Safety Concerns with The Pender Harbour Dock Management Plan

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EXECUTIVE SUMMARY

The Pender Harbour Dock Management Plan contains at least two fundamental flaws which arise due to a neglect of the laws of physics in the drafting of the Plan. These issues are:

a. **The restriction of maximum float width to 1.5 metres:** This creates serious safety concerns related to the buoyancy and stability of floats constructed under this plan. This width limitation is simply unsafe, resulting in floats which are fundamentally unstable under even modest loading.

b. **The 43% light transmission criteria:** This is not achievable because it neglects the fact that there is some form of flotation (which has zero light transmission) required under the decking structure of any float. The seemingly arbitrary figure of 43% light transmission is quite simply not achievable in a floating structure, and particularly one in which the width is constrained to 1.5 metres.

In order to address the deficiencies identified above, and to avoid the initiation of legislated hazards, the PHDMP must be amended to reflect proper engineering design of all the elements of any dock system, and in particular the floating elements of same.

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July 15, 2019
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1.0 BACKGROUND

In 2018 the Pender Harbour Dock Management Plan (PHDMP) [1] ("the Plan") was published for public distribution after a number of revisions since its initiation in 2015. That document as it presently exists contains numerous restrictions on the size and configuration of docks (and their constituent components) to be used in Pender Harbour.

Major concerns arise from the PHDMP as written, specifically related to:

(a) **Section 8.4:** the maximum allowable width of ramps and docks, namely; *The size of all docks should be minimized. Access ramps, walkways or docks should be a minimum of 1.0 metre above the highest high-water mark of the tide. Access ramps and walkways should not exceed a maximum width of 1.2 metres. Docks should not exceed a maximum width of 1.5 metres.*

As the Plan does not distinguish between the various elements of a "dock", one must assume that this parameter will be applied to both fixed and floating elements. and,

(b) **Section 8.6:** issues of light penetration as they are impacted by the presence of the flotation material inherent in a float; specifically, *decking materials must allow for minimum of 43% open space allowing for light penetration to the water surface*.

This report will clearly demonstrate that both of these criteria are unachievable in a safe, recreational waterfront environment.

2.0 OBJECTIVE

In response to the publication of the Pender Harbour Dock Management Plan this document has been prepared by the named authors, (all of whom are owners of waterfront property in coastal BC), acting purely as concerned professionals. The objective of this report is to identify the serious technical deficiencies in the Plan as presently written, specifically with regard to the subjects identified above, and to suggest changes to the Plan which will ensure adequate safety for persons using docks on the BC waterfront.

3.0 TERMINOLOGY

It important to understand what component is being discussed when considering Dock Design Regulations/Standards, hence the following are offered for clarity:

a. Dock: A dock is a system of one or more components which permits access from (a boat at) the water surface to the nearby uplands. It typically consists of three main components:

   1) a pier,
   2) a ramp,
   3) a float.

b. Pier: The portion of a dock affixed to the land, which may overhang the water, especially at high tides. It is often also referred to as a jetty, although the latter term is more correctly a solid structure projecting into the sea and intended to influence currents and/or provide shelter.

c. Ramp: The hinged section of a dock which connects a pier to a float, and the slope of which varies with tidal conditions.

d. Float: A buoyant structure on the water surface which is secured by anchors, pilings or similar means to locate it in a relatively fixed position in order to permit boat access and/or mooring.

e. Stability: A measure of the resistance of a floating object to heeling (tilting) under off-centre loads, and ultimately the ability of any floating structure to resist overturning (Capsize). The stability of most self-propelled vessels is governed by a variety of international and or national standards including Transport Canada [2]. Some jurisdictions (including Transport Canada) define stability standards for barges. No such regulations or standards exist however for floats in Canada or the USA, and none could be identified for elsewhere.

f. Live Load: The weight of all non-fixed weights that can be on a float such as people, luggage, cargo, snow, ice, etc.

g. Dead Load: The net weight of a float as constructed and installed without any live load onboard.

h. Freeboard: The distance from the water surface to the top of the buoyant elements of a float. (Note: NOT the distance to the deck surface of a float.)

Figure 1 below illustrates the three components of a dock in a typical BC coast installation.

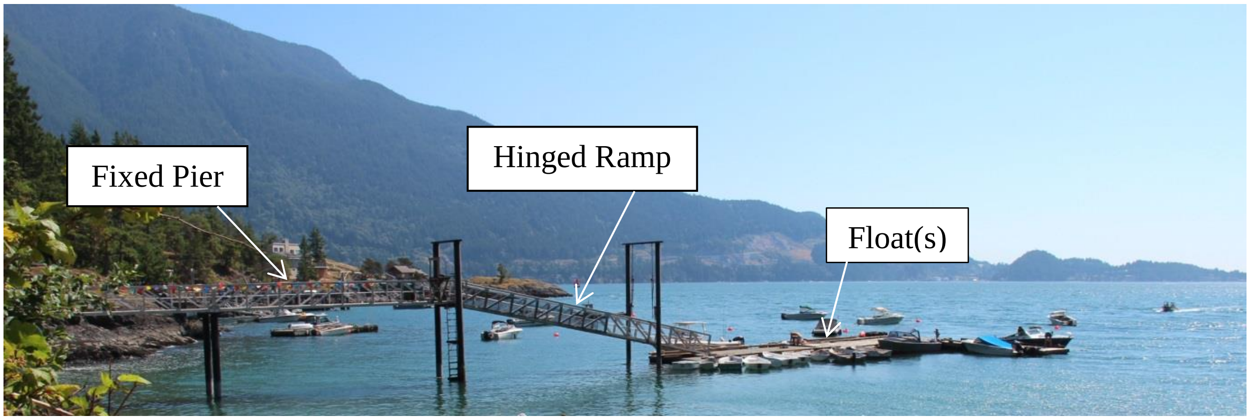

Figure 1 Typical Three Component Dock Installation on the BC Coast

4.0 SAFETY ASSESSMENT CRITERIA

Float safety should be established using science-based criteria, and evaluated in terms of:

(a) Maximum allowable heel (or cross slope) under normal usage including crowding to one side (as often happens),

(b) The ability of the float to safely support the maximum expected load, (its buoyancy), and

(c) The ability of the float to resist heeling and capsize (its stability).

The following sub-sections address what are considered to be various appropriate criteria against which a dock float can be evaluated.

4.1 Buoyancy

The amount of buoyancy in any float must be determined in accordance with the anticipated maximum load to be carried, including the self-weight (dead load) of the structure, and should have some reserve so that any induced heel does not submerge the upper edge of the buoyant elements. If this upper edge becomes immersed, then a floating object rapidly loses stability and can capsize. Based on a review of the literature, the following are representative of the various freeboard criteria cited, and hence are recommended as practical criteria for the amount of buoyancy necessary:

- **Sufficient to support the design dead load with a minimum freeboard of 375 mm**
- **Sufficient to support the dead load plus maximum live load with a minimum reserve freeboard of 75 mm**

4.2 Allowable Heel (Cross-Slope)

In the absence of any published regulatory criteria for the stability or allowable heel (cross-slope) of dock floats, one must rely on the guidance offered in relevant authoritative documents. A number of published sources have been consulted which offer differing criteria for the maximum suggested cross slope of walking surfaces for able-bodied persons as follows:

- Planning and Design Guidelines for Small Craft Harbors; ASCE [3]
- Bulkheads, Marinas and Small Boat Facilities; Pile Buck Inc. [4]
- Published papers on workplace safety [5]
- Marina Design and Construction, Bertlin [6]

Table 1 below presents a summary of the various cross-slope criteria reviewed:

Table 1: Summary of Float Cross-Slope Criteria

Source	***max. Cross Slope Criteria***	***slope***	***% slope***	***angle***	
				rad	*degrees*
ASCE [3]	25:3000	1:120	0.83%	0.008	0.48
[5]	10%	1:10	10.00%	0.100	5.71
Pile Buck [4]	6 degrees	1:10	10.51%	0.105	6.00
Bertlin [6]	15 degrees	1:3.73	26.79%	0.262	15.00

Clearly there is a significant range in these criteria, (as can be expected given the disparate audiences for the cited standards) however the lower limits (2° or less) are unrealistic for a basic float. That leaves the range of 5° to 15° to be considered as within the realm of possibility. This allowable slope must also be considered in the context of the BC coast where float surfaces are frequently very wet and slippery; hence one must be careful not to use criteria that may have been applied to Mediterranean type environments. It is our opinion that 5° is a sensible limiting heel criterion for the BC coast, however the more extreme criteria per [6] have also been evaluated (see Section 5.0).

4.3 Live Loads

The live load is the most significant variable in the design of any floating object, and on an uncontrolled device such as a float can lead to potentially hazardous situations as the average dock user is likely unaware that they could be overloading the float. Again, in the absence of any regulatory criteria for maximum float loading, the criteria used by Transport Canada (TC) [2] for passenger heeling effects on small passenger vessels is considered a useful standard to follow. The TC standard requires that a vessel withstand the heeling effects of all passengers aboard crowding to one side as follows:

- Four passengers per square metre; with a mass of 75 kg for each passenger
- Passengers shall be distributed on available deck areas towards one side of the vessel on the decks where muster stations are located and in such a way that they produce the most adverse heeling moment

Bertlin [6] proposes a similar though less onerous criteria; "*Floating jetties should preferably be not less than 2.5 metres width.... [underline emphasis added]. A design live load of 150 kg/m^2 may be used. They (jetties) should be designed so that they will tilt less than 15º when the total design load is applied to half the width.*"

Both the TC and Bertlin criteria have been evaluated in Section 5 following. It is important to note that the Bertlin criterion includes a MINIMUM float width requirement of 2.5 m, and this should not be interpreted as a maximum width limit.

5.0 STABILITY ANALYSIS

Using the various criteria outlined in Section 4 above, an analysis was performed using a typical float geometry based on the 1.5 metre maximum width defined in the PHDMP. A computer model was created based on a typical 5' x 20' (app. 1.5 m x 6 m) float design geometry (the model float) which appears in numerous websites and which is described by the supplier as "*a standard wood dock design in use in the US and Canada for over 20 years... (and which) has been used mainly for recreational docks on inland lakes and waterways"* and *"The design has been used in sheltered ocean environments in many locations on the BC Coast.*" Float billets come in various sizes and depths. The model float analysis was conducted for both the 12" (30.5 cm) deep billets shown on the drawing, and for an optional 18" (46 cm) deep billet. The model float geometry is illustrated in Figure 2 overleaf:

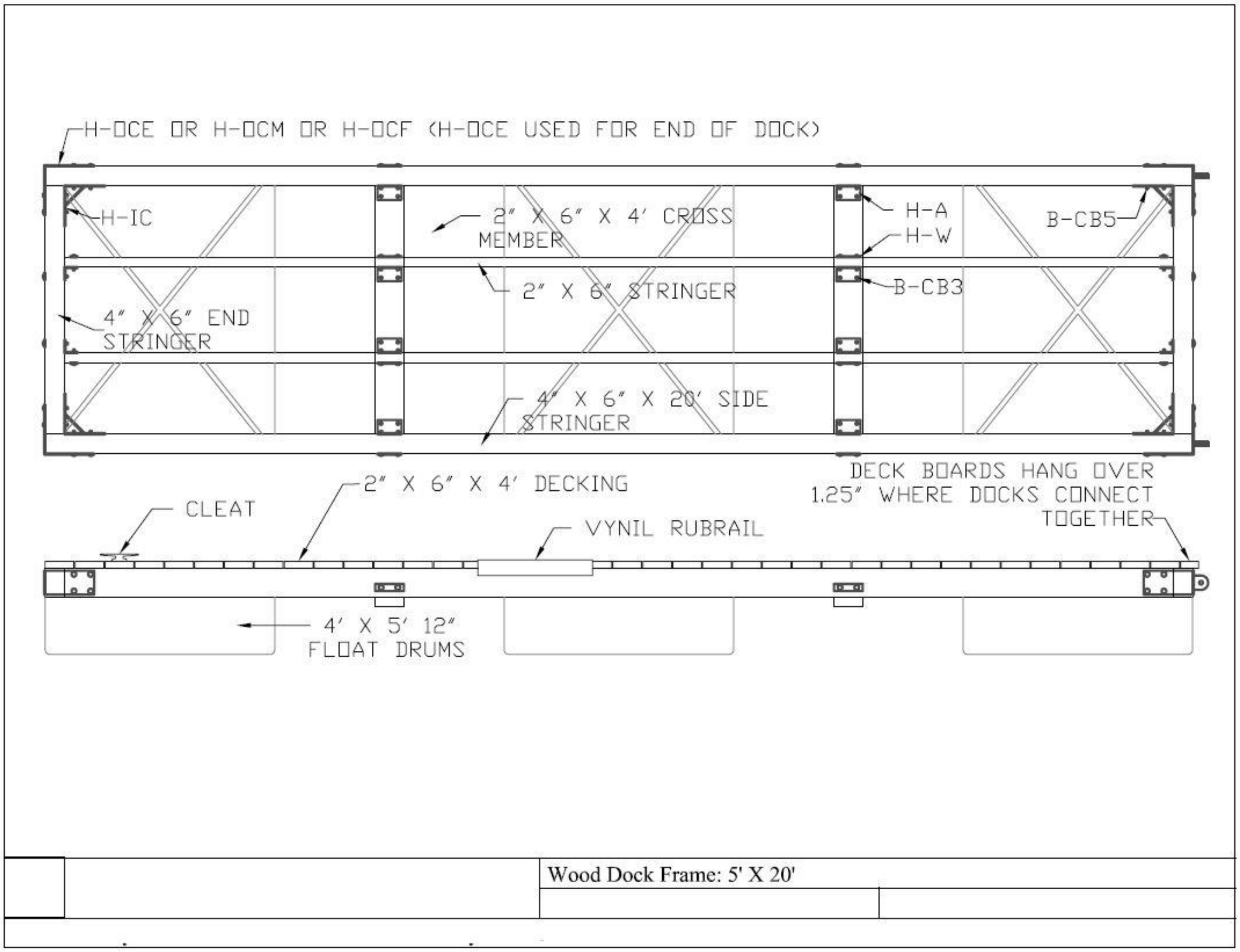

Figure 2 Typical 5' x 20' Wooden Float (with encased buoyancy billets)

The analysis was performed initially by simply checking the available buoyancy and freeboard, and if those tests were met then stability was calculated using GHS, a well-recognized hydrostatic and stability software tool widely used in the Naval Architecture community. It is important to note that the GHS analysis represents a free-floating, unconstrained object, hence a worst-case scenario, but one which nevertheless can and does occur. Floats positioned by pilings would be limited in their maximum slope by the piling bracket geometry and/or bracket strength. Floats located by anchors would also have some constraints on heel imposed by the anchor chains which requires much more rigorous analysis. However, floats positioned by rope anchors or by stiff legs are much less constrained and are therefore virtually free-floating.

The following parameters were used for analysis:

- Float width = 1.52 m (5')
- Float length = 6.09 m (20')
- Billet depth (a) = 0.30 m (per manufacturer's standard design)
- Billet depth (b) = 0.46 m (deeper to provide more buoyancy)
- Dead load (a) = 1,200 lbs. (544 kg) (estimated per manufacturer's data)
- Dead load (b) = 1,350 lbs. (612 kg) (estimated per manufacturer's data)
- Live loads:

  (A) TC Criteria:
  - load = 24 persons, based on the TC criteria of four persons/m^2, but applied only to the length (i.e. a strip of people 1 metre wide by the length of the float (~6 metres)
  - unit weight = 75 kg per person
  - total live load = 1,800 kg
  - TCG = 0.5 m from outside edge = 0.25 m from centre of 1.5-metre-wide float
  - VCG = 1.0 m above the deck surface

  (B) Bertlin Criteria:
  - total live load = 150 kg/m^2 = 1,350 kg
  - TCG = 0.375 m from centre
  - VCG of people = 1.0 m above deck surface

Table 2 shows the result of this analysis according to the various criteria discussed above.

Table 2: Float Stability Analysis

Float Geometry											
Length	**Width**	**Area**	**Billet Depth**	**Dead Load**	**Immersion**	**Light Draft**	**Freeboard**	**Pass / Fail**			
m	*m*	*sq.m.*	*m*	*kg*	*Kg/cm*	*m*	*m*				
6.1	1.5	9.28	**0.305**	454	5.71	0.08	0.23	.375 min.			
6.1	1.5	9.28	**0.457**	612	5.71	0.11	0.35	.375 min.			
Criteria	**Billet Depth**	**Live Load**	**Total Weight**	**Load Draft**	**freeboard**	**Pass / Fail**	**TCG**	**Heel Mmt.**	**Heel Angle**	**Freeboard**	**Pass / Fail**
	m	*kg*	*kg*	*m*	*m*		*m*	*t-m*	*degrees*	*m*	
TC	**0.305**	1800	2254	0.39	**-0.09**	float sinks	not applicable				
	0.457		2412	0.42	**0.03**	75 cm min					
Bertlin	**0.305**	1350	1804	0.32	**-0.01**	float sinks					
	0.457		1962	0.34	**0.11**		0.375	0.51	float is on verge of capsize		

The analysis summarized above clearly indicates:

1. Neither of the standard billets used in this form of float construction satisfy the minimum 375 mm freeboard criteria (Section 4.1) in the light condition. More buoyancy would be required, either with deeper billets (not terribly effective) or with the addition of more billets in the length of the float.

2. None of the geometries evaluated can satisfy the Transport Canada load criteria, never mind the heeling resulting therefrom. More buoyancy is required.

3. The analysis for compliance with the Bertlin criteria [6] indicates that the 18" deep billets meet initial buoyancy requirements but with even a much lesser live load than defined by the TC criteria the float is on the verge of capsize even with the live load on centreline. With just a minimal offset of the live load, this float will capsize.

This situation can be visualized as similar to that which arises when an adult stands up in a small rowboat. The centre of gravity of the load is very much above the centre of flotation, thus resulting in the instability. The width limitation proposed in the PHDMP is simply untenable for a safe float environment.

Based on this initial analysis and using criteria published in recognized engineering and/or regulatory standards, limiting maximum width to 1.5 metres for floating dock elements will lead to extremely unsafe conditions when floats are loaded to even a nominal capacity. Although the analysis considered only a typical 1.5 m x 6.1 m (5' x 20') float, heeling characteristics are not dramatically influenced by length. The impact of added width however is a square function rather than a linear function so doubling width increases stability (resistance to heel) by a factor of 4. Clearly wider floats are more resistant to heel and are therefore much safer. Various sources, e.g. [6] and [5], suggest 2.5 metres as a **minimum** float width but this must be tested for safety against the same or similar criteria.

6.0 LIGHT PENETRATION

While the environmental/biological objectives of the Plan are understood, the stipulated criteria of 43% light penetration to the water surface fails to recognize that beneath the decking surface, in the case of a floating structure, are elements of flotation which have zero light transmission capacity.

In the first instance, the selection of 43% as a criterion is odd and arbitrary; why not 40% or 45%...what critical threshold occurs at 43%??

Most critically however, any such criterion does not address the reality of the essential presence of flotation materials. Depending upon the design loading and the materials of construction, the flotation elements alone of any float would have from 0% light penetration (e.g. any construction with continuous flotation for the length and width of the float) to something in the order of 40% net available area between the flotation in the case of the Model Float examined in Section 5 above. That float is supported by three 4' long x 5' wide filled polyethylene billets in its 20' length. The analysis has shown however that this geometry lacks sufficient buoyancy and is effectively unstable under modest load, so the obscuring of the water surface would have to increase to something in the order of 80-100% just to satisfy the basic buoyancy/stability requirements. The presence of deck supporting structure, etc., never minding the decking material itself, would further reduce light penetration by at least another 5-10%. Thus, achieving a light transmittance of a minimum of 43% open area would require more than 100% transmittance in the remaining net available area (clear of the flotation billets). Even a glass deck cannot achieve more than 100% light transmittance so the requirement in Section 8.6 of the Plan simply cannot be achieved in a simple float configuration, especially one with a maximum width of 1.5 m.

It must be recognized that any light penetration requirement applied to floating structures will be in direct conflict with other fundamental design and safety objectives such as load capacity, stability, deck strength, mooring loads and impact resistance, which must take precedence.

7.0 RECOMMENDATIONS

In order to ensure dock float safety, basic engineering principles **must** be involved in the establishment of appropriate safety and loading criteria.

Float width: The PHDMP must be amended to reflect a safety-based analytical approach to float sizing limits, (for both buoyancy and stability) and very particularly for the width of any floating elements of a dock. Such a criterion absolutely should not implement an arbitrary width limitation as presently written. A float width of 1.5 metres has been demonstrated in this analysis to be simply unstable and thus very unsafe under even modest loads. Float width must be established as a function of the intended load capacity and mooring systems, and the environmental forces to which the float is subject in normal operation. Suitable limiting freeboard and maximum heel criteria under specific loading parameters should be included. Given that the general public using floats are likely unaware that they could be overloading the float, any such criteria must include substantial margins of safety.

Light Penetration: An absolute criterion for light penetration such as the 43% cited in the PHDMP is not achievable in any typical coastal float construction. It completely neglects the fact of the flotation components beneath the decking material. A light penetration requirement for floats will be in direct conflict with other fundamental design objectives such as total load capacity, stability, deck strength, mooring loads and impact resistance. This criterion should be eliminated for the floating elements of any dock system.

Further detailed analysis of any new criteria and associated limitations are required before becoming legislated requirements.

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