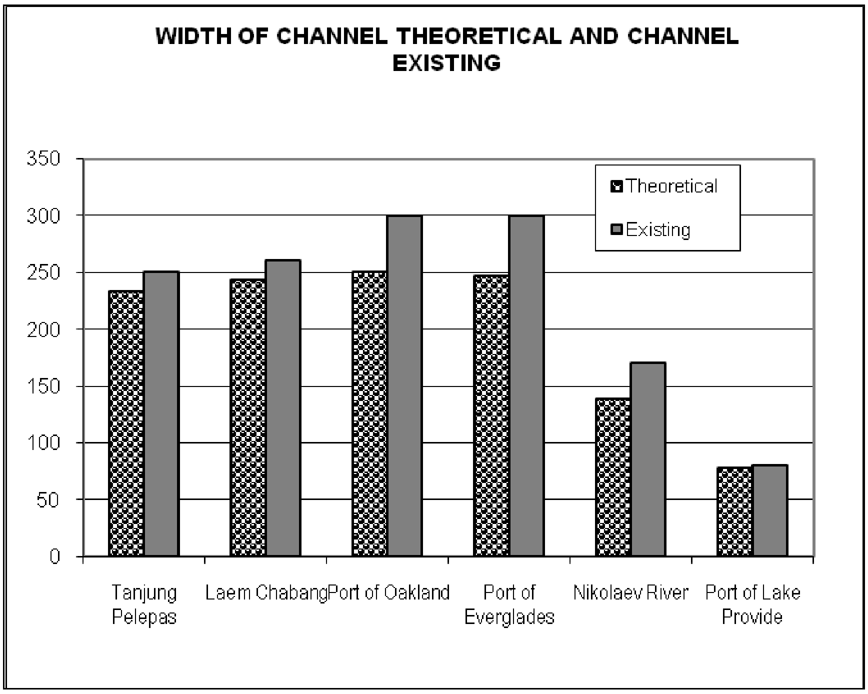

Figure 6. Width Channel Theoretical vs Channel Width Existing.

4.0 TURNING BASIN MATHEMATICAL MODEL

One characteristic of a port is the layout and the maneuverability of its turning basin. The turning basin is a circular area of the port used by ships to turn around in order to leave the harbor. Ships may turn around in the basin either independently or with the assistance of a tugboat, the need for which is determined by the radius of the turning basin. The radius of the turning basin determines the smaller radius, the less likely. The smaller the radius, the less likely it is that a ship will be able to complete the turn under its own power.

The United Nations makes the more general recommendation that the diameter of the turning basin be 3 times the length of the longest ship to enter the port. Another component of maneuverability is the vessel's stopping distance. Two ways in which a port can provide adequate stopping distance for ships are to either lengthen the distance of the channel (allowing an adequate distance for the ship to come to a safe stop) or to implement a "speed limit" at the port's entrance.

Port of Oakland the proposed turning basin will provide 50 feet (15.24 m) more clearance relative to the design vessel than the current 1200 feet (365.76 m) diameter turning basin provides for the 960 foot (292.608 m) design vessel, it means the size of turning minimum 1.25 times the length of ship. In addition, Senior Caption Mr. Kurt B. Braendekilde from Maersk's headquarters in Copenhagen came to this port in 1996 to evaluate the inner harbor turning basin and indicates that he did not foresee any problems turning the design vessel in a 1500 feet (450 m) turning basin at the proposed location.

For tug assistant

$$T_{B1} = 101.72 T_S^{\ 0.3401} \tag{8}$$

The depth of basin shall be minimal 1.1 times full load draft (deepest) of the ship to enter the port below the datum level, in considering the extent of the oscillatory motion of the ship due to the natural conditions such as waves and tidal currents.

5.0 CONCLUSION

The containerships port development in waterways tend to increase because there is no breakwater needed and to reduce the congestion. Another way to demonstrate the energy efficiency of waterways transport is to measure the number of miles that one-ton of cargo can be moved for a gallon of fuel consumed by each mode of transportation. The waterways transport more efficient in comparison with other modes such as carrying by rail and truck. The proposed methodology provides rational, quantitative, and statistically consistent method for determining underkeel clearance for the largest vessel or largest vessel expected to operate in the waterways. Roughly speaking, underkeel clearance in the difference between the depth available in the waterways and the lowest instantaneous vertical position of the vessel hull experienced during transit.

The equations of the depth, widths of channel regarding the tonnage of ships are proposed. These equations are shown to be a good method to determine not only the channel dimension but also overall estimation of port marine facilities. Most vessels are turned either just before berthing or when leaving the berth. The minimum diameter required for turning will depend on whether the vessel has tug assistance or without tug assistant.

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APPENDIX

List of Vessels Size And Tonnage

Name of Vessels	**Tonnage**	**Container** (TEU's)	**Length** (m)	**Beam** (m)	**Depth** (m)
Star Fraser	12,593	1000	187.30	29.40	11.82
Star Ikebana	16,916	1300	185.00	31.00	12.00
Holstein	3,544	372	103.50	16.00	6.09
Baltic Trader	6,066	547	116.40	19.20	7.10
Holstein	3,544	372	103.50	16.00	6.09
Jenna Chatherine	3,458	366	98.43	16.90	5.93
Med Taipei	38,443	2794	269.69	32.20	11.53
Rhein Partner	5,504	508	99.95	18.50	6.55
Werder Bremen	8,270	700	121.35	18.20	6.69
Ming Longevity	24,841	1850	210.12	32.26	11.52
Zim Mumbai	23,400	1750	187.69	28.41	11.32
Rhein Trader	3,948	400	103.51	16.01	6.09
Cscl Yantian	33,717	2466	207.40	29.80	11.40
Cgm Cayenne	14,928	1162	163.00	22.30	8.12
Heeredwinger	1,138	205	90.60	13.75	4.30
Kindia	19,077	1450	168.00	27.20	8.75
Laust Maersk	51,498	3700	266.34	37.30	14.00
Madison	60,144	4300	294.12	32.22	13.50
Maersk Apapa	19,798	1500	166.20	27.40	9.60
Maersk Barcelona	26,772	1984	239.26	30.51	12.20
Maersk Constantia	42,867	3101	258.50	32.26	13.15
Maersk Felixstowe	23,054	1726	183.90	25.30	9.90
Maersk Itajai	24,625	1835	194.06	28.20	9.70
Maersk Jarry	11,873	950	139.05	24.15	9.20
Maersk Montreal	15,475	1200	203.06	25.46	9.82
Maersk Toledo	41,642	3016	270.64	32.20	13.03

Maersk Tayama	38,184	2776	256.10	32.29	13.20
Majestic Maersk	60,144	4300	294.12	32.22	13.50
Orion	21,916	1647	178.00	28.20	11.50
Sea Land Commitment	59,538	4258	289.52	32.22	11.67
Sea Land Mistral	50,922	3660	245.00	32.22	12.00
Sirius	21,916	1647	178.00	28.20	11.50
Cosco Atlantic	24,783	1846	210.00	32.26	11.52
Cosco Bremerhaven	54,639	3918	275.70	32.21	12.02
Cosco Singapore	33,919	2480	220.00	30.60	11.90
Cosco Ling Yun He	25,562	1900	179.70	27.60	10.70
Cosco Na Xi He	47,175	3400	242.85	32.20	12.02
Cosco Elegance	52,939	3800	276.50	32.20	12.50
Cosco Shan He	52,939	3800	274.99	32.20	11.50
Hyundai Baron	62,579	4469	275.10	37.10	13.62
Containership IV	12,536	996	154.50	27.75	8.90
Capenorth	19,855	1504	175.02	26.51	10.50
Carmen	15,129	1176	186.02	22.67	10.62
Dirch Maersk	60,230	4306	275.00	37.10	12.50
Dollart Trader	33,746	2468	168.00	26.70	10.81
Glasgow Maersk	60,691	4338	292.00	32.25	12.20

List of Vessels Size And Tonnage (continue)

Name of Vessels	**Tonnage**	**Container** (TEU's)	**Length** (m)	**Beam** (m)	**Depth** (m)
Hanjin Bremen	40,432	2932	240.00	32.22	11.72
Hanjin Dalian	34,207	2500	201.50	32.25	12.20
Hanjin New York	36,628	2668	241.10	32.20	11.73
Hanjin Portland	55,821	4000	289.50	32.20	13.02
Hanjin Singapore	40,432	2932	242.00	32.21	11.70
APL France	57,982	4150	293.50	32.20	12.00
Amrum Trader	7,175	624	132.30	19.20	6.92
Elisabeth	4,639	448	107.98	14.40	6.00
Emma	5,533	510	113.00	16.40	6.06
Contship Action	39,827	2890	209.50	32.20	12.50
Contship Auckland	29,466	2171	195.57	30.20	11.02
Contship Vision	37,925	2758	192.50	32.25	13.30
ALK	8,270	700	121.35	18.20	6.69
Ambassador Bridge	41,685	3019	241.00	32.21	12.54
Atlantic Bridge	24,783	1846	210.10	32.21	11.51
Brooklyn Bridge	47,982	3456	276.52	32.20	12.02
Garden Bridge	48,631	3501	238.60	32.26	12.40
Gulf Bridge	27,781	2054	210.01	32.26	11.51
Margaretha	10,691	868	133.95	22.50	8.70
Northen Virtue	38,645	2808	196.00	32.20	11.50
Rainbow Bridge	39,985	2901	249.00	32.20	12.53
Tower Bridge	27,997	2069	226.80	32.21	11.53
City of Cape Town	35,648	2600	258.55	32.31	13.02