Chapter 12: Weather and Oceanography

Introduction

Boat crews operate in constantly changing environments. Weather and sea conditions interact causing many different types of situations. It is important to understand these conditions and how to operate in them. The information in this chapter will concentrate on the effects the environment has on the water and the problems these effects can cause. It will not provide an explanation of advanced meteorology or oceanography.

Great Salt Lake, due to its hyper salinity, is a very unique environment for boating and creates its own challenges not experienced on other bodies of water. The denseness of the water (waves), the fact that boats float higher on Great Salt Lake compared to other bodies of water can change stability.

Wind, fog, rain, and cold temperatures (sea and air) can be very dangerous. Any of these can complicate the simplest mission, not only increasing danger, but also lessening the survival probability of persons in distress.

Effects of wind, current, and storm surge can also dramatically affect a boat’s behavior. A VO must understand how outside influences cause the boat to react in different ways.

In This Chapter

This chapter contains the following sections:

Section A. Weather

Introduction

One of the greatest hazards to the boat crew occurs when its members must work close inshore or in heavy weather. The waves, seas, and surf can present the greatest challenges to seamanship and survival skills. The operating AOR will provide its own unique weather characteristics.

Great Salt Lake is large enough that weather conditions can be radically different in Carrington Bay as opposed to Grantsville Bay. Or conditions up-lake can have different weather phenomenon compared to the southern part of the lake.

Wind Forecasting can be seen on http://www.sailflow.com/en-us/Search/ViewResults.aspx#41.203,-112.604,8,2

Real-time wind direction and strength can be seen on http://www.wrh.noaa.gov/slc/current/meso.wfrnt.php

In This Section
This section contains the following information:

Wind

A.1. Air
High winds account for considerable destruction in the marine environment every year. And Great Salt Lake is no exception. Everyone knows water seeks its own level; the same is true with air. Air tends to equalize its pressure by flowing form a high-pressure area to a low-pressure area, producing wind.

A.2. Onshore and Offshore Breezes
Many are familiar with onshore and offshore breezes on the ocean. But they may find it hard to believe that Great Salt Lake has the same phenomenon. Wind changes drastically because the sun warms the earth. The land warms faster than the surface of the water and radiates heat to the overlying air, warming it. This warm air rises, reducing the atmospheric pressure in that area. The air offshore over the lake is cool, and cool air is dense and heavy.

The cool air from offshore flows inland in an attempt to equalize the pressure differential caused by the rising warm air. This flow produces wind, known as sea breeze. After sunset, the inland area cools more quickly than the water, and the wind diminishes.

Sea breezes typically reach their highest speeds during the period of maximum heating (i.e., during id-afternoon). At some times of the year land breeze can be established late at night or early in the morning. For this breeze to occur, the sea surface temperature must be higher than the air temperature over land, along with weak winds prior to the breeze.

NOTE: Wind direction is the compass heading from which the wind blows.

A.3. Beaufort Wind Scale

The Beaufort Wind Scale (see **Table 12-1**) numbers define a particular state of wind and wave. The scale allows mariners to estimate the wind speed based on the sea state.

NOTE: The Beaufort Wind Scale takes into account water density of fresh water (zero salt) or sea water (3% salt). It does not take into account Great Salt Lake water, which ranges in a salinity of 7% to 27%. This will throw some of the sea-state condition descriptions off for Great Salt Lake.

Table 12-1
Beaufort Wind Scale

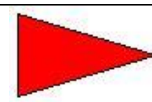
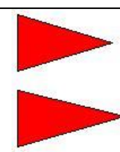
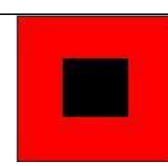
Beaufort Scale	Wind Speed (Knots)	Indications	Approximate Wave Height	Davis Sea State
0	Calm	Mirror like	0	0
1	1-3	*Ripples with appearance of scales	.25	0
2	4-6	*Small wavelets that do not break. Glassy appearance	0.5-1	1
3	7-10	*Large wavelets. Some crests begin to break. Scattered whitecaps.	2-3	2
4	11-16	Small waves becoming longer. Fairly frequent whitecaps	3.5-5	3
5	17-21	Moderate waves. Pronounced long form. Many whitecaps	6-8	4
6	22-27	Large waves begin to form. White foam crests are more extensive. Some spray	9.5-13	5
7	28-33	Sea heaps up. White foam from breaking waves begins to blow in streaks along the direction of the waves	13.5-19	6
8	34-40	Moderately high waves of greater length. Edges of crests break into spindrift foam blown in well-marked streaks in the direction of the waves.	18-25	6
9	41-47	High waves. Dense streaks of foam. Sea begins to roll. Spray affects visibility	23-32	6
10	48-55	Very high waves with over-hanging crests. Foam in great patches blown in dense white streaks. Whole surface of sea takes on a white appearance. Visibility affected	29-41	7
11	56-63	Very high waves		8
12	64 knots or greater	Very high waves		8

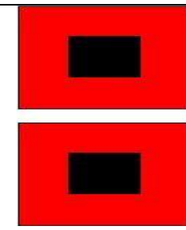
*Indicates sea state description that does not closely resemble Great Salt Lake conditions. It takes more wind to cause the dense water of Great Salt Lake to react to it.

A.4 Weather Warning Signals

The National Weather Services provides radio weather broadcasts on VHF Marine Band radio. Great Salt Lake State Marina also issues daily weather forecasts and warnings. Flag signals posted on www.gslmairna.com as well as hoisted on the marina flag pole announce weather warnings. These weather warnings and their flags are summarized in **Table 12-2**

Table 12-2
Marine Advisories and Warnings for Great Salt Lake

Marine Advisories and Warnings	Winds	Day Signal Displayed at Marina
Watch	Used when the risk of a hazardous weather or hydrologic event has increased significantly, but its occurrence, location or timing is still uncertain. A watch means that hazardous weather or a negative storm surge at the GSL Marina is possible.	
Advisory	Issued when a hazardous weather or hydrologic event is occurring, imminent or likely. Advisories are for less serious conditions than warnings, that cause significant inconvenience and if caution is not exercised, could lead to situations that may threaten life or property. It is also used for advising of a significant negative storm surge at the GSL Marina that is occurring or may occur.	
Warning	A warning is issued when a hazardous weather or hydrologic event is occurring, imminent or likely. A warning means weather conditions pose a threat to life or property. People in the path of the storm need to take protective action. It is also used for warning of a very significant negative storm surge that may trap boats in or out of the GSL Marina for a significant duration of time.	
Small Craft Advisory	Fairly strong winds up to 30 knots (34mph) are possible and/or sea conditions dangerous to small craft operations are forecast.	
Gale Force Warning	Gusts from 31 to 45 knots (36 to 52mph) are possible. Dangerous sea conditions are possible.	
Storm Warning	Gusts of 46 to 65 knots (53 to 75mph) are possible. Dangerous sea conditions are possible. Lightning is possible for the Great Salt Lake	

Hurricane Force Warning	Gusts exceeding 65 knots (75mph) with dangerous sea and weather are forecasted for the Great Salt Lake. Damage to boats, properly tied and secured in their slips or in dry storage areas, is possible	

A.5. Tooele Twisters

Tooele Twisters are small water spouts that are so named because the come from the direction of Tooele. These spouts are formed during pre-frontal winds due to the location of the marina. Pre-frontal winds come from the south. As strong winds pass along the east and west side of the Oquirrh Mountains as well as over the top of the mountains it tends to drag the air out of the marina area (north side of the mountains) forming a miniature low pressure. As this pressure or void gets low enough the strong gusting wind from the Tooele valley bends to the right to fill the void near the marina. As the wind bends it accelerates and can start to spin in a cyclone pattern.

Tooele Twisters can be very violent and are nothing to mess around with. This phenomenon occurs in the general marina vicinity and does not occur farther north on the lake.

A.6. Tornadoes

Tornadoes are rare but not unheard of on Great Salt Lake. They have been sighted coming out of the Tooele Valley just west of the marina as well as north of Antelope Island.

A.7 Weather Fronts

Weather fronts generally approach from the southwest or northwest. Frontal patterns are more common from October through May. Fronts create pre-frontal winds followed by post-frontal winds. These winds can be very violent and can last for days causing very large waves. Destructive wall clouds can be associated with the passing of a front. Tooele Twisters often occur during pre-frontal winds

A.7.a. Pre-frontal Winds

Great Salt Lake and the associated Great Salt Lake Desert are so massive and so different in their temperature that the two together act as a turbo booster for winds and storms. Pre-frontal winds are southerly flows. They can last two to three days prior to the passing of the front. As the front gets closer the wind will build in strength and gusts will become more frequent. Gusts near the Great Salt Lake Marina can be very violent. Gusts over 100 mph are not unheard of and gusts over 75mph happen quite frequently in the winter and fall. Winds farther up the lake can sustain strengths of 50 to 70mph.

A.7.b. Post-frontal Winds

Post-frontal winds can be just as strong as pre-frontal winds. Post frontal winds can create sustained winds of 40 to 70mph. They are typically not as destructive though as they do not created sudden gusts or Tooele Twisters. They do not typically last as long as pre-frontal winds and usually blow over in less than a day.

A.8 Monsoonal Weather Patterns
Monsoonal weather patterns occur from June through September. Afternoon thunderstorms are a result of a monsoonal pattern. Strong micro-bursts are associated with these weather patterns during the downdraft of thunderheads. Thunderstorms usually blow over after an hour or two unless you are in the freight train pattern.

Thunderstorms and Lightning

A.9 Thunderstorms
Thunderstorms have violent vertical movement of air. They usually form when air currents rise over locally warmed areas or a cold front forces warm air aloft. Thunderstorms are dangerous not only because of lightning, but also because of the strong winds and the rough, confused seas that accompany them. Sharp intermittent static on the AM radio often indicates a thunderstorm. An approaching thunderstorm can be particularly dangerous to boaters near the Great Salt Lake Marina because the Oquirrh Mountains often hide the approaching thunderstorm until it is upon the marina area.

A.10. Lightning
Lightning is a potentially life-threatening phenomenon associated with some storms. Not all storms are thunderstorms, but all thunderstorms have lightning. Lightning occurs when opposite electrical charges within a thundercloud, or between a cloud and earth attract. It is actually a rapid equalization of the large static charges built up by air motion within the clouds. Lightning is very unpredictable and has immense power. A lightning “bolt” usually strikes the highest object on the boat, generally the mast or radio antenna. A mast with a full grounding harness affords excellent protection.

WARNING: Fiberglass radio antennas are not suitable protection, and antennas with loading coils offer protection only to the height of the loading coil. (see **Figure 12-1** through **Figure 12-3**) Underwriters’ texts such as the National Fire Protective Association manuals describe a proper grounding system.

Lighting events are one of the few times that a SAR mission may have to be postponed on Great Salt Lake until after the threat of lightning has passed.

A.10.a Grounding Systems
Most commercially available vessels do not have a grounding system. A boat can minimize being struck by lightning by staying in port (assuming there are higher objects about) during thunderstorms and by installing a ground system similar to those found on buildings and other land structures. The grounding system provides lightning a path to reach ground without causing damage or injury. **Figure 12-1** and **Figure 12-2** show the lightning protected zone for a motorboat and a sailboat. **Figure 12-3** diagrams how a grounding system can be installed on a boat.

NOTE: A grounding system on a boat provides lightning with a path to reach the water without causing severe damage or injury. Despite the high number of boats on the water, reports of lightning strikes on boats are rare.

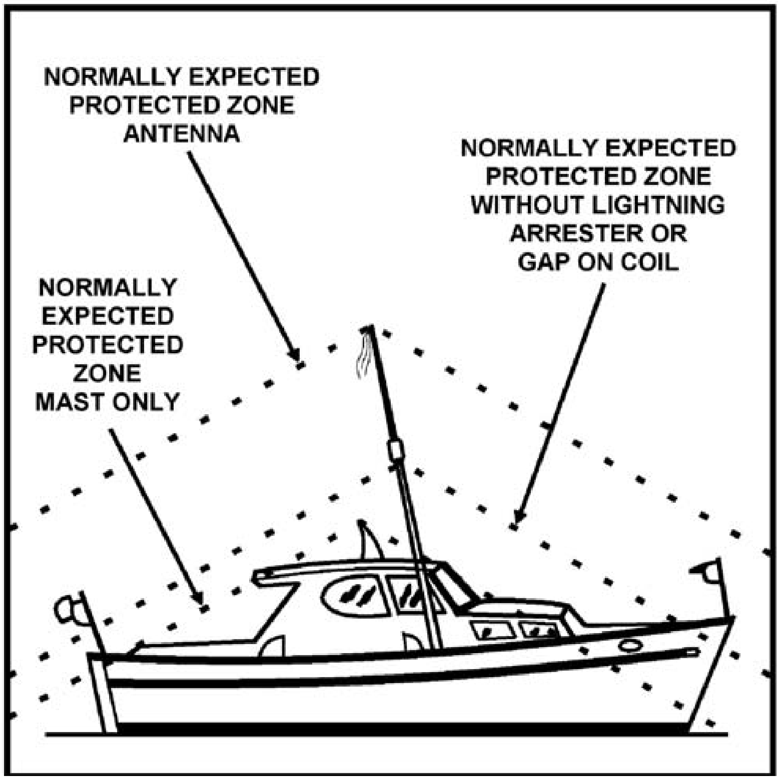


Figure 12-1
Lightning Protected Zone on a Motorboat

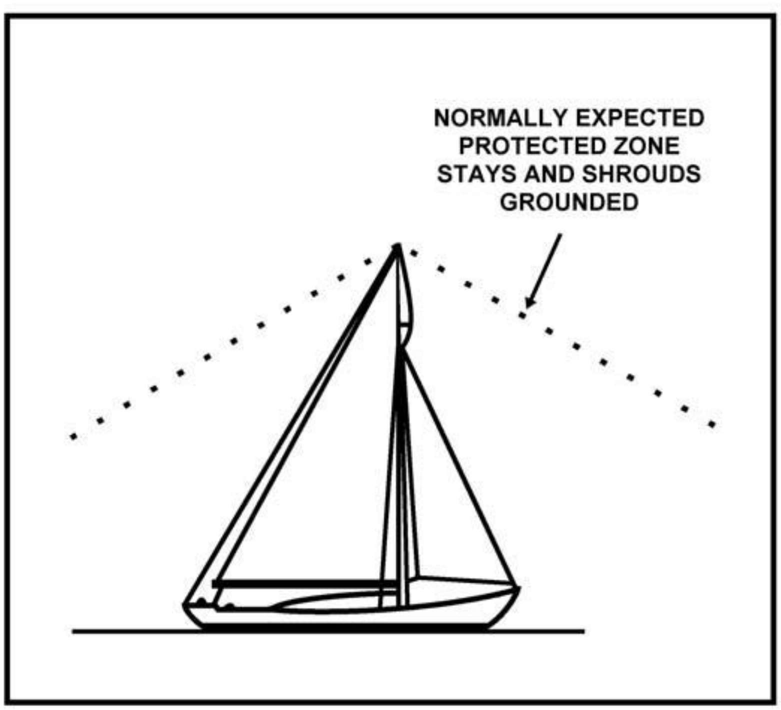
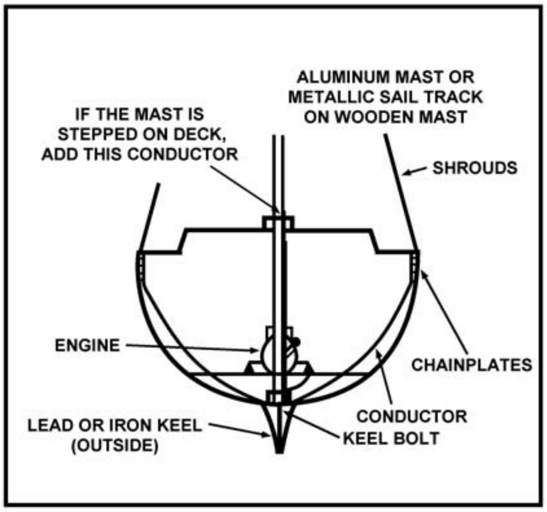


Figure 12-2

Lightning Protected Zone on a Sailboat



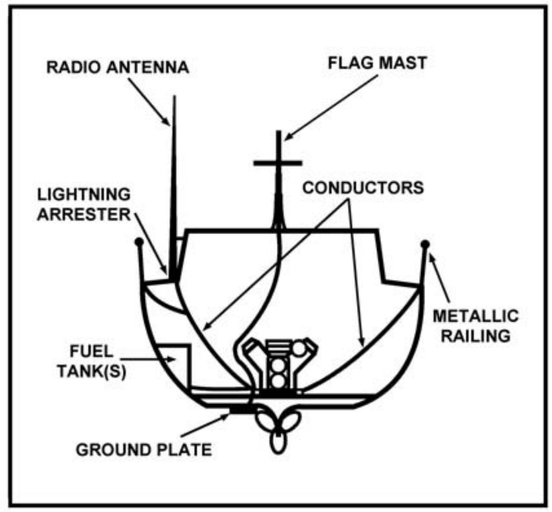


Figure 12-3
Grounding System on a Sailboat and a Motorboat

A.11 Distance From a Thunderstorm

The boat's distance from a thunderstorm can be estimated by knowing it takes about five seconds for the sound of thunder to travel each mile.

- Observe the lightning flash
- Count the number of seconds it takes for the sound of its thunder to arrive.
  Convert to miles by dividing the number of seconds by 5.

NOTE: Counting "One thousand one, one thousand two, one thousand three, one thousand four, one thousand five," will aid in correctly counting seconds.

A.12 Safety

If caught in a lightning strike area, the following procedures apply:

Step	Procedure
1	Head for shore or the nearest shelter
2	While underway, stay inside the boat, keep crewmembers low, and stay dry
3	Avoid touching metal, such as metal shift and throttle levers and metal steering wheels
4	Avoid contact with the radio
5	If lightning strikes, expect the compass to be inaccurate and onboard electronics to suffer extensive damage

Fog

A.13 Description
Fog is a multitude of minute water suspended in the atmosphere, sufficiently dense to scatter light rays and reduce visibility. Fog makes locating anything more difficult and also makes the voyage to and from the scene more hazardous. Fog is a fairly common phenomenon during December and January on Great Salt Lake when a high pressure parks over northern Utah.

A.14. Advection Fog
The most troublesome type of fog to mariners is advection fog. Advection means horizontal movement. This type of fog occurs when warm, moist air moves over colder land or water surfaces. The greater the difference between the air temperature and the underlying surface temperature, the denser the fog. Sunlight hardly affects advection fog. It can occur during either the day or night. An increase in wind speed or change in direction may disperse advection fog: however, a slight increase in wind speed can actually make the fog layer thicker.

A.15. Radiation (Ground) Fog
Radiation fog occurs mainly at night/early morning with the cooling of the earth's surface, which cools faster than the surrounding air. The air near the surface is stagnated by light winds, then cooled to its dew point by the colder surface, producing a shallow layer of fog. It is most common in the middle high latitudes, near the inland lakes and rivers, which add water vapor to the fog. It clears slowly over water because the land heats and cools three times faster from night to day than water. Sunlight burns off radiation fog by warming the air. Surface winds break up the fog by mixing the air.

A.16 Fog Frequency
Fog on the Great Salt Lake is most common from December through January but can occur as early as mid-November and last well into February. Great Salt Lake has experienced 20 to 41 straight days of fog before.

A.16 Operating in Fog
When operating in fog, utilize the following procedures:

Step	Procedure
1	Slow down to allow enough time to maneuver or stop (i.e., operate the boat at a safe speed).
2	Display the proper navigation lights and sound appropriate sound signals
3	Employ all available navigation aids
4	Station a lookout well forward and away from the engine sounds and lights, to listen and look for other signals. Navigation rules require the use of a proper lookout.

NOTE: Remember, fog increases the chance of a collision or grounding.

ICE

A.17 Salinity

Temperature and salinity govern the freezing point of water, however, wind and currents can slow the formation of ice by mixing in warmer water from below the surface. Fresh water freezes at 32°F, but the freezing point of seawater (not Great Salt Lake) decreases to 28°F because of its salinity, which is the concentration of the dissolved solutes (often referred to as salt) in the water. It is not known how cold it must get before Great Salt Lake water will freeze but the lake can regularly get to 24°F and not freeze.

This is not to say Great Salt Lake doesn't have ice on it. In fact Great Salt Lake can have very large ice sheets on her near river inlets. Ice forms on Great Salt Lake when her waters get very cold and when there is a high pressure camped over the lake. This causes winds to become quite calm. Fresh water flowing in from the river inlets will actually flow on top of the GSL water not mixing well with it. This layer then freezes causing large ice sheets and bergs. Once the initial cover of ice has formed on the surface, no more mixing can take place and the ice will thicken. If currents are strong enough ice sheets can break off and float with the current. Ice sheets will begin to break up once a strong enough wind event occurs. Ice sheets near Antelope Island and in Ogden Bay can last for a month or two during the coldest parts of the winter. Ice sheets near the Goggins and in the main body of the lake will break up with the first significant wind event.

A.18 Topside Icing

One of the most serious effects of subfreezing air temperatures is that of topside icing, particularly if the ice continues to accumulate. This icing is caused by freezing spray, which is an accumulation of freezing water droplets on a vessel, caused by some combination of cold seawater, wind or vessel movement. Precipitation may freeze to the vessel as well. Ice will continue to accumulate as long as freezing spray continues to occur, in turn, causing increased weight on decks, superstructures, and masts. Ice also produces complications with the handling and operating of equipment, and creates slippery deck conditions. The ice accumulation causes the boat to become less stable and may lead to capsizing. Luckily this is not a common problem on the Great Salt Lake but it can be a serious factor for smaller craft like duck boats.

NOTE: The easiest and most effective way to minimize icing is to slow down.

Forecasting

A.19. Sources of Weather Information

Listening to either a news media broadcast meteorologist or NOAA Weather Radio, coupled with local knowledge, should make everyone informed weather-wise. Also, many old common weather "hunches" are often correct, but should not be the only source without some basic weather knowledge and a tool (e.g., barometer or thermometer) with which to crosscheck the belief. Using multiple sources to confirm personal hunches is recommended.

NOTE: Be wary of weather forecasts from broadcast networks in Salt Lake City. Most of these forecasts are Wasatch Front based and do not always take into consideration the conditions that may prevail in the Oquirrh Mountains or over the Great Salt Lake. Very often the conditions can be quite different along the Wasatch as opposed to the Great Salt Lake.

A.19.a. Weather Forecast Links
General weather forecasts can be found on the internet. Below are a few:

NOAA Weather Map Graphic: http://www.hpc.ncep.noaa.gov/basicwx/day0-7loop.html

Weather Forecast for Magna (Weather near the GSL Marina:
http://www.weather.com/weather/today/84044

Weather Forecast for Tooele: (weather upstream from the lake):
http://www.weather.com/weather/today/Tooele+UT+84074:4:US

Five Day Forecast and Current Conditions (Salt Lake): http://www.ksl.com/index.php?nid=88

NOAA Zone Forecast: http://www.wrh.noaa.gov/slc/forecast/textproduct.php?pil=ZFP

NOAA Area Forecast Discussion:
http://www.wrh.noaa.gov/total_forecast/getprod.php?prod=XXXAFDSLC&wfo=SLC

A.19.b Wind Forecasting and Observations
Good wind models can also be found on the internet. Some are forecast models while others are real-time wind observations on the lake and upstream (up weather) from the lake.

Sail Flow Forecasted Wind Models: http://www.sailflow.com/en-us/Search/ViewResults.aspx#41.203,-112.604,8,2

Wind Map General Continental US Wind Patterns: http://hint.fm/wind/

Wasatch Front Mesonet Map (real-time wind): http://www.wrh.noaa.gov/slc/current/meso.wfrnt.php

Weather Station at Great Salt Lake: http://www.findu.com/cgi-bin/wxpage.cgi?call=KF6RAL-6

A.19.c. Radar and Satellite Imagery
Radar and Satellite images are also key forecasting tools. They allow you to track approaching fronts or thunderstorms as well as predict what monsoonal weather is likely to do in the afternoon heating of the day.

Doppler Radar for Northern Utah:
http://radar.weather.gov/radar.php?rid=MTX&product=N0R&overlay=11101111&loop=no

NWS Doppler Radar for Northern Utah:
http://radar.weather.gov/radar_lite.php?product=NCR&rid=MTX&loop=yes

NWS Satellite Imagery for Northern Utah: http://www.wrh.noaa.gov/satellite/?wfo=slc

A.20. Weather Indicators
Even experts are far from 100% correct. However, the following generalized table, **Table 12-3**, can assist in forecasting weather changes:

Table 12-3
Generalized Weather Indicators

Condition	Deteriorating Weather	Impending Precipitation	Clearing Weather	Continuing Fair Weather	Impending Strong Winds
Clouds					
Clouds lowering and thickening	X				
Puffy clouds beginning to develop vertically and darkening	X				
Sky is dark and threatening to the west					X
Clouds increasing in numbers, moving rapidly across sky	X				X
Clouds moving in different directions at different heights	X				X
Clouds moving from east or northeast towards the south	X				
Transparent veil-like cirrus clouds thickening; ceiling lowering		X			
Increasing south winds with clouds moving from		X			

the west					
Cloud bases rising			X		
Rain stopping, clouds breaking away at sunset			X		
Clouds dotting afternoon summer sky				X	
Clouds not increasing or instead decreasing				X	
Altitude of cloud base near mountains increasing				X	
Sky					
Western sky dark and threatening	X				
A red sky in the morning	X				
Red western sky at dawn		X			
Gray early morning sky showing signs of clearing			X		
Red eastern sky with clear western sky at sunset				X	
Clear blue morning sky to west				X	
Precipitation					
Heavy rains occurring at night	X				
Rain stopping, clouds breaking away at sunset			X		

Temperatures far above or below normal for time of year	X				
A cold front passing in the past four to seven hours (in which case the weather has probably already cleared)			X		
Fog, Dew, and Frost					
Morning fog or dew			X		
Early morning fog that clears				X	
Heavy dew or frost				X	
No dew after a hot day		X			
Wind					
Wind shifting north to east and possibly east to south	X				
Increasing south wind with clouds moving from the west		X			
Strong wind in the morning	X				
Gentle wind from west or northwest				X	
Bright moon and light breeze				X	
Winds (especially north winds) shifting to west		X			

and then south					
Barometer					
Barometer falling steadily or rapidly	X				
Steadily falling barometer		X			
Barometer rising			X		
Barometer steady or rising slightly				X	
Visual Phenomena					
A ring (halo) around the moon	X				
Distant objects seeming to stand above the horizon		X			
If on land, leaves that grow according to prevailing winds turnover and show their backs					X
Halo around the sun or moon		X			
Smoke from building stacks rising			X		
Smoke from building stacks lowering	X				X
Bright moon and light breeze				X	
Audible Phenomena					
Very clear sounds that can be heard for great		X			

distances					
Dull hearing, short-range of sound				X	
Static on AM radio	X				

Section B. Oceanography

Introduction
Oceanography is a broad field encompassing the study of waves, currents, and tides. It includes the biology and chemistry of the oceans and the geological formations that affect the water. Boat crewmembers must have an appreciation of all these factors to safely operate in an ever-changing environment. Some major distinct conditions occur in the Great Salt Lake due to its hyper-salinity, large size, and shallowness.

In This Section
This section contains the following information:

Waves

B.1. Description
By understanding how waves form and behave, boat crewmembers know what to expect and how to minimize danger to both boat and crew.

B.2. Definitions
The following definitions will help in understanding waves:

Term	Definition
Breaker	A breaking wave
Breaker Line	The outer limit of the surf. All breakers may not present themselves in a line. Breakers can occur outside the breaker line and seem to come from nowhere
Comber	A wave on the point of breaking. A comber has a thin line of white water upon its crest, called feathering
Crest	The top of a wave, breaker, or swell
Fetch	The distance over water in which seas are generated by an unobstructed wind of a constant direction and speed
Foam Crest	Top of the foaming water that speeds towards the beach after the wave has broken, properly known as white water

Frequency	The time interval between successive wave crests passing a fixed point
Interference	Waves refracted or reflected can interact with other waves. This action may increase or decrease wave height, often resulting in unnaturally high waves. Interference may result in standing-wave patterns (waves that constantly appear to peak in the same spot). Interference can be of particular concern because it may result in a boat being subjected to waves from unexpected directions and of unexpected size.
Period	The time, in seconds, it takes for two successive crests to pass a fixed point
Seas	The combination of waves and swells, generally referred to as seas
Series	A group of waves that seem to travel together, at the same speed
Surf	Several breakers in a continuous line
Surf Zone	The area near shore in which breaking occurs continuously in various intensities
Swell	Swells are waves that have moved out of the area in which they were created. The crests have become lower, more rounded and have a longer period than waves. On the ocean, they can travel for thousands of miles across deep-water without much loss of energy.
Trough	The valley between waves
Wave Height	The height from the bottom of a wave's trough to the top of its crest; measured in the vertical, not diagonal. Waves on Great Salt Lake can reach 8 to 10 feet in vertical height. During high water years waves can reach heights of 18 feet.
Wave Length	The distance from one wave crest to the next in the same wave group or series
Wave Reflection	Any obstacle can reflect part of a wave. This includes underwater barriers (e.g., submerged reefs or bars), although the main waves may seem to pass over them without change. These reflected waves move back towards the incoming waves. When the obstacles are vertical or nearly so, the waves may be reflected in their entirety.
Wave Refraction	Refraction means bending. Wave refraction occurs when the wave moves into shoaling water, interacts with the bottom and slows. The first part of the wave slows, causing the crest of the wave to bend towards shallower water. As a result, the waves tend to become parallel to the underwater contours. The key to the amount of refraction that occurs is the bottom terrain. This can also occur when a wave passes around a point of land, break wall, or an island. While different segments of the wave travel in different depths of water, the crests bend and the waves change direction constantly. This is why wave fronts become parallel to the underwater contours and the shoreline, and why an observer on the beach sees larger waves coming in directly toward the beach, while offshore they approach at an angle. Waves refracted off shoals can produce dangerous seas. As the waves pass on each side of the shoal, they refract from their original line of travel toward each other. The angle from where they meet behind the shoal produces a pyramid-type sea where the wave crests meet. (see **Figure 12-4**)
Waves	Local waves generated from the action of the wind on the water's surface (and sometimes earthquakes). Waves usually have a shorter period than swells.

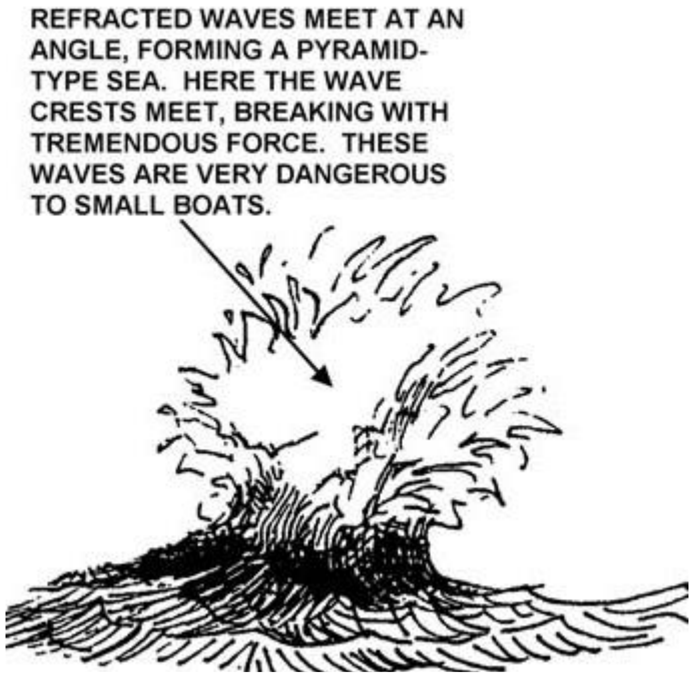


Figure 12-4
Wave Refraction

B.3. Wave Types
The wind generates waves by moving over the water's surface. As wind speed increases, white caps appear. As the wind continues from a constant direction and speed over a given area (fetch), the waves become higher and longer. The Beaufort Wind Scale (**Table 12-1**) shows the size of waves in open water for a given wind strength. Remember that the Beaufort Wind Scale does not precisely match up to Great Salt Lake conditions due to the hyper-salinity of the water. There are two major types of waves:

- More choppy waves found in shallow water (e.g., in bays and inland lakes).
- Broad, rounded waves associated with deep-water. (see **Figure 12-5**)

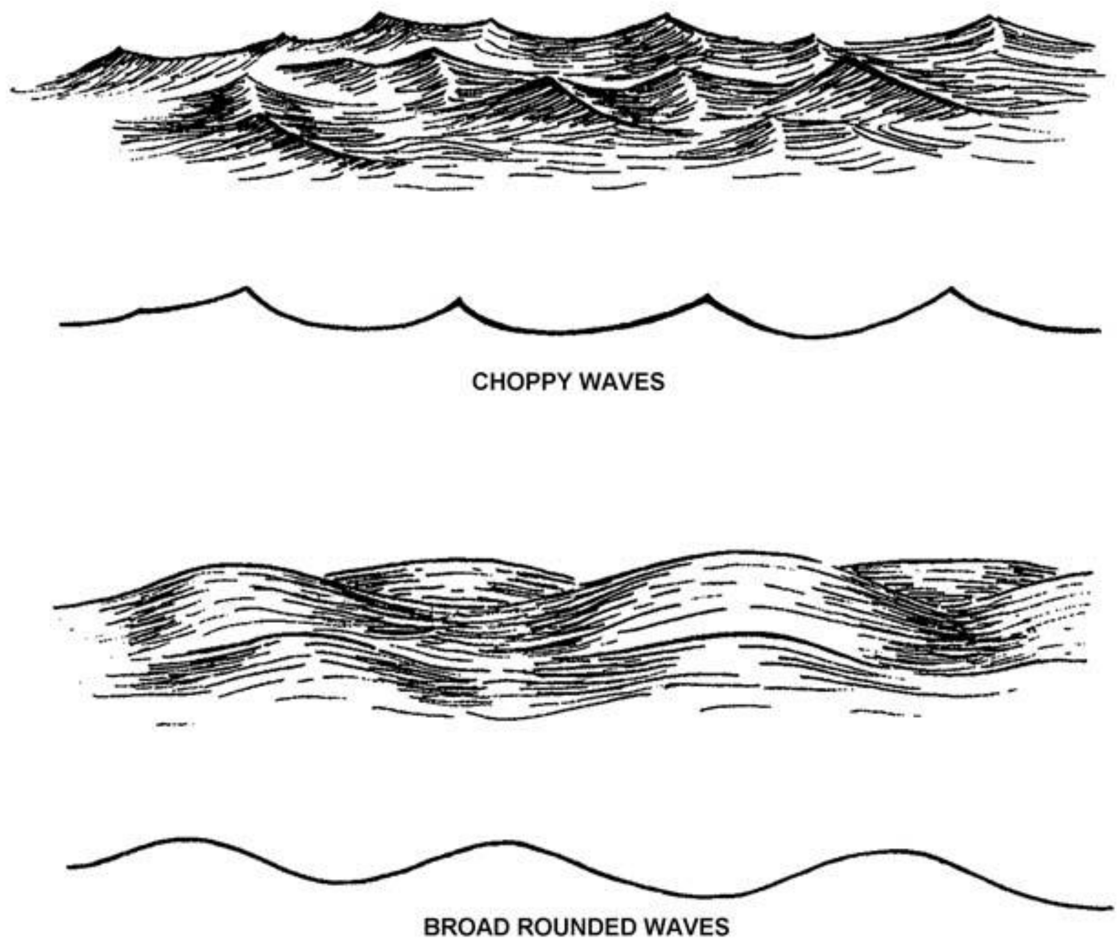


Figure 12-5
Two Major Types of Waves

WARNING: An eight foot breaking wave can drop as much as thirty tons of water on a boat and can swamp and/or severely damage it.

B.4. Breaking Waves

Breaking waves are the most dangerous kind of wave for boat operations. How dangerous the wave is depends on the ratio of wave height to length, and on wave frequency. Steep sloped waves are the most dangerous. There are three main types of breaking waves:

- Plunging waves.
- Spilling breakers.
- Surging breakers.

More information on operating in heavy weather and surf is listed in *Chapter 20, Heavy Weather Addendum*

B.4.a. Plunging Waves
Plunging waves result when there is a sudden lack of water ahead of the wave, such as in a steep rise of the lake floor. This situation prevents the wave from traveling along, and causes the crest to be hurled ahead of the front of the wave and break with tremendous force. (see **Figure 12-6**) These will be common where a wave hits an abruptly rising lake bed near reefs or by Eardley or Miera Spit.

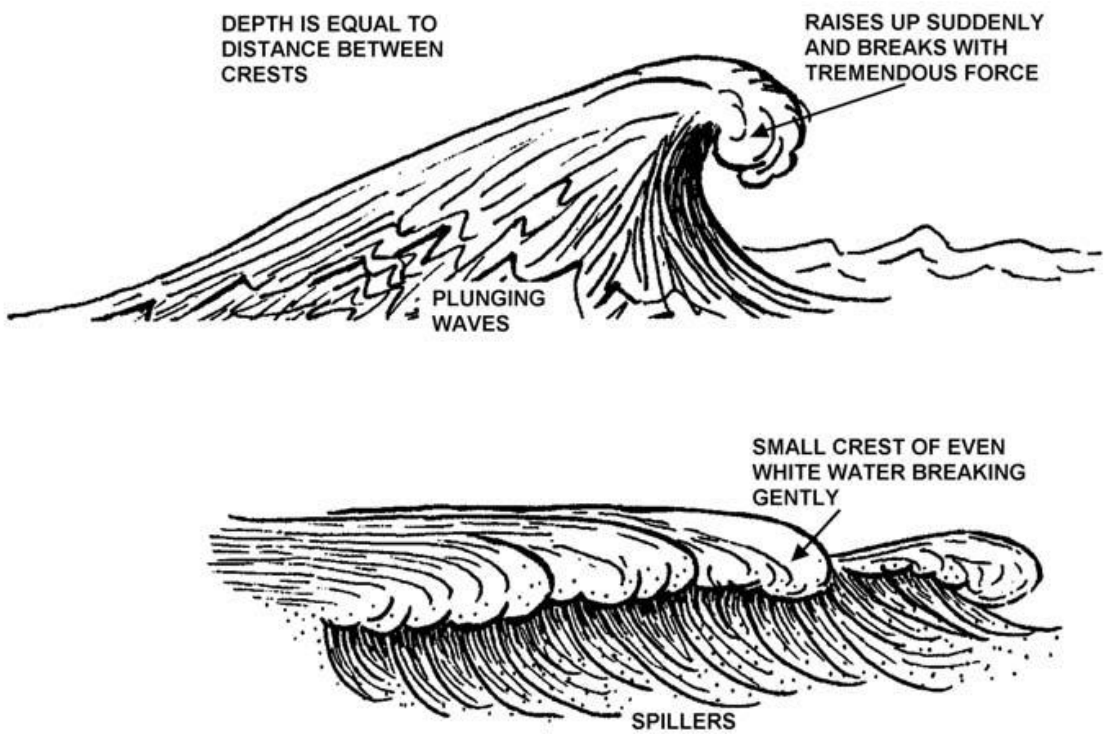


Figure 12-6
Plunging and Spilling Waves

B.4.b. Spilling Breakers
Spilling breakers result from waves of low steepness moving over a gentle sloping lake floor. They normally have a small crest of white water spreading evenly down the wave, and break slowly without violence. (see **Figure 12-6**) These waves are common along the very shallow beaches on the lake where the beach drops off very slowly. They will also be common inside reef areas of the lake.

B.4.c. Surging Breakers
A surging breaker occurs on very steep beaches. The wave builds very quickly and expends its energy on the beach. It is very unlikely that a surging breaker will be encountered by a boat unless beaching it on a very steep beach. And there aren't a lot of very steep beaches on the lake outside of Eardley Spit.

B.5. Deep-water Wave
A deep-water wave is a wind wave where the depth of the water is greater than one-half the wavelength.

B.6. Shallow Water Wave
A shallow water wave travels in water where the depth is less than one-half the wavelength. If the depth of water is small in comparison to the wavelength, the bottom will change the character of the wave.

NOTE: As the waves travel out from their origin, they become swells developing into a series of waves equidistant apart which track more or less at a constant speed. Consequently, it is possible to time series of breakers.

B.7. Wave Series
Wave series are irregular because of constant shifting of wind direction and speed. Storms over the lake create masses of waves that build up in groups higher than other waves. Breakers vary in size and there are no regular pattern or sequence to their height. But while the space or interval between series of breakers may vary, it is fairly regular. Despite the interval, breakers tend to stay the same for hours at a time.

The height and period of a wave depends on:

- The speed of the wind.
- The amount of time the wind has been blowing.
- The distance over water which the wind travels unobstructed, known as fetch. Nearness to land will limit fetch, if the wind is blowing offshore.

The lifecycle of a wave consists of its:

- Generation by wind.
- Gradual growth to maximum size.
- Distance traveled across the lake
- Dissipation as wind decreases or when the wave impacts against the sore or an object.

NOTE: Currents going against the waves can make the waves steeper.

B.8. Surf
Irregular waves of deepwater become organized by the effects of the contact with the bottom. They move in the same direction at similar speeds. As the depth of water decreases to very shallow, the waves break and the crests tumble forward. They fall into the trough ahead usually as a mass of foaming white water. This forward momentum carries the broken water forward until the wave's last remaining energy becomes a wash rushing up the beach. The zone where the wave gives up this energy and the systematic water motions is the surf. (see **Figure 12-7**)

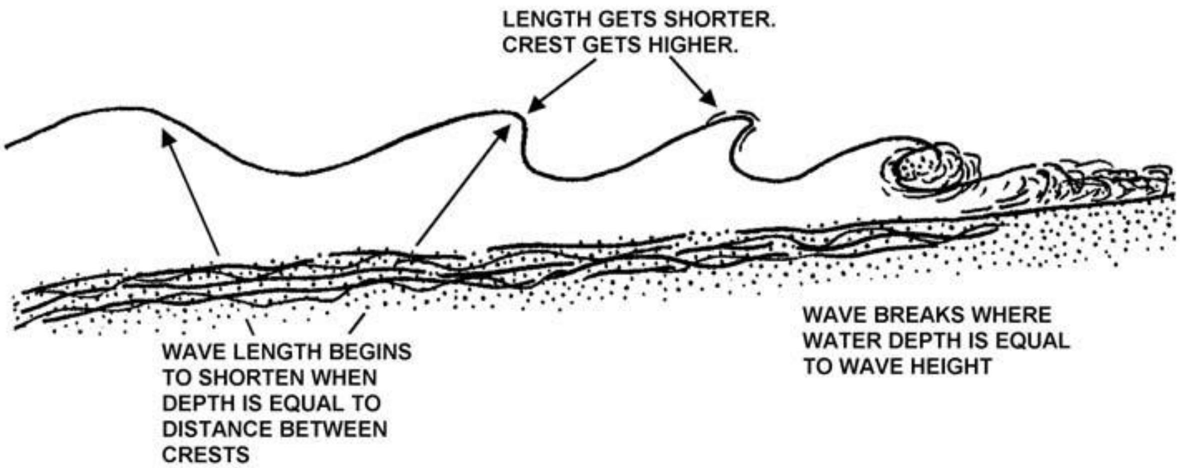


Figure 12-7
Surf

WARNING: Stay out of wave's curl.

Sometimes there are two breaks of surf between the beach and the outer surf line. These breaks result from an outer sand bar or reef working against the wave causing the seas to pile up. The movement of water over such outer bars forms the inner surf belt as the water rolls toward the shore. The surf that forms around an inlet depends on the size of approaching swells and the bottom contours. The waves' speed and shape change as they approach shallow coastal waters. They become closer together (as their speed slows) and steeper as they contact the bottom. This change typically happens at a point where the water is approximately one half as deep as the wave's length.
As a wave steepens, its momentum will cause it to fall forward or curl. It is this momentum that gives a curl of breakers its tremendous force.

NOTE: Operators can size up the surf situations by comparing the swell height and length with the water depth.

Currents

B.9. Description
Great Salt Lake has two types of currents depending on what causes them:

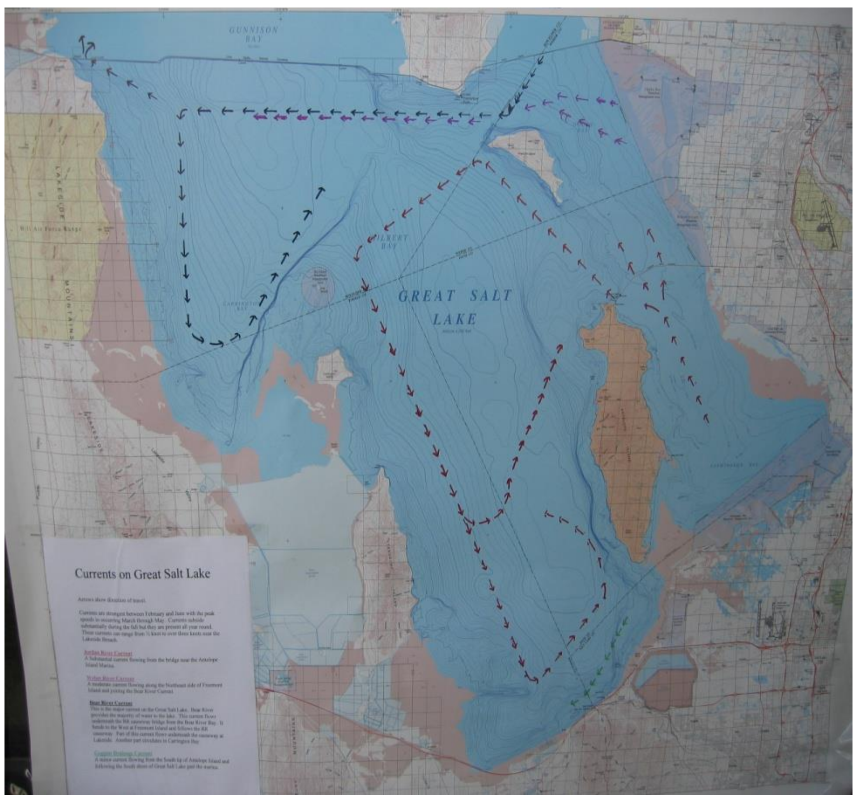
- River currents caused by the rivers pouring into the lake
- Surge currents caused by storm surge
- Longshore Currents

NOTE: Current direction is the compass heading toward which the water moves.

B.10. River Currents

Great Salt Lake has several rivers or tributaries that flow into it. These cause currents on the lake's surface. Some of these currents can be quite strong in the spring and early summer with the snowpack runoff. The currents are strongest in the spring reaching speeds of up to 3 knots in some areas of the lake and are slack in the late summer or early fall with strengths of only a quarter knot. The three main currents of Great Salt Lake are:

- Jordan current.
- Bear Current
- Goggins Current



B.10.a. Jordan Current

The Jordan River flows into the southern end of Farmington bay and moves along the east shore of Antelope Island before exiting into the main body of the lake through the Davis Causeway bridge near the Antelope Island Marina. The current then meanders up along Fremont Island before bending down to the southwest towards Hat Island. It then flows south along Hat, Carrington and then Stansbury Island before being bent back to the northeast by Eardley Spit. The current flows back towards Antelope. This zone between Eardley Spit and Antelope is known as Tumbleweed Alley or the Confluence because of all the tumbleweeds that blow in from Tooele Valley and get caught in this current.

B.10.b. Bear Current
The Bear Current is fed primarily by the Bear River flowing first into Bear River Bay and then exiting out into Ogden Bay where it is joined and pushed to the west by the Weber River flowing into the Great Salt Lake on the east side of Ogden Bay. This current then flows east between Promontory Point and Fremont Island (Fremont Strait) and flows west along the railroad causeway where it is split with one part of the current going north through the causeway breach and the other part flowing south along the Lakeside Mountains before bending counter-clockwise to flow northeast along the ridge of Carrington and Hat Island.

B.10.c. Goggins Current
The Goggins Current is the simplest of the currents. It forms south of Antelope Island from the Goggins, North Canal and Lee Creek flowing in along the southeast shore of the lake. It then flows generally west to southwest towards the Great Salt Lake Marina before simply dying out.

B.11. Longshore Currents
Longshore currents run parallel to the shore and inside the breakers. They are the result of the water transported to the beach by the waves.

Caution: Watch for and avoid eddies. They can abruptly change speed and steering control of boats.

B.12. Storm Surge Currents
Storm Surge Currents are currents caused by the movement of water by wind. On the main body of the lake they will not be as noticeable as in narrow channels such as Fremont Strait or when approaching marina entries. Watch the video of a storm surge current at the mouth of the Great Salt Lake by going to the following link: http://gslmarina.ning.com/video/storm-surge-entering-gsl-1

B.13 Wind Effects on Current
Wind affects the speed of currents. Sustained wind in the same direction as the current increases the speed of the current by a small amount. Wind in the opposite direction slows it down and may create a chop.

B.14 Effects on Boat Speed
When going with the current, a boat's speed over ground is faster than the speed/RPM indication. When going against the current, a boat's speed over ground is slower than the speed/RPM indication.

B.15. Effects on Boat Maneuverability
When working in current, the boats maneuverability depends on its speed through the water. Although a boat has significant speed in relation to fixed objects (e.g., a pier) when going with the current, a boat lacks maneuverability unless there is sufficient water to flow past the rudder. When going into the current, maneuverability is usually improved as long as enough headway is maintained. However, at slow speeds, even a small change in course can have the bow swing greatly as the water flow pushes on one side of the bow.

B.16. Crossing the Current
When crossing the current to compensate for the set, a boat may be put into a crab (i.e., the boat may be forced off course by the current or wind). Because of this maneuver, the boat heading and the actual course made good will be different. When the boat is crabbing, the heading will not be the intended

course of the boat. Therefore, navigate the current or wind by sighting on a fixed object (such as a range) or by marking the bearing drift on an object in line with the destination. Piloting in currents is covered in more detail in Chapter 14, Navigation**.**