4.0 Physical Environment

A detailed report (Oceans Limited 2005) describing climate, wind and physical oceanography of the Project Area and surrounding vicinity is provided in Appendix 1. This section provides summaries of the major components of the physical environment of the Project Area and part of the Study Area. Detailed descriptions of this general area have been included in several recent documents including the White Rose Oilfield Comprehensive Study and supplement (Husky 2000, 2001a), Husky exploration drilling EAs and update for Jeanne d'Arc Basin (LGL 2002, 2005a, 2006a), Orphan Basin exploration drilling EA and addendum (LGL 2005b, 2006b), Husky 3-D seismic EA and update (LGL 2005c; Moulton et al. 2006a), and Orphan Basin 3-D Seismic EA (Buchanan et al. 2004).

4.1 Geochemical

4.1.1 Geology

A geological overview of the Grand Banks and the White Rose site, including the physiography and surficial sediments, is contained in the White Rose Comprehensive Study and supplement (Husky 2000, 2001a).

4.1.2 Chemical Environment

4.1.2.1 Water Chemistry

Chemical characteristics of water on the Grand Banks were described in the White Rose Comprehensive Study and supplement (Husky 2000, 2001a). Aspects of water chemistry discussed in that document included dissolved oxygen, suspended particulate matter, inorganic nutrients, trace metals and hydrocarbons. A full suite of water characterization was completed in the Whiterose EEM baseline in 2000. The seawater parameters considered relevant by Husky to the design considerations for the seawater injection system were discussed in a recent report on seawater quality (JWEL 2001). These parameters are listed below.

- pH
- Salinity
- Specific gravity
- Density
- Total suspended solids (TSS)
- Total dissolved solids
- Dissolved oxygen concentration (DO)
- Dissolved carbon dioxide concentration
- Sulphides
- Temperature at surface and seabed

- Ion concentrations
- sodium (Na)
- potassium (K)
- calcium (Ca)
- magnesium (Mg)
- chloride (Cl)
- bicarbonate (HCO_3)
- sulphate (SO_4)
- carbonate (CO_3)
- Phytoplankton and zooplankton
- equivalent spherical diameter
- concentration
- vertical distribution of planktonic organisms in the water column
- distribution of Chlorophyll A and Nitrate-N by depth
- fish eggs

For each of these parameters, historical data from the offshore region of NAFO Division 3L were extracted from the Marine Chemistry Data Archives by the Department of Fisheries and Oceans (DFO) and compared to data collected during baseline characterization surveys for Terra Nova and White Rose in 1997 and 2000, respectively. The ranges of values for the White Rose and Terra Nova baseline data generally fell within the ranges of values extracted from the archives for the offshore region of 3L.

4.1.2.2 Sediment Chemistry

Chemical characteristics of sediments on the Grand Banks were described in the White Rose Comprehensive Study and supplement (Husky 2000, 2001a). The sediment chemistry was discussed in terms of particle size, trace metals, and hydrocarbons. In general, the Grand Banks sediments are relatively pristine, particularly compared to some inshore areas.

A full baseline EEM characterization study was conducted on the Whiterose field in 2000. The Husky EEM program was implemented in 2004 and there are sediment chemistry data from the 2004 and 2005 sampling in Significant Development Area White Rose (Husky 2005, 2006). Hydrocarbons >C10-C21 and >C21-C32 were detected in sediments collected in 2004 but not during baseline work in 2000. Maximum concentrations were detected about 300 m from the northern and southern development wells. Barium concentrations were also higher in the 2004 sediment samples, compared to baseline detection, particularly near the southern drill centre. Maximum barium concentrations occurred about two kilometers from the southern drill centre. Similar results were found during the 2005 sampling of the Husky EEM program (Husky 2006). According to the Husky EEM report (Husky 2005), sediment concentration patterns of >C10-C21 hydrocarbons and barium were excellent indicators of drilling activity for the White Rose development. Increased levels of fines and sulphur were limited to within one kilometer from source. During the EEM field program in 2005, samples were taken in the area around the expected West WR Ext to complement those taken in the Northern and Southern WR Ext previously. These samples support both EEM and Ocean Dumping permitting functions.

4.2 Climate

The report (Oceans Limited 2005) in Appendix 1 provides detailed text, figures and tables related to climate in the Project Area and much of the Study Area.

4.2.1 Overview

Typical of middle latitude regions of the planet, the weather over the northwestern portion of the North Atlantic Ocean is characterized by frequent interchange of low and high pressure systems much of the year. These circulation systems are embedded in, and steered by, the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes, which arises because of the normal tropical to polar temperature gradient.

With cooling of the atmosphere during fall and winter, there is an increase in the south to north temperature gradient, an attendant strengthening of the westerly winds aloft and an increase in the potential for storm development.

4.2.2 Seasonal Differences

The prevailing upper level pattern during the winter season causes low pressure systems to move through the Newfoundland region on a northeastward track, their course and intensity being dependent on the details of the upper level flow and the available potential energy. During some winters, northwesterly winds that prevail over the northwestern North Atlantic are stronger than normal. Such winters tend to be colder than normal, leading to greater ice growth along the Labrador coast and to a more extensive incursion of sea ice over Newfoundland waters.

With increasing solar radiation during the spring of the year, there is a general warming of the atmosphere that is relatively greater at higher latitudes. This decreases the north-south temperature contrast, lowers the kinetic energy of the westerly flow aloft and decreases the potential energy available for storm development. The main track of the weaker low pressure systems typically lies through the Labrador region and tends to be oriented from the west-southwest to the east-northeast. With low pressure systems normally passing to the north of the region in combination with the northwest shoulder of the sub-tropical high to the south, the prevailing flow across the Grand Banks is from the southwest during the summer season. Wind speed is lower during the summer and the incidence of gale or storm force winds relatively infrequent. There is a corresponding decrease in significant wave heights.

The prevailing southwesterly flow during the late spring and early summer tends to be moist and it is relatively warmer than the underlying surface waters on the Grand Banks. Cooling from below coupled with mixing of the air in the near-surface layer frequently results in saturation of the air, the condensation of water vapour and the development of advection fog, which may persist for days at a time. The incidence of advection fog and the frequency of poor visibility are normally highest during July.

On occasion, when an upper level high pressure circulation centre forms and persists over the southern portion of the United States as a westward extension of the sub-tropical high, an upper level trough tends to become established over the east coast region of Canada. While this upper pattern prevails, low pressure systems will tend to develop further south and track through the Newfoundland and Grand Banks regions.

The hurricane season in the North Atlantic Basin extends from June through November. While the incidence of tropical depressions, storms, hurricanes or the remnants of such systems is infrequent, the risk of occurrence is greatest between August and October. The frequency of occurrence of tropical systems, or their remnants, affecting the region in any particular year is low and varies from none to a few. In accordance with the upper level circulation during the period, these systems normally approach the region from the south to southwest.

Tropical storms and hurricanes obtain their energy from latent heat of vapourization that is released during the condensation process. Since the capacity of the air to hold water vapour is dependent on temperature, the trajectory of the systems over the cooler waters of the northwest Atlantic normally reduces the available water vapour supply and leads to a weakening of the systems. The rate of weakening, however, may be slow. As tropical systems weaken, they frequently evolve into conventional but rather substantial extra-tropical storm systems. Conditions on the Grand Banks associated with tropical cyclones and their remnants vary widely from relatively minor events to major storms.

4.2.3 Marine Climate Data Sources

Marine weather observations recorded on board vessels and drilling platforms on the Grand Banks are the primary data source upon which the climate statistics for the Project Area have been developed. Shipboard observations are taken on a volunteer basis under a program of international cooperation that began in the mid-nineteenth century. When taken, these observations are typically made at the main synoptic observation times of 0000, 0600, 1200, and 1800 UTC, following World Meteorological Organization (WMO) practices and procedures.

Since the 1970s, the COADS database for the Grand Banks has been augmented with routine marine weather observations taken by observers on board exploration and production platforms, in accordance with guidelines established by the National Energy Board (NEB) (1994) and the C-NOPB. Frequently referred to as MANMAR reports, these observations are also taken in accordance with the practices and procedures described in Environment Canada (1996).

Rig, vessel and marine synoptic observations may include the following parameters:

- platform identifier;
- date and time;
- position, direction and speed of travel;
- wind direction and speed;
- air temperature, wet bulb temperature, dew point temperature and sea surface temperature;
- sea level pressure, three-hour characteristic and amount of pressure tendency;
- total sky cover, type of low, middle and high cloud and height and amount of base cloud layer;
- visibility;
- present and past weather (precipitation type, obstructions to vision, and so forth);
- period and height of the local wind waves (sea); and
- direction, period and height of the primary and secondary swell.

While drilling operations are being conducted, a Datawell Waverider non-directional wave buoy is normally deployed approximately one kilometre (0.5 nautical miles) from the platform. Wave buoys provide real-time measured wave data, which are incorporated into the marine weather reports. Normally, the critical wave height and peak spectral period derived from the buoy data are archived for use in determining wave climate statistics for the area.

Hindcast wave data provide a valuable source of wave information that may be used when measured wave data are not available, or when the period of record is short or discontinuous. In addition to providing a time-series of conventional wave statistics over an extended period, hindcast model output also provides directional spectra at each grid point and time. The spectra can be manipulated to provide wave direction parameters that may not be available from other sources.

Wave hindcasts are conducted by providing a time-series of arrays of analyzed surface winds to a numerical wave model. In broad terms, the output is dependent on the accuracy of the input wind data, the resolution model grid and on the skill of the model.

The following data sets have been used to derive the marine climate statistics in recent assessments of the Project Area and immediate surrounding area:

- AES-40 wind and wave hindcast dataset covering the North Atlantic Ocean that was developed by Oceanweather Inc. of Cos Cob, Greenwich, Connecticut under contract to Meteorological Service of Canada (MSC), Environment Canada.

- Comprehensive Ocean-Atmosphere Data Set (COADS) Long Marine Report dataset consisting of marine weather and sea state observations from vessels and platforms at sea obtained from MSC.

- Marine weather observations from Husky/Bow Valley East Coast Project and Husky Oil Operations Ltd. (Husky Oil) exploratory drilling operations on the Grand Banks during the 1980s and 1990s.

  These data were extracted from the Canadian Offshore Oil and Gas Environmental Data CD-ROM (March 1997) compiled by Marine Environmental Data Service (MEDS), Ottawa.

- Hibernia nine-year continuous environmental data time-series for the period January 1, 1980 through December 31, 1988. This data set was prepared under contract to the Hibernia Management and Development Company Ltd. (HMDC) by Seaborne Limited. The time-series is a composite of three-hourly marine weather observations (wind speed and direction) and Waverider buoy data (significant wave height and peak period) from a number of drilling programs on the Grand Banks. It also contains current direction and speed data. The wind speed data are from anemometers located approximately 80 m above the sea surface. This data set provides a reasonable estimate of the wind and wave climate in the area and, moreover, is sufficient to enable persistence studies to be carried out and to gain an appreciation of the interannual variability that can be expected.

4.2.4 Winds

In the vicinity of the Project Area, the mean or most frequent wind direction is from the west to west-southwest during the winter and from the southwest during the summer months. Monthly wind speeds are typically lowest during June, July and August. Average wind speeds are highest during the winter, with maximum monthly wind speeds exceeding 30 m/s in February. Variability of wind speed on the Grand Banks is typically highest during the winter months.

4.2.4.1 Wind-generated Waves

The wave climate in the vicinity of the Project Area includes the effects of locally generated wind-waves and swell that propagates into the area. The highest sea states in the area occur during severe storm systems that track through, typically from October to March. Storms of tropical origin occur most often during late-August to October period.

Generally, the lowest and highest monthly mean significant wave height occurs in July and January, respectively. As with wind speed, variability of wave height on the Grand Banks is typically highest during the winter months.

4.2.5 Air and Sea Surface Temperatures

In winter, average sea surface temperatures in the vicinity of the Project Area are higher than the mean air temperatures. The opposite occurs in summer. Monthly average air temperatures are typically just below 0°C at the coldest time of the winter and approximately 13.5°C at the warmest time of summer (i.e., August). The range of sea surface temperatures is smaller than that for air temperatures.

4.2.6 Visibility and Causes of Restricted Visibility

During the warmer months of the year, visibility in the vicinity of the Project Area is often restricted by mist and fog. Snow causes reduced visibility during the winter season. The lowest visibility conditions occur in July, often less than one kilometre. Fog type is primarily advection fog which is formed was relatively warm, moist air is advected over the colder water surface. October is typically the month reporting the most days with good visibility.

4.3 Physical Oceanography

The report (Oceans Limited 2005) in Appendix 1 provides detailed text, figures and tables related to physical oceanography in the Project Area and much of the Study Area.

4.3.1 Water Masses

There are two water masses on the eastern Newfoundland Shelf: (1) the cold intermediate layer water (CIL), and (2) the Labrador Current water (LCW). The low-salinity CIL is measured on the Shelf from late spring to fall, and it characteristically has temperature and salinity ranges of 0 to 1.84ºC and 32 to 33.5%, respectively. The CIL can extend from shore to over 200 km offshore and to depths of 200 m. The LCW is a combination of outflow waters from Baffin Bay and Hudson Strait, mixed with remnants of the West Greenland Current. The Labrador Current originates from Hudson Strait and flows southward over the Labrador and Newfoundland Shelf and Slope to the tail of the Grand Banks. The Labrador Current becomes two branches on the southern Labrador Shelf; an inner branch with approximately 15% of the transport and the main outer slope branch with the remainder of the transport. The outer Labrador Current branch typically flows along the continental slope between the 300 and 1500 m isobaths.

The LCW exhibits seasonal and vertical variability in its temperature and salinity properties. Over the Slope (outer branch), the LCW is generally warmer and saltier than over the Shelf (inner branch).

Historical temperature and salinity data have been extracted from the Bedford Institute of Oceanography (BIO) archive. In addition to data collected by BIO, this archive includes data of the DFO, the Marine Environmental Data Service in Ottawa, the national Oceanographic Center (NODC) in Washington, and various universities and consulting firms.

4.3.2 Currents

The large scale circulation off Atlantic Canada is dominated by well established currents that flow along the margins of the continental shelf. The primary circulatory feature in the Study Area is the Labrador Current which transports sub-polar water to lower latitudes along the continental shelf of eastern Canada. As indicated in the previous section, the Labrador Current consists of two major branches. Characteristic current speeds on the Slope (outer branch) typically range between 25 and 40 cm/sec while those on the Shelf (inner branch) are generally much lower. The outer branch exhibits a distinct seasonal variation in flow speeds in that the mean flows in September and October are almost twice the mean flows in March and April.

Currents at the White Rose field area are comprised of semi-diurnal and diurnal tidal currents, direct wave-driven currents, inertial currents, geostrophic currents and low frequency mesoscale currents resulting from such factors as meteorological disturbances, meandering and eddy formation in the Labrador Current, and the propagation of continental shelf waves generated by up-stream distant storms. The Project Area occurs in an area of transition between the stronger outer branch of the Labrador Current and the weaker, less organized flow characteristics of the shallower Shelf waters of the Grand Banks.

Recent data (since 1984) related to immediate sub-surface, mid-column and near-bottom currents have been collected by moored current meters and ADCP units in the general vicinity of the White Rose field. Based on these collected data, the predominant direction of the complex currents in the vicinity of the Project Area is to the east-southeast. This is consistent with the presence to the north of the outer branch of the Labrador Current. Current speeds measured at the three column locations are as high as 89.9 cm/sec in immediate sub-surface waters, 43.7 cm/sec in mid-column waters, and 50.6 cm/sec in near-bottom waters. Highest current speeds typically occur during the fall coincident with the passage of low pressure systems. Mean current speed ranges in the vicinity of the Project Area approximate 10 to 27 cm/sec in immediate sub-surface waters, 9 to 12 cm/sec in mid-column waters, and 6 to 11 cm/sec in the near-bottom waters.

4.4 Extremes

The report (Oceans Limited 2005) in Appendix 1 provides detailed text, figures and tables related to extremes in the Project Area and much of the Study Area.

4.4.1 Wind and Wave Extreme Analysis

Wind and wave extreme analysis has utilized the AES-40 wind and wave hindcast dataset for the North Atlantic Ocean prepared by Oceanweather Inc. of Cos Cob, Connecticut under contract to the MSC. Data from as early as 1954 has been used in the analyses. Extreme value estimates for wind and waves for return periods of 1, 10, 25, 50 and 100 years are presented in Tables 4.17 and 4.18, respectively, of the Husky exploration drilling EA for Jeanne d'Arc Basin area (LGL 2005a).

4.5 Ice and Icebergs

The description of the ice environment in the vicinity of the Project Area is based on information and data available in the White Rose Comprehensive Study and supplemental report (Husky 2000, 2001a) with available updates. Two forms of floating ice, sea ice and icebergs, occur in the area. Sea ice is produced when the ocean's surface layer freezes, resulting in loosely-packed and pressure-free ice. Sea ice floes are typically small and in advanced stages of deterioration. Icebergs are composed of freshwater ice from glacier-compacted snow. Grand Banks icebergs originate primarily from the glaciers of West Greenland.

4.5.1 Sea Ice

Sea ice cover in the Project Area occurs for an average of four weeks once every three years. The peak period of occurrence is February to April. Ice concentrations are typically low to moderate (20 to 60% coverage). Data indicate that floes larger than 100 m in diameter are present in the project Area only 10% of the time. Indications are that mean floe diameters in offshore areas south of 49°N are less than 30 m. The thickness of most of the sea ice that occurs on the Grand Banks ranges from 30 to 100 cm, based on CIS ice chart data for periods of ice coverage (1985-2001) that exceeded four weeks duration. Mean sea ice drift speed is typically about 0.25 m/sec, primarily in a southeast direction.

4.5.2 Icebergs

During the last ten years, an average of 900 icebergs reached the Grand Banks each year. Of these, only a very small proportion passed through the general vicinity of the Project Area. Iceberg numbers in the area are typically highest from March to early June, peaking in May. The majority of icebergs that reach the Grand Banks are rated as small when compared to known iceberg size. Iceberg drift speeds on the Grand Banks range from 0 to 1.3 m/sec, and average 0.25 to 0.3 m/sec.