Chapter Ten

WATER PROBLEMS

The Gulf of Oman represents the eastern boundary of the Eastern Coast Region of the UAE. Two desalination plants in Qidfa and Fujairah get intake water from the Gulf and the Gulf receives the hot reject brines, which is loaded with chemicals and marine pollutants. However, the impact of desalination industry on the marine environment within the study area is outside the scope of this study. The water problems dealt with in this chapter are surface water problems and groundwater problems.

10.1 Surface Water Problems

The main surface water hazard affecting the study area is flash floods. Despite the absence of permanent rivers or streams in the study area (Rizk and Alsharhan, 2008), flash floods used to cut roads and destroy homes and farms.

10.1.1 Factors Controlling Flood Velocity

The factors controlling flow velocity include: gradient, channel shape, size and roughness and discharge. Gradient is the change in channel elevation with distance. Gradient varies greatly from a stream to another and at different locations along the channel.

Topographic gradient in the study area is ranging between 0.0001 downstream to 0.0004 in the upstream. The steeper the gradient the less energy is needed to move water. In the study area, the mountains range in elevation from 500 to 1000 m and the width of the coastal plain is rather narrow, varying between 4 and 8 km (Rizk and Alsharhan, 2008).

The shape of channel cross section determines its resistance to stream flow. The most efficient channel is the semi-circular (Figure 10.1). The shape of stream channel controls flow velocity. Two channels of the same cross-sectional area can have different flow velocities because their shapes are different. Channel volume and roughness also controls flow because of the friction between moving water and channel bottom and sides. Large volume channel increases flow capacity. Smooth channels lead to laminar flow while rough channels cause turbulent flow. The shapes of wadi channels within the study area are predominantly semi-circular (Figures 8.2 and 8.3), indicating their high efficiency in transmitting flood water.

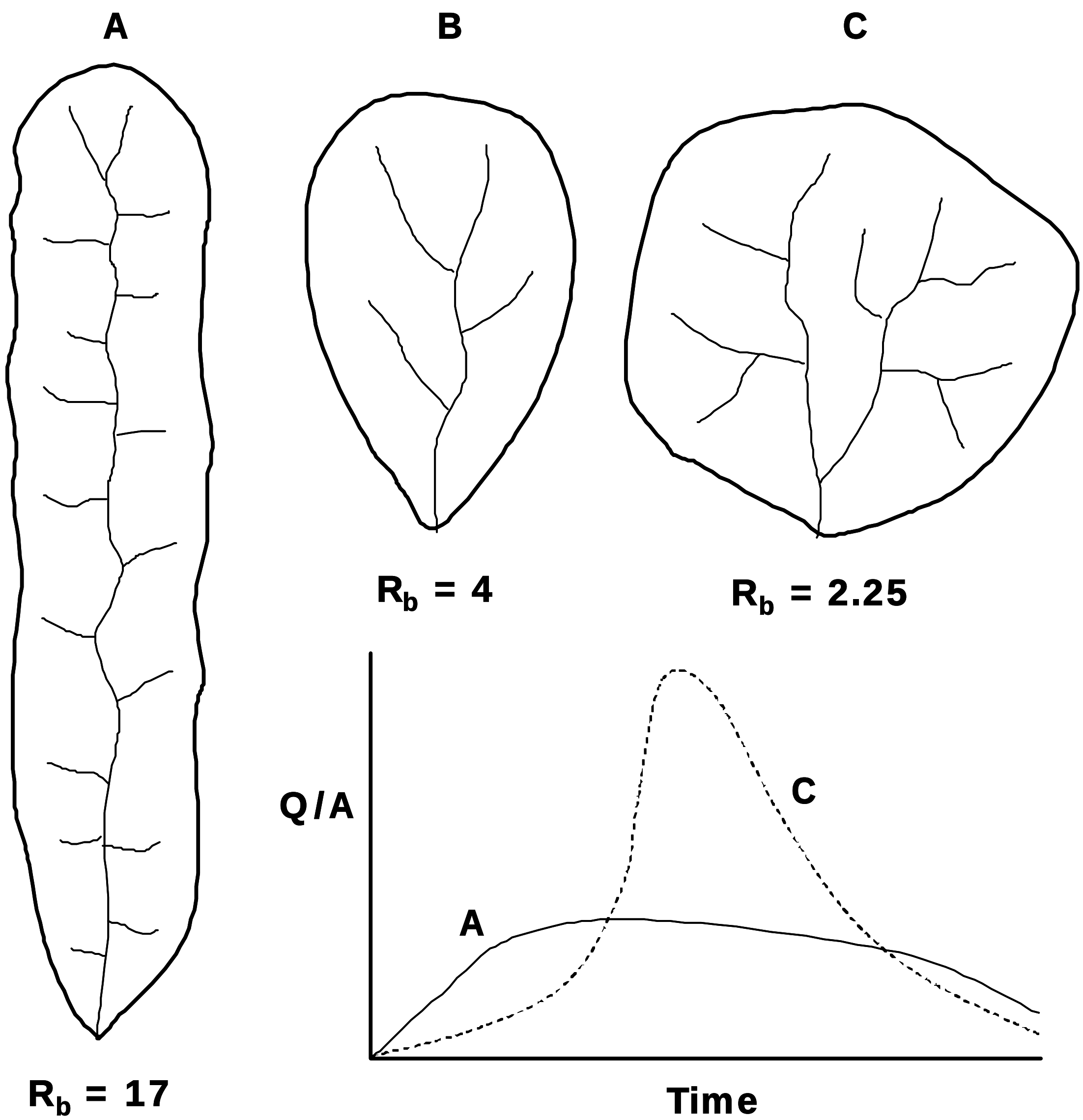

Figure 10.1 Theoretical surface runoff hydrograph according bifurcation ratio (R_b), modified after Patton (1988) (Rizk and Alsharhan, 2003).

Discharge is the amount of water moving through the cross section of stream channel at certain location during a unit time. Discharge is measured in cubic meters or cubic feet per second. Stream discharge is calculated by multiplying the cross-sectional area by water velocity at certain point. Rivers discharge is far from being constant because of change in annual rains. When discharge increases, wadis move faster and widen and deepen their channels to accommodate the increase in river water. Recharge capacities of main wadis the Eastern Coast Region, including the study area, are listed in Table (8.1). This table shows that recharge capacity varies between 3.3 million cubic meters (MCM) in Wadi Zikt and 5.5 MCM in Wadi Wurayah.

10.1.2 Factors Controlling Flood Volume

The factors controlling flood volume include: area of the drainage basin, climatic conditions, vegetation cover in addition to other factors. The catchment area is the total area from which the drainage basin receives water. It controls the amount of rain contributing to stream flow and affects stream length, shape and gradient. The amount of water in stream is directly related to the area receiving rainfall, rainfall duration and intensity. When soil infiltration capacity reaches maximum, an additional rain runs off on the ground surface. The volume of surface runoff depends on rainfall intensity (Rizk and Alsharhan, 2003).

In dense forests, the amount of water intercepted by plants varies between 8 and 35%. This amount of water is large enough, as it can cause floods in areas lacking of such plant cover. Due to the prevailing arid condition vegetation cover is minimal or completely missing within the study area. Additional factors controlling the amount of water in a wadi during a certain period of time include deficit in soil moisture, depth to groundwater and previous rain events.

10.1.3 Morphometry and Flood Potential

The dominant drainage pattern in most catchment areas (Figures 8.1-8.2) is of the elongated trellis type, which is structurally controlled. Most of the catchments are generally characterized by highly permeable surface cover. The wadis are floored by gravel and alluvial deposits. These relatively permeable surfaces coupled with low to moderate drainage density values reflect a low efficiency in discharging the rainwater by channel flow, thus increase in water loss via infiltration. Physiographic characteristics of the basins such as relief ratio, drainage density and bifurcation ratio reinforce the higher groundwater potentiality in most of wadis. The low relief ratio (1.04-1.08) for most of the wadis indicates low overall slope and hence low runoff velocity.

In spite of the absence of permanent streams in UAE, there are numerous dry drainage basins that can carry surface water during occasional heavy rainstorms. Tributaries discharging these drainage basins start at eastern mountainous region and drain eastward in the Gulf of Oman. Some drainage basins can carry very large amounts of water over a very short period of time forming flash floods that may disastrous damage to roads and sporadic settlements. The most prominent drainage basin within the study area is Wadi Zikt (Figure 8.2). Wadi Zikt is a sixth (6^{th}) order stream with a total numbers of streams of 488 different orders (Figure 10.2). The basin shape is elongated with a total area of 121 km^2.

Stream Order	Number of Streams
1	363
2	91
3	24
4	7
5	2
6	1

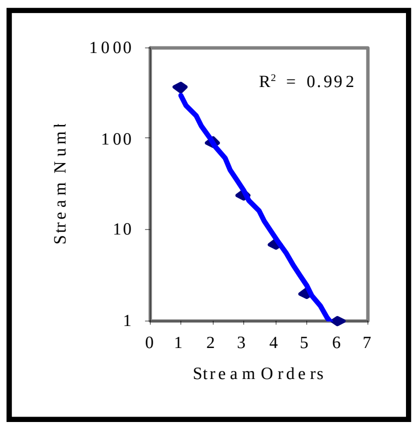

Figure 10.2 Graph illustration the correlation between stream order and stream number in Wadi Zikt, the main drainage basin within the study area (ALHOGARATY).

Bifurcation ratio (R_b) is the ratio of the number of streams in any given order to the number of streams in the next higher order, and is expressed by the following relation:

$R_b = N_u / N_{u+1}$

Where

R_b = bifurcation ratio,

N_u = number of streams of a given order, and

N_{u+1} = number of streams of the next order.

The R_b values normally lies in the range 2-5 (Horton, 1945; White et al., 1992). The R_b of drainage basins in the Northern Oman Mountains in the UAE varies between 2.0 and 5.6 (Rizk et al., 1998d). The average bifurcation ratio (R_b) of Wadi Zikt is 3.04. According to McCullagh (1978), drainage basins with small R_b values are potentially subject to flash floods, whereas the basins of large R_b values commonly have reduced flooding ability.

Drainage density (D_d) is a measure of the cumulative length of all streams in a drainage basin (L) over its total area (TA). The D_d of the basins in the Northern Oman Mountains varies between 1.4 and 2.5 (Rizk et al., 1998d). Basins with high D_d have short path of overland flow and high runoff velocity. In contrast, runoff on basins with low D_d induces high infiltration rates and underflow.

Stream frequency (F_s) is the number of streams per unit area. Stream frequency of basins in the Northern Oman Mountains varies between 0.5 1.3 (Rizk et al., 1998d). According to stream frequency, minimum floods are predicted to occur through wadis with low F_s (F_s = 0.5) and the maximum floods are expected in wadis with high F_s (F_s = 1.3). The stream frequency of Wadi Zikt is 0.95.

The steeper the stream gradient, the shorter the runoff residence time, and the higher the potential for flooding. The basin relief (B_r) depends on gradient, relief ratio and ruggedness number (Patton, 1988). Basin relief in the Northern Oman Mountains varies between 100 and 800 (Rizk et al., 1998d).

The circular basins are the most favorable for short runoff distance (Figure 10.1). The shape of the basin, however, is not the only criterion of flooding and should not be taken as a separate entity. The circular basins (small R_b) are potentially more susceptible to flash floods, whereas elongated basins (large R_b) have commonly reduced floods (Patton, 1988). The hydrogeologic significance of the calculated geomorphic parameters is assessed by applying the approach outlined by El Shamy (1992). This approach involves the graphical relation between R_b and F_s (Figure 10.3).

According to El Shamy (1992), drainage basins can be sorted into three fields A, B and C. Field C is characterized by drainage basins of considerable groundwater potentiality and low flooding possibility. Field A, on the other hand, includes drainage basins of high flooding possibility and low groundwater potentiality. Field B includes drainage basins of both moderate possibility of flooding and groundwater potentiality. The studied drainage basin (Zikt basin) is located in Field A, indicating high flooding possibility and low groundwater potentiality. According to Rizk et al. (1998d), Wadi Zikt has very high risk of flash flooding (Figure 8.2 and 8.3).

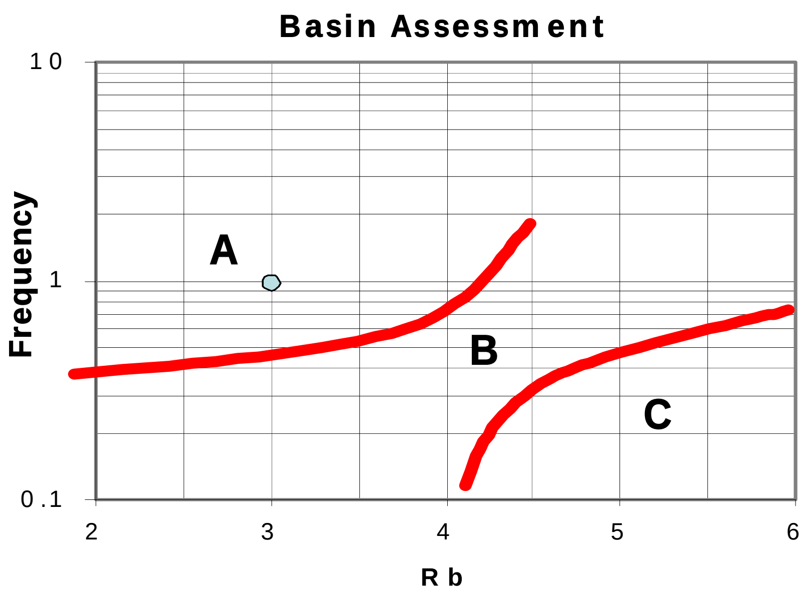

Figure 10.3 Graph illustration the correlation between stream order and stream number in Wadi Zikt, the main drainage basin within the study area (ALHOGARATY).

10.1.4 Flood Control

Now, about 120 million cubic meters (MCM) of flood water is harvested by about 115 recharge dams, which are constructed near outlets of major wadis and designed to divert major part surface runoff water down to recharge groundwater (Figure 10.4).

Flash floods in the study area occur in association with strong, short lasting rain storms. Because the porosity and permeability of the prevailing igneous and metamorphic rocks are low, relatively large volumes of rainwater move over the land surface as surface runoff. This flow begins in the mountainous areas in the west near the proximal end of watersheds and moves towards the Gulf of Oman in the east. The study area is mostly dry and lacks surface runoff, because of low rainfall millimeters per year (120 mm/yr) (Rizk et al., 1997), high natural evaporation (3,360 mm/yr) (Ministry of Agriculture and Fisheries, 1993), scarce vegetation cover and low porosity.

Topographic maps, aerial photographs, and satellite images show that the mountain ranges of the Eastern Coast Region have 70 drainage basins, 58 of them within the UAE (Figure 8.1). The catchment areas of these basins vary between 5 km^2 (Wadi Dadinah, Al Fujairah) and 500 km^2 (Wadi Al Bih, Ras Al Khaimah) (Al Shamesi, 1993). Some large wadis have more than one runoff event per year, others may have surface runoff once in several years, and the rest of the wadis may remain dry for even longer periods.

The Ministry of Agriculture and Fisheries (now the Ministry of Environment and Water) has constructed 45 large dams across the outlets of main wadis, providing a total surface-water storage capacity of 75 MCM (Table 8.1). By the end of 2008, the total number of dams in the UAE reached 115 dams with total storage capacity of 120 MCM. These dams protect against flood and assist the recharge of groundwater. The advantages of groundwater recharge dams in Eastern Coast Region, as summarized by Al Asam (1994) include: groundwater recharge, conservation of floodwater lost to the sea or desert, storage of surface water for irrigation, preservation of agricultural soil and prevention of soil and plant scourage by floodwater, protection against flood damage, and accumulation of silt in artificial reservoirs of these dams and improvement of soil properties.

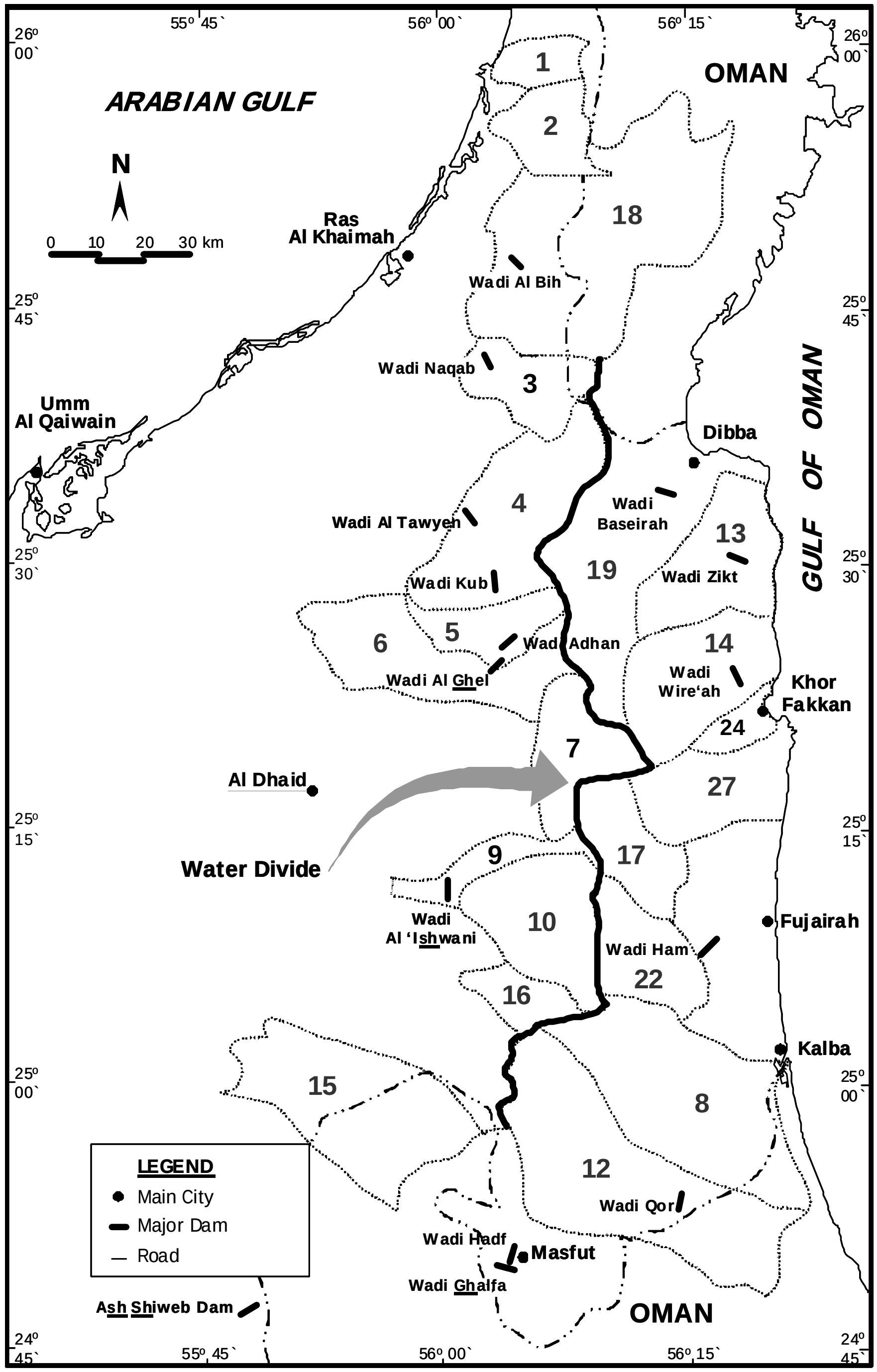

Figure 10.4 Major drainage basins in the Eastern Coast Region of the UAE and locations of main groundwater recharge dams (Rizk and Alsharhan, 2008).

10.2 Groundwater Problems

The major groundwater problems within the study area are: depletion, increasing salinity, water hardness, increasing SAR and deteriorating quality.

10.2.1 Groundwater Depletion

The hydraulic head maps of the Quaternary gravel aquifer within the study area in 2005 and 2009 show a clear decline in groundwater levels (Figures 8.19, 8.20 and 10.5).

The hydraulic heads within the study area in 2005 decreased from 150 m above mean sea level (amsl) in Wadi Wurayah basin (Well WUR1) in the west to less than 5 m amsl in Wadi Zikt (Well ZKT6) in the northeast.

The groundwater flows for the west to the east towards the Gulf of Oman. Similarly, the hydraulic heads in 2009 decreased from 150 m amsl in Wadi Wurayah basin (Well WUR1) in the west to less than 5 m amsl in Wadi Zikt (Well ZKT6) in the northeast.

However, a considerable decline in groundwater levels was observed the southeastern part of the study area at the boundaries between the buffer and transition zones (Figure 10.5). This figure shows that the least drop in groundwater was in the east, along the Gulf of Oman coast, northeast, northwest and west, while the maximum groundwater level decline was in Wadi Wurayah basin (centered around Well WUR5; Figure 10.5). The maximum groundwater level decrease of 20 m (Well WUR5) in four years (between 2005 and 2009) indicated an average annual decline of groundwater levels in the study area represents a serious environmental problem because this drop will certainly induce saline water in the Gulf of Oman, which bounds the study area from the east, to intrude into the fresh groundwater within the study area.

The main reason behind the serious groundwater level drop within the study area and, the UAE in general, is excessive groundwater pumping for all purposes. The natural recharge of groundwater from rain is one tenth of groundwater exploitation (Rizk and Alsharhan, 2008).

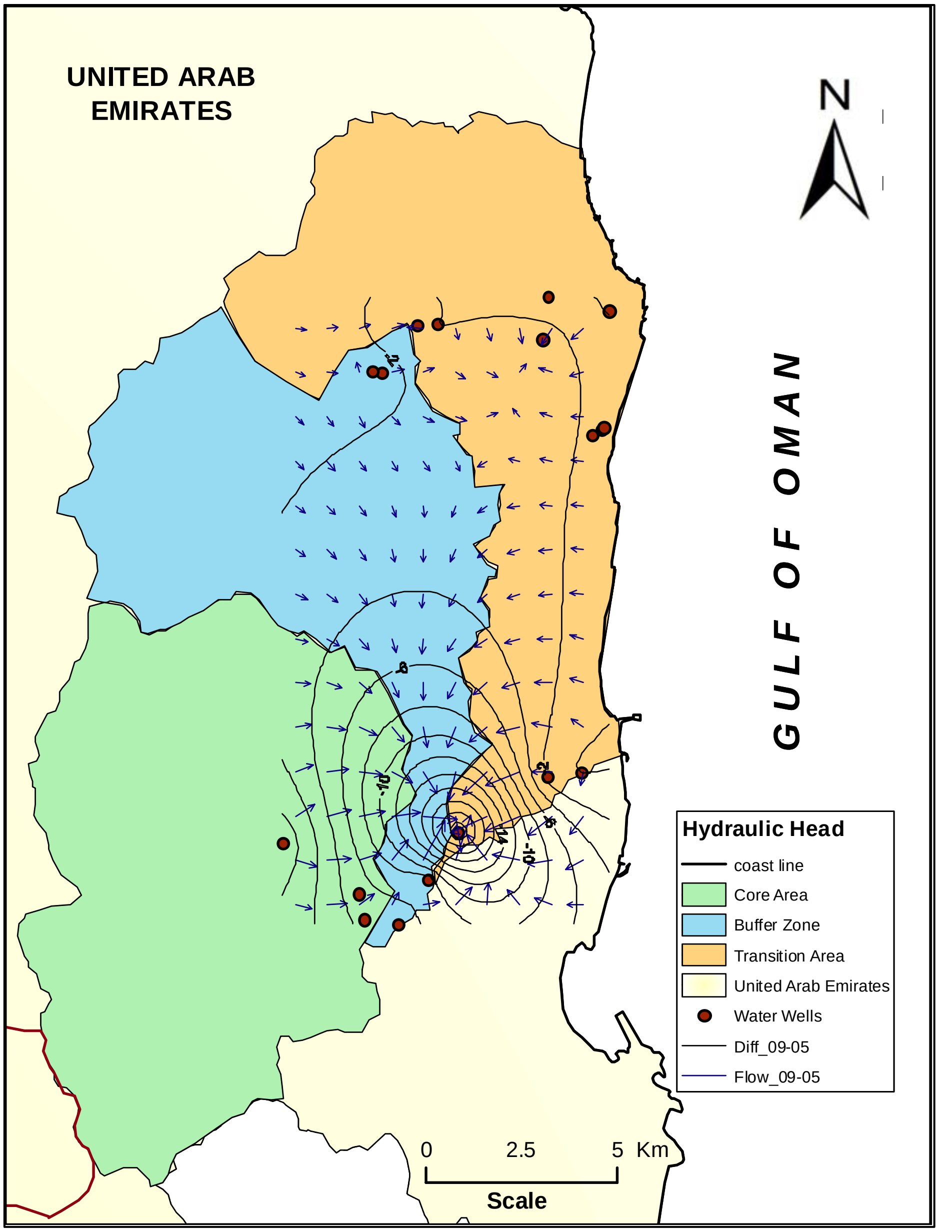

Figure 10.5 Difference in heads within the Quaternary gravel aquifer within the study area, in meters above mean sea level, between 2005 and 2009 (ALHOGARATY).

10.2.2 Increasing Groundwater Salinity

Investigation of the 2005 and the 2009 isosalinity contour maps (Figure 9.8 and 9.9), show inland shift the same isosalinity contour in 2009 compared with 2005, indicating increase of groundwater salinity. Figure 10.6 shows the difference in salinity between 2005 and 2009, which indicate the salt-water intrusion phenomenon at the transition zone.

10.2.3 High Groundwater Hardness

The iso total hardness contour map of groundwater within the study area in 2005 and 2009 (Figures 9.38 and 9.39) illustrate that the groundwater in the eastern and northeastern parts of the study area is hard (TH > 200 mg/l) to very hard (TH > 300 mg/l), which stops the soap action and make water use for domestic purposes difficult. The reason for high groundwater hardness within the study area can be attributed to saline water influence and high magnesium and calcium ions in the Ophiolite rocks dominating the area. Upon dissolution, these rocks enrich groundwater with calcium and magnesium ions, which increases total hardness.

10.2.4 High Sodium Adsorption Ratio

The sodium adsorption ratio (SAR) and salinity determine the suitability of groundwater for irrigation. Figures 9.40 and 9.41 are iso SAR contour map of groundwater within the study area in 2005 and 2009, respectively. Both figures indicate that the use of groundwater for irrigation in the Dadinah area (SAR >10) can have limited hazardous effects on both plants and soil.

10.2.5 Deterioration of Groundwater Quality

The groundwater pollution in the study area can result from natural and human-related sources. The unconfining nature of the Quaternary alluvial aquifer within the study area can increase its vulnerability to pollution. The fresh groundwater within the study area is bounded on its eastern side with a huge salt water body; the Gulf of Oman. Excessive groundwater pumping has already induced salt-water intrusion the southern part of the Eastern Coast Region (Sherif et al., 2005), directly south on the study area. The prevailing aridity and scarcity of rain reduce groundwater recharge. This allows pumping of poor-quality from deep horizons in the aquifer.

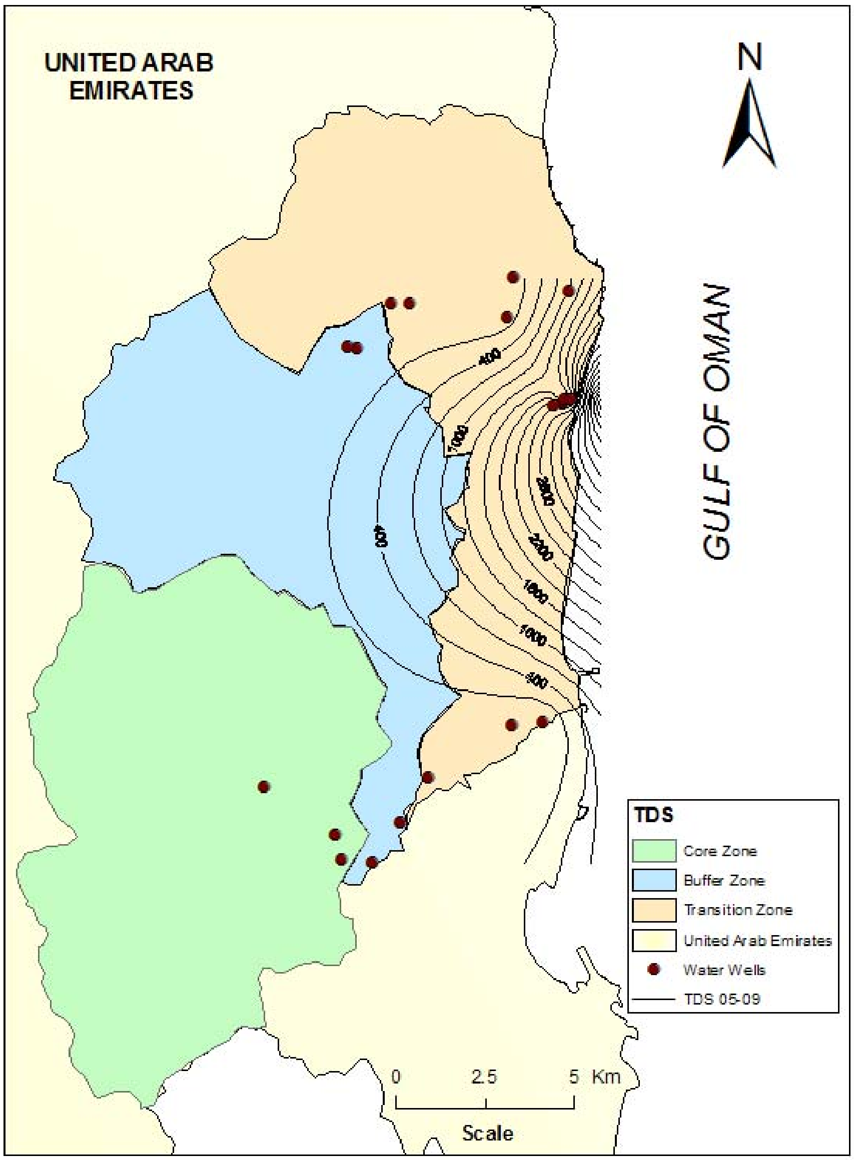

Figure 10.6 Difference in salinity within the Quaternary gravel aquifer within the study area -between 2005 and 2009 (ALHOGARATY).