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The Impact of Urbanization on Natural Resources

Tetouan, Morocco

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The views herein are those of the authors and do not necessarily reflect those of the Office of Housing or the U.S. Agency for International Development.

PREFACE AND ACKNOWLEDGEMENTS

This report is the result of a project initiated by the United States Agency for International Development and sponsored by the Office of Housing and Urban Programs of the Bureau for Private Enterprise and the Development Resources Office of the Bureau for Europe and the Near East. The project was conducted during the fall and winter of 1991 and is an attempt to develop and test a methodology that analyzes the impacts of urbanization on the natural resources of a developing country. The project was conducted by DPRA Incorporated, IRG Ltd. and RDA International, and this report is submitted to fulfill USAID Contract No. PDC-5517-I-00-0104-00, Delivery Order No. 7.

The project team was coordinated by Mr. Stephen McCarthy and data gathering efforts for the methodology development in stage I by Ms. Cynthia Pantazis, both of DPRA Incorporated. The team and principal authors were Mr. Paul Anid and Mr. David Currie of DPRA Incorporated, Mr. Christopher Shaw and Ms. Tomi Curtis of IRG Ltd. and Mr. David Tarnas of RDA International.

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The views expressed in this report are those of authors and do not necessarily reflect those of USAID or the Government of Morocco.

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LIST OF ABBREVIATIONS

GATT:	General Agreement on Trade and Tariffs.
IUCN/UNEP/WWF:	International Union for the Conservation of Nature and Natural Resources, United Nations Environment Program, and the Worldwide Fund for Nature (formerly World Wildlife Fund).
PNUD:	Programme des Nations Unies pour le Developpement.
PNUE:	Programme des Nations Unies pour l'Environnement.
RdM/DRAMM:	Royaume du Maroc, Delegation Regionale des Affaires Maritimes de M'diq.
RdM/ IAVH:	Royaume du Maroc, Institut Agronomique et Veterinaire Hassan II.
RdM/MARA:	Royaume du Maroc, Ministère de l'Agriculture et de la Reforme Agraire, Direction des Eaux et Forets et de la Conservation des Sols avec Direction Provinciale de l'Agriculture (Cellule des Etudes).
RdM/MARA/DEFCS:	Royaume du Maroc, Ministère de l'Agriculture et de la Reforme Agraire, Direction des Eaux et Forets et de la Conservation des Sols.
RdM/MARA/DPAE:	Royaume du Maroc, Ministère de l'Agriculture et de la Reforme Agraire, Direction de la Planification et des Affaires Economiques.
RdM/MARA/DPAT:	Royaume du Maroc, Ministère de l'Agriculture et de la Reforme Agraire, Direction Provinciale de l'Agriculture de Tétouan.
RdM/MARA/SFT:	Service Forestier de Tétouan.
RdM/MCIM:	Royaume du Maroc, Ministère du Commerce, de l'Industrie, des Mines et de la Marine Marchande, Direction des Mines et de la Geologie, Division de la Geologie.
RdM/MDMMM:	Royaume du Maroc, Ministre des Peches Maritimes et de la Marine Marchande.
RdM/MHAT:	Royaume du Maroc, Ministère de l'Habitat et de l'Amenénagement du Térritoire.

LIST OF ABBREVIATIONS (cont'd)

RdM/MI/DUA:	Royaume du Maroc, Ministère de l'Intérieure, Direction de l'urbanisme et l'architecture, Division de la planification urbaine.
RdM/MI/MT:	Royaume du Maroc, Ministère de l'Intérieur, Municipalité de Tétouan, Agence Nationale de Lutte Contre l'Habitat Insalubre.
RdM/MI/PT:	Royaume du Maroc, Ministère de l'Intérieur et de l'Information, Province de Tétouan.
RdM/MI/RDE:	Royaume du Maroc, Ministère de l'Intérieur et de l'Information, Régie des Eaux, Tétouan-Larache-Chefchaouen.
RdM/MI/SG:	Royaume du Maroc, Ministère de l'Intérieur, Secrétariat Général, Direction de l'Urbanisme, de l'Amenagement du Térritoire et de l'Environnement, Centre d'Activité Régional, Programme d'Action Prioritaire.
RdM/MSP/DEPS:	Royaume du Maroc, Ministere de la Sante Publique, Direction de l'Epidémiologie et des Programmes Sanitaires, Service de Contrôle Epidémiologique.
RdM/MSP/DRH:	Royaume du Maroc, Ministere de la Sante Publique, Division de la Formation Ecole de Cadres.
RdM/MTP:	Royaume du Maroc, Ministère des Travaux Publics, de la Formation Professionelle, et de la Formation des Cadres, administration de l'hydraulique direction de la recherche et de la planification de l'eau direction de la re ion hydraulique du Loukoss-Tétouan.
RdM/MTP/PT:	Royaume du Maroc, Ministère des Travaux Publics, Province de Tétouan.
RdM/OPM:	Royaume du Maroc, Office of the Prime Minister.
RdM/ONEP:	Royaume du Maroc, Office National de l'Eau Potable.
RdM/ONP:	Royaume du Maroc, Office National des Peches.
RdM/ONP/ISPM:	Royaume du Maroc, Office National des Peches, Institut Scientifique des Peches Maritimes.

LIST OF ABBREVIATIONS (cont'd)

RdM/SSEC:	Royaume de Maroc, Sous-Secretariat d'Etat au Commerce, a l'Industrie, Aux Mines et à la Marine Marchande, Direction des Mines et de la Geologie, Division de la Geologie.
ROI:	Region of Influence of Tétouan.
TUM:	Techniques Urbainnes Morac.
USAID/S&T:	U.S. Agency for International Development, Bureau of Science and Technology.
USAID/M:	U.S. Agency for International Development, Morocco.
USAID/W:	U.S. Agency for International Development, Washington.
WB/AOD:	World Bank, Agricultural Operations Division, Country Department II, Europe, Middle East and North Africa Regional Office.
WB/ID:	World Bank, Infrastructure Division, Country Department II, Environment Division, Technical Department.

EXECUTIVE SUMMARY

In 1991, the United States Agency for International Development (USAID) sponsored a study to devise methods for investigating the effects of urban growth on the natural resources of Tétouan, a city in northern Morocco. This study is the third undertaken in a tri-part series to examine the effects of urbanization on the developing world; two previous studies focused on economic growth and public health issues.

The examination of urbanization's effect on Tétouan's natural resources had two goals: to alert host-country officials to the environmental problems caused by urban growth and to establish criteria that USAID could apply elsewhere in determining which natural resources are most threatened by urbanization. These criteria could then be used to set priorities when making investments in developing nations.

Before going to Tétouan, the study team developed a methodological framework that could be applied to any city or region. Using this framework, team members would identify a key natural resource, such as a river or a wetland, for example, and then determine the resource's size and importance. With this physical survey done, the team would then ascertain the extent to which the resource was jeopardized by an urban-related activity, such as the construction of housing or the release of effluents by an industry.

Located 45 kilometers south of the Strait of Gibraltar, Tétouan was chosen to be the test site for this methodology at the behest of the USAID components that sponsored the study: the Office of Housing and Urban Programs (APRE/H) and the Office of Development Resources, Bureau for Europe and the Near East (ENE/DR). A city that has grown rapidly, and somewhat haphazardly, in the past two decades, Tétouan now has a population of 300,000, and some analysts predict that the population will reach 500,000 in the next 20 years. Like many other rapidly growing cities in developing nations, Tétouan depends heavily on its immediately surrounding area to provide such resources as fuel, water, and building materials.

The study team ranked the threats to the Tétouan area's diverse natural resources as severe, moderate, or slight. Four natural resources were considered to be severely threatened: 1) coastal land and water; 2) terrestrial flora; 3) freshwater downstream of Tétouan; and 4) wetland flora and fauna. As the city of Tétouan has expanded over the years, these critical resources have become more and more degraded.

According to the study team, plantation forests and freshwater in the immediate vicinity of Tétouan are moderately threatened, and agricultural land and marine fisheries are only slightly threatened by the city's rapid growth.

The damage to Tétouan's coastal lands comes from two sources. The first, commercial and residential development of the area's beaches, is not, strictly speaking, the direct result of urbanization. It is instead caused by the growth of tourism in the region. However, the second source of harm, the removal of sand for use in construction, stems directly from urbanization and results in the erosion of sand dunes. Tétouan's coastal waters also are

gravely endangered by urban growth. Sewage disposal, livestock grazing, and solid waste disposal all pollute coastal waters, thus jeopardizing both the local ecosystem and the expanding tourist industry.

As urban development encroaches on coastal land and water, Tétouan's spread severely jeopardizes the area's terrestrial flora. Increasingly, land once covered by natural vegetation is put to other uses, such as subsistence agriculture or grazing for livestock. Within the next 20 years, much of the local flora may disappear.

The degradation of resources is by no means confined to the immediate vicinity of Tétouan; water downstream from the city is polluted by untreated wastewater discharged into the Martil River.

Human activities severely threaten wetland flora and fauna. As coastal lands are developed, connections between the major wetland in the area, Lac Smir, and the Mediterranean Sea become more tenuous. The construction of a dam at Lac Smir and the dike on the coast have effectively cut the natural flow of fresh water and seawater into the wetland. As a result, the composition of the water in the wetland has changed and the types of flora and fauna prevalent in the wetland area have changed as well. One dramatic result of this change is the increase in the insect population, a phenomenon that may directly affect tourism.

The urbanization of the Tétouan area poses a moderate threat to the region's plantation forests. As the city grew, the demand for wood to use as fuel (for brick kilns and bath houses) grew as well. In addition, new forest growth is being systematically removed both to prevent the spread of fires and to provide employment. There is a reforestation program to counteract the effects of these losses, but people who converted forests into agricultural land are opposed to reforestation.

Also moderately threatened by urbanization, Tétouan's freshwater supply is intimately linked to the fate of the area's plantation forests. Although a dam has recently been completed, pollution and constraints on the supply of water may cause a water shortage within 10 or 12 years.

Agricultural lands and marine fisheries are the natural resources least threatened by the process of urbanization. Although both resources are economically important and have experienced major changes, they are not in jeopardy as a result of Tétouan's growth. Also, they do not have an immediate impact on the quality of life in the city.

All of these threats to the natural resources of Tétouan can be mitigated, at least to some extent, by human intervention in the form of technology or of policy decisions. Although the study team was not charged to suggest appropriate courses of action for USAID or the government of Morocco, the report concludes with a set of brief recommendations for follow-up studies and activities.

TECHNICAL REPORT

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1.0 INTRODUCTION

During recent years the U.S. Agency for International Development has devoted considerable attention to the phenomenon of increasing urbanization and its relationship to the environment in developing countries. Population growth in the developing world has placed tremendous pressure on rural economies, predominantly agricultural, to support this growth. The result has been a dramatic increase over the past 25 years in the trend toward rapid urbanization. Historically this increase in urbanization has been attributed to urban migration driven by deteriorating conditions in rural areas and the perception that more favorable ones exist in urban areas.

The process has been age selective. Most immigrants are of child bearing age, with the result that the phenomenon's rate is expected to accelerate, due now to rapid internal urban growth. It is projected that by the year 2000 major percentages of developing countries' populations will live in urban areas.

Such areas, as centers of production and consumption activities, require raw materials as inputs and expel waste byproducts as outputs. The pressure placed on natural resources as a result of these activities, and the synergistic effect of their impacts, forms the underlying conceptual framework for this study.

This report is the result of a study jointly sponsored by the Office of Housing and Urban Programs of the Bureau for Private Enterprise of USAID, Washington and the Bureau for Europe and the Near East, Development Resources Office and the USAID Mission to Morocco. It is the third study undertaken in a tri-part series designed to analyze the impacts of urbanization from three distinctly different perspectives. The previous two studies focused on human health and economic development; this study attempts to investigate the impacts of urbanization on natural resources, focusing on an ecological perspective.

1.1 CONCEPT

The study attempts to analyze the relationship between urban activities and the surrounding natural resource base and then to identify, quantify, and rank by degree of degradation the resources directly impacted by urban related activities. Impacts were classified into two major categories: "chemical impacts," those impacts related to activities resulting in urban generated residuals, and "physical impacts," extraction, excavation activities that directly impact the resource physically. The study was phased in two stages, each with distinct tasks to be performed under the overall scope of work.

Stage I was aimed at developing a methodology that would allow for a rational framework in the analysis of socio-economic growth and development trends as they relate to the quantity

and type of activities that result in both chemical and physical impacts on natural resources. It also included preliminary analysis of data for a specific site.

The primary task in developing the methodology was to develop an analytical framework that would enable the determination of 1) the degree of impact, both present and future, on the resources identified; 2) the ecological, physical, and economic losses associated with those impacts; 3) a ranking of resources adversely affected by these activities; and 4) recommendations for managing impacts on the natural resources. The methodology should be sufficiently universal in its design and approach to allow for replicable applications under different settings and conditions.

A secondary task under Stage I was to perform a pre-site analysis using the methodology's framework to examine available data and identify resource-activity-impact linkages that appeared to warrant further investigation during the field work. This analysis also would provide a preliminary idea for setting study boundaries and identifying key resources. The pre-site analysis would have to rely almost exclusively on secondary source data.

Stage II involved a field application of the methodology, which would test its effectiveness as a tool for examining present resource impact as a result of urban generated activity and, in its capacity to project future resource impact based on data projections, its usefulness as a planning tool for AID and host governments. The field application also would serve to prove or disprove some of the hypotheses regarding resource impact linkages that emerged during Stage I. The field application site chosen by USAID was Tétouan, Morocco.

1.2 THE STUDY TEAM

While one would assume that some of the phenomena and linkages in an analysis of urbanization and resource degradation will be generic, the selection of the site will have a definite impact on the composition of the study team. Geographic factors such as a coastal vs. landlocked site obviously will dictate the necessity for certain disciplines. In addition, other variables linked to activities, e.g., does the site selected have a large industrial base, also will influence the team.

Based on an assessment of the site specific variables that were present in Tétouan, a study team was assembled that brought together a mix of disciplines believed necessary to accomplish the tasks. The study team consisted of the following:

- Natural Resource Economist with a specialty in forest economics;
- Environmental Engineer with a specialty in urban and industrial waste impact on surface and ground water;
- Urban/Regional Planner;

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- Marine/Coastal Resources Specialist; and

- Ecology/Bio-Diversity Specialist.

1.3 THE METHODOLOGY

Given the study's overarching purpose to investigate urbanization's impact on natural resources, the methodology was designed as a process to focus on the dynamic relationships present in the population-activity-resource triad. As such, information and data on population and growth trends formed the foundation for the impact assessment.

Five distinct sequential steps are at the core of the methodological approach the team developed:

1) Selecting the key resources to be examined at a particular site.

2) Quantifying those resources in physical, geographic, productive, and/or economic terms.

3) Identifying the urban-based activities that impinge upon the resources.

4) Quantifying the degree of impact of each of those activities in each resource.

5) Ranking the resources according to the severity of their degradation.

Site-specific conditions dictated which resources were considered either most relevant or likely to be most vulnerable. The resources identified were then quantified to establish a benchmark or baseline for the variable. This was done on both a present and, depending on data sources, an historical basis. Human activities including all potentially positive and negative actions that would affect the quality and/or the quantity of the resource were listed. Through the utilization of a number of methods including rapid appraisal techniques, direct observation, and available secondary source data, the impacts on resources resulting from activities were quantified. The methods used for quantifying the degree of impact varied according to the activity-resource relationship, the nature of the impact and the available means for measurement, and data sources. Based on the results of quantification and measurement of the impact, the level of impact was estimated and ranked as slight, moderate, or severe.

The tool for recording these interactions was an impact matrix, setting human activities against identified resources. Activities were listed along the vertical axis of the matrix under the general headings of chemical and physical. After impacts were quantified and ranked as high, medium, or low, the matrix was then used to compare the extent of the degradation in relation to its relative importance or scarcity in physical terms. In addition to direct human impacts, the matrix allows for the description for the interdependent impacts among resources,

for example the increased rate of soil erosion resulting from deforestation. It should be noted that the rapid assessment techniques used by the team in gathering field data would not permit an in-depth, quantitative analysis of resource impacts, but rather were designed to ascertain the capacity of the methodology to describe the relationships and to draw as clear a picture as possible of present and future given the allotted time and data constraints.

1.4 RESOURCES

Three main categories of resources were chosen by the study team for analysis: land, water, and biota. Air was not included in the study because air quality does not appear to be significantly impacted upon by urban activities nor itself present a significant impact on other natural resources. Each of the three main resources was further defined into resource sub-sets:

LAND	WATER	BIOTA
forest land	groundwater	habitats
agricultural land	surface water	species
rangeland	fisheries	
wetlands		
coastal land		
urbanized land		

Each resource sub-set was analyzed from three different perspectives:

1) The quantity of the resource from a present and where possible an historical perspective. How much of the resource in question is there and where is it? Example: Area under natural and/or plantation forest cover.

2) What are the key human urban-based activities that impinge upon the resource? Example: Commercial or informal fuelwood gathering.

3) What are the measurable impacts on the resource in "physical" and "chemical" terms? Example: Loss of forest cover.

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2.0 THE SITE

Tétouan is located in northern Morocco, approximately 45 km south of the Strait of Gibraltar, situated on the slopes of the Dorsale Calcaire (the coast chain of the Rif Mountains) overlooking the Martil River and the Mediterranean Sea (Figure 2.1). It is one of two major urban centers on the Tingitanic Peninsula, the other being Tangier. While Tangier faces the strait and is oriented toward the Atlantic Ocean, Tétouan is situated about 7 km inland from the Mediterranean along the Martil River.

Two features of Tétouan's recent evolution have been particularly significant. One is growth in all directions, especially to the northeast along the route to Sebta. The other is the development of large-scale facilities in the Martil area that have had a decentralizing effect. These include the industrial zone and the Faculte des Lettres on the road to Martil, the teachers' college in the town itself, and the proposed sports complex and administrative center in Touabel. In all likelihood, within the next two decades growth out from Tétouan and growth out from Martil will meet in a "mini-conurbation"[1] along the Martil road.

2.1 REGIONAL SETTING

The Tétouan region has experienced continual growth attributed to four aspects of the city's location. First, the Martil River provides a ready supply of fresh water. Second, most of the city's land is high enough to avoid flooding during the rainy season. Further, municipal wastes can flow downhill into the Martil River without pumping. Third, the city's proximity to the sea facilitates utilization of its resources. Finally, the city benefits from a climate moderated by the Mediterranean Sea.

Tétouan sits on a south-facing slope just inside the water gap defined by the Martil River as it passes through the Rif Mountains and enters the coastal alluvial plain. The periodically inundated land along the river to the south of Tétouan restricted development in that direction. The city has grown to the east, following the valley carved by the Martil, and to the west, on the coastal plain between Tétouan and the sea. Development to the east has been primarily small-scale and residential, while development westward toward the sea has involved mainly larger scale industry and agriculture which can cope with the more difficult hydrological conditions.

[1]Group of cities or larger towns.

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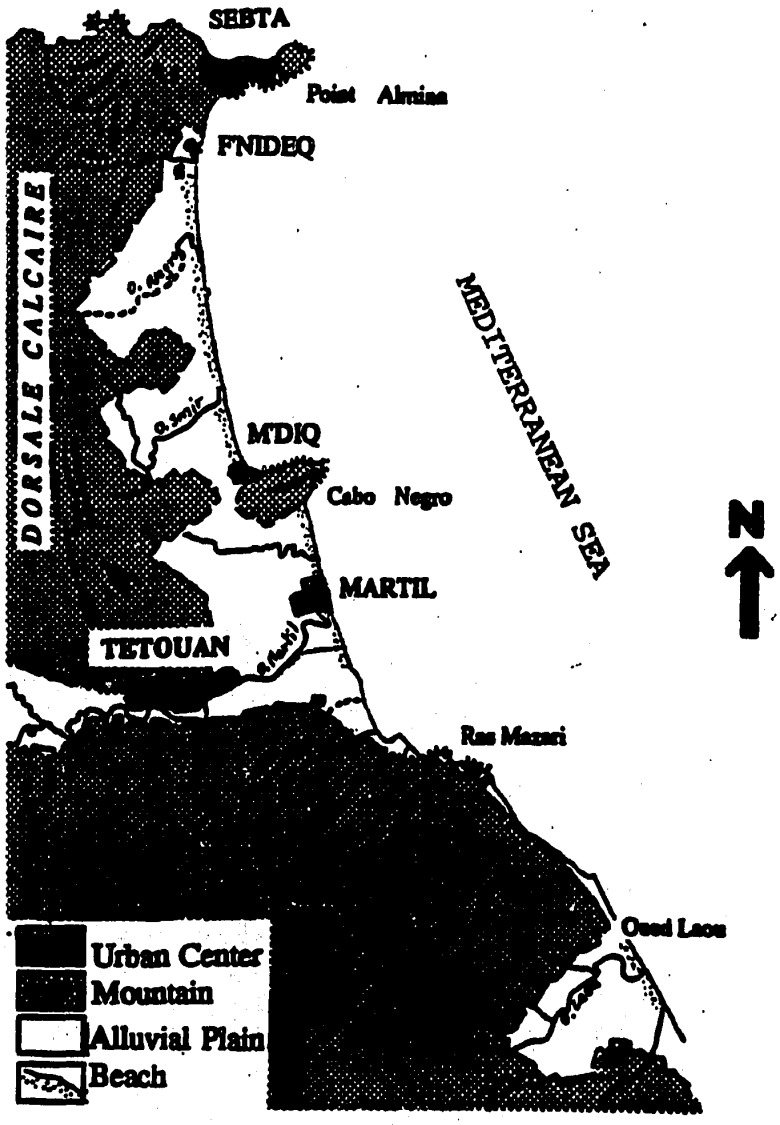
Figure 2.1

Regional Location Map



The Martil River is the largest river in the region, and it has traditionally supplied much of the fresh water to Tétouan. Extensive development also has taken place along the coast. The coast region is bounded by Ras Mazari in the south and Cabo Negro in the north. In the center of this coastal strip, just above the Martil estuary, lies the town of Martil. The smaller town of Azla is located next to the old estuary of the Martil near Ras Mazari.

Martil is a fishing and summer recreation village that has become a suburb of Tétouan. Since the 1950s it has grown toward the north along the beach toward M'diq, bordering the left bank of the dead arm of the Martil River. The area has a poorly articulated urban fabric with extensive clandestine housing and minimal infrastructure.

Around the rocky heartland of Cabo Negro is the fishing village of M'diq. M'diq is characterized by extensive clandestine housing, representing approximately 67 percent of all built parcels. Almost half of its residents are employed at the port or in the fisheries sector.

The Smir River has an extensive wetland near the mouth of Lac Smir, its estuary. North of the Smir is the small community of Restinga Smir, and farther north is the town of F'nideq. F'nideq is a summer recreation village that acts as the entry port to Morocco via Sebta. It, too, contains several zones of clandestine housing. Because the Tétouan coastal area is an important tourist destination for Europeans and Moroccans alike, the summer population increases to three to four times that of winter for each of the three satellite centers.

The climate is typically Mediterranean, with an oceanic influence. Winters are cool and wet; summers are hot and dry. Summer temperatures can exceed 35°C in the valleys and interior basins. The coastal plain is warm and semiarid, while the uplands have a warm, subhumid climate. A constant wind, the *charqui*, blows from the northeast at ground speeds of up to 35 kph. From November to March *gharbi* winds blow from the west and the Atlantic Ocean, bringing rain.

2.2 REGION OF INFLUENCE

The study team applied a resource specific approach to determine the boundaries of the Region of Influence (ROI). Consequently each of the resources examined--land, water, biota, and their subsets--incorporated a unique geographical area influenced by the growth of Tétouan. The application of the resource driven approach for setting the boundaries of the ROI becomes a salient component of the methodology.

The team elected to examine both direct and indirect linkages of urbanization which resulted in the inclusion of the three coastal satellite towns in the ROI of most resources. These satellite towns with whose economies Tétouan has become intrinsically linked are Martil, M'diq, and F'ndiq.

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Land Resources. Among the RsOI identified, coastal resources, plantation forests, and agricultural lands, in addition to biotic resources, yielded the largest and the most diverse ROIs. These are all categorized as land resources.

The coastal zone was defined as land within about 500m of the shoreline, or at least to the inland side of the coastal dunes, including the nearshore waters out to about the 20m depth. The primary resources examined on the coastal zone were coastal forests, wetlands, estuaries, dunes, beaches, and nearshore water. Interdisciplinary analysis was applied to delineate linkages because the resources could be handled in other resource sectors, specifically forests, biological resources, and water.

In defining the extent of coastline to be included in the study, assessments had to be made about factors other than direct or indirect linkages to urbanization. Many activities are taking place along the coast, most notably sand excavation to satisfy the construction needs of urban Tétouan. The team further discovered that the construction of tourism developments in support of Tétouan's promising tourist industry has become essential to the regional economy. Although this activity is separate and distinct from the urbanization of Tétouan city, the team elected to include with the ROI areas developed independently of the city whose environmental degradation would affect Tétouan's economic future.

The largest plantation forest lies in the immediate vicinity of urban Tétouan (Jbel Zem Zem V). However, the ROI for this resource included areas beyond the province of Tétouan, specifically the neighboring provinces of Chefchaouen and Larache. The ROI was expanded because it was discovered that Tétouan's demand for fuelwood could not be met by the surrounding forest.

The ROI for agricultural land was limited to farmlands. The team determined that the damage urbanization can have on agriculture results from a direct encroachment on farmlands. In addition, agricultural practices directly or remotely linked to urbanization (e.g., forest clearing for planting purposes) can severely affect the natural resource base around a city without being a direct urban impact. This was true in Tétouan which is known for its limited agricultural sector.

Water Resources. The ROI for water resources was defined as the region from which Tétouan, Martil, F'nideq, and M'diq satisfy their freshwater needs and discharge their effluent. These localities rely on four watersheds for these needs. For the purpose of this study, the team elected to focus on the larger and more productive Martil and Smir basins.

The Martil watershed occupies 1220 km^2 and is drained by the Martil River, the Alila River, and three other tributaries. The Martil funnels into a large flood plain with a very high water table. The Smir watershed has an area of 250 km^2 and is drained by the Smir River, which funnels into the alluvial coastal plain of M'diq.

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The Negro and Kendissa are smaller and make only a minor contribution to the overall water budget of the region. The Negro watershed drains the Negro River and produces the lowest annual runoff of the four watersheds. Together with the Kendissa River's watershed it has an area of less than 150 km^2.

Further, the increased construction of hydraulic structures (dams, pumping sites, river water intakes, dikes) and other facilities (water and wastewater treatment plants, wastewater outfalls) beyond the city limits expanded the ROI for water resources. As a result, those areas directly surrounding a utility and extending to where the impacts became negligible were included in this ROI. Subsequently, a distinction was made between sources of water located upstream of Tétouan and the satellite towns and sources of water located downstream which act as receptors for used water. This approach facilitated a cleaner, more comprehensive description and quantification of activities and impacts.

Biotic Resources. Finally, the least extensive ROI was that delineated for biotic resources. The team determined that the only sensitive and vulnerable systems (lakes, wetlands, forests) were located close to the city. Consequently, only the major ecosystems, fauna, and flora of ecological importance under the influence of Tétouan were identified.

2.3 HISTORICAL DEVELOPMENT

Tétouan's expansion commenced in the 1940s under Spanish administration. At that time, development was directed east toward Martil. From 1970 to 1980 an influx of Moroccans from Europe overcrowded the main city center, the Medina. Consequently, development spread outside the city's northern and eastern walls along the slopes of Jbel Dersa, spreading westward in conjunction with persistent growth east toward Martil and north toward Touabel (Figure 2.2).

Around 1980, the Moroccan government set an exchange rate that would encourage returning guest workers to repatriate their money. Next came a program of subdivisions (by both state and private land owners) that permitted people to buy serviced land for construction. Before this, about two-thirds of housing construction was "clandestine," meaning that the owners or occupants of the house were squatting on government land and that no building permit had been issued. The areas characterized by clandestine construction lack infrastructure. The city is trying to control this practice, and as a result, virtually all new development in the past five years has been clandestine housing up the slopes of the Dorsale Calcaire.

2.4 ECONOMIC FRAMEWORK

The unique history and recent growth of the Tétouan region have generated a local boom economy with a questionable foundation. Regional economic growth in the 1970s and early 1980s was based on workers' remittances. Salaries earned abroad, usually in the European Community (EC), financed local growth as Moroccans returned home and settled in Tétouan.

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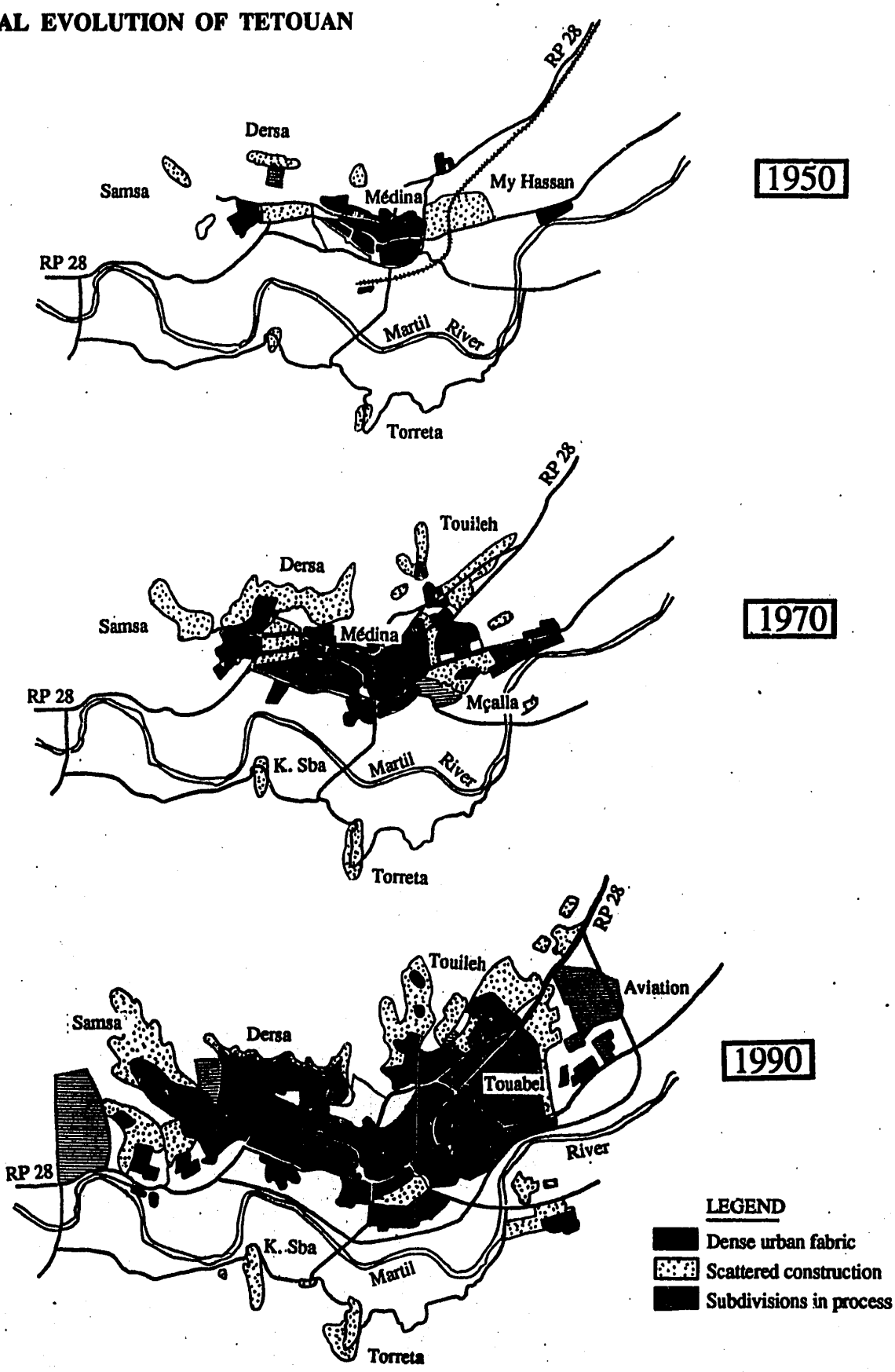
Figure 2.2

SPATIAL EVOLUTION OF TETOUAN



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With the imposition of rules restricting immigration by France and other EC countries, Morocco faces significant unemployment in the 1990s and sustained migration into Tétouan is unlikely.

The coast also has been utilized for development. Tourist complexes serviced primarily by Tétouan and smaller communities are being constructed along the coast. A broad alluvial plain with wide sandy beaches north of the Martil River has proven to be ideal for recreational development. To the south of the Martil River, the mountains come nearly to the sea, preventing large-scale use of the waterfront.

Recent decisions by the central government indicate that the restrictions on trade that have ordered commercial activity in Tétouan are receding with general economic liberalization. The *dirham* is scheduled to become fully convertible in 1993, coinciding with the advent of trade liberalization in the EC, Morocco's largest trading partner (EIU 1991). With convertibility will come further depreciation, making all imported goods relatively more expensive, at least in the short term (especially those priced in currencies in the European Monetary Union). Moreover, strengthening international trade ties through GATT and the Arab Maghreb Union (AMU) could lead both to removal of import tariffs and a crackdown on illegal trade.

Descriptive information on the current regional income is limited and the most recent available for the Province of Tétouan was for 1981 (see Table 2.1). In 1981, public administration accounted for approximately 31 percent of the official sources of income (parallel market activity not included) with commerce being the second most important area of economic activity. Tourism has been designated a growth area and has increased in importance and as a source of income from 2.4 percent in 1981 to an estimated 5.0 percent today. It is significant to note that agriculture plays a relatively minor role in the regional economy (2-4 percent of income compared with about 18 percent for the country as a whole).

Clandestine commercial activity or the parallel market is a significant part of the regional economy but difficult to quantify. It is clear, however, from references in official documents as well as discussions with local government officials that a significant flow of goods comes across the border from Sebta to F'nideq without the payment of customs, duties, or import tax. Small appliances, clothing, and cosmetics make up the bulk of the illegal trade and are transported to major retail centers in Tétouan. It is estimated that 60 percent of those identified as employed in trade are involved in the "parallel market" (RdM/MHAT, 1984a: Economie, 21). A second part of the parallel market and potentially the larger part is the production and marketing of *cannabis* as hasish or kif which finds its way into the European market.

The commercial base of the economy, therefore, should not be considered permanent. In fact, future hopes for economic expansion revolve around tourism development. The residential building boom is geared toward high- and upper-middle income seasonal residents. However, as in other tourist markets in Morocco, tourism infrastructure has outstripped current demand

(EIU 1991): a significant number of vacancies are apparent, even in the summer season. There are, however, master plans for expansion of airport facilities at a number of cities in Morocco, including Tétouan, that would allow for handling increased numbers. A worldwide recession and uncertainty stemming from Moroccan political instability over the Western Sahara are the chief reasons for a short-term dip in tourist trade. In the longer term, Tétouan will face significant competition from other Moroccan resort areas, chiefly Tangier.

The net result of all these economic trends is that growth of Tétouan's economy is in the midst of a significant correction, following the expansion of the post-migration period in the mid-1980s. Current economic activity is based on trade and seasonal tourism; long-term growth of income and employment will depend not only on the growth of the national economy (for which the forecast is generally optimistic) but on productive domestic investment in tourism and successful competition against other Moroccan tourism regions.

2.5 POPULATION AND EMPLOYMENT

The population of urban Tétouan is currently estimated to be between 255,000 and 268,000 persons and for purposes of this study the figure of 268,000 is used (see Table 2.2). Available population data vary. Population projections to the year 2001 (REM/MHAT 1984a) of the urban development plan (SDAU) completed in 1981 proved to be higher than those of the census.

Another point of contention is the growth rate. Analysis of birth and mortality trends, verified by field surveys, led the SDAU to posit a constant natural growth rate of 3.0 percent. However the migration rate developed by SDAU (about 0.7 percent in 1991) is disputed by the agencies charged with developing water supply and sewerage systems. One could certainly argue the case for a lower immigration component of the growth rate, basing the claim on the economic outlook for Tétouan. On the other hand, the United Nations Mediterranean basin study (EMP) currently under way bases its work on an anticipated 3.4 percent average annual rate from 1987 to 2000.

For purposes of this study, a range of 3.4-2.8 percent has been used. Adding the population of the satellite towns brings the regional population to about 600,000. It would thus appear that it is reasonable to assume that the urban population of the Tétouan region increases by about 100,000 each decade. The next census is scheduled for 1992.

Recent data on the employment structure in Tétouan is limited; however, available data revealed significant unemployment in 1981 (35 percent against a national average of 9.6 percent) [RdM/MHAT 1984a]. Over the past ten years, unemployment in the province is reported to have remained high. Approximately 29 percent of the population was in the "economically active population (EAP)" category, generally representing that portion of the population between the ages of 15 to 65 that is ready, willing and able to work. Assuming the population of Tétouan to be approximately 250,000-270,000 places the number of EAP at 72,000-78,000.

A comparison of sectoral employment and employment growth for Morocco and Tétouan are shown in Table 2.3. Public administration and commerce account for more than 40 percent

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Table 2.2. Population and Population Projections for Urban Tétouan

Source	1981	1991	2001	2011
SDAU	213,025	255,250	304,100	426,100
DPRA Study Team	-	268,059	369,310	488,638
----------Growth Rate----------				
SDAU	4.4%	3.7%	3.6%	3.4%
DPRA Study Team	-	3.34%	3.07%	2.8%

Source: RDM/MHAT, 1984b.

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Table 2.1. Sources of Income as a Percent of Gross Domestic Product in Morocco and the Province of Tétouan

Source	Morocco 1990	Tétouan 1981 1/
	----------percent----------	
Public Administration	15.7	30.9
Commerce	20.2	22.2 2/
Manufacturing	17.5	12.5
Merchant/Financial Services	11.9	12.1
Buildings and Public Works	4.9	8.3
Transport & Communication	5.2	5.1
Tourism	0.5	2.4
Energy	3.4	2.3
Agriculture/Forestry/Fisheries	17.7	2.3
Other	-	1.6
Mining	3.4	0.1
Total	100.0	100.0

1/ 1990 data for Tétouan are not available.
2/ Parallel market not included.

Sources: EIU 1991, RdM/MHAT 1984a

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Table 2.3. Sectoral Employment and Employment Growth Morocco and Tétouan

	Morocco		Tétouan	
	Jobs by Sector 1981 (percent)	Rate of Growth 1960-1981 (percent)	Jobs by Sector 1981 (percent)	Rate of Growth 1960-1981 (percent)
Public Administration	8.6	+14.0	21.8	+13.1
Commerce	5.8	+3.1	*20.6	* +9.6
Manufacturing	13.9	+10.0	19.2	+5.1
Merchant/Financial Service	11.1	+15.0	16.1	+11.0
Buildings/Public Works	6.3	+27.6	11.6	+21.7
Transport/Communication	2.4	+4.1	4.6	0.0
Tourism	0.5	+4.9	3.1	+15.7
Mining and Energy	1.1	+9.2	1.8	+26.6
Agriculture/Forest/Fish	46.5	+3.5	1.1	-9.8
Other	3.7	-	-	-
Total:	100.0	-	100.0	-

* Parallel market not included, judged to employ close to twice the number employed by legitimate commerce (RdM/MI/PT 1991).

Sources: EIU 1991, RdM/MHAT 1984a

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of total employment in Tétouan compared with only 14 percent for Morocco as a whole. Local job growth has dramatically outstripped national job growth in both commerce and tourism. It is worth noting that the Ministry of Interior's 1990 monograph on the provincial economy estimated employment of 20,000 in the parallel market (almost twice the number employed by legal commercial concerns).

This range was adopted as a mid range of rates suggested by several governmental agencies. It considers the economic outlook of Tétouan and the decreasing growth rate observed in 1972 to 1982 period.

2.6 CURRENT LAND USE AND INFRASTRUCTURE

2.6.1 Land Use

The total surface area in the Tétouan study area is approximately 130,000 ha of which 3,000 ha are within Tétouan's municipal boundaries. The urbanized area of Martil is approximately 372 ha and that of M'diq, 143 ha. Most of the remaining area within the basin is in forestry, farming, or is used for extensive grazing. This is shown in Figure 2.3.

The spatial organization of Tétouan and its satellite Martil is shown in Figure 2.4. Within the municipal boundaries of Tétouan, 1450 ha are in housing (48%), 800 ha in public facilities (27%), and 550 ha in the road network (18%). Outside the municipal limits but within the city's zone of influence are another 3500 ha, which may someday be annexed to the city for the purpose of infrastructure provision. At present Tétouan consists of 14 neighborhoods, of which two are outside the municipal boundaries and one which is half within and half outside the boundaries. The arrows indicate the directions that growth is taking: Tétouan and Martil are growing toward each other, essentially on agricultural land.

The urban fabric has been shaped by several unique factors that are likely to continue if no countermeasures are taken:

> A linear configuration. The historic development of the city has been on an east-west axis, later extending toward the northeast and M'diq.
>
> A unique pole of attraction. Like most Moroccan cities, the Médina and the city center form Tétouan's center of gravity for commercial development. They represent the coexistence of traditional and modern, an important element of social cohesion.
>
> A belt of clandestine housing. Because of the limited absorptive capacity of the Médina and geographic constraints within the municipal boundaries, a belt of clandestine housing has developed along the flanks of Jbel Dersa that includes the neighborhoods of Samsa in the west, Dersa in the center, and Touelah in the northeast.

Figure 2.3

LAND USE IN THE TETOUAN BASIN

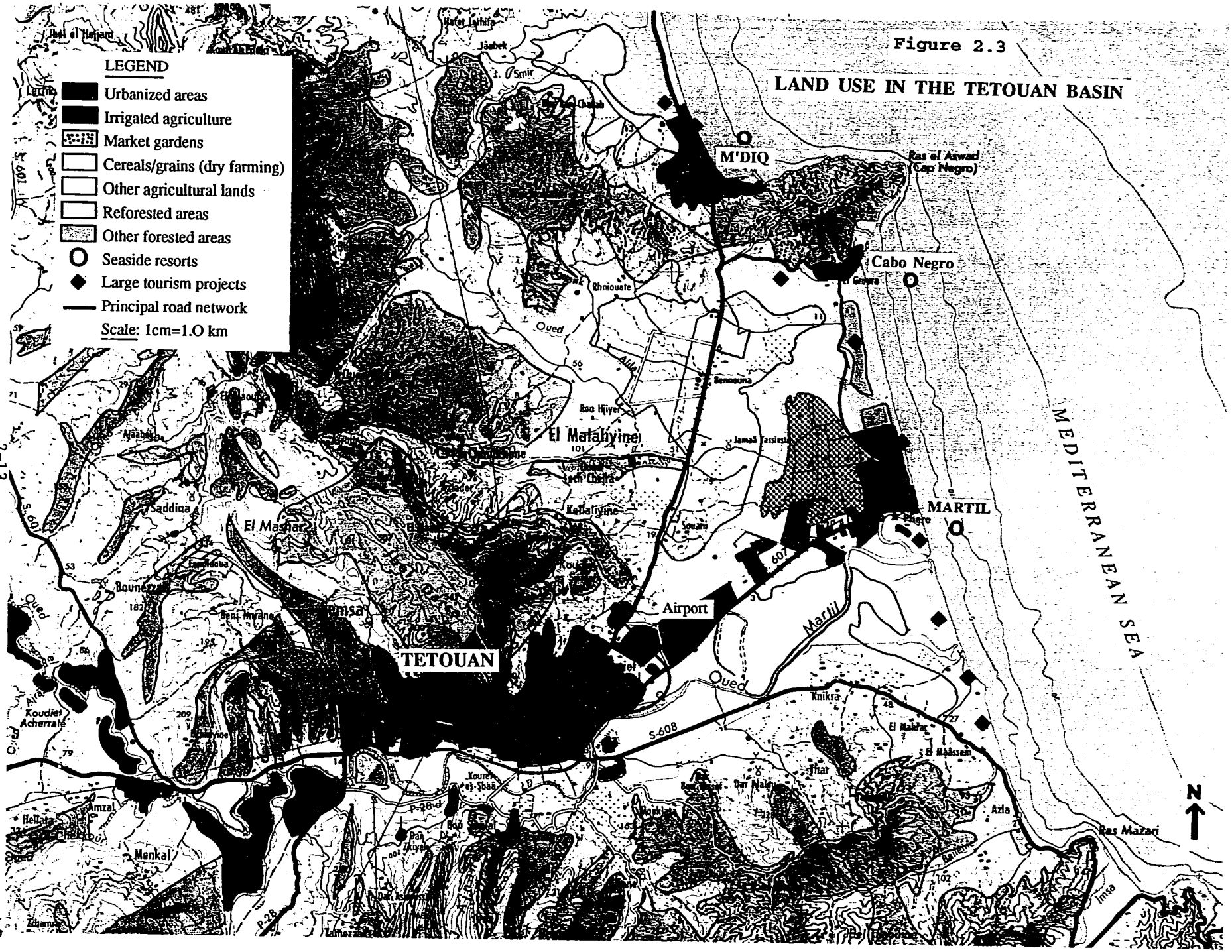
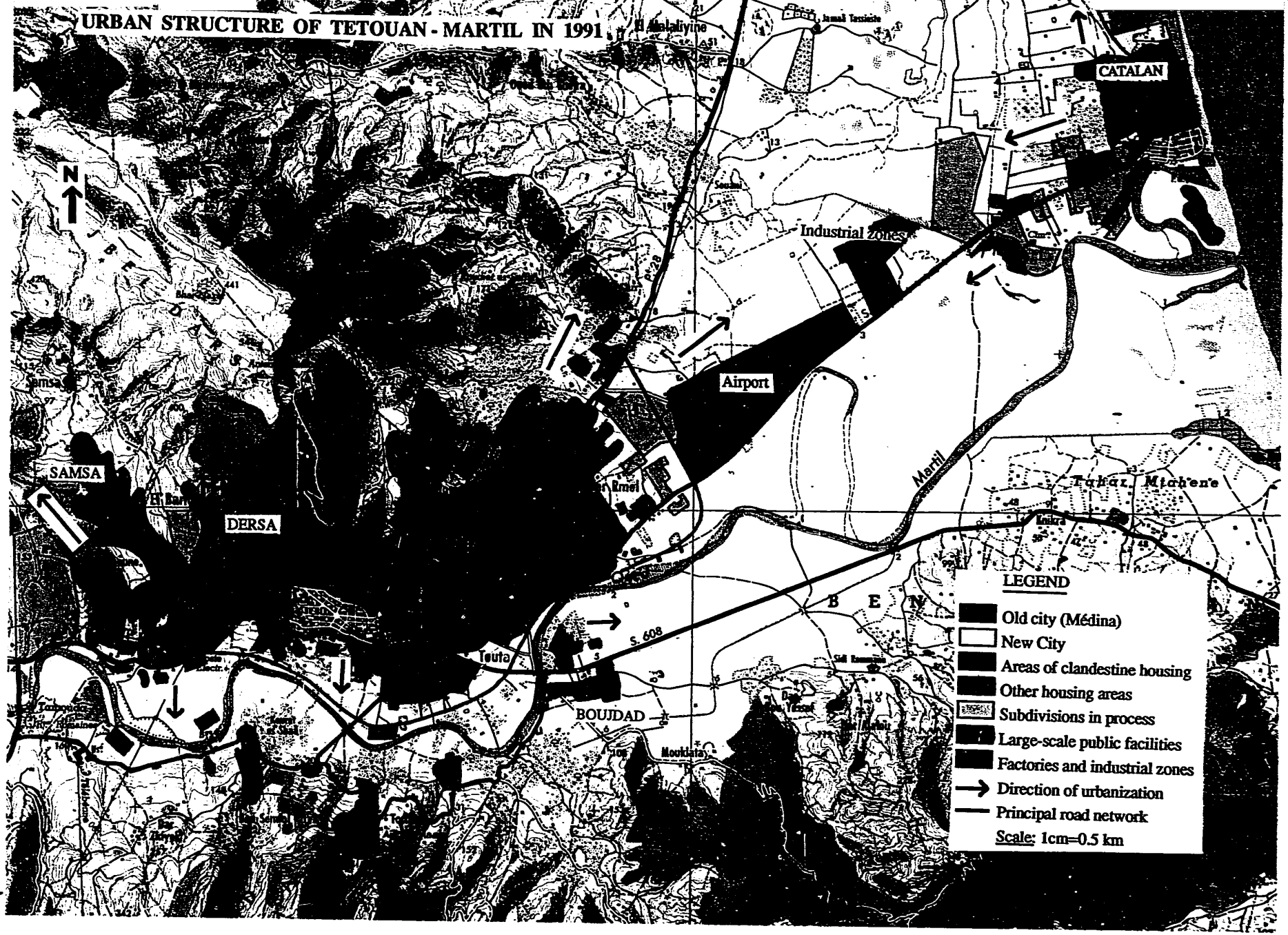


Figure 2.4

URBAN STRUCTURE OF TETOUAN - MARTIL IN 1991



Leapfrog development. The rest of the urban area is characterized by dispersed settlements located around facilities such as hospitals or educational institutes or within private or public subdivisions.

Peri-urban centers. There is a functional relationship between these areas and the city. Tétouan has an influence over their spatial development and these centers have a direct effect on the orientation of urban development. The most significant community development is east along the road to Sebta, followed by that along the route to Martil and finally along the route to Oued Laou. Boujdad, for example, a neighborhood on the southern bank of the Martil River, outside the municipal boundary but closer to the center of town than many neighborhoods within the city, is expected to increase by a factor of 19 (2600 to 50,000) within the next two decades.

2.6.2 Infrastructure

Tétouan is relatively well served by the standard components of urban environmental infrastructure, even though there are some problems. Almost 85 percent of its households are connected to the domestic water supply. There are currently pressure problems due to the shortage of water, and houses in the hilly areas are often without water despite their connections. This will be remedied when the Smir Dam comes on-line. In addition, the *Skoundo* (from the Spanish *segundo*), a secondary water source, comes from a spring and provides water to about 400 houses in the Médina. Unfortunately it is fed by contaminated groundwater so it is suitable only for fountains or gardens.

A similar situation holds for domestic wastewater. Approximately 70-75 percent of all households are connected to the sewerage system; the other 25-30 percent use cesspools. This situation will be corrected by the "Project de developpement urbain," the USAID-supported program to bring sewerage lines to Dersa-Samsa and build a treatment plant.

Providing electricity poses no problem. In 1987 there was a capacity for 64,000 hookups, far more than the number of households in the city. Figures on solid waste are quite disparate, but a conservative estimate is that the city produces 120 tons per day, approximately 400 grams per capita. Of this total, 70 percent is collected and hauled to a landfill.

2.7 TÉTOUAN IN THE FUTURE

In terms of land use, Tétouan will still be largely residential in 2011. An area on the right bank of the Martil is slated for further industrial development, but it is no larger than the existing industrial zone. Except for tourism development along the coast and planned expansion of airport facilities to handle increased tourism, there are no large-scale infrastructure projects proposed for the area that will require great amounts of land. Thus, the following sections evaluate land needs for uses chiefly related to habitation and its ancillary requirements such as roads, schools, and commercial areas.

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2.7.1 Development Constraints

The SDAU used three categories of constraints in the 1984 urban development plan: topography, soils, and the preservation of natural areas of environmental value (including agriculture).

Differing grades of slope found within the Tétouan municipal area will present varying degrees of difficulty for future development. Slopes exceeding 25 percent found on the flanks of mountains around Tétouan are natural limits to urbanization. Likewise slopes of no more than 3 percent as those found in the Martil basin present difficulties with drainage and waste disposal. Most of the area between 4 to 15 percent is already developed. Even though land with slopes between 15 and 25 percent is expensive to provide infrastructure to, these areas (Dersa, Samsa, and Touelah) are experiencing continued development.

Of the six principal soils found in the study area, only the high clay variety found in the wetlands areas of the Martil plain presents a constraint to development. Areas of environmental value designated for protection by the SDAU were zones of intensive agriculture, forests, zones subject to fluvial erosion, and picturesque sites.

2.7.2 Land Requirements for the Year 2011

Estimates of land needed for household construction are largely based on population projections. There are two sources of population projections for Tétouan, TUM and SDAU. TUM estimates a population of 505,000 by the year 2010, SDAU estimates a population of 426,100 by 2011. The TUM source projects that the population will grow by 109,600 between the years 1989 and 2000 and by an additional 140,000 by 2010; SDAU projects increases of 48,850 and 122,000 in roughly the same intervals (1991-2000 and 2001-2011) (see Tables 2.2 and 2.4). Based on the norm of 93.5m^2/person, this translates into estimated additional land requirements of 457 ha by 2001 and 1,140 ha by 2011 (SDAU) or 1,025 ha by 2000 and 1,309 ha by 2010 (TUM).

SDAU stated that there were 1,610 ha of developable land left in the study area. This figure eliminated those areas that fell into the development constraint categories outlined above. According to the tables, land appropriate for urbanization will be nearly filled by the year 2011 using SDAU projections or, using TUM projections, there will be a considerable shortfall.

2.7.3 Zones of Urban Extension

The following five zones are expected to be the principal areas of urban extension within the next decade:

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Samsa-Slaoui. This area grew greatly during the 1970s, even though access to it is difficult. Provision of sewerage and other facilities by USAID over the next few years will likely result in a population of about 100,000 by the turn of the century.

Eastern Zone. This consists of the neighborhoods of Touabel and Toualeh and areas along the road to Martil. By the year 2001, its population may reach 113,000. Infrastructure and other general purpose use will require about 330 ha in Touabel-Toualeh and 55 ha along the Martil road. The urbanization of this area will be sparked by the creation of a secondary commercial center, a new administrative center, and various public facilities such as a hospital and an urban park.

Table 2.4
Land Needed for Urbanization 1982-2010

	1982	1989	2000	2010
Population	203,500	255,400	365,000	505,000
Households	39,130	49,110	70,190	97,110
Urbanized area (ha)	974	1460	2485	3794
Additional area required/period	--	486	1025	1309

Source: TUM, "Appercu sur l'urbanisation de la ville de Tétouan 1982/2010" 1990

M'hannech-M'sallah. Located southeast of the city center, these areas will likely gain 15,000 inhabitants to reach a population of 31,000 in 2001. This sector, dominated by "habitat economique quadrillé" (see glossary) exercises a strong attraction for the middle class because of proximity to the city center.

Boujdad-Oued Laou. Because of its proximity to the city center and the absence of any constraints, this zone may have 50,000 inhabitants by 2001, contrasted with 2600 in 1981. It is now a low-income area characterized by very modest "habitat economique spontané" (see glossary) and a total lack of infrastructure. The proposed new industrial zone nearby should attract additional working class residents, and the development of a plan by the province of Tétouan to encourage middle-income housing may change the nature of this area.

Torreta-Kouret Sba. While not now within the municipal boundaries, these areas are already feeling the pressures of urban development from Tétouan. Torreta is a low-density area of villas for the middle-upper income residents; it will probably attract 3000 or 4000 additional residents. Kouret Sba, an area that has developed near the cement plant, will grow to 12,000 inhabitants.

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3.0 MAJOR FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The relationship between urban activities and the area's natural resources is complex and interconnected. Not only is there usually a direct causal link between an activity and a resource impact, but usually a variety of indirect or secondary impacts must be understood in order to rank the level of threat to the various resources. The natural resources themselves are linked in a dynamic ecological cycle so that the degradation of one resource affects not only the resource itself but also a wider resource base in and around the urban area.

3.1 DESCRIPTION OF ALL MAJOR FINDINGS ON RESOURCE IMPACTS/ACTIVITIES LINKAGES

Linkages: How One Human Activity Affects Many Resources:
Human activities are divided into chemical and physical categories. The first category includes effluent-generating activities that affect the quality of the receiving bodies: coastal and inland water bodies, lands and land covers (plantation forests, terrestrial biota). The physical category includes the activities that directly affect the physical integrity of each resource. Both categories are linked to urbanization activities of Tétouan and its satellite towns. Table 3.1 shows the major resource linkages. Table 3.2 summarizes in one matrix the overall effects of urbanization (considered as independent human activities) on the resource base.

Table 3.1. Linkages Among Resources

	Coast	Water Upstream	Water Downstream	Forest	Wetlands
Coast			X	X	X
Water upstream				X	
Water downstream	X	X			
Forest	X				
Wetlands	X	X	X		
Agriculture	X		X	X	
Fishery	X		X		X

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Table 3.2. General Matrix of Urbanization Effect on Natural Resources in Tétouan Dependent Variables: Resources

Independent Variables	Land Resources					Water Resources		
	Coastal Resources	Plantation Forest	Agri-cultural Lands	Terrestrial Vegetation	Wetlands	Water Upstream	Water Downstream	Fishery Resources
Human Activities								
Chemical								
Wastewater discharge	X	--	I	--	I	I	X	X
Landfill leachates	--	--	O	--	--	O	X	--
Industrial Wastes	--	--	O	--	--	O	X	O
Fertilizers	--	--	O	--	--	O	I	O
Irrigation with ww	--	--	I	--	--	O	--	--
Solid waste dumping	I	--	--	--	--	O	I	--
Physical								
Sand and gravel extraction	X	O	O	--	X	I	X	--
Encroachment[1]	X	O	I	--	X	--	O	--
Extraction for fuel wood	O	I	--	I	--	I	--	--
Harvest of non-wood produce	O	O	--	O	--	--	--	--
Grazing	X	I	--	X	--	O	--	--
Nettoyage[2]	O	X	--	O	--	O	--	--
Agricultural conversion	O	X	--	X	--	I	O	--
Groundwater overpumping	I	--	O	--	O	O	I	--
Hydraulic structure (Dams)	I	--	--	--	X	O	I	--

[1]Construction on beach, dunes.
[2]Cleaning for fire prevention

KEY
X = severe impact: substantial decline in 10-20 years
I = moderate impact: minor decline in 10-20 years
O = slight impact: decline over 100 years
-- = not applicable
* = on shell fish population only

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Impacts are described in categories labeled severe, moderate, or slight. A severe impact means substantial degradation of the quality and/or the quantity of the resource in 10 to 20 years; a moderate impact means only minor effect on the resource within the same time period; a slight impact means no effect before 100 years.

An overview of the matrix shows that physical activities have the most severe impacts on coastal resources, terrestrial biotic diversity, and plantation forests. Each of the physical activities affects more than one of the resources studied. For example, sand and gravel extraction has a severe impact on coastal resources and downstream waters, a moderate impact on upstream waters, and a slight impact on plantation forests and agricultural lands.

Considering activities in the chemical category, one single activity seems to cause more damage than several others combined. Domestic and industrial wastewater discharges are the only urban-related activities with severe consequences on water quality, terrestrial biota, and wetlands. The remaining chemical-related activities have only moderate, slight, or no effects on the resources.

Examples help to show how other human activities can affect several different resources.

Sand excavation causes primarily the loss of the beach and contributes to additional coastal erosion, but it also erodes the coastal forest, provokes saltwater intrusion into the coastal aquifer, and disturbs natural ecosystems along the coast. The economic implications on the future of the tourism industry in Tétouan are serious. In the same fashion, effluents generated in the Tétouan urban area severely pollute the receiving water bodies (Martil, Smir, and F'nideq Rivers, wetlands, and nearshore waters), converting them into dead or badly contaminated systems. This pollution degrades coastal water (thereby affecting its tourism value) and the nearshore artisinal shellfish fishery. It also contributes to significant changes in downstream wetland ecology, which can affect the local fishery and cause the proliferation of mosquitoes and other insects in the wetland.

Forest degradation also provokes a chain reaction: forests are cleared for farmlands and trees are cut to satisfy fuelwood needs in Tétouan. As a result, the forests' biological diversity is lost. In addition, erosion of the denuded soils leads to heavy siltation in downslope reservoirs. As a result, water supplies are threatened: 50 percent of the Nakhla reservoir capacity has been lost. The reservoir created by the Smir Dam also is expected to have a similar siltation problem. As more reservoirs fill with silt, more dams are built to increase reservoir capacity, because 70 percent of the region's freshwater supplies come from surface water sources. Unfortunately, each new dam reduces the flow of water downstream, and areas such as Lac Smir downstream of Smir Dam suffer significant changes in their ecology from reduced water flow.

Linkages: How Specific Resources are Affected by Various Human Activities:
In this section, each resource will be analyzed in terms of what activities affect its quantity or quality and by the severity of the impact. Table 3.2 illustrates that each resource is affected

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by several physical and chemical activities. For example, coastal resources are severely affected by four urban-related activities: wastewater discharge, sand and gravel extraction, development, encroachment, and grazing. Also, grazing, *nettoyage*, fuelwood cutting, and encroachment severely damage the terrestrial resources. Similarly, plantation forests and wetlands are being damaged by more than one activity in the physical category.

Discussed first will be the land resources including coastal resources, plantation forests, agricultural land, terrestrial vegetation and wetlands. Next will be a discussion of water resources including surface water and groundwater upstream and downstream of Tétouan city proper with all its waste discharges and a discussion of marine fisheries.

3.1.1 Land Resources

The coastal resources within the Tétouan Region of Influence:
Due to their economic and ecological importance and the number of significant impacts from the urbanization of Tétouan, coastal resources are the most severely threatened. These impacts come from the urbanization of Tétouan city proper and its satellite towns and also from the development of the coastal tourism complexes. In general, this development has had a severe impact on coastal dunes, forests, and beach habitats through physical destruction or degradation and increased coastal erosion.

Wastewater discharge from Tétouan is released into the Martil River and flows into the Mediterranean Sea just south of Martil town. This situation degrades coastal water quality by adding high amounts of organic matter, nutrients, and potential bacterial contamination. It also increases the human health risk for swimmers and other ocean recreation users. As the coastal waters become more contaminated, the tourism value of the beach and bathing waters fronting Martil town drops significantly. As a result of waste disposal, complaints of foul smelling coastal areas have been expressed by tourists already. In addition, high levels of nutrients flowing into the coastal waters from wastewater discharge and fertilizers can also cause an increase in the incidence of "red tide," a toxic contamination of shellfish. These toxic shellfish can cause severe human health problems, and therefore the situation is causing a decline in the shellfish fishery. The contribution of nutrients from fertilizers is small relative to wastewater discharge. Additional contamination of the shellfish can come from industrial wastes, though this is also contributing only slightly to the decline in the fishery relative to wastewater discharge. In the ecology of the Lac Smir wetland, another coastal resource discussed separately below, wastewater discharge from M'diq also is having a moderate impact.

Wastewater discharge problems result from the lack of adequate sewage treatment systems in Tétouan, Martil, and M'diq. This will only get worse as the urban population continues to grow in these areas. Cesspools handle almost all wastewater in Martil, and most of these are probably ineffective because of the high water table. More houses and more people will only make this situation worse. Consequently, the value of the area as a tourist destination may drop, and therefore the viability of this economic sector could weaken considerably. The only

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way this would change is if a sewage treatment system were built large enough to handle the entire metropolitan area's wastewater.

Sand and gravel extraction is a major threat to the integrity of the coastal area. It has caused significant loss of shoreline, coastal forests (both natural and plantation), and beaches. In general, it causes a severe increase in coastal erosion. The main reason sand and gravel is extracted is to provide for the burgeoning construction industry. Construction will continue to grow as population grows in the Tétouan area, though it may taper due to overbuilding. But in general, more people need more houses which require more sand for the concrete construction. If the rate of extraction continues, the beaches in front of the Alila River south to Martil town will diminish, until they reach the depleted state of the beach fronting Azla to the south, which is now little more than a small pebble beach. The coastal plantation forest north of Martil is the most severely threatened of all forest land experiencing sand extraction. In addition, sand extraction may cause saltwater intrusion into the coastal aquifer.

Encroachment of structures on the coastal beaches, dunes, and forests causes significant problems because it interrupts the natural movement of sand, resulting in the loss of the beach and shoreline. This construction is mostly for the tourism industry, and the industry probably will continue to grow as the tourism industry grows. More and more people from Morocco, Spain, and France vacation in the area, and facilities will continue to be built to serve them. There may be a slowdown in construction to allow the facilities' occupancy rates to improve. There also may be a slowdown if coastal environmental conditions continue to worsen.

Livestock graze along the coastal area in the forests, along the estuaries, and even among the coastal dunes. This results in the loss of the dune habitat consisting of dune grasses and associated animals and of the forest habitat consisting of either eucalyptus or coniferous forests and other associated flora and fauna. Without the grasses to hold the sand, the dunes will be eroded and contribute significantly to an increase in coastal erosion and loss of beaches. The driving force behind this grazing activity is the fact that traditionally, people graze their animals on any available land, regardless of whether they own it. There is little public awareness of how to manage grazing to prevent erosion, because overgrazed land is a common sight. This overgrazing problem in the coastal area will not improve unless there is improved management of grazing or fences to keep the animals away from fragile coastal areas.

Solid waste dumping occurs along the river beds, in the estuaries, along the beaches, and in the coastal forests of the area. This problem is especially bad during the summer months with the high influx of Moroccan tourists camping along the beach area, without sufficient solid waste collection programs and facilities. This dumping has a significant detrimental impact on the visual quality of the area and somewhat diminishes the quality of the wetland habitat of the estuaries. It also reduces the tourism value of the coastal area. This condition will worsen as both the resident and tourist populations increase.

Groundwater pumping in the coastal area can have a moderate impact on the groundwater quality if too much is pumped out and seawater can intrude into the freshwater aquifer. Freshwater floats on the more dense seawater, but if it is reduced at a rate greater than the replenishment rate, the groundwater becomes increasingly saline. This increase in minerals in the groundwater also may be due to the large number of septic tanks in Martil; to the natural mechanism of aquifer discharge and possibly recharge from the Martil River during which some seawater intrusion may occur; or possibly, to coastal erosion from sand excavation. This overpumping is a result of continued agricultural and urban development in the coastal area, which probably will continue over the next 10-20 years.

Dams and dikes (hydraulic structures) have a moderate impact on coastal resources. Smir Dam reduces the freshwater input into the Lac Smir coastal wetland area (see Section 4.4, Biotic Resources/Biodiversity) and threatens its biological integrity. Blocking this water flow has reduced the water level in Lac Smir, which exposes and kills a number of different flora in the area. This is exacerbated by a dike built across the connection of Lac Smir and the Mediterranean Sea, which prevents salt water from replenishing the brackishwater marsh and prevents any organism from entering the marsh. Normally, juvenile fish and crustaceans grow up in the brackishwater lake, eating mosquito larvae and other organisms. The Smir Dam is needed for drinking water resources for the Tétouan metropolitan area and will limit freshwater flow to Lac Smir for decades to come. The dike at the sea connection, however, is a much more temporary structure. The problem can be solved relatively easily within ten years. Allowing a certain amount of freshwater flow to keep the water level normal and removing the dike to allow seawater and marine organisms to enter the marsh will reduce any negative impacts of the dam.

Finally, extraction of fuelwood, harvest of brush and scrub cover, *nettoyage*, and agricultural conversion all contribute slightly to further impacts on the coastal forest land and areas of the Martil River flood plain.

Plantation Forests:
In general, the plantation forests' productivity is declining due to *nettoyage* (literally cleaning up the undergrowth), conversion to agricultural land, overharvesting of wood products, and grazing. Lesser impacts are felt from sand and gravel extraction, encroachment, and harvest of non-wood produce.

Nettoyage is the intentional and government-subsidized "cleaning" of the forest floor. All natural regeneration is thwarted in this manner in order to prevent forest fires and generate employment opportunities. *Nettoyage* is evident in all plantation forests, especially along major roads where careless smokers may start fires by discarding cigarettes from passing cars. No change is expected in this situation. *Nettoyage* is causing a severe impact on the plantation forests because the trees are not able to reproduce and, by virtue of monocultural planting, are particularly vulnerable to disease, fire, and the combined degradation from fuelwood collection and grazing.

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Conversion of forests to agricultural land is occurring at an alarming rate in all plantation forests. This is causing severe impacts given the permanence and extent of conversion activity. This conversion involves the physical removal of the natural vegetation. It is related both to small-scale agriculture and to the clandestine cultivation of *Cannabis* for hashish and kif production.

Extraction for fuelwood has a moderate impact on plantation forests based on the supply and demand model described in Section 4.2, Plantation Forests. Given reforestation trends and conservative assumptions on new productive forests coming on line, actual supply remains above the required supply, given urban demand until 2011. Degradation from overharvesting is apparent in all plantation forests to some extent but most apparent in forests just west of M'diq, known as the Zem Zem plantation. This fuelwood is consumed by *hamams* (public baths), bakeries, brick factories, and limestone kilns.

Grazing by cattle, sheep, and goats is permitted, in fact encouraged, throughout the plantations, resulting in the consumption and trampling of seedlings. This directly endangers the replication of the forest. Given the time horizons for plantation forest regeneration, and the rate at which animals are consuming these shoots, the effect will be major in the intermediate term as the current stands of *Pinus halipensis* will die off and nothing will be left to replace it. Also, despite the current replanting campaign, the lack of current grazing restrictions will doom a considerable portion of these new trees unless they are inaccessible due to topography (a condition which obviously applies to a very small percentage of new plantations).

Sand and gravel extraction affects plantation forests slightly by excavating the hillsides on which the forests are standing. As discussed above under coastal resources, the most threatened of plantation forests is the coastal stand of eucalyptus north of Martil. Though the impact will continue over time, it will not be severe within 20 years. Moreover, the plantation forests are far more threatened by other human activities.

Encroachment of urban housing on plantation forests is slight and does not threaten the integrity of the resource over the medium term--only in the long term. This encroachment is visible in the Dersa Samsa area and the forests above, and to a lesser extent around Cabo Negro with the spread of M'diq. The problem may increase given the pressure to build on ever steeper hillsides which tend to be the only type forested.

Harvest of non-wood produce, such as cork, myrtle, and briar, occurs in all plantation forests but is concentrated in communal forests on the outskirts of Tétouan. This harvest has a slight impact on plantation forests because, although there is a noticeable impact, no decline is anticipated in the forest due directly to the harvest of non-timber products.

Agricultural Land:
The overall impact of human activities on agricultural land is slight given the resource's low baseline productivity. The greatest impact of conversion and degradation of farm land is to the cultural heritage and lifestyle of the area, not to the productivity of the land.

Activities that have a moderate effect on agricultural land include direct conversion of land to urban development, irrigation using water contaminated by waste water and, to a lesser extent, industrial wastes and other materials. Sand and gravel extraction and groundwater overpumping also are slightly affecting agricultural land.

Encroachment of housing construction into agricultural land will continue to reduce the amount of land available for farming and have a moderate impact over the 10-20 year period. This may increase, given the associated increased value of the land once it is developed. This encroachment is evident along the road between Tétouan and Martil especially, and also some across the river from Dersa Samsa. It can be argued that this conversion is probably a net positive, given the added land value.

Irrigation using the Martil River is practiced on about 30 hectares of cropland downstream of Tétouan. Some of the crops grown here are food crops. The Martil River is contaminated with wastewater and, to a lesser extent, by landfill leachates, industrial wastes, and other materials. This impact is considered moderate because only 30 ha are being irrigated with this water, and this amount is not expected to change significantly. Nonetheless, food crops from this area could be contaminated with bacteria that could cause cholera. Unofficial reports from Tétouan indicate that cholera has been a problem in the past. The golf course at Cabo Negro uses treated wastewater for its irrigation, but this is much safer for the environment than untreated wastewater and presents little risk to human health. In fact it is a useful way to reduce dependence on potable water for turf.

Sand and gravel extraction is evident on agricultural lands but has a slight impact considering the low productivity of the land. However, left unregulated over the long term, this activity could result in aesthetic and physical damage given the pockmarks left behind in the terrain and the land's inability to recover. This could lead to exposing the water table to even more pollutants, given its proximity to the land surface. Sand and gravel extraction probably will continue considering that even when the construction slows down due to overbuilding, simultaneously other sand sources, such as beaches, will be regulated or priced out of the market, thereby forcing collectors to agricultural lands.

Overpumping of groundwater, as discussed above, can result in salt water intrusion into the coastal aquifer. If the groundwater used for irrigation by the coastal farmers becomes more saline, there may be problems with crop growth and productivity. However, this is considered only a slight impact because the effect is gradual and this low-lying agricultural land along the coast and in the floodplain of the Martil River is not very productive.

Terrestrial Vegetation:
Very little remains of the natural forest vegetation of Morocco. The natural forest in the Tétouan area is being severely degraded primarily by grazing and agricultural conversion and secondarily by extraction of fuelwood, harvesting of cork, briar and other plants, and *nettoyage*.

Intensive grazing by livestock on the ground level vegetation prevents natural regeneration. *Nettoyage* activities also prevent regeneration by clearing out undergrowth and the necessary mulch for new growth. This is compounded by the fact that replanting efforts concentrate on rapidly growing species, neglecting native species.

Conversion of the natural forest land to agriculture involves the physical removal of the natural vegetation. This is related both to small-scale agriculture and to the cultivation of *Cannabis*.

The natural forest vegetation in the immediate Tétouan area already is severely degraded. The only remaining areas of natural vegetation are the forests of Zem Zem and Cabo Negro. The need for fuel, natural products, and fodder is driving this degradation, and it will only increase as population increases. Land clearing for agricultural conversion is projected to eliminate half of the remaining forest within five years. Because grazing prevents natural regeneration, the natural flora can be expected to disappear entirely.

Wetlands:
Lac Smir, the wetland located at Restinga-Smir, is the most important wetland in the region. A wide variety of local and migratory birds utilize the area, which has a diverse ecology of flora and fauna. It is being severely threatened by two main factors: restriction of fresh and salt water supply by hydraulic structures (the Smir Dam and a coastal dike) and encroachment of agriculture and tourism development. In addition, wastewater discharge is degrading the water quality. Groundwater pumping also may contribute slightly to changes in water salinity, although the effect would be minute compared to the effect of the dam and dike. The other wetlands in the area are already severely degraded (e.g., along the Martil River) or much less extensive.

Construction of the Smir Dam has eliminated the flow of freshwater into the wetland. Construction of a coastal dike between the wetland and the marina at the Kabila tourist complex has eliminated the supply of saltwater to the wetland and has prevented use of the wetland by larval fish and crustaceans. This has reduced the nursery habitat for the coastal marine fish, a food source for the local population. Loss of the marine biota already is apparent. Because there are no small fish to eat insect larvae in Lac Smir, large mosquito populations develop. This has prompted the extensive use of pesticides, further degrading water quality. Major shifts in the diversity of plant species also are expected in five to ten years.

The freshwater situation may actually improve moderately in the future, after the Smir reservoir is completely filled. Some freshwater flow may be restored, if not all the water is needed for urban purposes.

Progressive encroachment by tourist development near the coast and by farming inland has reduced the area of the Lac Smir wetland by about 20 percent in the past five years. The pressure from tourism facilities is expected to continue, though perhaps at a lesser rate of growth.

Wastewater discharge from a sewage treatment plant at M'diq continues to flow into the wetland. This facility already is trying to process more wastewater than it was designed to process. The wastewater discharge certainly will affect the water quality of the wetland over the next 10-20 years, thereby changing its ecology. This is also discussed below in the water quality section. Toxic effects on wildlife typically become apparent in two decades. Changes in migratory patterns and population density parallel the deterioration of biotic conditions.

3.1.2 Water Resources

Water downstream of Tétouan:
The Martil River downstream of the pollutant discharge points from the Tétouan urban area already is severely degraded. The pollution comes from wastewater discharge, landfill leachates, and industrial wastes, and to a lesser extent, from fertilizers and solid waste dumping. The pollutant load in its lower reaches far exceeds the river's natural capability for self purification. As population grows, the pollution front will move farther upstream, thereby potentially contaminating additional drinking water intake points. Already the level of bacterial contamination (500 times higher than U.S. standards) of the Martil River has caused the closure of one river intake, which had supplied the city with 200 l/sec of potable water. In summer time, the conditions are even more severe. All of the water samples for the Martil River had microbial indicators higher than acceptable standards. Also, levels of fecal contamination of the beach area indicate that 100 percent of the seawater samples taken near Martil beach had microbial levels exceeding U.S. standards for bathing waters. All of this contamination not only significantly degrades the ecology of the river and coastal water into which it empties, it also presents a potentially significant public health risk. More than 30 ha of agricultural land growing food crops in the lower Martil River plain use the Martil River water for irrigation. The potential for food contamination is significant.

Other nonpoint sources of pollution also are suspected such as leachates from the city's landfills into the groundwater and river. This might cause severe impacts on the quality of surface water as well as on the groundwater pumping sites and wells downstream. More than 50 percent of the public groundwater supply comes from pumping sites within 1200m of the two municipal landfills. One site already has recorded levels of iron and manganese 60 times higher than U.S. standards.

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The groundwater located downstream of Tétouan is being contaminated by a number of sources: the Martil River itself; widespread prevalence of cesspools in areas with a high water table; and possibly overpumping of wells causing salt water intrusion. All wells around the lowest section of the Martil River and at the coastal zone in the Smir aquifer have levels of contamination significantly higher than U.S. standards. The Smir aquifer is experiencing intrusion by effluents from the overloaded wastewater treatment plan in M'diq.

Several physical activities also impact water downstream. Sand and gravel extraction is having a severe impact on water quality. The increased turbidity and resuspending of the sediments, some of which may be contaminated, contribute to water quality degradation. In addition, extraction activities can cause severe problems with nearshore water quality and loss of riverbank and estuary habitat. Groundwater overpumping can cause some increase in salinity in the groundwater due to saltwater intrusion into the aquifer. If the water from a coastal well is being drawn out faster than it can be recharged, the seawater can move higher in the water table. Hydraulic structures are having a moderate impact on downstream waters primarily by reducing the flow of rivers below the dams. This can reduce the quality of the water and the ecology by lowering the level of the stream and estuary. Encroachment into downstream waters, such as the causeway blocking the Martil River, can have an impact on downstream water quality. This engineered barrier prevents the Martil River from meandering. It also makes the dead arm of the Martil River permanently stagnant. The water quality in this dead arm already was bad, and it is worse as a stagnant open cesspool. Agricultural conversion also is causing a slight impact on downstream water resources in areas where river banks are being filled farther into the river for agricultural land. However, this is not common.

Water Upstream:
The Nakhla Dam, constructed in the late 1950s, and the Smir Dam, expected to be operational in 1992, created the two major water reservoirs in the region. Because these reservoirs are upstream of any pollution sources, the water quality for both is relatively good. However, each reservoir is experiencing siltation. This comes as a result of clearing of forest for fuel and, to a lesser extent, agriculture.

In the absence of a comprehensive watershed management plan, the watershed forest for both reservoirs is being degraded. Clearcutting practices leave the soil unprotected from rains, causing significant soil erosion and siltation in the receiving reservoirs. About 50 percent of the regulated volume of Nakhla Dam has been lost to siltation, and the new Smir Dam is expected to lose 180,000 m^3/year of its 34 Mm^3 volume.

Marine Fisheries:
The fisheries resources exploited by the fishermen of the Tétouan area consist primarily of two sectors: the large tuna fishery and the stocks of sardines and other small pelagic (deepwater) or demersal (bottom-dwelling) fish. There also is a small artisinal fishery for shellfish off Martil, using small boats with simple equipment.

Tétouan's urbanization only slightly impacts the overall fishery resources utilized by the fishermen of M'diq, Martil, and Azla. Most of the fisheries appear to be operating at a sustainable level, and any depletion is a result of overfishing rather than pollution. However, at a much more local level, two small fisheries are experiencing severe impacts: the shellfish habitat off Martil, south to the Laou River, and the shrimp nursery habitat in Lac Smir. These impacts are direct results of wastewater discharge into the Martil River and the change in ecology in Lac Smir due to the blockage of freshwater and saltwater by the dam and dike.

Wastewater discharge into the Martil River and leaching from cesspools in Martil contribute high levels of nutrients, some heavy metals, and bacterial contamination to the nearshore waters. Nutrients can exacerbate the problem of red tide, a phenomenon that renders shellfish toxic for humans. Recent studies found toxic shellfish in waters from Martil River south to the Laou River. In addition, heavy metals and bacteria in the sediment or water can be accumulated in the shellfish, because they are filter feeders. Both of these problems increase the risk to public health.

As discussed above concerning the wetland, the changes in nursery habitat caused by the Smir Dam, encroachment, and wastewater discharge can reduce populations of shrimp and other marine species that are of local value.

3.2 CONCLUSIONS AND PROJECTIONS BASED ON FINDINGS

Direct construction, sand excavation on the coastal dunes and beaches, and pollution related to urbanization pose the most severe and immediate threats to coastal resources. If construction without adequate setback from the shoreline continues, along with sand excavation and livestock grazing of the coastal dunes and forest, the coastal resources will be degraded to the point where few visitors will wish to return. Both the ecological integrity and value to tourism will decline dramatically within a decade. A tourism-based economy is a fragile one. Tourism depends on a clean and beautiful environment. Once that is spoiled, the ecology and the visitors' confidence and desire to return are extremely difficult to restore.

Another severe problem is that the Martil River and the groundwaters downstream of Tétouan are extremely polluted, and time for effective correction is running out quickly given the resource's utility and effect on other resources.

Finally, the biological diversity of the terrestrial fauna is being dramatically reduced by uncontrolled use of the forests. What little remains of this habitat is virtually unprotected.

Also seriously threatened, although perhaps less urgently than the resources discussed above, are the Lac Smir wetland, the potable water supply, and the plantation forests. The diminished water supply to Lac Smir already is causing the lake to shrink and is threatening its biota. Particularly in view of the uniqueness of the region, this wetland should not be neglected. Tétouan's potable water supply is clearly limited; it will probably become

critically low earlier than the current projections indicate. Although much plantation forest remains, the forest resource is being mined unsustainably for fuelwood. If measures are not taken, the forests will cease to be able to supply fundamental resources within the medium term on the scale required by urban dwellers.

Other problems are less urgent. Local activities do not pose a serious threat to the productivity or quantity of agricultural lands or fisheries. Agricultural land seems actually to be increasing, albeit at the expense of the forest. Unfortunately, marginal productivity is on the decline. Finally, the terrestrial and freshwater fauna are already so seriously degraded that further development is unlikely to make matters worse.

3.3 BRIEF RECOMMENDATIONS FOR REMEDIATION AND POSSIBLE MANAGEMENT OF RESOURCE IMPACTS

The team studied several recommendations concerning the environmental impacts of urbanization in Tétouan that were made in government reports or discussed with various officials. Based on this study's findings, the team recommends the following:

Coastal Resources:

* Expand the current regional tourism development plan to include management measures related to coastal resources protection, including coastal and marine protected areas, beach protection, open space, public recreation areas, wastewater treatment, grazing restrictions, and alternative tourism development areas;

* Establish protected areas for nature tourism and open space in the Cabo Negro forest, the eucalyptus forest between Martil and the Alila River, the Alila River estuary, Lac Smir, Ras Mazari, and Ras Timezourga (RdM/MHAT, 1984a (Document 12);

* Strictly enforce the prohibition of sand excavation on beaches and dunes while substituting crushed sand from inland sources;

* Require a 100m construction setback from the shoreline (high reach of the high annual wave), or at least prohibit construction behind the coastal dunes, (RdM/MI/SG, 1987, PNUE, 1991); and

* Develop tourism projects in the mountains and other inland areas to take the pressure off the coast.

Establishing protected areas and a conservation regime represents a very low-cost proposition for Tétouan. The 100-meter setback could increase capital development costs insofar as buildings may need to be taller to take advantage of ocean views and may require slightly more complex access systems to the beach to protect dunes. Similarly, enforcement of the beachsand excavation ban would require a small increase in the marginal cost of building for construction companies forced to pay licensing fees and costs of trucking sand and gravel

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from legitimate inland areas. If sandstone conversion becomes the major source of construction material in the future (and this is a possibility), then the increased marginal costs could be substantial. A concerted effort by public authorities to prevent clandestine mining would ensure that such costs were distributed throughout the industry and would prevent any one company from gaining a competitive edge.

The major cost of such a scheme would arise from enforcement of the 100-meter setback along the coast between M'diq and F'nideq where the highway runs within 100 meters of the beach. In these areas, the ban would effectively remove the real estate from potential development, reducing its financial value and making it susceptible to intrusions of other kinds (e.g., more extensive grazing). The cost of taking off line a potentially valuable stretch of land could be mitigated somewhat by selling specific sections of the beach to private resorts for beachgoers while placing a lien on development.

A comprehensive coastal water quality and marine life monitoring program should be developed and implemented for the Tétouan coast. This should include monitoring for "red tide" (the toxic shellfish problem) and characterizing the plume from the Martil River. (A suggested program is described in Appendix F.) Using university expertise to design and launch such a program would minimize start-up costs; such a program need not require a substantial capital investment beyond outfitting existing laboratories with the equipment necessary to run the program. Mustering the political will to ensure success of both a program and a new conservation regime is the most important challenge to those realizing the need for investment in coastal resources.

Fisheries:

* Monitor the presence of toxic shellfish in the area and determine trends. Establish a public education campaign regarding this problem.

* Evaluate the management, enforcement, and extension programs for the local fishery and develop recommendations for improvement.

Biological Diversity:

* Take measures to retard the decline of the natural forests. The most obvious steps are to delimit the tracts of land having the best remains of original forest (e.g., Jbel Zem Zem, Cabo Negro) and to prevent grazing of livestock, land clearing, wood cutting, and other activities that degrade the forest environment.

* Ensure that Lac Smir has an adequate supply of freshwater (coming from the Smir River) and an adequate connection to the sea (perhaps by creating a channel around the existing marina).

* Attempt to protect riverbanks from development, sand excavation, and other activities that physically disturb them.

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Such measures would incur only the cost of enforcement by public agencies. Even an alternate channel from Lac Smir to the sea need not command a high capital cost and could be financed through a temporary increase in taxes payable by the relevant resorts, without interfering in the special investment code pertaining to tourism developers.

Water Resources:

* To salvage the Martil River, the discharge of domestic and industrial effluents should be stopped.

This is feasible only if an integrated plan of sewage collection and treatment is implemented. Such a plan is presently under way for the city of Tétouan, through a USAID project. The present plan, however, does not include the neighborhoods of Torreta, Kouret Sba, and Boujdad on the right bank of the Martil. In 2001, the three areas and a proposed industrial zone will generate a significant organic pollution load (equivalent to the load generated by 75,000 persons) that will go untreated into the river. Therefore, it is desirable to include in the sewage master plan provisions for covering those sources that might otherwise offset the benefit of the proposed wastewater treatment plant. As major contributors to the pollution load, industries should be made a part of the solution. The penalty or fee system should be proportional to the individual contribution to the total load. This can only be implemented once the proposed municipal treatment plan becomes operational. Otherwise, it is inconceivable that the community will pay for the industrially generated wastes. The team did not have access to the data required to estimate the costs of including the three additional neighborhoods in the sewage master plan. Clearly, however, an investment now would offset the need for future piecemeal infrastructural development and reduce future costs of treatment of the Martil River.

* Establish comprehensive spatial and temporal water quality monitoring programs for upstream and downstream resources, including coastal waters as mentioned above.

Due to the high cost associated with the analysis of different parameters, the program should focus only on the major chemical or biological constituent of concern, resulting in significant cost savings. Indiscriminate and inconsistent monitoring, as is presently the case, yields an unclear picture of the situation.

* Restrict the use of untreated wastewater for irrigation in the Martil plain.

Agriculture officials should intervene with the farmers to demonstrate the health risks associated with the practice. Organic amendments and mineral fertilizers should be distributed to the farmers as incentives to abandon their irrigation method.

* Perform studies needed for a comprehensive wastewater management plan for Tétouan's satellite areas.

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The technical feasibility of the present sewerage plan in the town of Martil needs to be reassessed. The difficult hydrogeological conditions in that area, including a high water table and limited drainage, might decrease the efficiency of the sewer material used. A more detailed study is needed. Encasing the sewers in concrete might give additional protection and watertightness to the system.

* Implement plans for expanding the M'diq wastewater treatment plant.

Immediate technical support for wastewater treatment technology is needed within the agency (RDE) in charge of the sector. Operations at the existing plant might be significantly improved if such assistance were provided. The costs of installing an adequate treatment system are high and current plans are to finance the construction through user fees. What is not clear is the adequacy of collection systems and the extent to which financing will be made available.

* Improve the municipal landfills to reduce their impact on water quality.

The municipal landfills in Tétouan and its satellite towns are technically hazardous, unsanitary, and uncontrolled dump areas located above important groundwater resources. In addition to an urgent need for new engineered sites, immediate attention should be given to mitigating the impact of the present sites on the underlying aquifers. The aquifers represent a valuable water resource, as surface waters alone cannot satisfy the region's needs in the long run. Immediate mitigation steps are detailed in Appendix C-6. The potential cost of remedying the situation is extremely high. The benefits of such an investment are difficult to calculate; the costs include the costs of doing nothing and suffering increased health risks, development costs of alternative water capture technologies, and costs of continued resource degradation. Such a potentially high capital investment requires much further study to identify the costs and benefits involved.

* Initiate a watershed management plan to minimize soil erosion and decrease siltation rates in the dams.

Although detailed recommendations are beyond the scope of the project, it is necessary to undertake a long-term study to accurately quantify the problem and link it to on-site agricultural practices in the watersheds. Only then would it be possible to undertake mitigation actions based on specific changes in agricultural practices. An incentive program oriented toward the farmers, coupled with a comprehensive reforestation plan, which could even include fruit producing trees as part of the incentive, should then be implemented.

Forests:

* Use the World Bank delimitation project to assess the total number of plantations, species composition, variable rates of growth, extent of degradation, and rate of degradation.

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* Eliminate the state's subsidization of forest degradation by giving control over market prices to the communes. Allow the communes to operate on a cost recovery system in order to finance the labor and input costs of continuous reforestation through the producer price of wood products.

* Provide tax incentives to offset the capital cost of industrial conversion from wood toward alternative sources of energy (toward the natural gas that will become available in the mid-1990s via the Algeria/Morocco/EC pipeline). Target briqueteries, limekilns, and *hamams*; let the bakers continue to bake with wood fires.

* Alter the employment function of the forest from *nettoyage* toward reforestation of unforested areas, relying on public education and roadside clearing to avoid forest fires.

Agricultural Land:

* Identify the costs of surveying open land and policing frequently mined areas and compare them with the subsidization and social costs of mining for construction materials.

The open access to former agricultural lands provided to the cement company and construction firms represents an implicit government subsidization of those private concerns, because this free public good is harnessed for private profit. The extent of mining is not known but is suspected to be very high given the demand for construction materials in the region.

Government Resource Management:

* Conduct an institutional analysis to determine and evaluate the governmental powers and ways to maintain and enforce effectively the development controls so that infrastructure can be provided within the context of development. This analysis must include looking at the gaps or overlaps in jurisdiction.

Economic:

* Redirect toward comprehensive long-term development the existing urban planning and development sector.

The costs of establishing legal regimes and research programs are relatively small compared to the long-term infrastructural and aesthetic costs of permitting uncontrolled development to continue. An extensive public sector dedicated to urban planning and development already exists and needs to be redirected to better incorporate the current trends of settlement in the region, rather than planning for future development in an information vacuum. This arm of regional government cannot plan effectively without a clearly articulated and enforceable legal regime of permits for construction. Significant benefits, apart from those resulting from better organized development, can be captured by increasing the cooperation and efficiency with which different governmental departments interact on issues of urbanization, allocation, and consumption of natural resources.

RESOURCE SPECIFIC TECHNICAL SUPPLEMENT

4.0 LAND RESOURCES

4.1 COASTAL RESOURCES

For the purposes of this report, the coastal zone is defined as the strip of coastal land with an average width of about 500 meters including all the beaches, dunes, estuaries, and areas experiencing a marine influence, plus the nearshore waters going out to a depth of about 20 meters. This would include waters that are commonly used for marine recreation. An overview of the coastal resources, human activity, and measurable impacts is provided in Table 4.1.

4.1.1 Quantity and Quality of Coastal Resources

In 1967, the Moroccan government established several *Zones d'Aménagement Prioritires* (ZAP) to stimulate tourism development. Among them was the northwestern Moroccan coast extending nearly 70 km from Ras Mazari in the south to Sebta in the north. The mild summer climate, relatively calm seas, shallow waters, and wide sandy beaches of this coast are very attractive to Moroccans and foreigners alike. The urbanization of Tétouan affects this entire area and is affected by it in a number of ways. Because this area has been planned and is to be managed as a whole tourism development zone, this report also will address the entire area (RdM/MI/SG, 1987).

The coastal area immediately adjacent to the Tétouan metropolitan area is bounded by Ras Mazari in the south and Cabo Negro (a/k/a Ras el Aswad) in the north. This coastline is characterized by expansive fine white sand beaches 10-400 meters wide with associated dunes and small patches of coastal forests. In terms of size and quality of sand, the best beach is at Cabo Negro. The beach near Azla has been eroded, is narrow and is mostly pebbles. Coastal forests are located just north of Martil in the Alila River area (mostly planted eucalyptus) and on Cabo Negro and Ras Mazari, which host mostly degraded coniferous forests on the ridges and farther inland. North around the rocky headland of Cabo Negro is the fishing town of M'diq. From M'diq north to Sebta, the coast is characterized by a wide fine white sand beach with some remaining dunes with associated microenvironments.

Along this coast, the current flows primarily from the north to the south (PNUE, 1991). Annual input of sediment from the rivers in the area to the coast is estimated at 400,000 m^3, with an unknown amount brought in from deeper waters of the sea. In their natural undisturbed state, the beaches are stable with some erosion and accretion during the year.

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Table 4.1 Coastal Resources

The Resource

- Coastal land about 500m wide including all beaches, dunes, estuaries, and areas of marine influence and nearshore water to a depth of 20m.
- Area bounded by Ras Mazari on the south and Ras el Aswad on the north.
- Area characterized by fine white sand beaches 10-400 meters wide.

Human Activity	Measurable Impacts
Urban and Tourism Development • 24 developments in operation or under construction • 26 developments in the planning stage • Primary engine of economic growth. Provided 5.2 percent of income in 1990	• Destroys natural ecosystem • Encroaches upon and destabilizes sand dunes, beaches and coastal forests • Coastal erosion • Interrupts littoral sediment transport
Commercial and Recreational Ports • 3 ports M'diq, 80 slips Kabila, 180 slips Marina Smir, 300 slips • Expansion planned at M'diq and on the Martil River	• Marinas trap sand naturally transported by coastal currents • The dike built at Kabila Marina blocks seawater from entering Lac Smir, thereby degrading this brackishwater wetland habitat
Agriculture • Cropland along Martil Plain • Livestock grazing	• Dunes and Forests ecosystem destroyed by livestock grazing
Sand Excavation • Extensive Mining - Authorized extraction increased from 200,000 m^3 in 1986 to 500,000 m^3 in 1990. Projected to 630,000 m^3 in 1995, 970,000 m^3 in 2010 - Estimated unauthorized mining equal to authorized mining	• Significant loss of beaches and coastal dunes • Reduction of sand for beach replacement • Erosion of coastal forest • Reduce quality of beaches
Recreational Use • Public use of beaches for swimming and camping	• Inadequate means to handle and direct dumping • Human and solid waste - diminishes quality of resource • Fecal coliform presents high risk • Contributes to polluted water
Solid and Liquid Disposal • Large scale dumping • Informal littering	• Significantly degrading wetland and beach environments
Overall Impa cts	• Very serious impact on coastal dunes, forests, beach habitats • Increased coastal erosion • Slight overall impact on coastal water quality; a few specific areas significantly impacted

4.1.2 Human Uses of the Coastal Area

Human uses of the area are urban development, resort development, commercial and recreational ports, agriculture, and sand excavation; recreational uses including camping and hunting; nearshore water use including swimming, diving, boating, and commercial and recreational fishing; and direct and indirect waste disposal.

Urban and Tourism Development
The built area of this coastal zone consists primarily of urban development in the towns of Azla, Martil, M'diq, and F'nideq and resort development. Ten tourism developments are in operation and 14 more are under construction. An additional 26 developments are in the planning stage. These projects, which include a combination of hotels, condominiums, and bungalows, are expected to occupy 1200 ha of coastal land (RdM/MI/PT, 1991d) (see Table 4.2).

Table 4.2
Tourism Projects along the Tétouan Coast

Stage of development	Number of operations	Area (ha)
Existing operations	10	140.00
Under construction	14	151.40
Authorized	10	314.20
Under design	16	594.40
TOTAL	50	1,200.00

(RdM/MI/PT, 1991d)

Most of these developments are intended for foreigners or a growing class of Moroccans with higher socioeconomic status and more disposable income (RdM/MI/SG, 1987). Many of the residential developments between Restinga Smir and F'nideq are said to be planned to draw higher-income Moroccans.

Tourism in Tétouan represents a rapidly growing sector of the economy (see Appendix A). Employment in the tourist sector increased 15.9 percent between 1960 and 1981 and accounted for approximately 2.4 percent of all jobs in Tétouan in the early 1980s, compared with the overall Moroccan average of 0.5 percent. Morocco has favored growth of the tourism sector since the early 1980s as part of a diversified development plan, and Tétouan has selected this sector as a primary engine of growth for its future. Estimates indicate that the share of income created by tourist spending in 1990 had doubled since 1982 to 5.2 percent.

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New employment envisaged through current tourism planning in Tétouan totals 8700 permanent positions and 10,700 temporary and recurring positions, an optimistic figure given the current low occupancy rate and the large share of Moroccan citizens in Tétouan's clientele. If created today, those jobs would make the tourism sector among the largest employers in the region; tourism spending could generate as much as 7 to 10 percent of provincial income. These factors together indicate that Tétouan must guard jealously the fragile foundation of its tourism industry.

Commercial and Recreational Ports
There are three ports in the area: M'diq, a state-financed port for both fisheries and recreational use with 80 recreational slips and a much larger area dedicated to fisheries; Kabila, a privately developed marina with 180 slips; and Marina Smir, located at Restinga Smir, which was developed with state funds and provides 300 slips for recreational boaters. M'diq's port is to be expanded, and another port is proposed for the dead arm of the Martil River estuary to be used for fisheries and recreational purposes. The state would be the primary sponsor of its construction and management; the proposed port is in a very preliminary planning phase.

Agriculture
Agricultural uses of the coastal zone are evident adjacent to or infringing upon the coastal dunes or forests. This includes cultivated cropland along the Martil plain between the towns of Azla and Martil and livestock grazing nearly everywhere along the coast (see Section 4.3, Agricultural Lands).

Sand Excavation
The burgeoning construction industry in the Tétouan area has generated a strong demand for sand, clay, and gravel. These materials are taken from inland sites, sand excavation is evident at the beach at the mouth of the Alila River, near Martil on the inland dunes, and in many areas near the Restinga Smir area and north near the tourism developments closer to F'nideq. It has reportedly occurred extensively in the past on the beach near Azla and just north of M'diq. Some of this excavation is legal, but much of it seems to be done clandestinely.

Due to the high salt content, beach sand reportedly is less desirable than riverbed sand for construction purposes. The marginal cost of beach sand, however, is far lower than alternative sources, given the reduced transaction costs. Authorized sand removal from riverbeds and other locations requires a removal fee of 400 Dh (about $50 at 8.49Dh/$) per truckload. Clandestine removal can save not only the removal fee, but also the high costs of capital equipment given the predominance of smaller trucks and a greater reliance on labor inputs. Given the open evidence of sand mining along the beach and in coastal forests, especially between Martil and Cabo Negro, there appears to be little enforcement of regulations prohibiting beach sand mining.

Demand for sand has been significant for at least the past decade and is increasing. The number of authorizations for sand removal increased 20 percent from 1989 to 1990. Since 1986, authorized extractions from riverbeds has increased from 200,000 cubic meters to 500,000 cubic meters in 1990[1]; overall demand for sand for construction is anticipated to grow from an average of 630,000 cubic meters per year through 1995 to 970,000 cubic meters per year by 2010 (RdM/MTP 1991). According to estimates, the clandestine industry satisfies approximately half of the annual demand.

Recreational Uses
Both visitors and locals use the coastal area for recreational purposes. The local community frequently uses the beach at Martil, the most accessible and highly used beach in the area. The banks of the Alila River and the beach at its mouth also are heavily used for camping during the summer months, as are several sites between the Alila River and Martil town, the area near the dead arm of the Martil River estuary, and several stretches of beach between Restinga Smir and F'Nideq. The camping takes place on the beach and also in adjacent coastal forests.

Solid and Liquid Waste Disposal
Solid waste is dumped on the banks of the Alila and Martil rivers and at the beaches close to the mouths of both rivers. Other areas used for disposal are the coastal forests north of Martil, the waterfront of M'diq, the banks of Lac Smir, and the coastal dunes north of Restinga Smir. Although there is obvious littering, some of this appears to be dumping of large loads by truck. Liquid wastes are dumped into Lac Smir and the Martil River, which empties into the sea by Martil town (see Section 5.1, Surface Water, for more detailed discussion).

4.1.3 Human Impacts in the Coastal Area:

Impacts from these human uses of the coastal zone come from the urbanization of Tétouan city proper and its satellite towns and also from the development of the coastal tourism complexes themselves. In general, they have had a severe impact on coastal dunes, forests, and beach habitats through physical destruction or degradation and increased coastal erosion. They also have a slight negative impact on coastal water quality.

Degradation of Coastal Habitat
Building directly on the beaches and dunes or in the coastal forests effectively eliminates the natural ecosystem and replaces it with an exotic environment of contained, landscaped gardens among buildings. Dunes and forests are being destroyed or severely degraded by livestock grazing. This results in the loss of the dune habitat consisting of dune grasses and

[1] Personal communication with Ministère des Travaux Publiques, Province de Tétouan, October 1991.

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associated animals and the forest habitat consisting of eucalyptus or coniferous forests and other associated flora and fauna. Not only do these ecosystems have a value in their own right as a part of nature, but they also play an important role in helping to stabilize the sand in the dunes and beaches to prevent coastal erosion.

The very large camping grounds established in the summer at the Alila and Martil river mouths also cause significant waste problems because of inadequate means to handle human and solid waste. Indiscriminate dumping of solid and liquid wastes along the river's banks and coast clearly diminishes the quality of these wetland areas.

Construction of the Kasila Marina includes a dike which blocks the movement of seawater into the estuary and wetlands of Lac Smir. This is changing the characteristics of this wetland significantly as discussed in Section 4.4.3, Wetlands.

Coastal Erosion

Coastal erosion is occurring for several reasons: sand excavation on the beaches or dunes, construction too close to the beach, and marinas interrupting the littoral (nearshore) sediment transport.

The effects of sand excavation are very serious. They include: 1) loss of the beach and coastal dunes that are being excavated directly; 2) reducing the amount of sand available for downstream beach replenishment, resulting in the eventual loss of the sandy beaches down current of the excavation site; 3) erosion of the coastal forest; and 4) reducing the quality of the beaches for local recreation and tourism. Ongoing excavation is degrading the beach at the mouth of the Alila River. Sand excavation at the beach and dunes near Azla has resulted in significant erosion, resulting in loss of public and private property. This has left only a pebble beach with little fine sand. The coastal forest north of Martil is being eroded as the inland dunes are excavated and the very roots of the trees are exposed. The trees topple and the loss of the eucalyptus forest continues.

Construction of houses in Martil or in the tourism complexes also can cause coastal erosion. In Martil, for example, a solid block of houses has been built on the edge of the beach. Local officials report that because this construction blocks the wind and consequent movement of beach sand, the beach is getting narrower each year. As the summer winds blow from the northeast, they move the beach sand inland. In a natural state, the sand would be caught by the dunes, which move slowly inland. However, without any dunes, the sand piles up against beachfront buildings. During the winter, when the wind shifts to blow from the west, in the natural state the dunes would slowly release the sand and move toward the sea, thereby replenishing the beach. However, the buildings block the wind so the sand is not pushed back on the beach toward the sea. Consequently, the beach is eroding.

The marinas built along the coast also can contribute to coastal erosion by trapping some of the 30,000 m^3 of sand that is naturally transported by coastal currents (RdM/MI/SG, 1987).

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The Kabila marina, for example, must dredge its marina basin annually to remove these sand deposits. This dredged sand would then be used for replenishing the beaches just adjacent to the south, thereby manually doing what is naturally done with the littoral sediment transport (PNUE, 1991). Winter storms exacerbate these coastal erosion problems.

Water Quality
The main impacts on water quality experienced in the coastal zone are periodic reports of badly polluted waters by Martil beach, including reports of fecal material floating in the bathing waters and skin lesions and infections experienced by swimmers. This is discussed in more detail in Section 5.1, Surface Water.

Conclusion
Combined, the various sources of coastal degradation pose a severe threat to the resource in both the short and longer terms. Setting aside the aesthetic and intrinsic value of the resource, degradation of coastal areas threatens to undermine the tourism sector, which is at a very vulnerable stage in its development. Tourism today represents a small but very dynamic source of regional income and employment. Allowing degradation of the resource base to continue will dramatically reduce Tétouan's ability to compete and will remove the central underpinnings of future economic growth in the region.

4.2 PLANTATION FORESTS

Provincial and local authorities do not agree on the extent of existing forests, both natural stands and plantations. Descriptive data are limited, but what is clear from observation and conversations with forest experts is that the vast majority of natural forests which originally stood within the Region of Influence and within the province of Tétouan have been seriously degraded. This section will focus on replanted forest resources. The natural forest resources that remain are considered under Section 4.4, Biotic Resources/Biodiversity. An overview of human activity affecting these resources and measurable impacts is presented in Table 4.3.

The most destructive period for the area's forest production occurred under Spanish rule in the first half of this century. Tétouan was considered the wood store for Spain at a critical point in Spanish development, and the forests were extensively harvested.

4.2.1 The Resource

Within the watershed bordered by F'nideq to the north, the Martil plain to the south, and the ridge of the Dorsale Calcaire lies approximately 4500 hectares of plantation forest at various stages of development. The plantations are monospecific and limited primarily to seven species of pine and two varieties of eucalyptus. The most common species in the plantation areas are *Pinus pinea*, *Pinus radiata*, *Pinus halepensis*, and *Pinus pilaster*. In addition, approximately 30 percent of agricultural lands are planted with windbreaks, the vast majority of which are single-row stands of *Cedrus atlantica*.

Table 4.3 Overview of Plantation Forests

The Resource

Within the immediate Region

- Area bordered by F'nideq (North), Martil plains (S), and west ridge of Dorsale Calcaire - 4500 hectares (seven species of pine and two varieties of eucalyptus)
- Area North of Tétouan (Zem Zem V)--1100 hectares (pine and eucalyptus)

Within the Region of Influence

- The three provinces of Tétouan, Chefchaouen, and Larache contain approximately 148,000 hectares; 47,000 ha of plantation forests have been reduced to 27,300 ha (by 42 percent) over 20 years

The plantation forest is the source of fuelwood construction materials and nonwood materials.

Human Activity	Measurable Impacts
Fuelwood	
• Formal production accounts for 25 percent of supply in Provincial Tétouan	• Greatest urban-based threat to the long-term productivity of the forest
• Shortfall is made up by clandestine overharvesting from natural stands and imports from other provinces	
• Fuelwood used as energy source in bakeries, *hamams* (public baths), brick factories, lime kilns	
Construction	
• Poles for temporary scaffolding	
• Poles are generally recycled	
Nonwood Forest Products	
• Myrtle	
• Briar	
• Cork	
• Production is highly variable	
Recreation	
• Tourists who hunt (no revenue data exists)	
Employment	
• State hired workers for reforestation, *nettoyage* cleaning of undergrowth, and fire guards	• *Nettoyage* - reduces the forests' ability to regenerate
• Employment for 3100 individuals	
Conversion to Agricultural Land	
• Settlement in forest for - traditional crops - livestock (graze in forest) - *Cannabis* culture for hashish or kif	• Farmland has nearly doubled, severely reducing the size of forests

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The largest plantation forest in the immediate area of urban Tétouan is known as Zem Zem V and ranks among the most important for its potential as a future resource. Approximately 1100 hectares have been planted with large tracts of *Pinus halepensis* and smaller areas of *Pinus canariensis*, *Pinus pilaster*, *Pinus pinea*, and *Eucalyptus gomphocephala*. The largest trees, between two and six meters tall, stand among bushes of myrtle and briar and occasional groves of cork oak.[2] The region is punctuated with small farms and notable for the lack of any vegetation taller than a few meters over 90 percent of the area.

Because urban Tétouan is meeting demand for forest products through imports from inland Tétouan, Chefchaouen, and Larache, these three provinces constitute the forest resource. Although the province of Tétouan is celebrated as containing the greatest forest resource in the country, definitions and estimates of the existing forest in this area vary widely. For example, The World Bank's estimate falls in the 148,000 hectare range, of which approximately 28,000 hectares is plantation (WB/AOD, 1990: 61, 79). Unfortunately The World Bank estimates are not further quantified. However, the results of a survey based upon aerial photographs between 1966 and 1986 reveals that total forest in the ROI declined from 47,100 ha to 27,300 ha (Boukil et al., 1987: 43). This represents a 42 percent decrease in the size of the forest (Table 4.4). Likewise, the area covered by mattoral, a tough thorny scrub vegetation, declined from 150,974 hectares to 93,816 hectares, also a decline of 40 percent. Mattoral replaces the forest understory when heavy grazing occurs. It also is grazed but is better able to withstand heavy grazing than the forest understory. Apparently much of the land taken out of forest and mattoral was converted to farmland: farmland expanded from 82,800 ha to 159,700 ha, a 92 percent increase.

Much of the 11,000 ha of Tétouan's forest is older plantation that has been moderately or severely degraded, due primarily to overharvesting, grazing, and fires, which reportedly are set by rural farmers to clear agricultural land. Rural opposition to reforestation campaigns continues to frustrate local officials.

The World Bank is in the midst of implementing a massive demarcation campaign in the Rif area, including provincial Tétouan and Larache. The purpose of the campaign will be to set boundaries on existing forests and draw up the necessary legal documents to establish title by the state.

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[2] Myrtle, briar, and cork all represent significant non-wood materials that are formally produced in other regions of the province and of Morocco (see 4.2.2, Human Activities, Other Productive Capacity). Evidence of clandestine harvesting of the cork oak, as well as grazing and animal feed collection from trees, was noticeable throughout Zem Zem V.

Table 4.4
Forest Degradation, Mattoral Degradation and Increase in Farmland in the Provinces of Tétouan, Chefchaouen, and Larache, 1966-86

	1966			1986		
	Forest	Mattoral (scrub)	Farmland	Forest	Mattoral (scrub)	Farmland
	----------hectares----------					
Tétouan	11,099	59,785	40,519	4,032	31,609	75,762
Chefchaouen	27,648	79,220	36,386	19,912	52,574	70,768
Larache	8,399	11,969	5,879	3,412	9,633	13,202
Total	47,146	150,974	82,784	27,356	93,816	159,732

Source: Boukil et al., 1987

4.2.2 Human Activities

The forest in Tétouan is not only a source of fuelwood and non-wood products. Local authorities perceive it as a crucial barrier against erosion of watersheds, a natural protector of regional highways, and a source of recreation, tourism revenue, and employment. Many rural groups consider the forest a prime source of agricultural land.

Fuelwood

Fuelwood collection represents the greatest urban-generated threat to the future production of the forest resource. In Tétouan, it is used primarily as an energy source in the *hamams* (public baths), bakeries, brick factories, and lime kilns and is not used for household cooking.[3] In social terms, both the bakeries and *hamams* are vital for the local population; bread baked in wood-fired ovens and social gatherings in the baths constitute fundamental elements of Moroccan culture in this region. Conversion to fossil-based energy generation may well become cost-effective for industrial production of bricks and lime (especially with

[3] Even in lower-income neighborhoods, the primary cooking fuel is butane. Charcoal and firewood are used occasionally for flavor purposes. A large majority of urban housing is wired for electricity.

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the development of new natural gas supplies),[4] but for cultural reasons wood likely will continue to serve as a key energy source in the baths and bakeries for the foreseeable future.

Information on the actual supply and demand for fuelwood in urban Tétouan is limited. It is generally estimated that formal domestic production of fuelwood in Morocco equals only 45 percent of domestic consumption (WB/AOD, 1990: 283 et seq.). Published government statistics on production in provincial Tétouan indicate that the imbalance between demand and supply is even more acute in this heavily forested region. In 1989, the province officially produced 14,070 steres or 21,646 cubic meters. Urban consumption was estimated at 88,761 cubic meters or 250 kg per capita. The shortfall is made up through clandestine overharvesting of fuelwood from plantations and natural stands and through imports from other regions, leading to degradation.

At a rate of consumption limited to 1.3 metric tons per household per year (RdM/DEFCS, 1990b), the urban population of Tétouan currently requires 19,000 to 31,500 hectares of forest, assuming an average productivity of 5 cubic meters/ha/yr and 3 cubic meters/ha/yr respectively.[5] Price data in local markets is not gathered over time. However, a check of the price for a stere of fuelwood in the city of Tétouan sold in November 1991 indicated the spot price was Dh100 (RdM/MARA/DEFCS M'diq personal communication), about $12 at current exchange rates (Dh8.49/$). (A more complete discussion of the supply and demand for fuelwood is contained in Section 4.2.3, Measurable Impacts).

Nettoyage

The organizations responsible for forest maintenance are the local communes, small communities of residents who oversee forest production, reforestation, and the general maintenance of the resource in that area or *nettoyage* (the cleaning of undergrowth). Revenue earned through public sale of forest products and from the government in exchange for labor is channeled through the commune and creates a large, if variable, income source. Total commune receipts from forestry increased from Dh135,000 in 1977 to more than Dh2 million in 1990, peaking at Dh3.3 million in 1989 (Service Forestier, 1991).

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[4] In April 1991, Morocco signed an agreement with Spain and Algeria for the construction of a natural gas pipeline extending from Algeria through the Strait of Gibraltar. It is expected to provide 10 billion m^3 of natural gas annually to the EC, beginning in 1995. Two billion m^3 will be diverted to Morocco annually for its own use (EIU, 1991).

[5] The World Bank estimates that current rates of productivity of pine plantations in Morocco vary between 2.5 m^3/ha/yr and 7.0 m^3/ha/yr [Note: conversion formulae for fuelwood by The World Bank: 1 stere = 0.65 m^3 = 0.47 metric tons; 1 m^3 = 0.72 metric tons; 1 metric ton = 1.39 m^3] (WB/AOD 1990: 247).

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Through the communes, the forests serve as a major employer. The province of Tétouan considers reforestation and *nettoyage* to be a reliable and long-term source of productive employment for rural residents. Other jobs created by the state include guarding against fires. (Hiring of guards was noted as a major reason for decreased degradation [RdM/MI/PT, 1988] and against penetration of plantations by grazing and informal fuelwood and animal feed collection.) The Service Forestier noted in 1983 that such employment had provided an average of 115,000 work days per year on a steady year-round basis over the previous five years. Local officials estimated that, including reforestation activities and production of non-wood commodities, total employment averaged 925,000 workdays annually (RdM/MARA/DPAT, 1983: 17). Assuming 300 days of work per person per year, government programs in forest production anticipate a total annual employment of nearly 3100 individuals.

In part because of the employment factor, natural regeneration of plantation resources has been intentionally thwarted. The removal of ground cover by temporary laborers, part of an extensive campaign against forest fires, has prevented natural regrowth in many forested areas, especially those closest to urban areas and highways. Local forest officials defend the policy on biological grounds as well: removing ground cover removes the trees' competition for water and nutrients. Nearly 2,600 tons of undergrowth was removed from forests in Tétouan in 1989 (see Table 4.5).

The forest region in Jbel Dersa, for example, contains extensive stands of plantation pine all approximately three meters apart and 20 years old, below which grows a limited cover of sage, palm, and a few species of flowering shrubs amid broad expanses of open dirt and rock. No smaller saplings are in evidence. The Service Forestier notes that the state is ready to replace forests after harvesting through planned clearcut; the Tétouan region currently has three nurseries with four permanent laborers (and 200 occasional laborers) and a productive capacity of 3550 trees per year, anticipated to increase to 6500 trees annually.

Construction

Demand for wood to serve as temporary scaffolding is also considerable in a city involved in major construction. Multiple construction sites revealed that eucalyptus poles are used for scaffolds and bracing concrete and drying brick walls. Supply is reportedly met primarily through forests in Larache, and construction firms use the same poles on many sites.

Other productive capacity

The forests also serve a critical role in the local economy as sources of recreation. No data exist on off-season revenue from tourists who hunt, but the Service Forestier noted that local hotels anticipate increased business from European hunters (see Section 4.4, Biotic Resources/Biodiversity).

Communes not only produce fuelwood but also non-wood products from the forest, including myrtle, an herb mashed and cooked into a medicinal oil; briar, a bush whose roots are fashioned into tobacco pipes for export; and cork. The little data that exists (Table 4.5) indicates that production by semester is highly variable.

Table 4.5
Wood Production and Other Forest Production
Province of Tétouan, 1989 and First Semester of 1990

	1989 (1)	1989 (2)	1990 (1)
Wood Products			
Firewood (steres)	8,920	5,150	3,192
Piece wood for local use (m^3)	2,815	200	1,106
Other Forest Products			
Briar root (quintals)	14,950	---	643
Briar flowers (tons)	600	560	---
Myrtle (tons)	---	2,150	---
Undergrowth (tons)	---	---	2,593
Cork (steres)	---	---	5,726

Source: RdM/MI/PT, 1988-1990

Conversion to Agricultural Land

There has been a significant decline in the area devoted to forests in the Region of Influence. As land in forest and mattoral declined significantly between 1966 and 1986, land in farms nearly doubled from 82,784 ha to 159,732 ha. The lack of a formal land tilling system has led to the development of single and multiple family farms in the midst of degraded forest. Squatters reportedly must pay a fine but then are not forbidden to work the land (RdM/MARA/DEFCS/M'diq interview).

Specific data do not exist that can be used to describe the extent of land clearing nor the type of production resulting from the clearing. The author of the comparative photo study which generated the data, M. Boukil, reported that as much as 50 percent lies fallow in any given year, a fact that could reflect both poor soil productivity and misreporting of cropping to local authorities.

The reasons for agricultural settlement of the forest are unclear. Urban growth does not seem to be spurring agricultural expansion in the region (see Section 4.3, Agricultural Lands).

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Farmers settle land both to cultivate traditional crops and raise livestock (which graze in the forest) and/or to respond to incentives created by dealers in hashish or kif. Three independent sources reported that part of the clandestine commerce in the area included trade in drugs. One individual described a process whereby dealers will induce farmers to cultivate small tracts of land in the forest and pay, on their behalf, the settlement fines incurred, thereby achieving a permanent supply source. Certainly the dramatic increase in agricultural settlements, coupled with a lack of increased regional agricultural productivity, could be explained by this phenomenon. Regardless of the cause, large tracts of forest are being subsumed for agriculture by squatters, who rarely are evicted from public land.

4.2.3 Measurable Impacts

Agricultural conversion, *nettoyage*, animal grazing, and fuelwood collection all threaten the long-term productivity of the plantation forests. Agricultural conversion and overgrazing do not seem to arise from urbanization but nevertheless are a serious threat to the forest resource. *Nettoyage* clearly has a severe impact on the forests' ability to regenerate. This human activity springs from the need to employ large numbers of people and to guard against forest fires; the economic condition that compels local authorities to provide employment through *nettoyage* also generates significant replanting.

The greatest threat related to urbanization is fuelwood gathering. To develop a better understanding of this activity an analytical model was developed that compares the current demand trends and urban population trends with existing fuelwood resources. The model is based on the assumption of a constant demand for fuelwood of 1.3 m^3 per household per year (or 250 kg per person) with supply coming exclusively from sustainable production of remaining undegraded stands augmented by mature plantation coming on line for production in 1995 as a result of the national reforestation campaign (see Appendix B for more detail).

As shown in Figure 4.1, the area within the ROI devoted to plantation forests is adequate to sustain urban Tétouan demand for fuelwood into the foreseeable future. The figure depicts the area dedicated to the production of wood given the remaining undegraded resource and addition to it under the reforestation campaign (▬ in the figure). An assumption that wood is produced at an average rate of 3 m^3/ha/yr through 2011 (+) allows a small but steady surplus over total consumption by urban Tétouan (P=3m^3). Increasing sustainable production to 7 m^3/ha/yr (▲) demonstrates that the region could experience a much larger wood surplus as soon as 1997. Because the forests of provincial Tétouan, Larache, and Chefchaouen provide fuelwood and timber for many urban locations throughout the nation, producing a substantial sustainable surplus over the total required for urban Tétouan is crucial. Furthermore, if the average productivity of a hectare of forest were 7 m^3/ha/yr, urban demand for fuelwood in 2011 (assuming no changes in industrial consumption) would require only 14,000 productive hectares (see also Appendix B). Clearly, the rate of production is the most important factor for future sustainability of the forest resource.

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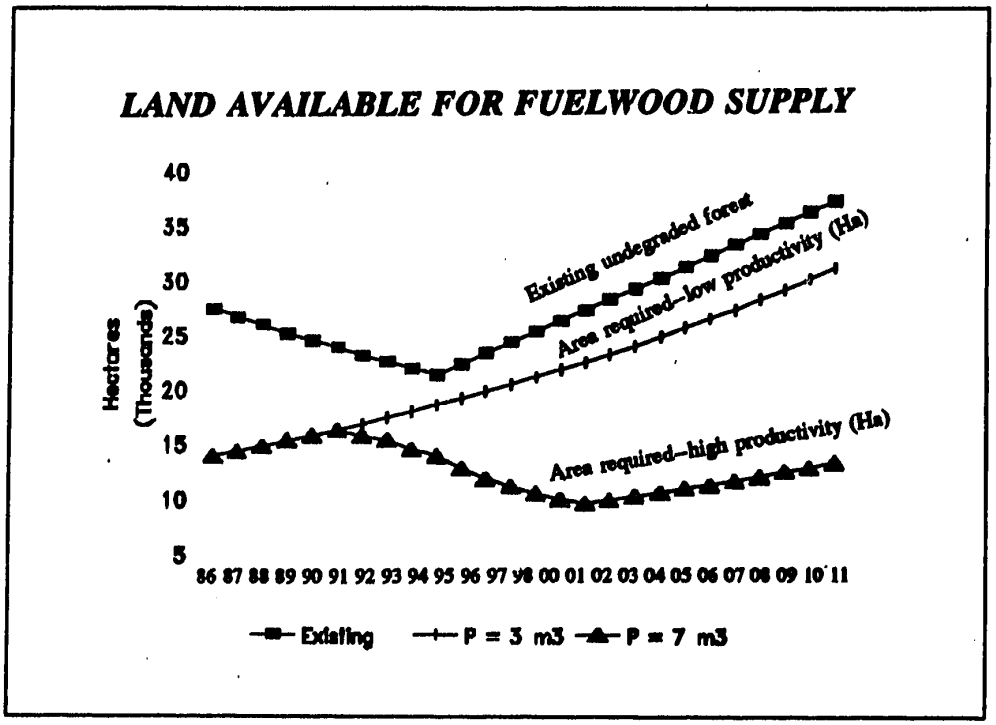
Figure 4.1



Continuing urbanization of Tétouan therefore poses a moderate rather than severe threat to the existing forests in the region of influence for the following reasons:

1) Forests are considered not a renewable resource as much as a replicable resource, given the importance of employment generation through reforestation projects. The almost total degradation of natural forests has generated a continuing commitment to plantation forestry. While plans for expanded forest generation and extensive existing resources promise to meet urban demand for the foreseeable future, degradation and overharvesting of existing plantations are significant.

   The prevention of the forest regeneration along with other impacts, most importantly agricultural conversion, does threaten the resource in the medium term.

2) Urban demand for forest products is limited to traditional energy use in *hamams*, bakeries, lime kilns, and brick factories. Some of that use is likely to slacken in the coming years.

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3) The major threat to the ROI's forest resources is not urban demand for forest products but a combination of agricultural expansion not directly related to urban growth and rural opposition to reforestation.

4) Changes in how the resources is managed--chiefly greater attention to productivity--could maintain the employment value of the resources while meeting urban needs sustainably.

4.3 AGRICULTURAL LANDS

Agriculturally, Tétouan is not a major agricultural region compared with other parts of the country. Agriculture, stock-breeding, and fishing together contribute less than 3 percent to provincial GDP and account for 1.1 percent of provincial employment (against a national average of 46.5 percent). The sector's share of regional employment declined almost 10 percent between 1960 and 1981. In the same period, agricultural settlement of the forest almost doubled in total area (see Section 4.2, Plantation Forests). An overview of this resource is provided in Table 4.6.

4.3.1 The Resource

Agriculture in the ROI is primarily conducted for subsistence. A few low-value-added crops are raised. Neither the region of influence nor the province in general have contributed to the recent development in Morocco of high-value-added pre-season tomatoes and other produce destined for the EC. Throughout the province, approximately 50,000 hectares is cultivated annually, approximately 30 percent of which produces in two sequential seasons. Eighty-four percent of cultivated land is planted with cereals including wheat, corn, and sorghum (RdM/MHAT, 1984b: Economie), and in any given year roughly 20 percent lies fallow. In addition to cereals, Tétouan farmers raise a variety of other crops. Tétouan is the national leader in production of "other legumes," primarily beans, and contributes to national production of sunflowers, nuts, sugar beets, and sugar cane (RdM/MARA/DPAE, 1991).

Exact figures are unavailable on market share of produce sold locally versus exported to other Moroccan regions. Local agriculture officials agree that a small portion of land is dedicated to meeting regional urban demand for cultivated produce; a much larger proportion is dedicated to grazing of livestock for regional rural and urban consumption. Urban demand for locally grown produce could have a major impact on the local price regime, employment in the agricultural sector, and profitability of the land resource. An informal survey of the produce for sale in the main *souk* (market) in the business district of Tétouan revealed, however, that the majority of produce was trucked in from more fertile southeastern regions. Fresh meat and local milk were in evidence.

Productivity is low compared with national averages. Winter cereal production, for example, averaged 6.88 quintals (1 qx=100 kg) per hectare against a national average of 10.41 qx/ha.

Table 4.6 Overview of Agricultural Lands

The Resource

- Minor role in Region of Influence
- Provides 2.4% of GDP
- 1.1% of employment
- Ag employment has declined 16% from 1960 to 1980

Crop Production

- 50,000 hectares (20 percent fallow)
- 84 percent
- 16 percent legumes, tomatoes, other fruits and vegetables

Livestock

- Informal grazing on all available land

Human Activity	Measurable Impacts
• Conversion of land to urban use - Limited to date - Very high future potential	• Loss of agricultural land and forest
• Abandonment of farms	• Loss of production • Forest is being converted to cropland clandestinely
• Mining on crop or pasture land primarily clay for brick - Commercial - Clandestine	• Destruction and disfigurement of agricultural land • Aesthetic effect
• Irrigation of about 1,000 hectares	• Some raw sewage in irrigation water -- potential fecal contamination • Impact on health

Overall Impacts

The overall impact of human activities on agricultural land is slight, due to the resource's low baseline productivity. The greater impact of conversion of agricultural land is not to its productivity but to the cultural heritage and lifestyle of the area.

Spring cereals (primarily corn) averaged 4.79 qx/ha against a national average of 8.09 (RdM/MHAT, 1984b: Economie). Despite the location of most agricultural lands on the Martil and Smir plains, the land has only a shallow layer of topsoil, a high water table (a few meters in places), and low soil permeability. Annual flooding and high moisture during eight months of the year result in extensive waterlogging; during the remaining four months, the lack of irrigation is considered a serious constraint to productivity (RdM/MARA/DPT[1]).

In contrast to crop agriculture, livestock breeding is a small but thriving subsector. Grazing of sheep, goats, and cattle takes place not only on traditional agricultural plots but in the city, on the beach, in the forest, along major highways, in solid waste landfills--virtually anywhere a morsel of food might be found. The "resource" for the purposes of livestock breeding is therefore limited only by the ability of animals to gain physical access to the land.

4.3.2 Human Activities

Activities affecting the resource include direct urbanization, mining, measures to increase productivity to meet urban demand (minimal), irrigation using contaminated wastewater (municipal and industrial), agroforestry, and raising of livestock for milk and meat.

Urbanization

In a few cases, development of planned and actual *lotissements*--subdivisions--tends to have accounted for the conversion of agricultural land to urban development. An area of 400 hectares of agricultural land along the Martil River has been reduced to 100 ha by development. In Torreta, a total of 100 cultivated hectares has been reduced to 70 ha (RdM/MARA/DPAT interviews). Although the total lost to date is not great in proportion to all agricultural lands, indications are that urban encroachment may accelerate (see Section 2.7, Tétouan in the Future). Given the development of residences for higher-income buyers in many instances, land conversion in these cases clearly increases the market value of the land, notwithstanding the current lack of demand by renters and buyers.

Mining

Mining of former farmland for construction gravel and sand was evident in several locations along the Martil riverbed. Both large-scale authorized mining operations and clandestine mining took place in land abutting productive fields. In one case, the resulting pits revealed a high water table and the germination of wetland vegetation. Mining for clay used in the region's single cement factory and several briqueteries has absorbed a considerable portion of agricultural land. Given the building boom in Tétouan, demand for clay is likely to increase. Briqueteries currently produce an average of 9000 bricks daily, excavating an area of 5000 m^2 annually (RdM/MHAT 1984b: Environment: 7), and clay is readily and cheaply available in formerly cultivated land. Exact figures are unavailable on the amount of formerly or currently cultivated land used for this purpose.

Irrigation and Agroforestry

Irrigation is not widely practiced in the Martil or Smir plains, due to the high marginal costs of infrastructure and the lack of opportunities for economies of scale: in the region of influence most farms are less than one hectare in size and farms larger than five hectares represent only 6 percent of total cultivated land (RdM/MARA/DPT [1]). Irrigation takes place on some 500 ha of agricultural lands along the Alila River. An additional 500 ha scattered throughout the region are irrigated through wells. Cabo Negro resort turf and landscape areas make limited use of treated wastewater for irrigation. In addition, 30 ha of agricultural land along the Martil River are irrigated with wastewater from Martil.

Many farmers have planted stands of cedars around the perimeter of their fields as windbreaks; many other farms appear abandoned to wasteland or grazing as their owners reportedly have fled to urban areas in search of employment. Exact figures are not available to quantify this phenomenon. At the same time, there seems to be a dramatic increase in the settlement of forested areas for agriculture; whether the newer cultivations are primarily for subsistence or cash crops is not known.

Livestock

Raising of cattle, sheep, chickens, and other livestock for meat and dairy also constitutes a minor industry and a prevalent use of open land, beaches, fallow fields, and forests. Farmers in the Zem Zem V forest were observed breaking off branches of the few remaining non-plantation trees for animal feed. Production figures for milk and meat during the first half of 1990 demonstrate that production is not insignificant (see Table 4.7).

Table 4.7
Meat and Milk Production
Province of Tétouan, 1990(1)

	Number of Head	Yield
Cattle	8682	1322 tons
Sheep	13,466	172 tons
Goats	5164	54 tons
Poultry	557,207	848 tons
Milk	--	7.4 million liters

Source: RdM/MI/PT 1990.

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4.3.3 Measurable Impact

The impact of these various human activities on the resource is slight, given the resource's low baseline productivity. Although comparative rates of return could not be prepared in the time allotted for this study, it is likely that they would reveal that use of relatively unproductive agricultural land for grazing, extraction of raw materials, and suburban development all constitute far more economical uses of the land than agriculture. The aesthetic effect of random mining, the implicit subsidization of companies that are permitted to extract raw materials free of charge from common property, and open grazing by livestock of public lands are three issues that deserve further consideration by the Tétouan authorities. In addition, 30 ha of agricultural land along the Martil are irrigated with wastewater from Martil. The potential health effects of fecal contamination on produce are significant but as yet unmeasured.

Agriculture and livestock farming have not constituted a major source of income for Tétouan in the past and do not promise to do so in the future. Changes in the structure of the provincial economy are making market competition nearly impossible and minimal survival very difficult for crop farmers of the Martil and Smir plains; livestock farmers seem to be faring better because of the urban demand for freshly butchered meats and the broad accessibility of grazing lands in the plains and degraded forests. The greatest threat of the common trends toward conversion of agricultural land is not to the productivity of the land but to the cultural heritage of the Tétouan farming community.

4.4 BIOTIC RESOURCES/BIODIVERSITY

The biological diversity on Earth represents a genetic library of information about possible ways to survive the conditions that exist on the planet. It is imperative to preserve this diversity (i.e., this information), both for its intrinsic value and for its potential value to humanity. The following sections evaluate the state of the biota in each of the major habitat types in the Tétouan area incorporating discussion of the resource, human uses, and impacts.

4.4.1 Terrestrial Flora

The Tétouan area includes two distinct biogeographic provinces. The coastal plain has a warm semiarid climate and sedimentary soils, whereas the uplands are wetter and have alkaline, calcareous soils. These two areas have characteristic flora (Appendix E-1) that are distinct to this part of Morocco (Duvall, 1988; Mallyani, 1988).

Very little remains of these indigenous flora. Logging during the first half of the century was reportedly very intensive, denuding large areas. Subsequent clearing of land for agriculture has further reduced the forests. The proportion of original forest that remains is unknown, despite the large quantity of forestry data available. Vegetation maps (A. Boukil, unpublished) and personal observation suggest that the forests that once covered northern

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Morocco now exist as scattered individual trees or small groups of trees, mainly in the severely degraded "forests" of Jbel Zem Zem and Cabo Negro. The team never observed anything that could be characterized as an original stand of native trees.

The remaining native forest is under severe pressure. Large areas of land are converted to agriculture each year (Tables 4.8 and 4.9). It is not clear exactly what factors drive this process; among the possibilities are shifting agriculture, regional population growth, and *Cannabis* cultivation (see Section 4.2, Plantation Forests). Whatever the cause, the annual rate of loss of forested land (Table 4.8) suggests that the half-life of the remaining native flora is approximately five years.

Table 4.8
Changing Vegetation Cover, Based on Evaluation of Aerial Photographs Taken in 1966 and 1986, in a Study Area in Southern Tétouan Province. Adapted from Boukil et al., 1987.

	1966		1986		Net change		Annual change	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area/yr (ha)	%/yr
Forest	11100	10.0	4030	3.6	- 7070	-63.7	- 353	-3.2
Scrub	59800	53.7	31600	28.4	-28200	-47.1	-1410	-2.4
Agriculture	40500	36.4	75800	68.0	+35200	+87.0	+1760	+4.4

Table 4.9
Changing Area in Natural Forest and Reforestation. The Data are Taken from a Study Area in Southern Tétouan Province in 1966 and 1986. Adapted from Boukil et al. 1987.

	1966	1986	Total change		Annual change	
	Area (ha)	Area (ha)	Area (ha)	%	Area (ha)	%
Forested	8799	561	-8238	- 92	-412	-13
Reforested	1664	3389	+1725	+104	+86.3	+3.1

Other human activities are accelerating the demise of the forest. Nearly all of the land in the study area (e.g., 92.2 percent in the Smir River watershed [Boukil et al., 1988]) belongs to the state, which imposes virtually no restrictions on its use by individuals. Consequently, sheep, cattle, goats, and donkeys graze virtually everywhere, eliminating the understory. Wood is

cut for local use or sale in Tétouan, and lower branches of trees are harvested to provide forage for animals. *Nettoyage* allows little or no natural regeneration.

Reforestation will not improve the situation. Although extensive reforestation has taken place in the study area, it is clear that preservation of biodiversity is not a goal of the program. Only a very small number of species are even considered for reforestation (RdM/MARA/DECFS, 1978). In practice 81 percent of the reforestation in northern Morocco consists of a single species, *Pinus halepensis* (Pin d'Alep). A few other species also are planted (Appendix E-1), but the native flora do not figure among them. The cork oak (*Quercus suber*), which once covered most of the area, is described as being too difficult to cultivate in nurseries. The goals of reforestation are apparently to prevent erosion, to produce harvestable wood rapidly, and to provide employment (Boukil et al., 1988). Measures to sustain existing forest were never mentioned by any document or official.

In addition, natural regeneration will not preserve the indigenous flora. The undergrowth is generally so heavily grazed that spontaneous regeneration from seedlings in both natural and plantation settings is virtually nil, except perhaps in the most remote areas. *Quercus suber* has some success reproducing vegetatively, but not sexually. Thus, species that are not actively reforested seem doomed to disappear.

The forest understory has suffered the same fate as the trees. The understory vegetation (Appendix E-1), when grazed by livestock, is replaced by mattoral, a tougher, thorny, scrub vegetation. The mattoral is also used as forage by livestock, but it is able to tolerate moderate levels of herbivory. While the mattoral vegetation is not in imminent danger of disappearing, it too is declining, with a half-life of 21 years.

4.4.2 Terrestrial Fauna

Information about native animal populations is very scarce. Several species in the Rif Mountains are thought to be endangered, mainly due to loss of habitat (Duvall, 1988). Development in the study area is unlikely to affect this.

Much of the native fauna of the area probably has already disappeared. Many animal species (especially birds) require specific types of vegetation to survive and to breed. The degraded state of the vegetation suggests that much of the accompanying fauna is probably even more degraded. It would require extensive additional study to determine which species have suffered and to what extent. At this point, it is unlikely that further development in the area will make the situation worse, except insofar as the remaining habitat for animals continues to disappear.

Hunted animals are a special case. As of January 1, 1992, the European community banned all hunting within its boundaries. Morocco represents the nearest attractive hunting region for western Europe. A well-regulated hunt could conceivably attract significant numbers of

visitors at a time of the year that is otherwise very quiet. Over the past decade, there has been a steady increase in the number of hunting permits issued (Appendix E-2). Of these, 85 percent are issued to foreigners. Clearly, there is a potential to overexploit prey populations.

The Moroccan authorities recognize this potential, and a system of permanent and rotating game preserves (amodiations) has been established. The latter are privately managed and monitored. They limit the number of hunters and they promote protection of wildlife habitat. This scheme appears to be effective: before privatization, each state game warden monitored, on average, 25,000 ha of land; now, each private warden monitors 500-1000 ha (A. Sekkate, personal communication).

Based on the hunt statistics provided by the amodiations for partridge, rabbit, and hare, there is no evidence that hunting is reducing population density. Catch per unit effort has remained essentially unchanged since 1981. However, large-bodied, slowly reproducing animals such as deer and boar are far more likely to suffer from overhunting than are rabbits. Moreover, rabbits and hares undoubtedly tolerate degraded habitat to a much greater extent than do larger and more specialized species. Unfortunately, no data appear to exist for the larger mammals, water birds, or for non-game species in general. Anecdotal reports of declining poaching due to declining stocks do exist (Sekkate, 1991). Therefore, we conclude that although there is no extensive evidence of overexploitation of game species, the question requires further study.

4.4.3 Wetlands: Lac Smir and Surrounding Marshes

The Tétouan area has been designated an area of very high ecological sensitivity (WB, EIB, 1990), principally because of the importance of its wetlands to migratory birds. Paleotropical migrant birds from the western half of Europe pass through Spain and over the Strait of Gibraltar to wintering grounds in Africa. The first important wetland area that they encounter in northern Africa is Lac Smir, at the mouth of the Smir River. The wetlands around Lac Smir, one other wetland farther south in Tétouan province (the mouth of the Loukos River), and four wetlands in Tangier province are the main bird habitats in northern Morocco (Sekkate, 1991).

Lac Smir is physically very diverse. In 1988, it included approximately 3 km^2 of open water, bordered by 30 km^2 of land that is permanently wet or seasonally flooded. The lake contains a strong salinity gradient, varying from $1^0/_{00}$ (one part per thousand of salt) where the Smir River enters to $35^0/_{00}$ near the sea (Bekkali, 1987).

This physical diversity permits an exceptionally wide variety of aquatic plants. The wetlands contain abundant emergent vegetation, dominated by salt-tolerant species in more saline areas (e.g., *Salicornia fructcosa* and *Juncus martinus*) and freshwater species upstream (e.g., *Phragmites communis*, *Typha angustifolia*, and *Tamarix gallica*).

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Lac Smir is equally rich in aquatic fauna. It is noted as an important stopover for migratory birds, as well as a permanent wintering ground for waterfowl. A census of aquatic birds on Lac Smir on January 11 and 16, 1984, identified 16 resident species (Appendix E-3). The lake has also traditionally hosted an impressive variety of fish and crustaceans (Appendix E-4).

The fauna of Lac Smir also are important economically. Many of the aquatic birds on Lac Smir are very attractive game species for hunters. The natural value of these diverse bird communities in terms of ecotourism should also not be overlooked. Finally, the shrimp and other crustaceans that use Lake Smir as a breeding ground are potentially valuable to the local fisheries.

Three aspects of development now threaten the biological integrity of Lac Smir: interruption of the source of freshwater, interruption of contact with the sea, and inputs of untreated wastewaters. Prior to 1988, freshwater entered Lac Smir mainly through the Smir River and secondarily through groundwater during the winter months. The Smir Dam, constructed to supply drinking water to the Tétouan network, has eliminated surface inputs of freshwater to Lac Smir entirely since that time. At about the same time, the marina associated with the Kabila tourist complex was constructed. The natural mouth of the Smir River and the marshland north of Lac Smir were filled in. A dike on the eastern end of Lac Smir cut communication with the Mediterranean.

These development activities have had serious consequences for the resident biota. The freshwater flow is the main source by which water is renewed in the lake. Its elimination has already led to a significant decline in the water level. Consequently, shallow areas of the marsh have been exposed and have dried out, destroying their biological usefulness. Elimination of the freshwater flow also has caused the entire system to become stagnant. Stagnant waters that are rich in organic matter (e.g., marshes) rapidly become anaerobic and usually generate significant quantities of methane (a potent greenhouse gas) and hydrogen sulfide (which is toxic and foul-smelling). Anoxia leads to death of most of the fauna, except those that live in the surface film (e.g., mosquito larvae).

Elimination of the connection between Lac Smir and the Mediterranean affects both the salinity of the system and its accessibility to marine organisms. Groundwater, whose salinity is about $1^{0}/_{00}$, is now the sole source of water to the lake. Much of the existing flora is halophytic: it will not tolerate low salinity indefinitely. The lake also was used by numerous marine organisms such as shrimp, eels, and fish as a breeding ground. These animals no longer have access to the lake. Fish and eels, in particular, formerly provided natural control of mosquitoes by preying on the mosquito larvae. Mosquitoes are a serious problem in the area (RdM/MI/PT, 1988, 1989), and one that the locals report is worsening.

Wastewater inputs to Lac Smir also pose several problems. Wastewaters generally contain high levels of organic matter, heavy metals, and xenobiotic organics (e.g., pesticides, PCB's).

Decomposition of the organic matter accelerates deoxygenation of the water. Wastewater also includes disproportionately high levels of inorganic nutrients (nitrogen, potassium, phosphorus), which stimulate plant growth and which in turn tend to reduce plant diversity. Many heavy metals and xenobiotics are clearly highly toxic to animals in general and to birds in particular, often interfering with reproduction and development.

Most of the effects described above are acute. Loss of marsh area and exclusion of marine biota are apparent already. Major shifts in plant composition can be expected in five to ten years. Toxic effects on wildlife typically become evident in two decades. Changes in migratory patterns and population density parallel the deterioration of biotic conditions.

4.4.4 Other Wetland Areas

There are numerous other minor wetland areas in the Tétouan region, particularly along the banks of the Martil and Alila rivers. The banks of the Martil have been heavily developed for industry, agriculture, and mining. Most of these areas are devoid of native flora or fauna. However, in the infrequent areas in which vegetation along the streambed has been relatively undisturbed, aquatic waterfowl are abundant. Wetlands on riverbanks are often particularly desirable ones because they are not generally favorable habitat for mosquitoes. Development immediately along the shores of the rivers destroys the natural vegetation and eliminates their biological utility. Sand excavation on riverbanks is particularly devastating.

It has been suggested that a strip of seasonally inundated land extending north from the Tétouan airport to the Alila Rivèr be considered as a site for a pond-wetland wastewater treatment facility (Carrol, 1991). The area has relatively low biological diversity due to the seasonal nature of flooding. Continuous flooding with treated wastewater might actually be beneficial by promoting further wetland development. Possible negative effects include exposure of waterfowl to waters rich in metals and xenobiotics. The proposal merits a more detailed environmental assessment.

4.4.5 Freshwater Biota

Biological diversity is low in the lakes near Tétouan. Almost all of the standing freshwater is in the reservoirs that provide Tétouan's water supply. Because precipitation in the area is almost entirely seasonal, the water level in these reservoirs fluctuates dramatically. These fluctuations preclude the growth of rooted aquatic plants. Without these plants, the bottom-dwelling invertebrates upon which fish feed do not flourish, so that the fauna of such reservoirs is very poor. Development is unlikely to threaten it.

The Martil River is a potentially rich habitat for aquatic organisms. The severe pollution in the river has led to the disappearance of the normal invertebrate fauna along much of its length. Instead, one finds very species-poor assemblages of invertebrate organisms that

tolerate high levels of pollutants (e.g. *Tubifex* spp.; M. El Alami, Université Abdelonalek Essaadi, unpublished data).

Finally, the dead arm of the Martil River is another potentially interesting freshwater habitat. The arm now receives large amounts of untreated sewage from the town of Martil. Since its connection with the Martil River was severed by the construction of a causeway, the dead arm is now stagnant. No data are available concerning its biota; however, on its surface are large, floating mats of cyanobacteria. Cyanobacteria are characteristic of badly polluted systems. They often release toxins into the water and produce noxious odors. They generally constitute very poor food for aquatic animals. Again, further development is unlikely to make the situation worse.

In conclusion, the condition of the freshwaters in the region is so poor that biodiversity is hardly a question.

4.4.6 Coastal and Marine Biota

See Sections 4.1, Coastal Resources, and 5.4, Marine Fisheries.

5.0 WATER RESOURCES

Pressures from urbanization can have substantial impacts on water resources, from both degradation and over-exploitation. Water resources examined include surface water, groundwater, and marine resources. An overview of the resources, human activity affecting the resources, and measurable impacts from these activities is presented in Table 5.1.

Urbanization's impact is severe on the quality and quantity of surface and groundwater downstream of Tétouan and its satellite towns. Upstream resources are differentially affected: the quantities of surface waters are in general only slightly affected, whereas upstream water quality is to a certain extent moderately degraded.

5.1. SURFACE WATER

5.1.1. Resource Description

The ROI is composed essentially of the four coastal Mediterranean watersheds as shown in Figure 5.1. These four watersheds are:

- Martil,
- Smir,
- Negro, and
- Kendissa.

Although the four watersheds constitute separate entities, the existing infrastructures for water management, distribution, and treatment are intrinsically linked among localities in the basins. The resource should be globally shared, centrally managed, and planned in Tétouan to cover the needs of human activities in the four watersheds.

Precipitation is the renewable source that supplies water for use, management, and planning. Major precipitation data and other climatic parameters are summarized in Figure 5.2. The flow rate in the Martil (60 km) as measured at 13 km upstream of the river mouth shows an average of 0.27 m^3/sec during the driest month, versus a high of 43.15 m^3/sec during January. The average annual flow is 13.75 m^3/sec (MARA-Tétouan).

Actual hydrologic monitoring of the Martil indicates that the yearly net rainfall is 353 mm. This value translates into efficient annual runoff of 427 Mm^3 into the Martil drainage basin, 90 percent of the average annual runoff. However, the extreme regimes, which appear to occur every ten years, can drastically increase (893 Mm^3 in 1968-1969) or decrease (119 Mm^3 in 1982-983) the annual input.

Table 5.1. Overview of Water Resources

Resource	Human Activity	Measurable Impacts
SURFACE WATER The ROI consists of four separate watersheds linked to Tétouan and the surrounding localities. The watersheds experience extreme fluctuations in water volume; for example the Martil ranged from 119 to 893 Mm^3 per year, according to recent statistics. **Watershed** — **Average runoff (Mm^3)** Martil — 427 Smir — 25 Negro — 12 F'nideq — 12	Solid and Liquid Disposal • 25,340 m^3 per day (9.2 Mm^3/yr) of industrial and domestic wastewater • Disposal of as much as 30 percent of generated solid waste into rivers • Leachate contamination from uncontrolled landfills Sand and Gravel Excavation • Extraction of undefined quantities of sand and gravel from mouths and banks of Martil and Alila rivers Infrastructure Developments • Building the Nakhla and Smir dams	• Deteriorated water quality, with numerous pollutants at levels above U.S. standards • Closure of one Martil river intake for domestic water • Free oxygen environment promotes odors and vectors • Deteriorated water quality, with various suspended solids • Siltation caused by clear cutting in watershed reduces regulated volume of water
GROUNDWATER The ROI has four aquifers, the largest being the Alluvial Martil-Alila, approximately 80 square kilometers. The aquifers are characterized as follows: Martil-Alila — Area (km²): 80; Recharge Rate (Mm^3): 13.8; Water Supplied (Mm^3): 6.6 Smir — Area (km²): 9; Recharge Rate (Mm^3): NA; Water Supplied (Mm^3): 1.7 Negro — Area (km²): 10; Recharge Rate (Mm^3): NA; Water Supplied (Mm^3): 0.7 F'nideq — Area (km²): NA; Recharge Rate (Mm^3): NA; Water Supplied (Mm^3): 0.6 • Level of exchange between aquifers and surface rivers is not well defined.	Solid and Liquid Disposal • Infiltration of effluents from private cesspools in Martil • Intrusion into Smir aquifer from wetlands receiving M'diq effluents • Contamination of Martil-Alila and Smir aquifers by landfill leachates Over-exploitation of Resource • Salt intrusion into all aquifers resulting from overpumping by private users	• Contamination levels frequently exceed U.S. standards for calcium, nitrates, sulfates, magnesium, and chloride at various locations of the aquifers • Chloride and sodium levels reach 7,000 and 3,000 mg/l, respectively, 35 times the U.S. maximum allowable level
MARINE FISHERIES • Stocks of sardines and other small deepwater or bottomdwelling species, including herring, bogue, mackerel, octopus, squid, and shrimp • Stocks of red tuna • Limited shellfish beds • Industry contributes nearly 2.3 percent of regional gross domestic product and accounts for less than 1.1 percent of employment	Commercial Fishing • Fishing based out of M'diq, Martil and Azla, as well as foreign ports, with little or no regulatory control over fishing • Contamination of the limited shellfish beds by wastewater discharge into nearshore waters. Martil is the only direct impact determined.	• Impacts appear to be minor, and only related to over exploitation • Over-exploitation of certain stocks (e.g., anchovies, bonito, and various selaciens) is only partially related to urbanization because the fishing efforts are exerted by fleets from foreign countries and other areas of Morocco

Figure 5.1

Watersheds

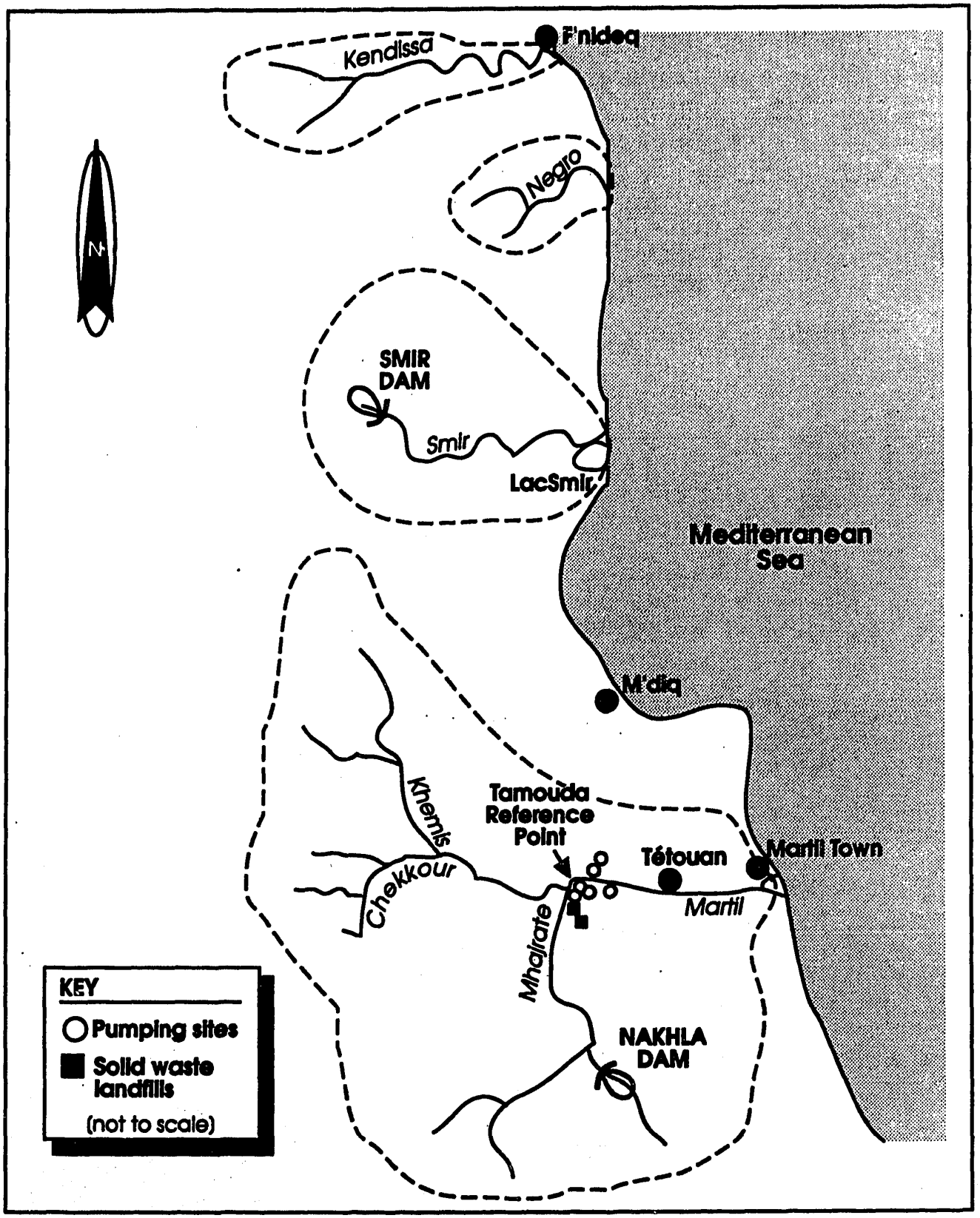

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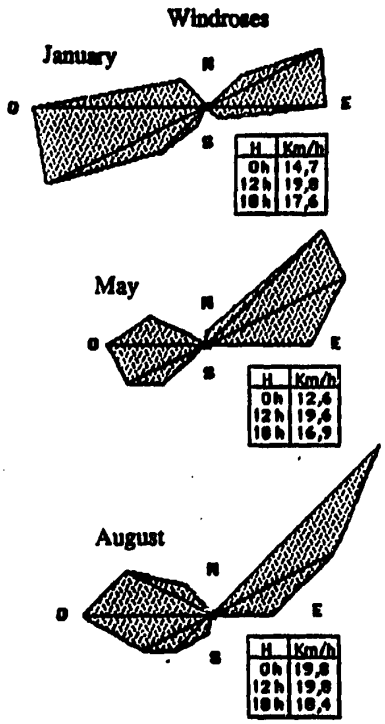
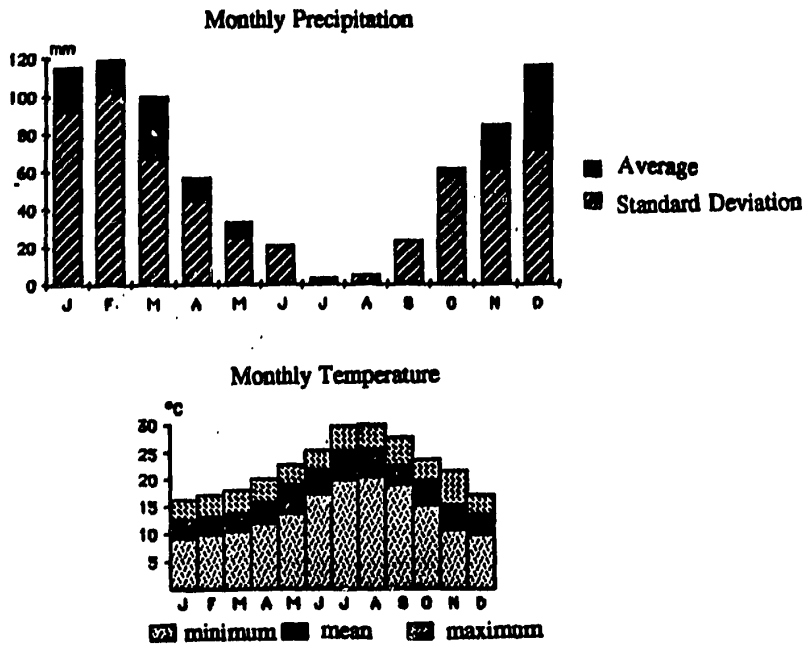
Figure 5.2

Tétouan Region: General Physical Data





Extracts from preliminary study for Martil development plan,

Province of Tétouan/Ministry of the Interior - 1991

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The average annual precipitation rate in the Smir basin is 955 mm/year, yielding an annual runoff in the river channel of 25 Mm^3. The Negro and F'nideq watersheds yield an average of 12 Mm^3 of water annually.

5.1.2. Identification of Adverse Human Activities

Water use for domestic, agricultural, and industrial purposes is not necessarily an adverse activity, provided that the amounts and the quality of water are preserved. To satisfy the intense urban demands, water needs to be trapped (i.e., by dams) or extracted (i.e., by wells) and treated before consumption. To achieve sustainable water production, this should be done while:

- minimizing physical disturbance of the exploitation site and its surroundings;
- evaluating upstream activities that may affect hydrological regimes;
- ensuring the integrity of conveyance structures for accommodating peak flows;
- preserving water as a sustainable and abundant resource that satisfies the urban demand with no treatment or limited treatment;
- preserving the mechanisms by which surface water sustains the presence of indigenous fauna and flora; and
- preventing water from becoming a vehicle for transmission of waterborne diseases.

The above criteria for water management constitute the basis for evaluating the impact of urbanization on water resources in the ROI. The resource will be divided within the ROI into two separate entities: one supplies Tétouan with domestic water but is geographically upstream of the city influence, the second is downstream of Tétouan.

Two categories of human activities, chemical-biological and physical, are affecting the surface waters in the ROI. The chemical-biological category includes:

- discharge of untreated industrial and domestic wastewater into the Martil River;
- discharge of untreated domestic wastewater into the other main rivers of the ROI; and
- input of solid wastes leachates into the Martil from the uncontrolled landfills in Tamouda.

The physical category includes:

- extraction of sand and mixed gravel from the mouths and banks of the Martil and Alila rivers (see Section 4.1, Coastal Resources);
- uncontrolled solid waste dumping into all rivers of the ROI; and
- the construction of the Smir Dam and the proposed construction of the Koudiat Guensoura Dam on the Mhajrate River (see Section 4.4, Biotic Resources/Biodiversity).

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5.1.2.1 Chemical-biological category

The Martil River is presently subjected to continuous input of domestic wastewater starting about 18 km upstream of the mouth. Thirteen outfalls carrying an estimated 22,100 m^3/day of raw wastewater are discharged into the river as are various untreated industrial effluents. The water quality monitoring program set up by the Direction de l'Hydraulique (DRH) can serve as a basis for estimating existing and future wastewater generation. This program, however, does not accurately reflect temporal and spatial variation of water quality along the river, nor does it cover some important parameters (e.g., heavy metals and xenobiotics). Therefore, only general trends can be drawn from the following analysis,

Table 5.2 provides estimated observed and projected loads of pollutants as a result of wastewater discharge in the Martil River. The figures show only annual average conditions representing the urban agglomeration of liquid wastes generated in Tétouan.

All of this pollution load generated by the city goes untreated in the last 18 km of the Martil. Its severity varies spatially and temporally along the river. For example, the biochemical oxygen demand (BOD_5) and the dissolved oxygen (DO) profiles reflect the location of each outfall or direct industrial discharge (Figure 1 in Appendix C-1). The BOD_5 level of treated wastewater in the U.S. is less than 20 mg/l, and a healthy river has a DO level close to saturation (9 mg/l O_2).

Compare those to values at a reference point (Tamouda bridge) located upstream of most pollution sources. BOD_5 reaches extreme values (3662 mg/l) at the first point of discharge, then drops downstream until the second main discharge, where it increases again (295 mg/l). Ultimately, the final BOD_5 level at the river mouth reaches an equilibrium value that depends on the prevailing flow regime. Also, the BOD_5 level drops between outfalls due to the physical process of dilution and the biochemical process of self-purification.

Dilution in the Martil River is expected to achieve BOD_5 abatement to the desired level only between December and April, and to a lesser extent during the months of October and May (see Figure 2 in Appendix C-1). Future projections, however, show that the minimum required flow rate for dilution increases with time. This indicates that dilution will be less efficient as Tétouan grows. The plans to build the Koudiat Genzoura dam on one tributary of the Martil will further worsen the present situation, because the flow rate from this tributary will drop to zero during the summer.

In summer, water re-aeration through the water-air interface and biochemical self-purification is the major contributor to reducing BOD_5. Calculations based on available data indicate that the Martil River is not long enough to provide the time necessary for self-cleansing (see Appendix C-2 for calculation). The river would need 29 km to start recuperating. However, the last outfall is less than 8 km from the mouth. As a result, the DO level is expected to drop to zero and remain at that level until the river mouth, where dilution with seawater occurs.

Table 5.2 Existing and Future Inputs of Domestic and Industrial Wastewater in the Martil River.

PARAMETERS	1991	2001	2011
Population	268,000	369,310	488,638
Per capita water consumption (l/d)	121	133	147
Percent population connected to water supply	85	95	100
WW discharged (%)	80	80	80
WW discharged per capita (l/d)	97	106	117
Total volume domestic WW (m^3/d)	22,100	37,190	57,170
Total volume industrial WW (m^3/d)	3,240	4,374	5,904
Total domestic & industrial (m^3/d)	25,340	41,564	63,074
BOD_5/d/cap (g/cap/d) 1/	54	54	54
Domestic BOD_5 load (kg/d) 1/	12,300	18,945	26,386
Industrial BOD_5 load (kg/d) 1/	2,575	3,476	4,692
Total BOD_5 load (kg/d) 1/	14,875	22,421	31,078
Equivalent population	275,462	415,203	575,518
Domestic suspended solids (kg/d)	8,000	12,000	16,560
Industrial suspended solids (kg/d)	12,000	18,000	24,840
Total suspended solids (kg/d)	20,000	30,000	41,400

Adapted from RdM/MI/PT, 1991a, Rdm/MTP, 1991a & b, Metcalf and Eddy, 1990, and industrial survey.

1/ See Appendix C.1 for details of industrial effluents evaluation.

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Even upstream of Tétouan, the levels of some ions reach levels beyond acceptable standards. For example, ammonium levels are nine times higher than U.S. drinking water standards. Also, chloride levels, although below the limits of acceptability, indicate the presence of an upstream source of contamination.

The magnitude of the biological pollution reaches a peak in the stagnant water of the Martil's dead arm. This section receives Martil wastewater effluents and is an open dump for solid waste. In the summer, the arm functions as a badly managed wastewater lagoon, developing odors and propagating vectors.

Domestic effluents are the main generators of the organic pollution; industry contribution is estimated at 21 percent of the total load. This latter figure is expected to decrease to 15 percent in the year 2011, when domestic effluents will have more than doubled but industrial effluents increased by only 80 percent. The main industrial polluters currently in Tétouan are:

- a slaughterhouse,
- a tobacco and match plant,
- a power plant,
- a tannery,
- a paper mill,
- a textile plant,
- a detergent plant, and
- non-point sources originating from the industrial zone of Martil.

In addition to their organic load, those point sources also add nutrients, metals, and other undefined xenobiotic compounds to the river, although the scarcity of data precludes a real characterization of this pollution. The paper mill, however, generates 50 percent of the total suspended solids (SS) (> 10 tons/day) and all of the sulphates (> 12 tons/day) discharged into the Martil. Heavy metals are also added; the industrial zone generates 50 kg of chromium (Cr) and significant amounts of mercury (Hg). Concentrations at the point of discharge into the river are 223 ug/l of Cr and 3 ug/l of Hg, almost six times the U.S. maximum allowable levels. Similarly, effluents from the detergent plant contain excessive amounts of phosphorus; the concentration in the river is 60 times the U.S. standard. In addition, effluents from the thermal power plant (RDE) might be a point source of hydrocarbons into the Khemis tributary. No information on the quality of these effluents is available. The twelve gas stations in the Tétouan area also may constitute a major pollution source into the Martil River. The practice of disposing of used oil into the sewer may be a significant cause of contamination by xenobiotics.

The situation of the Smir and Kendissa rivers is less well characterized. Both rivers, however, receive domestic wastewater effluents from M'diq and F'nideq. The rivers connect with adjacent wetlands that constitute receiving bodies for wastewater effluents. An undersized wastewater treatment plant, originally designed to serve a small tourist complex, inadequately attempts to treat the wastewater effluents generated by M'diq. With the increased load, the level of treatment cannot exceed five percent. The "treated" effluents are then discharged into the Smir wetland (see Section 4.4, Biotic Resources/Biodiversity).

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Overall, chemical, biological, and hydrological data are scarce, especially with regard to the Negro and Kendissa rivers.

5.1.2.2. Physical category

The extraction of sand from the Martil and Alila riverbanks is regulated through the public works department. Although quotas are given each year, the illegal extraction activities outnumber the allocated tonnage. The volume of sand extracted from the rivers seems to be substantial. However, only limited data were available (see Section 4.1, Coastal Resources). Similarly, the dumping of solid wastes into the rivers is a common practice, especially at the dead section of the Martil. Because only 70 percent of the solid wastes generated are collected by municipal service, it is probable that an undetermined portion finds its way to the river banks.

5.1.3. Measurable Impacts

To the extent data allow, measurable impacts are discussed for surface water primarily focusing on waters downstream of Tétouan. Surface waters in areas in the upstream reaches of the rivers in the ROI also are discussed.

5.1.3.1 Surface water downstream

The impact of human activities on the quality of water in the downstream section of the Martil River is devastating. The impacts measured in terms of the four criteria cited above show that in the present state, the lower section of the Martil has lost its mechanism for survival. The river has very limited self-epuration capacity left. This capacity is still present at the first outfall's location, but completely vanishes downstream. As population grows, the pollution front probably will move farther upstream. The dilution capacity also is expected to decrease. Analytical results indicate that even winter samples have higher levels of contamination than would be expected.

The magnitude of the biological pollution already has caused the closure of one river intake that formerly supplied the city water treatment plant with 200 l/sec of water for domestic use. At the intake point, the bacteriological contamination measured during high flow regime is 500 times higher than U.S. standards. In summer, conditions are expected to be more severe. In an attempt to move the intake upstream of the pollution sources, measurements at the projected site (Tamouda reference point) also showed significant levels of bacterial contamination but only a moderate level of chemical oxygen demand. Plans for installing this new intake are presently suspended. This pollution may be explained in part by the wastewater effluents originating from the rural commune of Ben Kerrich, upstream of Tétouan. The solid waste landfills, located upstream of the Tamouda point (Figure 5.1), 200 m and 600 m from the river reach, also may be a source of contamination. Direct overland runoff from the landfills to the river and/or leaching of contaminants from the landfill's bottom into the aquifer are possible scenarios. If verified, the impact might be severe on the quality of groundwater pumping sites and wells located downstream (discussed further in Section 5,2, Groundwater). This problem, however, may be offset by the relatively impermeable stratum underlying the region of the landfills and the dilution of the surface

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runoff water with the river water in winter. A detailed assessment of the hydrogeological conditions at the landfill sites is necessary to determine the potential for contamination from these sources.

With the development of new neighborhoods, e.g., Boujdad on the right bank of the river and farther east and Tougleh on the left bank, it is expected that the organic load will gradually increase into new sections of the river, which are relatively well preserved. Therefore, prior to developing definitive plans for the proposed sewerage system, a detailed study on the future pollution load from these areas is necessary.

One hundred percent of the samples taken along the Martil had microbial indicator levels higher than acceptable standards. Also, levels of fecal contamination of the beach area indicate that 100 percent of seawater samples taken near Martil beach (Regional Health, 1991) had levels of coliforms higher than the maximum allowable concentration in recreational waters in the U.S. Other data, however, show that the level of contamination is within acceptable limits (RDE, 1991). Although the correlation is difficult to establish, waterborne diseases data show the presence of paratyphoid, typhoid, gastro enteritis, and hepatitis in the ROI (Appendix C-3). Also, more than 30 ha of agricultural lands adjacent to the river in Tétouan are irrigated with untreated wastewater, and the produce is sold in the local market. This may constitute a source of food contamination in the city.

The impact of the Martil River on immediate coastal resources is potentially significant because the river does not have the 29 km estimated to be necessary for self-cleansing. The longer this distance, the slower the resulting plume is likely to dissipate. To assess real impacts, it is necessary to monitor the physical-chemical, biological, and transport p m of the plume.

The free oxygen environment in the Martil River during summer is promoting the development of odors and vectors. This latter problem has prompted the local authorities to spray insecticides regularly in populated areas.

5.1.3.2 Surface water upstream

The Nakhla Dam, constructed in the late 1950s, and the Smir Dam, expected to be operational in 1992, constitute the major hydraulic structures in the ROI. Located upstream of any major pollution source, those dams will satisfy all of the ROI's water needs for the next ten years. Siltation, however, is the major problem facing both dams. To date 50 percent of the regulated volume of the Nakhla has been lost to siltation, and the new Smir Dam is expected to lose 180,000 m^3/year of its 34 Mm^3 of volume. The siltation problem is linked to the absence of a watershed management plan but is only indirectly linked to the urbanization of Tétouan. The degradation of the watershed is the result of forest clear cutting for agricultural purposes and to satisfy Tétouan's fuelwood needs. Given the absence of data, it is very difficult to determine a quantitative link between deforestation and siltation.

Nakhla Dam is classified as an oligotrophic to mesotrophic system. Water quality is good, except for a slight thermal stratification between the top and the bottom water that leads to limited hydrogen sulfide formation. Upstream of the Smir Dam, water quality also is

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relatively good; except for a limited microbiological pollution, all other quality parameters have acceptable levels. Presently, however, the stored water in the Smir reservoir is encountering eutrophication phenomena largely because of the high nutrient levels after the first washing of the watershed. As a result, large volumes of the stored water were wasted. This eutrophication phenomenon, normal when a dam is new, is expected to dissipate after five to seven years of operation. In general, however, water quality in both dams is similar to that obtained by the conventional treatment operations at the old plant in Tétouan and the new unit in Smir.

The construction of those hydraulic structures is a direct consequence of the city's water demand. Their impact on the environment is twofold: a decrease of natural flow in the rivers potentially leading to zero flow during the dry season and less discharge into the sea and a risk of prolonged eutrophication of the water as a result of the nutrient input into the dam. The Smir River is suffering from both phenomena. Consequently, Lac Smir located at the Smir estuary is experiencing a significant impact (see Section 4.4, Biotic Resources/Biodiversity).

5.2. GROUNDWATER

5.2.1 Resource Description

Each of the four watersheds described above has its own aquifer domains. The alluvial Martil-Alila groundwater aquifer is the largest. It extends west, north, and south from Tétouan, 10 km east to west and 8 km north to south. It is characterized by a complex stratigraphy that extends from the ground surface to the impermeable layer 20-60 m below. The complexity of the structure makes it difficult to draw a clear picture of the litho-stratographic succession within the aquifer. The water table is generally between 2 and 5 m and less than 1 m near the coast. This usually results in poor drainage conditions and frequent flooding during the rainfall season. However, piezometric levels, which measure the distance between the water table and the ground surface, are pseudo-stable, although recent indications show a decrease in some coastal and central locations.

The hydraulic budget suggests that recharge is 95 percent due to rainfall infiltration. The level of exchange between the aquifer and both the Martil and Alila rivers is not well-defined, although there may be some exchange from the aquifer to the rivers. The volume of the annual recharge is 13.8 Mm^3, 48 percent of which is exploited for agricultural, domestic, and industrial needs. Less than 40 percent of the domestic needs in the ROI are supplied by groundwater. Sources include springs, pumping sites, and wells, located at the upper edges of Tétouan, M'diq, and F'nideq. However, a series of two springs and five pumping sites located in the Tamouda area southeast of Tétouan supplies 75 percent of the ROI groundwater needs.

The Smir and Negro aquifers have areas of 9 km^2 and 10 km^2, respectively. Approximately 20 percent of their area is located under wetland zones. In general, piezometric levels are stable in the Smir aquifer but sensitive to precipitation regimes in the Negro aquifer. Two pumping sites, one in each aquifer, supply 18 and 7 percent of the ROI groundwater needs, respectively.

The basic physical-chemical characteristics of the groundwater are given in Appendix C-4. In general, conductivity and chloride measurements, which reflect salinity levels, are higher near the coast as a result of the adjacent seawater.

5.2.2 Identification of Adverse Human Activities

Within the ROI, adverse urban effects on groundwater resources are considered primarily for groundwater resources at and downstream of Tétouan and the satellite towns.

Several adverse urban-related activities affect the quality and the quantity of groundwater downstream of the ROI. All of them fall under the chemical-biological category:

- infiltration of wastewater effluents into the Martil-Alila aquifer from private cesspools in the town of Martil;
- intrusion into the Smir aquifer of effluents from the wetlands receiving M'diq effluents;
- salt intrusion into the aquifers as a result of overpumping by private users; and
- contamination of the Martil-Alila and the Smir aquifers by leachates originating from the municipal landfills located above three main pumping sites.

5.2.3. Measurable Impacts

Groundwater quality is being differentially degraded depending on several factors:

- proximity of the aquifer to the lower section of the Martil River;
- widespread prevalence of cesspools in areas with a high water table;
- discharge of sewage effluents from M'diq on wetland located in high water table areas; and
- potential contamination from landfill leachates especially near pumping sites that supply 50 percent of the ROI's groundwater.

All wells around the lowest section of the Martil River and at the coastal zone in the Smir aquifer have levels of contamination significantly higher than U.S. standards. The contamination is particularly significant with respect to calcium, nitrate, sulfates, magnesium, chloride, and conductivity, which measures salinity in water. Part of the contamination might be due to natural phenomenon related to the proximity of the sea. However, overpumping, providing water for domestic and some limited agricultural uses, is drawing the water table below sea level, inducing seawater intrusion into the aquifer. At those locations, chloride and sodium levels attain values of 7,000 mg/l and 3,000 mg/l, respectively, which is 35 times the U.S. maximum allowable level. The mineral enrichment also might be due to the proliferation of cesspools in Martil, as this zone is not sewered. Another explanation is the natural mechanism of aquifer discharge and possibly recharge from a contaminated Martil River. Water exchange is likely during this process. The shrinking of the beach as a result of construction and sand excavation also may be contributing to saltwater intrusion into the coastal aquifer. However, data are not available to confirm the possibility.

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Nitrate levels generally are low, except for one area south of Martil where high levels of chloride and negative piezometric levels are encountered; these levels are seven times higher than U.S. standards. Local extractions for agricultural purposes might be responsible for the phenomenon.

The Smir aquifer seems also to suffer from discharging of wastewater into wetlands located above the aquifer, whereas the Negro and F'nideq aquifers have no significant levels of contamination. However, data on wells and pumping sites used for public supply show no significant levels of contamination.

Most of the contamination is localized outside municipal drinking water supply sites, although some pumping sites were previously exploited and closed because of poor water quality. Still, more than 2,000 individual wells in Martil and approximately 900 in Tétouan are used at dwellings for non-drinking purposes. These small wells, exploited at a low rate (less than 20 l/d), are affected by sewage cesspools that serve the majority of dwellings in Martil and dwellings throughout Tétouan. In periods of water shortage, the use of these wells and other public water points (*bornes fontaine*) increases significantly. A 10-year average of microbiological data from these wells show that more than 52 percent of samples collected in Martil and 30 percent of those in Tétouan have high levels of contamination. Unexpectedly, however, the 1990 data show only 7 and 13 percent. This single data point needs to be confirmed in the future. The old ancestral water distribution system (*Skoundo*) in the Médina, with its 400 intake points, also suffers from this contamination. Except for the 1990 data, more than 50 percent of the *Skoundo* samples tested are contaminated.

Although most of the contamination described above does not significantly affect the public groundwater supply, it is still disturbing that more than 50 percent of the supply originates from pumping sites located within a 1,200-m perimeter of two municipal landfills. One pumping site is already experiencing levels of iron and manganese 60 times higher than U.S. standards. This situation is prompting the water treatment plant to use additional chemical treatment to precipitate the metals. It is unclear whether this contamination is linked to the landfills or to a nearby metal scrap depository. Data on other heavy metals are not available. In the absence of updated and more complete information from these pumping sites, one can reasonably presume that the landfills constitute a serious threat to the downstream groundwater quality in the ROI.

The most significant upstream groundwater resources in the ROI are in the Dorsale Calcaire and the Haouz regions outside Tétouan. The cost of exploitation is, however, very high and it is unlikely that those resources will be exploited in the foreseeable future.

5.3 WATER SUPPLY AND DEMAND IN THE ROI

The quantitative aspect of water resources is governed by the newly built Smir Dam, which will erase the more than 160 l/sec water deficit in the ROI. At the same time, the reliance on groundwater resources and on downstream surface water will drastically drop. Water needs and demands are summarized in Table 5.3. Detailed resources are given in Appendix C-5. Using a best-case scenario, a new water deficit is expected in the year 2002 (Figure 1 in Appendix C-5) and even earlier if more conservative assumptions are used. Local water

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and demands are summarized in Table 5.3. Detailed resources are given in Appendix C-5. Using a best-case scenario, a new water deficit is expected in the year 2002 (Figure 1 in Appendix C-5) and even earlier if more conservative assumptions are used. Local water agencies, however, do not expect a water shortage before the year 2005, largely because of a lower projected population growth and higher anticipated equipment yield. In any case, to face the new deficit, reliance on groundwater is anticipated. In 2001, it is expected that 20 percent of water supplies will come from groundwater resources, versus 27 percent ten years later, especially because the construction of a new dam (Koudiat Gensoura) on the Mhajrate River is not expected before 2030. Similarly, river intakes could play a backup role to compensate for the increasing water shortage. For example, the reinstated Martil River intake (200 l/sec average annual rate) could delay the shortage or at least partly alleviate the deficit. It is therefore necessary to protect the quality of the downstream resources, first to protect the intrinsic value of water, and second to preserve an economically valuable water supply.

Table 5.3 Water Resources Versus Demand in the ROI.

	1991	1992	2001	2011
Available (l/sec)	703	1,403	1,436	1,483
Demand (l/sec)	866	872	1,373	2,076
Deficit or surplus	-163	+522	+63	-543

The Smir Dam was built in part because the marginal cost of treatment of water recovered from certain well sources on the Martil plain has increased dramatically with the reduction in quality of that water. Marginal treatment costs of water at the Nakhla Dam are far lower, given its higher quality. Likewise, after an initial five to seven-year period of treating for high organic materials in water recovered from the Smir Dam, the water quality will be better and the marginal cost of treatment of its outflow will be low relative to treatment of well water.

As in most parts of the world, water is significantly underpriced in Tétouan. Consumers pay according to usage at the rate of one Dh/m^3, with rates increasing for use above a certain threshold. Average annual use per household is estimated at 75 to 120 m^3/year, which is produced, treated and delivered at a total cost far higher than the price paid. Although a thorough accounting of water production costs could not be obtained during the study period, rough calculations were completed on cost recovery for water production. They indicate that under the current price regime, at the current rate of consumption, and given a 3.4 percent population growth rate, urban Tétouan could not recover the capital cost of construction of the Smir Dam until 2015. That cost--estimated by Hydraulique officials to total Dh300 million--includes neither interest charges on the construction loan, recurrent costs of production, treatment and delivery, inflation, nor the construction of additional water collection systems when the Smir is no longer sufficient to meet the needs of the urban population.

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5.4 MARINE FISHERIES

5.4.1 Quantity and Quality of the Resource

The fisheries resources exploited by fishermen of the Tétouan area consist primarily of two sectors: the stocks of sardines and other small pelagic (deepwater) or demersal (bottom-dwelling) fish, and the large tuna fishery. The first sector includes sardine, herring, bogue, and mackerel and, to a lesser extent, red mullet, melva, a wide variety of pelagic species, and some cephalopods including octopus, squid, and shrimp. In the past anchovy stocks also were found here, but the fishery has been depleted and is no longer significant. The second sector consists of the large red tuna, which migrates during the summer months within 1-3 km from the shore. Although 1990 was a peak year for catches of this large fish, preliminary reports indicate that the number of red tuna dropped dramatically in 1991. Some shellfish beds also exist in the nearshore area.

The fishing industry, oriented toward domestic supply, contributes less than 2.3 percent of regional GDP and accounts for less than 1.1 percent of employment (see Section 2.5, Population and Employment). The export of nearly all of the red tuna to Japan constitutes one of the few ways that provincial Tétouan generates foreign exchange; nevertheless, the fishery itself is very small in local economic terms and in relation to Morocco's large and growing fisheries trade.

5.4.2 Human Use of This Resource

The fishermen from the Tétouan area come from M'diq, Martil, and Azla. The total number of fishing vessels is small compared to those of other fleets also exploiting fishery resources in the same area. These vessels are coming from other ports in northern Morocco, from Spain, and from other countries. These other fleets are using much more efficient gear than are those from the Tétouan area.

Of the three Tétouan fishing towns, M'diq is the major port. Relative to other fishing ports of northern Morocco, it ranks fifth (RdM/ONP/ISPM, 1991a). The M'diq port has about 56 vessels, 39 of which are small boats that participate in the sardine fishery; the rest are trawlers in the pelagic fishery. There are two tuna processing plants, one transshipment warehouse in the port, and a small haul-out and repair facility. A canning factory is being planned. The port also has a small yacht club. A port expansion project, which would double the size of its basin, is being planned by the Public Works Department with completion projected within the next three to five years.

Martil and Azla have no port, though there are perhaps 60-80 boats participating in a nearshore artisinal fishery (using small boats with low-technology gear) that sells its catch locally. In the past, M'diq, Martil, and Azla were able to meet the demand for fish in the Tétouan area. Now, however, other ports such as Tangier and Larache are providing an increasing share of fish for the Tétouan market. Most of the catch is sold locally because there is no canning or freezing of the fish, except for the tuna.

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The existing regulatory regime for this fishery does not exert strong management control over the stocks. Mainly, there are rules requiring vessel licensing and restricting some types of gear. However, there are no limits on the number or size of fish that can be caught. Though each fisherman must report his catch, the catch of the artisinal fishermen is not well documented; some estimates are available for the catch by the artisinal fishermen of Martil but not for those of Azla (RdM/ONP/ISPM, 1991a). Local officials mentioned that some Moroccan fishermen sell their catches to Spanish vessels while at sea, therefore this portion of the catch does not show up in the statistics. For the fish-processing factories, the only permits and fees required are those necessary for operating any factory. Owners of the larger fishing vessels in M'diq have formed an association; the artisinal fishermen are not organized.

In 1990, the catch landed in M'diq weighed 6,036.7 tonnes (metric tons) and was valued at Dh 37.5 million (RdM/ONP, 1990; RdM/DRAM, 1990). Only 68 tonnes with a value of Dh 0.83 million (RdM/ONP/ISPM/, 1991a) was landed in Martil. In 1990, seven species made up more than 96 percent of the weight and value of the fish landed at M'diq. In order of value, these were red tuna, sardine, chinchard (herring), bogue, mackerel, melva, besugues, and rouget (red mullet) (see Table 1 in Appendix D) (RdM/ONP, 1990; RdM/DRAM, 1990). From 1981 to 1990, the overall fisheries catch in tonnes increased about 41 percent, from 4,288.2 to 6,036.7.

Local officials estimated that catch per unit effort (CPUE) was slightly increasing from 1981 to 1990 with a gradual increase in the number of active fishing vessels. Individual artisinal fishermen, however, reported gradual declines in CPUE. The net increase in CPUE could be explained by two factors. First, an estimated three, four or five trawlers, with much more efficient gear than artisinal fishing boats, have entered the fishery each year since 1984. Second, CPUE for the red tuna fishery increased dramatically since its introduction in 1985. From 1989 to 1990, there was an increase of about 500 percent for red tuna and 4 percent for all other species (see Table 2 in Appendix D).

In brief, the catch for most species was stable or grew slightly from 1980 to 1990. Statistics show a slow growth in the catch of sardine, chinchard, bogue, melva, and besugues. The mackerel catch fluctuated over time with a peak in 1990 of 536.7 tonnes. The rouget (red mullet) catch also fluctuated, dropping from 20.7 tonnes in 1981 to a low of 4.1 tonnes in 1984 and recovering to 23.3 tonnes in 1990 (see Table 3 in Appendix D) (RdM/ONdP, 1981-1990).

Several species have shown a significant decline in recent years, such as anchovy, bonito, and red tuna, as has the bulk catch of various selaciens (cartilaginous fish such as sharks and rays). The anchovy fishery showed a steady decline over this period, from 1,200 tonnes in 1981 to 3.0 tonnes in 1990. The bonito tuna (*bonite à dos rayés*) showed a significant drop from 46.8 tonnes in 1981 to 0.3 tonnes in 1990. Preliminary reports for the very valuable red tuna fishery indicated that after the major peak in 1990, there was a very significant drop in the 1991 catch to about 45 tonnes, only 8.4 percent of the 1990 catch. The bulk catch of various selaciens fluctuated significantly from 1.0 tonne in 1981 to a high of 254.8 tonnes in 1984 to 2.7 tonnes in 1990 (RdM/ONdP, 1981-1990) (see Table 3 in Appendix D).

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5.4.3 Human Impacts on the Fishery Resources

Impacts of urbanization of Tétouan are slight on the overall fishery resources utilized by the fishermen of M'diq, Martil, and Azla. This conclusion is based on four reasons:

1) most of the fisheries appear to be operating at a sustainable level;

2) the depletion of anchovies, bonito, red tuna, and some selaciens appears to be due more to overexploitation than to pollution (see Appendix D for more discussion);

3) fishermen from outside the Tétouan area are in part responsible for the overexploitation of certain stocks; and

4) the depleted stocks are being harvested not only for Tétouan, but also for the whole of northern Morocco, parts of Spain, and the Japanese tuna market. Because Tétouan is only a small part of this greater market, increased exploitation of these stocks is only partially influenced by any increased demand from the growing Tétouan area.

Impacts on offshore fisheries from the urbanization of Tétouan are certainly difficult to assess. It has been suggested that because many of these fish use the nearshore waters as feeding or nursery grounds, pollution in this area may have an effect on these stocks (WB/ID, 1990), but this is difficult to determine. Overall increases in marine pollution in this entire region may be having some effect on the region's pelagic and demersal fisheries, and the Martil River is certainly contributing to this general degradation of the region's marine water quality. However, the specific increase in marine pollution to the region from the urbanization of Tétuoan is very difficult to measure relative to the pollution from the rest of the Moroccan coast, from Spain, and from passing ships.

Even though the impact of urbanization of Tétouan on overall fisheries resources is slight, at a much more local level, two small fisheries resources are experiencing severe impacts: the shellfish habitat off Martil south to the Laou River and the shrimp nursery habitat in Lac Smir.

Tétouan city wastes carried in the Martil River and discharges of untreated wastes from the town of Martil already are having a noticeable impact on the nearshore shellfish habitat exploited by the artisinal fishermen of Martil and Azla. The specific concern is the release of high levels of nutrients, any heavy metals, and bacterial contamination in the effluent from the Martil River and Martil town, and their effects on shellfish. Nutrients can exacerbate the problem of "red tide," a phenomenon that renders shellfish toxic for humans. Recent studies have found toxic shellfish in the waters from the Martil River south to the Laou River (RdM/ONP/ISPM, 1991b). This occurs when a certain dinoflagellate (microalgae) is ingested by shellfish and becomes concentrated in their muscle. Higher nutrient input from waste-laden waters may increase the growth potential of this dinoflagellate.

In addition, there may be a problem with heavy metals or bacteria concentrating in the sediment and being ingested by bottom-feeding fish or filter feeders, such as shellfish. These fish and shellfish with concentrated levels of biotoxins, heavy metals, or bacteria may present a public health problem. Further study is necessary.

As discussed in Section 4.4, Biotic Resources/Biodiversity, the dramatic changes in the wetlands in Lac Smir, which are related to continued growth of Tétouan, now make the lake unsuitable as a nursery habitat for shrimp. This will have a severe impact on the small stocks of shrimp in this area, which no longer are able to carry out their life cycle there. The stocks probably will diminish because there are very few other brackishwater wetlands in the area.

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GLOSSARY

Aquifer: The water-bearing portion of subsurface earth material that yields or is capable of yielding useful quantities of water to wells.

BOD_5: Biochemical oxygen demand measures the oxygen required for the carbonaceous oxidation of organic compounds present in wastewater.

Critical deficit D_c: Lowest dissolved oxygen concentration in water as a result of the maximum impact of wastewater discharge.

Critical time T_c: The time needed by a river to reach the critical deficit D_c.

Dissolved oxygen: The concentration of dissolved molecular oxygen present in a body of water. At 20°C, the saturation value of dissolved oxygen in fresh water is 9.17 mg/l. This value represents the maximum concentration of oxygen that water can hold at 20°C.

Eutrophication: Natural or man-induced process in which bodies of water may become more productive through the introduction and the cycling of nutrients.

Habitat economic: Most common form of housing in Tétouan. It consists of three floors; the ground floor is either a garage or a shop, and the two top floors are residences for one household per floor. They are found either *quadrillé*, which is in authorized or serviced subdivisions, or *spontané*, that is constructed outside of municipal regulation. The latter is also referred to as clandestine housing.

Half-life: Time needed for reducing a concentration or a number by 50 percent.

Marginal cost, marginal benefit, marginal product: The cost, benefit, or result of producing one or more units. For example, if the unit cost (MC) is less than the net benefit (MB) of producing one more bale of hemp, production will be increased until no more marginal benefit can be realized, or until MC=MB.

Mesotrophic: Bodies of water that are intermediate between oligotrophic and mesotrophic. The latter have a higher productivity due to an abundant supply of algal nutrients; as a result, in the bottom, oxygen may be depleted.

Oligotrophic: Bodies of water that have a low level of productivity due to a severely limited supply of nutrients to support algal growth.

Parallel market: Trade in goods, services, or currency at unofficial prices, i.e., market-driven rather than government-regulated.

Self-epuration: Process by which natural water systems ensure the conversion of wastes through natural physical, chemical, and biological mechanisms.

GLOSSARY (cont'd)

Value added: Final price at market less all input costs; e.g., if a loaf of bread sells for Dh1 and the ingredients, fuelwood, labor, and transportation all total 80 centimes per loaf, VA = 20 centimes.

Xenobiotics: Synthetic organic compounds that resist natural processes of biodegradation. Often these compounds are toxic.

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APPENDIX A
Tourism

Although Tétouan has served historically as a tourism destination for Moroccans more than for Europeans or other foreign visitors (Table A.1), hopes for future growth of the tourism industry hinge on Tétouan's ability to attract clients from abroad. Long-term growth of the Tétouan tourist industry faces three problems that are unrelated to the natural resource base: overdevelopment of the Moroccan tourist industry in general, fierce competition from other tourist centers both within Morocco and at other locations on the Mediterranean, and a limited service economy to multiply the income and employment impact of tourism growth.

Overdevelopment of the national tourism infrastructure led in 1990 to an 8.5 percent increase in hotel capacity coupled with a decline in nights stayed (EIU 1990). The World Bank notes that this phenomenon is not new: a 1986 study of tourism in the 1970s concluded, "the [Morrocan] Government had overestimated future demand for tourism capacity, resulting in the design of an overly generous incentive system, and excessive investments in tourism areas in coastal areas, with possible negative environmental consequences" (WB/Environment Report 1990: 21). A recent and sustained decline in arrivals from traditional European markets (-6.6 percent from 1989) was offset in 1990 by 1.5 million Algerian visitors (+ 60.3 percent over 1989): the increase of visitors from other Maghreb countries is welcome but infrastructure has been geared to a wealthier clientele: 55 percent of all classed accommodation is four- and five-star hotels. In 1989, hotel capacity in Agadir increased by 16 percent and in Marrakech by 33 percent (EIU 1991).

Even apart from the short-term negative effects of the Gulf War on the tourist trade and the decline in arrivals attributable to a world recession, Tétouan will face significant competition from other Moroccan resorts both for domestic and foreign business. Relative capacity and occupancy rates for Tétouan versus other major tourist destinations in Morocco are weak (Table A.2).

Finally, Tétouan's tourism development plans continue to emphasize development of extensive resort complexes: in 1983, 72 percent of capacity lay in V.V.T. (*villages des vacances touristiques*) into which tourists are encouraged to withdraw. Further development of such capacity is the center of planning in the future. Linked commercial development in the region--restaurants, rental cars, cultural opportunities celebrating the unique Arab/European heritage of Tétouan--has not been planned as intensely, thereby limiting the potential multiplier effect of tourist income.

Table A.1
Origin of Tourists Arriving in Tétouan
1990 (1) v 1989 (1)

	1989 (1)	1990 (1)	Change (%)
France	6794	5492	-19.16
Spain	5657	5712	+0.97
USA	689	727	+5.51
Canada	289	275	-4.84
UK	1095	626	-42.83
Germany	2395	2084	-12.98
Italy	629	481	-23.53
Scandanavia	321	445	+38.63
Portugal	306	208	-32.03
Netherlands	255	286	+12.16
Belgium	547	575	+5.12
Switzerland	537	575	+7.08
Arab nations	1678	1554	-7.39
African nations	316	316	--
Other nations	1243	1119	-9.97
Moroccans	51,200	55,002	+7.42
Foreign residents	141	213	+2.16
Total	74,092	75,690	+2.16

Source: RdM/MI/PT, 1990.
Note: Most recent statistics available. Figures for last half of 1989 indicate higher proportion of Moroccan tourists during the annual summer influx in Martil and northern coastal areas.

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Table A.2
Tourist Capacity and Occupancy
Tétouan and Other Moroccan Locations

	Total Capacity	Average Occupancy
Tétouan	5158	25.6%
Tangier	8964	35.8
Fès	2962	47.7
Casablanca	5393	41.4
Rabat	3083	43.5
Marrakech	8752	41.0
Agadir	13,235	57.8
Average	5,943	(national) 40.5

Source: RdM/MI/DUA, data as of 12.31.83

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APPENDIX B
Forest Resource Analysis

The national reforestation campaign has a direct bearing on the forest resource of Tétouan because of the campaign's emphasis on northern regions. The national campaign seeks to replant annually an average of 38,540 hectares (WB/AOD, 1990).

The following analysis assumes for demand that:

1) the government quota of 1.3 metric tons per household per year is an accurate estimate of per household consumption;

2) the average household size prevailing in the 1980s will continue (5.2 individuals per household [TUM 1988]);

3) the per household fuelwood consumption rate will not decline;

4) the *hamams*' and bakeries' ability to increase production capacity to meet demand is unlimited.

Supply assumptions include:

1) existing nondegraded forest resources in Larache, Chefchaouen, and Tétouan are the only resources available for fuelwood production;

2) the current rate of degradation of 2.7 percent per year continues until 1995, at which point the national reforestation campaign will reverse the trend and net undegraded resources begin to increase at the rate of 1000 ha/yr (the actual campaign began in 1988 and plantations in the Rif region are estimated to average more than 38,000 ha/yr).

These assumptions intentionally represent a worst-case scenario to test the hypothesis that the forests are only moderately, rather than severely, threatened by urbanization. On the demand side, long-term future consumption *is* likely to decline on a per-household basis given industrial conversion to fossil fuels. On the supply side, Tétouan (and other urban centers in Morocco using the Rif resource) will continue to have access to all of the partially degraded forest that exists today. Moreover, the commitment to reforestation not only for wood supply but for employment generation remains strong in Tétouan and at the central government level; it is likely that far more than 1000 ha/yr will be available for wood supply to Tétouan in the years ahead.

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Because government planners allot wood consumption "quotas" on a per-household basis rather than in terms of anticipated sustainable yield or consumption capacity of existing *hamams*, bakeries, and industries, the model below is driven directly by population growth.

Appendix Table B.1. Projected Wood Supply and Demand for Urban Tétouan 1986 - 2011

Year	Urban Tétouan population	Hectares of forest required			Projected hectares of available plantation forest
		At constant yield of $3m^3$/ha/yr	At variable yield rates		
			Yield (m^3/ha/yr)	Hectares	
1986	231,731	13,892	3.0	13,892	27,356
1987	239,368	14,351	3.0	14,351	26,617
1988	247,267	14,824	3.0	14,824	25,899
1989	255,427	15,313	3.0	15,313	25,199
1990	263,856	15,819	3.0	15,819	24,519
1991	272,563	16,341	3.0	16,341	23,857
1992	281,558	16,880	3.2	15,825	23,213
1993	290,849	17,437	3.4	15,386	22,586
1994	300,447	18,012	3.7	14,605	21,976
1995	310,362	18,607	4.0	13,955	21,383
1996	320,604	19,221	4.5	12,814	22,383
1997	331,184	19,855	5.0	11,913	23,383
1998	342,113	20,510	5.5	11,187	24,383
1999	353,403	21,187	6.0	10,594	25,383
2000	365,065	21,886	6.5	10,101	26,383
2001	377,112	22,609	7.0	9,689	27,383
2002	389,557	23,355	7.0	10,009	28,383
2003	402,412	24,125	7.0	10,339	29,383
2004	415,692	24,922	7.0	10,681	30,383
2005	429,410	25,744	7.0	11,033	31,383
2006	443,580	26,594	7.0	11,397	32,383
2007	458,218	27,471	7.0	11,773	33,383
2008	473,340	28,378	7.0	12,162	34,383
2009	488,960	29,314	7.0	12,563	35,383
2010	505,095	30,281	7.0	12,978	36,383
2011	521,764	31,281	7.0	13,406	37,383

Conversion at 1.3 tons/household
0.72 tons = 1 m^3
Per capita fuelwood use = 250kg/yr
5.2 persons/household
Population growth at 3.3 percent[1]

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[1]An assumption that the population growth rate declines from 3.3 percent annually to 2.8 percent by 2008 results in a difference of only a few thousand hectares required for productive fuelwood production. At $3m^3$/ha/yr, the hectares required under the lowered growth rate is 29,513 (versus 31,281 above); at $7m^3$/ha/yr the total required under the lower growth rate is 12,648 (versus 13,406 above).

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APPENDIX C.1
Figures 1 and 2

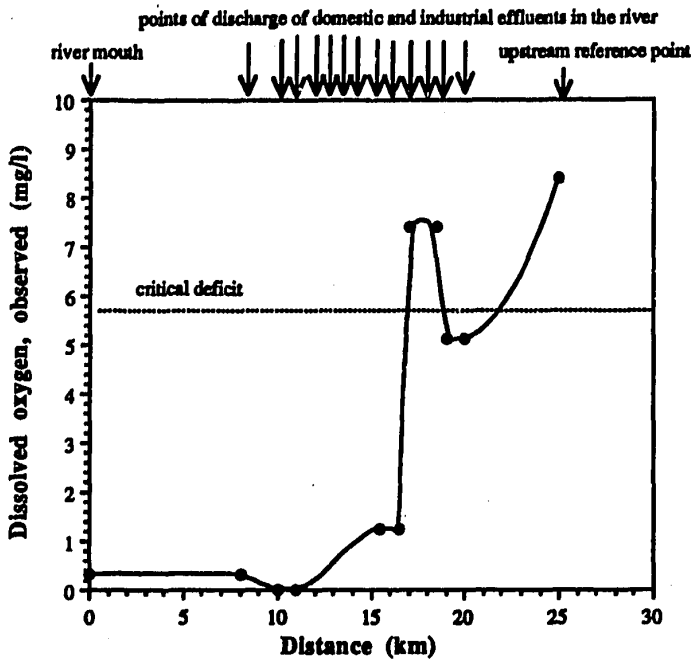
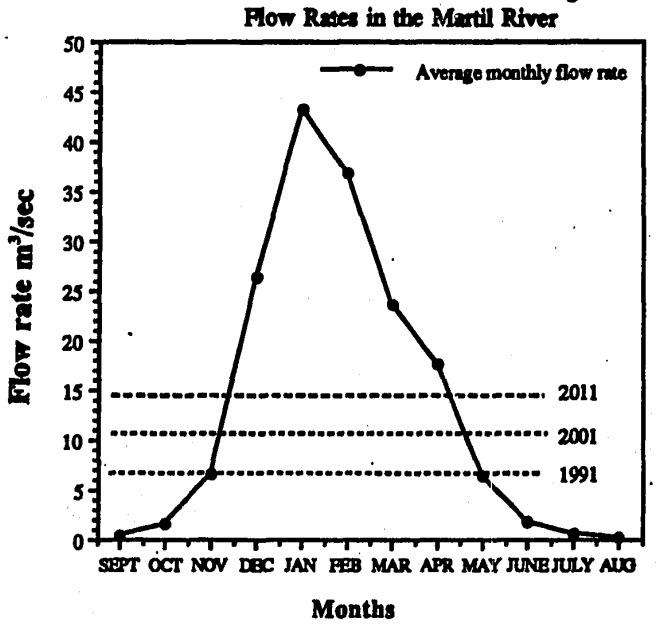


Figure 1. Dissolved Oxygen Profile in the Martil River.

Figure 2. Present and Projected Minimum Required Dilution Rates as Function of Year Versus the Average Monthly Flow Rates in the Martil River



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APPENDIX C.2
Calculations of the Self-epuration Capacity of the Martil River Based on Stsreeter-Phelps Equation

Basic Assumptions:

BOD_5 wastewater (ww): 587 mg 0_2/l
D.O. $_{ww}$: 2.5 mg/l
D.O. water: 9 mg/l
Flow rate water (average June through September): 0.9 m^3/sec
Re-aeration constant: 0.4 d^{-1} for 20°C

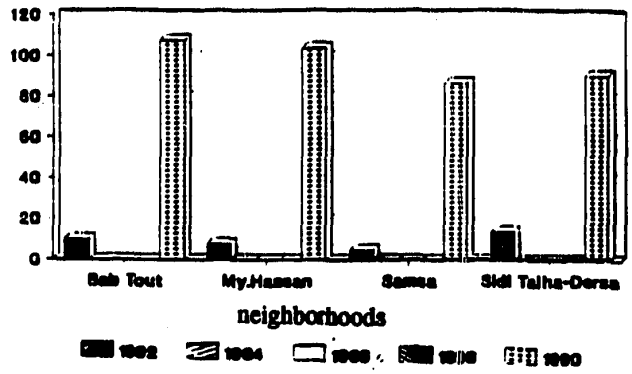
Main Results:

BOD_5 mix (wastewater + river water): 142 mg 0_2/l
Ultimate BOD_5: 208 mg 0_2/l
D.O. mix: 7.45 mg/l
$k = 0.25\ d^{-1}$, $k_2 = 0.34\ d^{-1}$ (temperature: 21.3°C)
Oxygen deficit: 1.388 mg/l
Critical deficit: 5.73 mg/l
Critical time: 3.38 d
Critical distance: 29 km

APPENDIX C.3

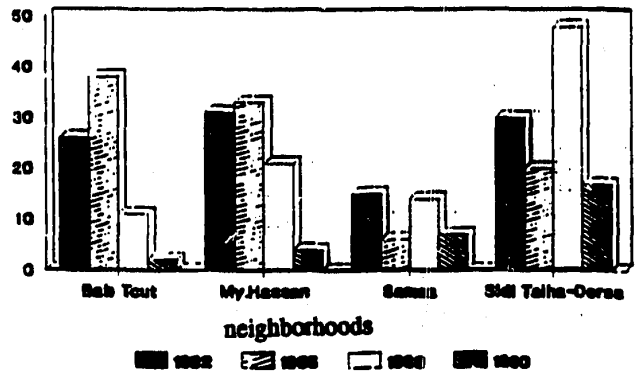
Waterborne Diseases Data in Tétouan
(RdM/MSP/DEP 1991)

gastroenteritis

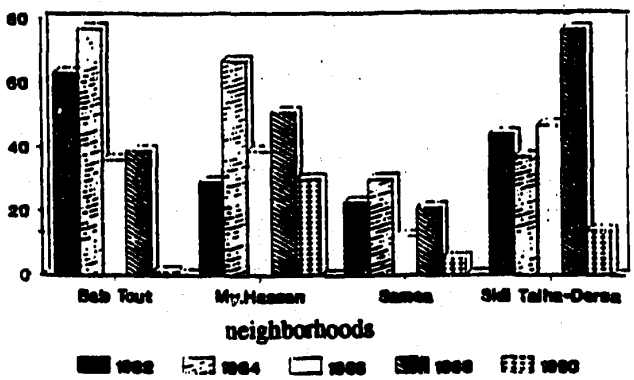


typhoid fever

Number of Cases



Hepatitis



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APPENDIX C.4
Chemical Characteristics of Groundwater in the ROI

	Conductivity microS/cm x 1000	Ca mg/L	Cl mg/L	SO_4 mg/L	Mg mg/L	Fe mg/L	Mn mg/L
U.S. Standards	2500	100	250	250	10	0.3	0.05
Lower Martil Sites*	8190	902	2551	130	286	0.3	--
Lower Martil Sites*	5620	9	1611	450	13	25	--
Lower Martil Sites*	11200	380	346	226	295	80	--
Higher Martil Sites‡	802	50	87	200	27	3.2	3.0

* Observation wells close to the coast
‡ Main pumping site (.501/sec)

Reference: El Morabiti, 1991; RDM/MTP, 1991a

APPENDIX C.5
Water Sources Available Within ROI (L/sec)

Groundwater	1991	1992	2001	2011
Torretta Spring	68	68	68	68
Tamouda pumping sites	125	125	148	150
Smir pumping sites	50	50	50	75
F'nideq pumping sites	20	20	30	40
Wells	40	40	40	50
Surface Water				
Nakhla Dam	400	400	400	400
Smir Dam	0	700	700	700
River intake	0	0	0	0
	703	1403	1436	1483

Reference: RdM/MI/RDE, 1989a, b; RdM/MTP, 1989b

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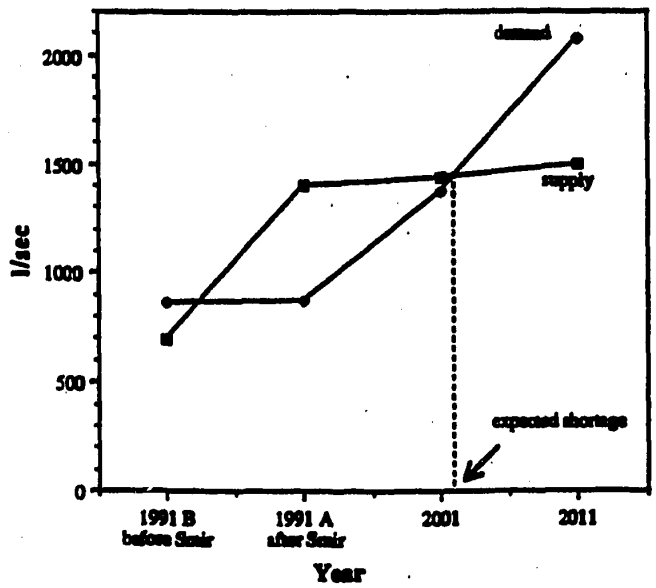
APPENDIX C.5
Figure 1

Fig. 1. Water supply versus water demand in the ROI.



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APPENDIX C-6
Water Recommendations

- Hydrogeologic and soil investigation to determine soil permeability and groundwater depth, flow, and contour map. This can be easily achieved by setting groundwater observation wells (no more than five cm in diameter and a minimum of three m penetration into the groundwater) around the perimeter of the site.

- Determine if possible the outlet(s) of the leachate by identifying the lowest points of the sites, drilling through the wastes layer, and pumping out the liquid if any.

- Determine the strength of the collected liquid in terms of BOD^5, total suspended solids, nitrates, alkalinity, calcium, iron, magnesium, manganese, zinc, and nickel.

- Monitoring of the water quality in the pumping sites beneath the landfill sites. Typical leachate composition should dictate the choice of the parameters to be analyzed. To minimize analytical cost, only the following parameters should be investigated: iron, zinc, manganese, nickel, magnesium, cadmium, alkalinity, suspended solids and pH. If excessive levels of metals are detected, only then should a rapid screening test for volatile organics, pesticides, and PCBs be performed.

- The use of the groundwater poses a major health risk if levels of contaminants are high. Also, the existing water treatment facility in Tétouan is not equipped to ensure the removal of those pollutants. The use of the contaminated pumping sites should then be discontinued. A detailed study on the future impact of these existing sites on the groundwater resources will then be warranted.

- Independently of the contamination potential, the old and the present landfill sites should be covered by 60 cm of topsoil to seal the wastes, to prevent uncontrolled burning, and to minimize odors. The sites also should be fenced to prevent access.

- The municipality should search for a new landfill site (the present one is close to saturation) only after a feasibility study is undertaken, probably with the assistance of international experts in the field.

APPENDIX D
Fisheries in the Tétouan Area

Table 1
Percentage of Total Weight (Tonnes) and Value (Dh) of Selected Species Landed in M'diq in 1990.

	Weight (tonnes)	% of total	Value (Dh)	% of total
Total of all fish landed	6,036.7	100.0	37,493,832	100.0
Red tuna	535.3	8.9	16,760,342	44.7
sardine	2,562.5	42.5	8,644,927	23.1
chinchard	950.8	15.8	3,543,244	9.5
bogue	801.0	13.3	2,855,428	7.6
mackerel	536.6	8.9	1,222,048	3.3
melva	311.6	5.2	1,637,596	4.4
besugues	117.6	2.0	708,998	1.9
rouget	23.3	0.4	532,468	1.4

(RdM/ONP, 1990; RdM/DRAM, 1990).

Table 2
Landings of Selected Species at M'diq by Year in Weight (1981-1990)

	Red Tuna	Sardine	Herring	Bogue	Mackerel	Melva
1981	0	720.0	819.2	290.8	83.0	12.1
1982	0	875.6	1,061.5	398.9	9.1	52.8
1983	0	910.9	1,355.3	427.1	52.2	21.3
1984	0	1,223.5	1,207.1	287.2	1,149.0	21.2
1985	0	1,130.3	1,483.8	479.8	156.4	13.1
1986	38.3	2,817.6	902.0	427.0	56.9	110.8
1987	109.9	3,391.6	1,027.7	508.3	149.1	72.0
1988	96.6	1,659.6	1,126.9	337.3	132.0	262.0
1989	49.7	1,339.2	1,868.6	782.7	194.0	296.0
1990	535.3	2,562.5	950.8	801.0	536.6	311.6

(RdM/ONP, 1981-1990; RdM/DRAM, 1990)

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Table 3
Landings of Selected Species at M'diq by Year in Weight (1981-1990) (continued)

	Besugues	Rouget	Anchovies	Various Selaciens	Bonito	Total catch
1981	61.4	20.7	1,184.4	956.3	46.8	4288.2
1982	40.9	14.0	489.1	107.6	15.6	3142.9
1983	43.6	5.6	136.3	213.9	27.1	3233.4
1984	41.3	4.1	107.2	254.8	22.8	4696.9
1985	76.1	14.1	40.0	211.2	13.9	4079.6
1986	73.9	20.6	72.5	35.0	13.5	4919.1
1987	64.3	19.0	3.8	47.1	43.8	5703.1
1988	105.3	27.0	6.7	4.9	26.1	4068.5
1989	201.3	41.8	2.4	4.8	18.5	5148.1
1990	117.6	23.3	2.9	2.7	0.3	6036.7

(RdM/ONP, 1981-1990; RdM/DRAM, 1990)

The Tuna Fishery. The fishery fleet of M'diq is mostly an artisinal fleet that participates in the sardine fishery and fishing of other pelagic stocks. There are a few trawlers that exploit both pelagic and demersal stocks. In 1985, the red tuna fishery was established using a barrier net system called a *madrague*, which extends out from shore 1-3 km. The net runs perpendicular to the shore, forcing the tuna into smaller enclosed areas running parallel to the shore, in which they are kept for as long as 2 months (see Figure 1). The tuna are fed and will continue to grow until they are harvested for market. The tuna is then processed (cutting off head and tail, and gutting the fish) and put on ice for shipping. Nearly all of this is exported by air freight to Japan.

Reasons for Reduction in Fish Catch. Responses from local officials and fishermen varied, but most agreed that the major reason for the drop in the catch of anchovy, red and bonito tuna, and selaciens (cartilaginous fish such as shark and rays) fisheries stocks was the increase in fishing pressure, due to both an increase in the number of total fishermen and boats (mostly from other ports) and to increased efficiency of gear. Pollution (both industrial and domestic) from Spain and Morocco and from passing ships was considered only as a secondary reason. Other concerns included climatic change creating an environmental stress on the tuna stocks in addition to the human pressure; catch of juveniles; increased efficiency of the fishermen by the illegal use of dynamite and the unregulated mesh size of nets (or using two nets of legal mesh size together, therefore effectively reducing the net size); and finally, increased fishing pressure of foreign fishermen illegally entering Moroccan fishing grounds.

For the fishery based in M'diq, Martil, or Azla, local officials identified the major problems that face the local fishery as being limitations of technology, infrastructure, education, and management, and not problems with local sources of pollution. These problems were specifically:

1) Most of the fishery fleet is artisinal, therefore the fishermen can only fish in the nearshore zone and stay at sea for a short time. Thus they are very dependent on the location of the fish stocks and on the sea and weather conditions. When a strong easterly wind blows, it is difficult to get out to the fishing grounds in the Mediterranean. During this time, most of the effort takes place on the Atlantic out of the port of Larache.

2) There is no education program, either in a school or in an extension program, for improving the fishing techniques of the fishermen.

3) The port of M'diq is very small, and the breakwaters and seawalls are ineffective in heavy seas. This problem is most evident in the winter.

4) There is no effective program for monitoring and managing the fisheries.

5) The haul-out facilities in the port of M'diq can handle only small boats (less than 40 tonnes). Larger vessels must go to another port for any repairs.

6) There is no place in M'diq to purchase spare parts for vessel engines.

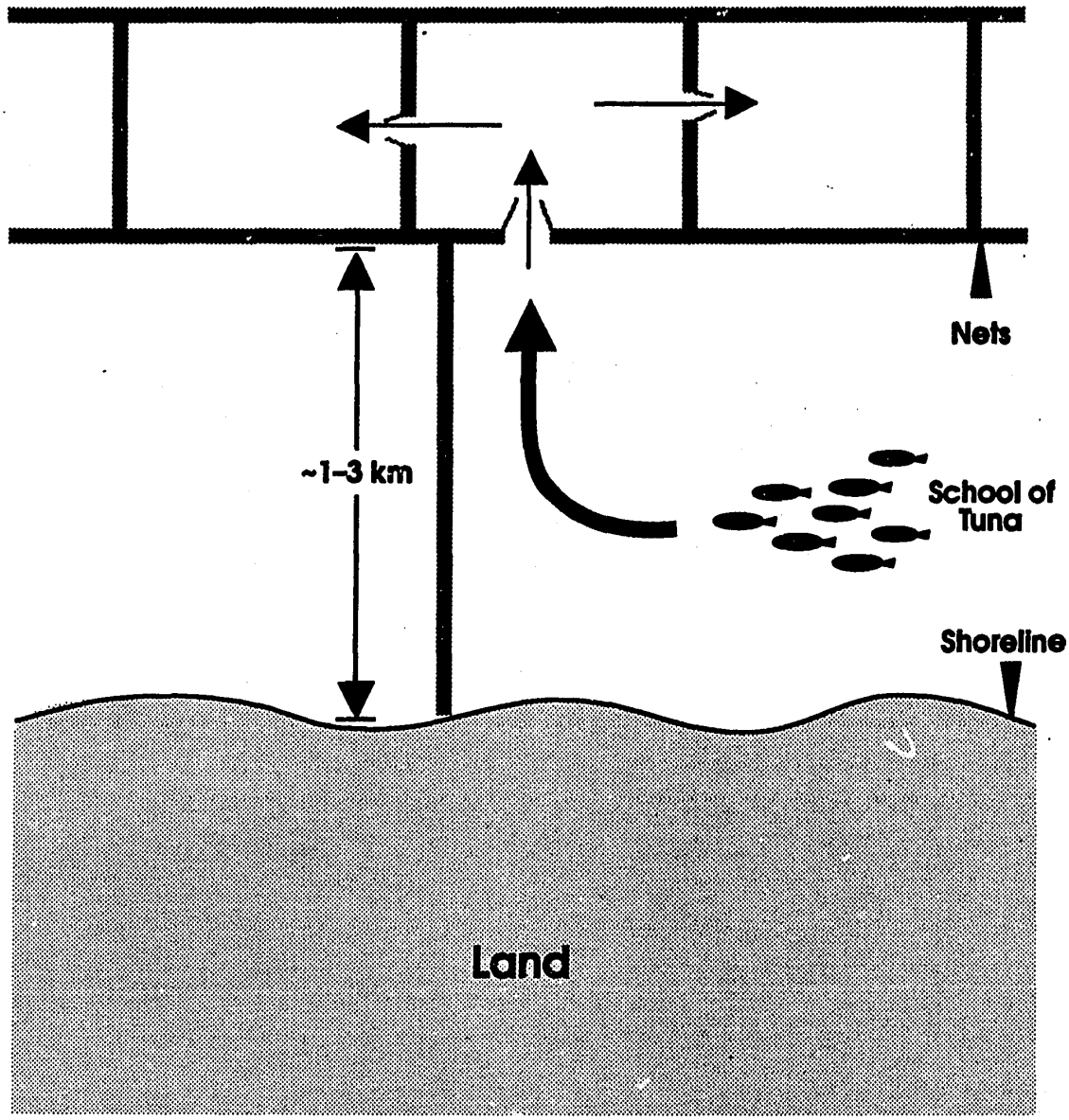
7) Fueling facilities are inadequate at M'diq, sometimes causing vessels to remain in port until additional fuel supplies can be imported.

The infrastructure problems will be ameliorated with the planned expansion of M'diq port. However, the technology, education, and management issues will remain.

APPENDIX D

Figure 1

Schematic Drawing of the Tuna "Madrague" Net Fishing Technique.



(not drawn to scale)

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APPENDIX E.1

Dominant plant species in the Tétouan area (based on Emberger, 1939; Mallayani, 1988). Note the lack of overlap between the natural oak understory and the mattoral that often replaces it. Note also that the species of trees involved in reforestation are not those originally common to the area.

Coastal plain trees *Quercus coccifera* (Chène Kermes)
Tetraclinis articulata (Thuya)

Upland trees *Quercus suber* (Chène liège)
and scattered stands of:
Pinus pinaster
Pistacia atlantica
Olea europea

Trees used for restoration
Pinus halepensis
Pinus pinaster var. *maghrebiana*
Pinus pinaster var. *atlantica*
Pinus pinaster var. *iberica*
Four other *Pinus* species
Three *Acacia* species
Cupressus sempervirens
Numerous *Eucalyptus* species

Oak understory
Arbutus unedo
Cistis albidus
Cistis arbustus
Cistis landaniferus
Cistis monspeliensis
Cistis populifolis
Cistis salvifolius
Cistis triflorus
Chamoerops humilis
Erica arborea
Halymium lasiocalycinum
Myrtis communis
Phillyrea angusitifolia

Mattoral

Ampelodesma mauritanica
Calycotome villosa
Chamaeropsumilis
Cistis albidus
Cistis crispus
Cistis monspeliensis
Cistis salvifolius
Erica ouistralis
Erica scoparia
Erica terminalis
Erica umbellata
Olea europea
Phyllirea angustifolia
Pistacea lentiscus

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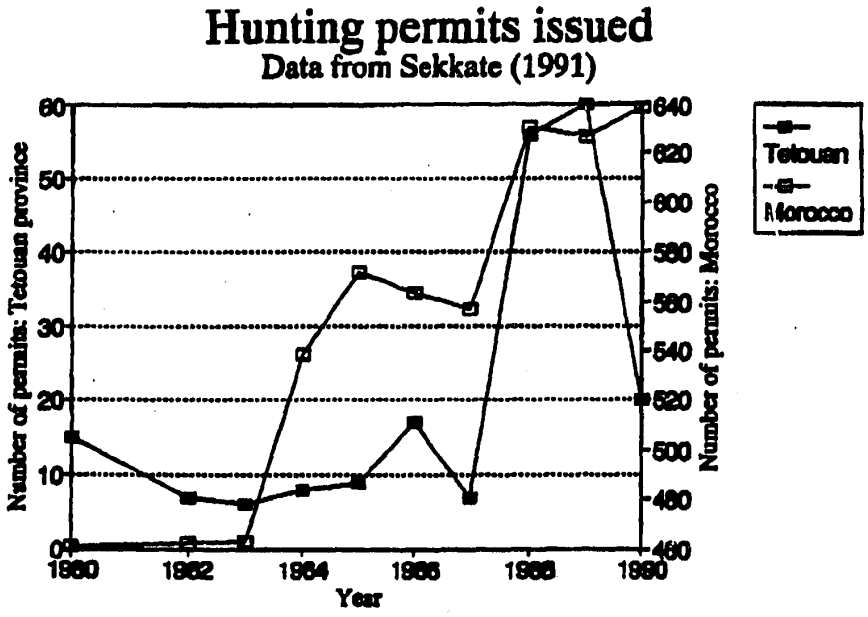
APPENDIX E.2



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APPENDIX E.3

Species of waterfowl observed at Lac Smir on January 11 and 16, 1984 (from Beaubrin et al, 1984).

Latin name	French common name
Anser anser	Oie cendrée
Anas clypeata	Canard souchet
Anas penelope	Canard siffleur
Anas platyrhynchos	Canard colvert
Ardea cindrea	Héron cendrée
Aythya ferina	Pligule milouin
Ciconia ciconia	Cigogne blanche
Circus aeruginosus	Busard des roseaux
Egretta garzetta	Aigrette garzette
Fulica atra	Foulque marcoule
Gallinago gallinago	Bécassine des marais
Gallinula chloropus	Poule d'eau
Himantopus himantopus	Echasse
Limosa limosa	Barge à queue noire
Netta rufina	Nette rouse
Plegadis falcinellus	Ibis falcinelle
Podiceps ruficollis	Grêbe castagneux
Tringa totanus	Chevalier gambette

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APPENDIX E.4
Main invertebrate taxa observed in Lac Smir (Bekkali 1988)

Phylum	Class	Order
Arthropoda		
	Crustacea	
		Amphipoda
		Copepoda
		Decapoda
		Isopoda
		Ostracoda
	Insecta	
		Coleoptera
		Diptera
		Ephemeroptera
		Odonata
Mollusca		
	Bivalvia	
	Gasteropoda	
Protozoa		
	Sarcodina	
	Foraminifera	

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APPENDIX F
Coastal Water Quality and Marine Life Monitoring Program

A comprehensive coastal water quality and marine life monitoring program would include:

I. Water quality parameters:
- Chlorophyll *a*
- Turbidity
- pH
- Fecal Coliform
- Enterococci
- $NO_3^- + NO_2^-$
- NH_4^+
- Total Nitrogen
- Dissolved Organic Nitrogen (Calculated)
- PO_4^{3-}
- Total Phosphorus
- Dissolved Organic Phosphorus (Calculated)
- Salinity
- Temperature
- Dissolved Oxygen
- Pre-selected toxic pollutants (heavy metals, pesticides used in the area)
- Sea/Water conditions (visual observations of surface currents (speed and direction) and wind (speed and direction) during sampling, as well as historical notes on immediate past weather conditions - such as high surf, rains, etc.)

These should be measured quarterly at low-tide conditions. Preselected toxic pollutants should be sampled once per year on sediments if none are found. If contamination of sediment is found, sampling should be done quarterly. For each resort or town area, at least two transects will be necessary with at least five stations per transect with samples taken at the surface, midwater, and bottom. The transects should be separated enough to allow monitoring of different biotopes, or areas of different influences (i.e., river discharges).

II. Marine life monitoring:

A. Quantitative parameters to be monitored include:
- Corals: number of species, percent cover
- Fish: number of species and individuals, size of individuals
- Macroinvertebrates: number of species and individuals
- Macroalgae: number of species, percent cover

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Substrate characteristics: topographic relief, sediment characteristics

Protected species (monk seals, sea turtles): number of species/individuals, location, behavior, sex

B. Qualitative: Breakage of corals, general health of reef system, litter on reef, level of fishing/diving effort. For turtles: look for presence of tumors and tags. Qualitative information of amount and coverage of sediment.

In general, marine life monitoring should be done twice per year. Selection of transects and monitoring stations must be decided on a site-specific basis.

III. Specific monitoring programs will be necessary for monitoring the presence and prevalence of toxic shellfish and fish ("red tide").

IV. Characterizing the plume from the Martil River also will be important. This can be done during low and high flow periods (summer and winter seasons) utilizing drogues and aerial photographs.