The technical approach to seabed mapping will focus on the use of swath or multibeam bathymetry systems, accompanied by appropriate ground-truthing. While the technologies are currently available to proceed with such an initiative, the commitment of sufficient resources by the federal government is required in order to proceed (Richard Pickrill, pers. comm.).

4.2 Climate

The north coast of British Columbia has a temperate climate regulated by the prevailing onshore flow of marine air. On a large scale, regional climate and weather patterns are dominated by two atmospheric pressure systems: the North Pacific High and the Aleutian Low. The North Pacific High dominates in summer months, producing north to northwesterly winds along the outer coast. In winter months, the Aleutian Low becomes dominant, producing winds from the south to southeastern sectors. These prevailing wind patterns are modulated by coastal topography and are interrupted for days or weeks by eastward-migrating high and low pressure systems, which can produce intense storms (Thomson 1981).

Climatic conditions impact both operation and safety of offshore drilling activities. A discussion of climate can be separated into two parts: conditions during normal, or average, periods and those during extreme events. In general, extreme events govern the design parameters which impact the safety of offshore operations, while normal conditions are more important for operational considerations, structural fatigue issues and in assessing and controlling environmental impacts associated with offshore hydrocarbon exploration and development activities. Normal meteorological conditions will be addressed in this section, with storm events described in Section 4.4.

The day-to-day meteorological factors affecting offshore drilling operations include winds, temperature, visibility and ceiling, wind chill and freezing spray (Petro-Canada 1983). An extensive system of land-based climatological stations is operated by the Atmospheric Environment Service (AES) of Environment Canada throughout the coastal areas of British Columbia. Parameters reported from these stations include radiation, humidity, pressure, visibility and cloud cover, temperature, precipitation and wind. Over 30 years of measurements are available for many coastal stations in British Columbia (AGRA 1998).

Petro-Canada (1983) performed extensive analyses of the historic records from land-based climatological stations surrounding Dixon Entrance and Hecate Strait. Based on the existing database at that time, Petro-Canada concluded:

> "Temperature extremes, wind chill and freezing spray are unlikely to pose serious problems to drilling operations off the Queen Charlotte Islands. Occasionally visibility and ceiling height would be low enough to restrict aircraft operations. Visibility is poorest in the summer and fall when advection fog occurs, and low ceilings are common in winter. The simultaneous occurrence of low visibility and low ceiling is rare."

Although many of the land-based climatological stations examined by Petro-Canada have since been decommissioned (Gary Myers, pers. comm.), the remaining stations, such as Sandspit, Langara and Cape St. James, will now have almost 20 years of additional measurements. Up-to-date information on available climate data can be obtained through the Climate Station Database maintained by AES (http://www.msc-smc.ec.gc.ca/climate/station_catalogue/index_e.cfm).

While it would certainly be worthwhile to update the analyses of historic climate data to include the more recent measurements, it is not expected that the above conclusions would change in any significant manner. The impacts of climate change are discussed in Section 4.5 of this report.

4.2.1 El Niño and La Niña

El Niño is a disturbance in the natural cycle of the ocean and atmosphere in which a warming occurs in the tropical sea surface waters of the eastern and central Pacific Ocean. This warming adds considerable amounts of heat and moisture to the earth's atmospheric circulation at the tropics resulting in large-scale changes to the earth's atmospheric circulation particularly at the tropics and to a lesser extent elsewhere around the globe. This occurs every two to seven years. La Niña is the cooler phase counterpart to the ENSO and weather conditions are in general opposite to those occurring during El Niño.

Impacts on British Columbia from El Niño include milder air temperatures, warmer coastal waters, rises in sea level, and a reduction in snowfall. The effects on total precipitation (rain and snow) vary considerably across British Columbia. While short-term changes in weather patterns are associated with the ENSO, it is not expected that this phenomenon would have a significant impact on the design and safety of offshore facilities.

4.3 Water Level and Ocean Currents

Variations in water levels are caused by several factors--of these, tides are by far the most significant in the northern coastal waters. Tides within the area of interest are mixed, predominantly semi-diurnal, meaning that there are two complete tidal exchanges per day. However, the mixed nature of the tides leads to significant inequalities in both the magnitude and the duration of successive exchanges.

In coastal waters, tides interact with bathymetry in a number of ways, leading to significant spatial variations in tidal range and timing of high and low water stands. In the waters surrounding the Queen Charlotte Islands, the mean tidal range varies from 3.0 m at the entrance to Queen Charlotte Sound to 4.8 m midway along Hecate Strait, and from about 3.5 m at the mouth of Dixon Entrance to 5.0 m at Prince Rupert. On a large tide, ranges can exceed 7 m at several coastal locations (Thomson 1981).

In addition to tides, significant variations in water level can result from factors such as storm surge; large scale, periodic, climatic cycles such as El Niño/La Niña; and the local effects of river runoff. Variations in water level are continuously measured at several permanent stations around the north coast (reference ports); shorter records have been obtained from the many secondary ports on both the Queen Charlotte Islands and the mainland coast. In general, knowledge of water level variations in the region is good (Bill Crawford, pers. comm.). Details on the locations of the primary and secondary ports can be obtained from the Canadian Hydrographic Service.

Tidal variations in water level are the primary driving force for ocean currents throughout the coastal waters of British Columbia. However, winds and freshwater inputs are also important contributors to the ocean current regime. As for the general climate in the region (Section 4.2), the ocean climatology can be roughly divided into summer and winter seasons based on the predominant wind direction. All three driving forces (tides, winds and freshwater inflows) interact with the local bathymetry to form complex circulation patterns throughout the region.

Knowledge of ocean currents is required for both engineering and environmental aspects of offshore exploration and development. The magnitude of currents impacting either fixed or floating structures plays a role in assessing structural loads, anchoring requirements, and expected scour depths. Current strength may also impact the timing of sensitive operations such as reconnecting to a wellhead. From an environmental perspective, the ocean currents in the area of an oil spill are perhaps the single most important factor determining the ultimate fate of spilled oil in the environment.

While it is a common requirement that exploratory drilling be preceded by site-specific current measurements by the operator, a broader-based knowledge of current conditions is still required in order to place the site-specific measurements into the context of regional and longer-term processes. The WCOEEAP (1986) recommended that:

> "...the Department of Fisheries and Oceans develop and implement a program to improve general knowledge of current movements in the region, and, in particular, in the area of a drilling location when one is proposed."

As a result of this recommendation, Fisheries and Oceans Canada implemented a major ocean research program in northern waters. Between 1989 and 1995, DFO undertook an extensive measurement program, including moored current meters, tide gauges, ocean drifters and measurements of water properties. This work has been funded by the Panel for Energy Research and Development (PERD) and DFO, with the primary goal of establishing a basic understanding of surface flows in the event of an oil spill. The focus of the field work was on summer conditions, based on the Panel's recommendation to limit drilling activities to summer months. A summary of the research program and the associated publications can be viewed at http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/qci/qci.htm.

Figure 4.3 shows the locations of current meter moorings in northern waters for the period from 1982 through 1995. Records varied in length between two and eight months.

In addition to the field measurement program, a series of numerical models have been applied to these waters (Hannah *et al*. 1991; Foreman *et al*. 1993; Ballantyne *et al*. 1996; Cummins and Oey 1997). These models vary in the numerical approach, grid formulation and resolution, and in the specific processes included in each model.

In summary, the existing database provides a reasonable picture of surface flows during summer months based on the ocean drifter data, and a good picture of regional, sub-surface flows from the moored current meters. Information on surface flows in winter months is limited, and measurements on the west coast of the Queen Charlotte Islands are insufficient to characterize flow patterns in that region. Long-term measurements, including the significant effects of the ENSO, are also not available at this time (Bill Crawford, pers. comm.).

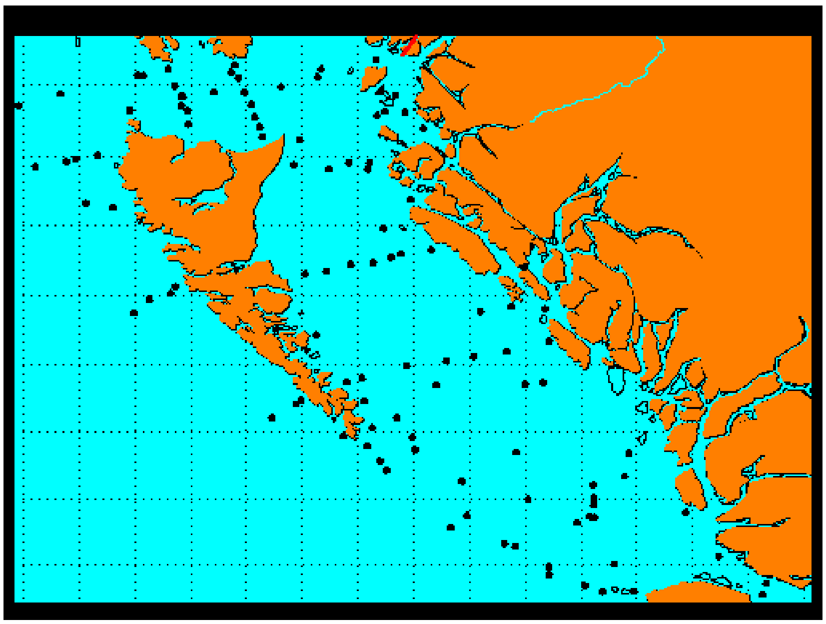

Figure 4.3 Current meter mooring sites for the period 1982 through 1995 (courtesy of W. Crawford, Fisheries and Oceans Canada).

With respect to understanding the regional processes, the various numerical models give a reasonable picture of tidal currents in northern waters, with the exception of Dixon Entrance, where internal tidal currents are significantly under-predicted (Crawford *et al*. 1998). Finer-resolution models may improve this predictive ability. Predictions of maximum tidal current speeds from an updated version of the Foreman et al. (1993) model are shown in Figure 4.4.

Since 1995, work has continued on defining the regional circulation patterns, and has focused on features such as the region around Cape St. James. The flow in this region is dynamic and complex, with current speeds reaching 2.5 ms^{-1}. Flow close to the cape is so turbulent that surface waters cool as they pass by, through the effects of mixing with deeper water (Crawford *et al*. 1995). A persistent plume of cold water is evident well to the west of Cape St. James on satellite images (e.g.