CONTENT

Description	Page
IV. REGIONAL ENVIRONMENTAL SYSTEM (SAR) DESCRIPTION AND TRENDS DEVELOPMENT AND REGION DETERIORATION DESIGNATION.	**16**
Overview.	16
Definition of the Project Area (AP) and Area of Direct Influence (AID)	16
Regional Environmental System (SAR)	17
IV.1 Delimitation and justification of the Regional Environmental System (SAR) where the project intends to be established.	18
IV.1.1. Numerical Simulation of Hydrocarbons Spill at Sea	19
IV.1.2. Regional Air Quality (land) monitoring and sulfur dioxide (marine) global plume monitoring	19
IV.1.3. General Territorial Ecological Regulatory Program (POEGT) Biophysical Environmental Units	19
IV.1.4. Environmental Management Units for Marine and Regional Ecological Regulatory Program of the Gulf of Mexico and the Caribbean (POEMRGMyMC)	19
IV.1.5. Environmental Management Units of the Ecological Regulatory Program of the State of Tabasco (POEET)	19
IV.1.1. Numerical Simulation of Hydrocarbons Spill at Sea	19
Results of modeling with GNOME	22
IV.1.2. Regional Air Quality Monitoring and Global Sulphur Dioxide Plume Monitoring	23
Monitoring the sulfur dioxide global plume	25
Results of air quality monitoring and global monitoring of sulfur dioxide (SO2)	26
IV.1.3. General Territorial Ecological Regulatory Program (POEGT) Biophysical Environmental Units	28
IV.1.4. Environmental Management Units for Marine and Regional Ecological Regulatory Program of the Gulf of Mexico and the Caribbean (POEMRGMyMC)	29
IV.1.5. Environmental Management Units of the Ecological Regulatory Program of the State of Tabasco (POEET)	30
Regional Environmental System Delimitation Summary	31
IV.2 Environmental system characterization and analysis	33
IV.2.1 Abiotic aspects	34
a) Climate	**34**
Temperature	35
Relative humidity and evaporation	35
Wind Speed	36
Climatological phenomena	36
Hurricanes.	36

Droughts 40
Northerlies 41
b) Geology and geomorphology 41
Lithological characteristics of the area 41
Regional geology 44
Stratigraphy 46
Relief Morphology and Features 47
Faults and fractures 49
Seismicity 52
Landslides, cave ins and other earth or rock movements. 54
Floods and Vulnerability before Climate Change 54
Possible volcanic activity. 58
c) Soils 59
Land types on the project site and SAR (FAO-UNESCO and INEGI) 59
Land area characterization 60
Results of soil characterization 63
Cationic Exchange Capacity 63
Organic matter. 63
Hydrocarbons in soils. 63
Polycyclic aromatic hydrocarbons in soils. 64
Polychlorinated biphenyls in soils. 64
Metals in soils. 65
Soil sampling in identified dams near the Property 66
Results 67
d) Surface and underground hydrology 67
Hydrological resources located in the study area. 67
Surface hydrology in coastal area 67
Water use 68
Vulnerability of surface water bodies 69
• Water quality analysis 70
Underground hydrology 71
Aquifer 27-02 “La Chontalpa” 72
Water quality in the aquifer 72
Median Annual Groundwater Availability 72
Aquifer 27-04 “Centla” 73
Median Annual Groundwater Availability 73
Coastal area and lagoon system 73
Physiography; bathymetry and marine currents. 73

Wind and marine currents direction and speeds 79
Low water season 79
Rainy Season 81
Northerlies season 82
Marine environment assessment 84
Project Oceanographic Campaign 84
Pre-existing influence sources 87
Water quality characterization (marine and land) 88
Total Petroleum Hydrocarbons (HTP) 88
Polynuclear polycyclic aromatic hydrocarbons (HAP) 88
Oil biomarkers (BMK) 89
BTEX Monoaromatic hydrocarbons 90
Metals 90
Sediment quality 93
Granulometry 93
Potential RedOx 94
Total Petroleum Hydrocarbons (HTP) 95
Polynuclear polycyclic aromatic hydrocarbons (HAP) 95
Oil biomarkers (BMK) 95
Metals 95
Enrichment Factors (EF) and Geo accumulation Index (Igeo) 103
Bathymetry of the lagoon system 107
Lagoon system El Carmen, Pajonal and La Machona 107
Mecoacan lagoon system 109
Water quality in SAR Coastal Lagoon Systems (SLC) 110
Salinity 114
Hydrogen potential (pH) 117
Water temperature 118
Dissolved Oxygen 119
Total Suspended Solids (SST) 120
Turbidity 122
Nutrients 124
Ammonium 124
Nitrites 124
Nitrates 124
Phosphates 124
Silica 125
Total Organic Carbon 127

Photosynthetic pigments: Chlorophylls a, b, c and pheophytins 128
Total Petroleum Hydrocarbons (HTP) 132
Polynuclear polycyclic aromatic hydrocarbons (HAP) 132
Oil biomarkers 132
BTEX Monoaromatic hydrocarbons 132
Metals 133
Sediment quality 142
Granulometry 142
Sediment texture 143
Total Petroleum Hydrocarbons (TPH) 144
Oil biomarkers 149
Metals 150
Enrichment Factors (EF) and Geo accumulation Index (Igeo) 154
Conclusions (metals, HC) 157
IV.2.2 Biotic aspects 158
a) Land vegetation 158
Methods of sampling land vegetation 158
Vegetation information analysis 160
Vegetation characterization in “Land facilities areas” 161
Cultured palm grove 161
Cultivated and induced grassland: 161
Coastal dunes 163
Aquatic vegetation 163
Secondary vegetation or tall grass 164
Vegetation in the Regional Environmental System (SAR). 164
Aquatic vegetation 164
Cultivated and induced grassland 166
Mangrove 167
Cultured palm grove 170
Secondary vegetation or tall grass 171
Floristic composition. 172
Vegetation distribution 173
Density 173
Diversity and Dominance Indexes 174
Species in the Project Area (Hokchi Plant and Metering Station) 175
Endemic species 177
b) Fauna 177
Land fauna sampling methods 177

Birds monitoring stations 177
Mammals direct search 178
Amphibians and reptiles transects 178
Fauna present composition and structure in the Project SAR 178
Wealth 179
Abundance 179
Diversity and similarity 181
Distribution 182
Birds Reproduction 183
Mammals 185
Amphibians 186
Reptiles 187
Threatened and endangered species in the defined SAR (Outside the property area) 187
Endemic species 188
Migratory species 188
Closed season species 189
Fauna of scientific or commercial value 190
Local consumption fauna 193
Harmful fauna 194
Ecosystem dynamics 196
Marine biota 198
Phytoplankton 199
Zooplankton 200
Benthos 200
Macrobenthos 202
Nekton 203
Marine system endangered species (NOM-059-SEMARNAT-2010) 204
Sea turtles 205
IV.2.3 Landscape 207
Evaluation Methodology 207
Visibility 211
Landscape quality (Visual) 211
Evaluation 214
Landscape fragility 214
Conclusion 217
IV.2.4 SAR Socioeconomic Factors (Cardenas, Comalcalco, Paraiso and Centla) 218
Municipality of Paraíso 218
Population and municipal demographics 219

Population growth trend 219
Indigenous population 220
Migration rate........ 221
Economically active population 221
Productive sector........ 222
Livestock Sector 224
Housing and poverty at municipal level........ 224
Illiteracy 225
Marginalization and social backwardness........ 225
Cultural 225
Municipality of Cardenas........ 227
Population and municipal demographics 228
Population growth trend 228
Indigenous population 230
Migration rate........ 231
Economically active population 231
Productive sector........ 233
Housing and poverty at municipal level........ 236
Illiteracy 236
Marginalization and social backwardness........ 236
Cultural 236
Municipality of Comalcalco 238
Population and municipal demographics 239
Population growth trend 239
Indigenous population 241
Migration rate........ 242
Economically active population 242
Productive sector........ 243
Housing and poverty at municipal level........ 245
Illiteracy 246
Marginalization and social backwardness........ 246
Cultural 246
Municipality of Centla 247
Population and municipal demographics 247
Population growth trend 248
Indigenous population 250
Migration rate........ 250
Economically active population 251

Productive sector ... 251
Housing and poverty at municipal level ... 254
Illiteracy ... 254
Marginalization and social backwardness ... 254
Cultural ... 254
Religious groups ... 255
Conclusion ... 255
IV.2.5 Environmental Diagnosis ... 256
Information and integration analysis ... 256
Ecological Regulations and UGAs included in the SAR ... 257
Hydrocarbon spill trajectory models at sea (GENOME) results ... 257
Abiotic aspects ... 260
Climate ... 260
Air Quality ... 260
Geology and Geomorphology ... 260
Seismicity ... 262
Floods and Vulnerability before Climate Change ... 262
Soils ... 262
Surface Hydrology ... 265
Water quality results (Lagoon System) ... 266
Water quality results (marine system) ... 269
Underground Hydrology ... 270
Biotic Aspects ... 272
Land vegetation and fauna ... 272
Vegetation in the Project Area: ... 272
Biota ... 273
Landscape ... 275
Socioeconomic factors ... 276

FIGURES

Description	Page
Figure IV. 1 Project Area (Platforms, Pipelines, Plant and Metering Station), Direct Influence Area (AID)	17
Figure IV. 2 Regional Environmental System (SAR), includes AP and AID	18
Figure IV. 3 Hydrocarbon dispersion to coastal area, Prevailing Winds (NE) Source: “Hydrocarbons Dispersion Study in the Hokchi Field Transport Pipeline”, June 2018	21
Figure IV. 4 Hydrocarbon dispersion to coastal area, Dominant Winds (N) Source: “Hydrocarbons Dispersion Study in the Hokchi Field Transport Pipeline “, June 2018	22
Figure IV. 5 Location of air quality monitoring points in the Paraíso, Tabasco, region. Source: own IMP.	24
Figure IV. 6 The trajectory followed for SO2 measurement during the oceanographic campaign in the area of influence of the Hokchi Project off the coast of Paraíso, Tabasco. Source: own IMP.	26
Figure IV. 7 Project Location, Ecological Regions and Biophysical Environmental Units	28
Figure IV. 8 SAR (UGA-67, UGA-69, UGA-70, UGA-71 and UGA-166) and Project location	29
Figure IV. 9 Location of the Project and UGAs of the POE of the State of Tabasco	30
Figure IV. 10 SAR Delimitation by Hydrocarbons Dispersion at Sea, Prevailing Winds (NE)	31
Figure IV. 11 SAR Delimitation by Hydrocarbons Dispersion in the Sea Dominant Winds (N)	32
Figure IV. 12 Climate according to Köppen’s classification, modified by E. Garcia. Source: Institute of Geography - UNAM, April 1989.	34
Figure IV. 13 Probability of tropical cyclones formation in the Gulf of Mexico and Caribbean Sea. Source: National Oceanic and Atmospheric Administration [NOAA].	37
Figure IV. 14 Frequency of tropical cyclones occurrence in the Gulf of Mexico and Caribbean Sea. Source: Munchener Ruckversicherungs, “World Map of Nature Risks” Munich, Fed. Rep. of Germany, 1988.	38
Figure IV. 15 Figure IV.14. Tropical Cyclones (1851-2014) in the Environmental System. Source: CENAPRED, “Atlas of Hazards by Natural Phenomena of the State of Tabasco”.	39
Figure IV. 16 Figure IV.16.- Hurricanes, Depressions and Tropical Storms Trajectories 1990-2016 (coast of Tabasco) Source: Meteorology Historical Analysis, IMP.	39
Figure IV. 17 Tropical storms and hurricanes recorded on the coast of Tabasco from 1990 to 2016. Source: Meteorology Historical Analysis, IMP.	40
Figure IV. 18 Drought hazard in the Project Area and SA. Source: CENAPRED, “Atlas of Hazards by Natural Phenomena of the State of Tabasco”.	41
Figure IV. 19 Land Geology of SA (coastal area of Cardenas, Comalcalco, Paraiso and Centla). Source: INEGI, Geological Chart of the State of Tabasco and Mexican Geological Service - CG Mineria-Economy Secretariat	42
Figure IV. 20 Marine Geology. Source: Geographic Information Systems, Institute of Geography, UNAM, October 1991	43
Figure IV. 21 Hokchi Field where the Central and Satellite Platforms (Marine Installations) will be located. Source: Report of the “Hokchi Geotechnical Survey Service” 2016	44
Figure IV. 22 Location Map of Mexico’s Oil Basins. Source: Report of the “Hokchi Geotechnical Survey Service” 2016	45

Figure IV. 23 Figure IV.23.- Regional morphology and bathymetry in the project area. Source: Report of the “Hokchi Geotechnical Survey Service” 2016 ... 48
Figure IV. 24 Faults and fractures in project area and surroundings. Source: Geología Marina, Asociación Mexicana de Geólogos Petroleros, A. C., March, 2006. ... 49
Figure IV. 25 Structural framework (Tectonism) of the Southeast Basins. Source: Report of the “Hokchi Geotechnical Survey Service” 2016 ... 50
Figure IV. 26 Tectonic events in the Southeast Basins ... 52
Figure IV. 27 Seismic areas in the Mexican Republic ... 53
Figure IV. 28 Seismic hazard in the Project’s SAR ... 54
Figure IV. 29 Most vulnerable areas, heading to the lagoon system el Carmen-la Machona. Fuente IMP ... 55
Figure IV. 30 Flood hazard ... 55
Figure IV. 31 Figure IV.31.- Coastal vulnerability index of the Tabasco coast ... 56
Figure IV. 32 Erosion caused by waves near Barra de Tupilco ... 57
Figure IV. 33 North side of the property where the Hokchi Plant will be located ... 57
Figure IV. 34 Figure IV.34.- Danger due to volcanic activity ... 58
Figure IV. 35 Soil sampling points in the Area where the Hokchi Plant will be located, Metering Station and its surroundings, Paraíso, Tabasco. ... 60
Figure IV. 36 Sampling at the points indicated in Figure 35 ... 62
Figure IV. 37 Soil sampling points near the Area where Hokchi Plant will be located ... 66
Figure IV. 38 Bathymetry in SAR defined for the project. Source: IMP, “Study of hydrocarbon spill dispersion Field Hokchi” ... 74
Figure IV. 39 Bathymetry and project location (30 m) in the marine part. Source: Institute of Geography of the UNAM map ... 75
Figure IV. 40 Bathymetry in SAR defined for the project. Source: IMP, “Study of hydrocarbon spill dispersion Field Hokchi” ... 76
Figure IV. 41 Average circulation and surface salinity in the Gulf of Mexico (April-July, left) and (September-March, right). Sources: “Characterization and Regionalization of Oceanographic Processes in Mexican Seas “, (Zavala Hidalgo, et. al., 2003), CONABIO. ... 77
Figure IV. 42 Sea surface temperature throughout the year (°C) Source: Climatological Atlas of Tropical Cyclones in Mexico, CENAPRED, 2014 ... 78
Figure IV. 43Lazo Current in the Gulf of Mexico. Source: Report of the “Hokchi Geotechnical Survey Service” 2016 ... 79
Figure IV. 44 .- Current velocities rose diagram in dry season. Concentric circles represent the probability in %. Source: IMP Hydrodynamic model. ... 80
Figure IV. 45 Wind rose in dry times. Source: IMP Hydrodynamic model. ... 81
Figure IV. 46 Sea currents velocities direction rose in rainy season Source: IMP Hydrodynamic model. ... 81
Figure IV. 47 Wind rose speeds in rainy season. Source: IMP Hydrodynamic model. ... 82
Figure IV. 48 Current velocities rose in northerlies season. Source: IMP Hydrodynamic model. ... 83
Figure IV. 49 Wind speeds rose in northerlies season. Source: IMP Hydrodynamic model. ... 83
Figure IV. 50 Campaign sampling stations in the project area and influence area ... 84
Figure IV. 51 Coastal stations for water quality assessment for in-process use. ... 85
Figure IV. 52 Percentage of sands, silts and clays in surface sediment samples at Hokchi Field Oceanographic Campaign sites. Sites marked with * represent proximity to exploratory oil wells; ** to developing oil wells ... 93
Figure IV. 53 Oxidation-reduction potential values in surface sediments of Hokchi Field. ... 94

Figure IV. 54 Nickel concentration (mg/kg) in surface sediment determined in Hokchi Field. Sites marked with * represent proximity to exploratory oil wells; ** to developing oil wells. 101
Figure IV. 55 Bathymetric map of Laguna el Carmen, Pajonal and la Machona Source: Institute of Marine Sciences and Limnology-UNAM.. 108
Figure IV. 56 Bathymetric map of the Mecoacan lagoon Source: Institute of Marine Sciences and Limnology-UNAM 109
Figure IV. 57 Location map of sampling points of the Lagoon System 111
Figure IV. 58 Distribution of sampling stations in Tabasco lagoon systems, sampled in March 2018. 115
Figure IV. 59 Salinity distribution in rainy season in October 1974, taken from Gonzalez et al., 2017. 116
Figure IV. 60 pH Results (UpH) in surface and bottom of the water column, sampled in March 2018 in 5 lagoon systems of Tabasco. 117
Figure IV. 61 Results temperature (°C) in surface and bottom of the water column, sampled in March 2018 in 5 lagoon systems in Tabasco. 118
Figure IV. 62 Dissolved oxygen results (mg/L) in surface and bottom of the water column, sampled in March 2018 in 5 lagoon systems in Tabasco. 120
Figure IV. 63 Results of total suspended solids (SST) in surface and bottom of the water column, sampled in March 2018 in Tabasco's 5 lagoon systems. 121
Figure IV. 64 Turbidity (UTN) results on surface and bottom of the water column, sampled in March 2018 in Tabasco's 5 lagoon systems. 122
Figure IV. 65 Aluminum concentration in water (mg/L) in the lagoons el Carmen (C1-C4), Machona (MA5-MA9), Tupilco (T10-T11), el Zorro (Z12-Z13) and Mecoacan (ME14-ME18) 140
Figure IV. 66 Concentration of vanadium in water (mg/L) in el Carmen (C1-C4), Machona (MA5-MA9), Tupilco (T10-T11), el Zorro (Z12-Z13) and Mecoacan (ME14-ME18) lagoons............ 140
Figure IV. 67 Concentration of arsenic in water (mg/L) in el Carmen (C1-C4), Machona (MA5-MA9), Tupilco (T10-T11), el Zorro (Z12-Z13) and Mecoacan (ME14-ME18) lagoons 141
Figure IV. 68 Factors analysis result for metal concentrations in water in the studied lagoons. 142
Figure IV. 69 Sediment gravimetric analysis results in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons. 142
Figure IV. 70 Coastal lagoon system sedimentary texture 143
Figure IV. 71 Coastal lagoon system sedimentary texture 144
Figure IV. 72 Nickel concentration in lagoons sediments: el Carmen (C1-C4), Machona (MA5-MA9), Tupilco (T10-T11), el Zorro (Z12-Z13) and Mecoacan (ME14-ME18). ERL value indicates sites representing an environmental risk. 151
Figure IV. 73 Metals concentrations in lagoons sediments.. 154
Figure IV. 74 INEGI's-2016 land use series VI and Marine-Land Project location. 160
Figure IV. 75 Cultivated palm grove associated with tall grass type tree species in the project area. 161
Figure IV. 76 .- Grassland with tree species vegetation present within the polygon 162
Figure IV. 77 Bermuda grass (Cynodon dactylon) cultivated grassland and star grass (Cynodon plectostachyus) in the area where the metering station will be located. 162
Figure IV. 78 Panoramic view in the northern part where the Hokchi Plant will be located, on the coast, we can see succulent species such as: goats foot (Ipomoea pes-caprae) and break white dish (Ipomoea stolonifera). 163
Figure IV. 79 Secondary vegetation view of the tall grass type 164
Figure IV. 80 Hydrophilic vegetation within the flooding areas polygon in the SAR 165

Figure IV. 81 Aquatic vegetation in SAR outside the property on the West side with hydrophilic species such as: bulrush (Typha latifolia) and root hair (Leersia hexandra). 166
Figure IV. 82 Induced grassland associated with coconut palms and shrub vegetation 167
Figure IV. 83 Panoramic view of the mangrove present with red mangrove (Rhizophora mangle) near the Tupilco Bar 168
Figure IV. 84 Red mangrove species (Rhizophora mangrove) in adult state and growing seedlings, observed at the sampling point more than 1 km to the South outside where the Plant will be installed (East side of the Laguna Grande de las Flores) 169
Figure IV. 85 Mangrove on the North side of the Mecoacan lagoon more than 10 km East of the project 170
Figure IV. 86 Coconut palm (Cocos nucifera) cultivation predominant within the coastal area anthropic activities. 171
Figure IV. 87 Secondary vegetation of tall grass. 172
Figure IV. 88 Richness and abundance comparison by taxonomic group 180
Figure IV. 89 Mexican biological corridors close to the project area, CONABIO, 2013. 183
Figure IV. 90 Chick of buff-bellied hummingbird (Amazilia yucatananensis) species observed (outside the project area) at the sampling point East of Laguna Grande de las Flores. 185
Figure IV. 91 Specimen of the species Leptodactylus melanonotus in the terminal phase of its metamorphosis. 187
Figure IV. 92 Graphic representation of species number within a CITES category per taxonomic group. 193
Figure IV. 93 Bird of prey devouring a small opossum observed inside the Flora-Fauna A polygon. 195
Figure IV. 94 Anthropogenic pressure on mangrove populations. 197
Figure IV. 95 Trophic network identified within the project area. 198
Figure IV. 96 Biomass distribution in relation to sediment type 202
Figure IV. 97 Sea turtle species distribution in the SAR of the Project Source: Hokchi Field Environmental Impact Statement 205
Figure IV. 98 Sea turtle distribution pattern in the Project SAR Source: Hokchi Field Environmental Impact Statement 206
Figure IV. 99 Area where the Hokchi Plant will be located (Part “A and B”), where observation points of the 3 landscape units to be evaluated are indicated. 208
Figure IV. 100 View to the Southwest of the property where the Project will be located, where the predominant vegetation of grassland and coconut crops is observed. 208
Figure IV. 101(a and b) Project Southeast Side taken from the Barra de Tupilco-Paraíso highway, where you can see the South-Southeast side of the Property with coconut crops and secondary herbaceous shrub vegetation. 209
Figure IV. 102 Image (a) View from the beach on the North side of the property where the surrounding coastal vegetation is observed, (b) Northwest part with grassland vegetation and coconut crop 210
Figure IV. 103 Paraiso municipality, Tabasco, location map 218
Figure IV. 104 Population growth trend 219
Figure IV. 105 Population density growth trend 220
Figure IV. 106 Population distribution 220
Figure IV. 107 Fall-Winter rainfed agricultural production 222
Figure IV. 108 Spring-Summer rainfed agricultural production 223
Figure IV. 109 Evergreen agricultural production 223

Figure IV. 110 Livestock production 224
Figure IV. 111 Municipality of Cardenas, Tabasco location map 227
Figure IV. 112 Population growth trend 228
Figure IV. 113 Population density growth trend 229
Figure IV. 114 Population distribution 230
Figure IV. 115 Fall-Winter rainfed agricultural production 233
Figure IV. 116 Spring-Summer rainfed agricultural production 234
Figure IV. 117 Evergreen agricultural production 235
Figure IV. 118 Livestock production 235
Figure IV. 119 Municipality of Comalcalco, Tabasco location map 238
Figure IV. 120 Population growth trend 239
Figure IV. 121 Population density growth trend 240
Figure IV. 122 Population distribution 240
Figure IV. 123 Fall-Winter rainfed agricultural production 243
Figure IV. 124 Spring-Summer rainfed agricultural production 244
Figure IV. 125 Evergreen agricultural production 244
Figure IV. 126 Livestock Production 245
Figure IV. 127 Municipality of Centla, Tabasco location map 247
Figure IV. 128 Population growth trend 248
Figure IV. 129 Population density growth trend 249
Figure IV. 130 Population distribution 249
Figure IV. 131 Fall-Winter rainfed agricultural production 252
Figure IV. 132 Spring-Summer rainfed agricultural production 252
Figure IV. 133 Evergreen agricultural production 253
Figure IV. 134 Livestock Production 253
Figure IV. 135 Marine and land facilities (Project Area "AP"), Direct Influence Area (AID) and Regional Environmental System (SAR) 256
Figure IV. 136 Possible affectations due to hydrocarbons spill from the Satellite Platform, Midpoint and Before Coastal Arrival of the Pipeline (Prevailing Winds) 258
Figure IV. 137 Possible affectations due to hydrocarbons spill from the Satellite Platform, Midpoint and Before Coastal Arrival of the Pipeline (Prevailing Winds) 259

TABLES

Description	Page
Table IV. 1 Mexican Official Standards and Periods for Evaluating Each Atmospheric Pollutant	23
Table IV. 2 Classification of air quality in terms of IMECA (*)	24
Table IV. 3 Air quality monitoring points geographical location.	25
Table IV. 4 Location in UTM (Datum WGS84) coordinates of the site quadrant and sampling points.	62
Table IV. 5 Results of hydrocarbons in soils analysis.	64
Table IV. 6 Statistical data on metals presenting results in soils.	65
Table IV. 7 Characterization study scope	86
Table IV. 8 Pollutants associated with oil and gas offshore operational sources	88
Table IV. 9 Analytical methods used for the determination of polycyclic aromatic and monoaromatic hydrocarbons in water column	89

Table IV. 10 Metals concentration in water column surface and bottom (mg/L) in Hokchi. 92
Table IV. 11 Determination coefficient (R2) between grain size (sands, silts, clays) and metals concentration in Hokchi Camp 94
Table IV. 12 Metals concentration in sediment (mg/kg) during the Hokchi oceanographic campaign in the Gulf of Mexico. The color code corresponds to the toxicity criteria established by NOAA for each metal. Concentrations lower to TEL represent a minimum risk, higher than TEL but lower than PEL represent a possible risk and higher concentrations than PEL, a probable risk. 99
Table IV. 13 Metals in sediment concentration (mg/kg). Continued 100
Table IV. 14 Table IV.14. Descriptive statistics of metal concentrations in sediments (mg/g) divided into zones in the Hokchi study area 102
Cuadro IV. 15 Factores de Enriquecimiento para los metales en el campo Hokchi 105
Cuadro IV. 16 Índices de geoacumulación (Igeo) para los metales en el campo Hokchi. 106
Table IV. 17Results of basic physicochemical parameters to determine water quality of some lagoon systems in Tabasco, Mexico, March 2018. 113
Table IV. 18 Turbidity quality intervals obtained as a function of transparency, modified by Betanzos, et al., 2011. 123
Table IV. 19 Water column nutrient statistics in March 2018 125
Table IV. 20 Nutrient values reported in literature. 127
Table IV. 21 Total organic carbon statistics in water column in March, 2018 128
Table IV. 22 Pigments and pheophytins in the water column statistics in March, 2018. 130
Table IV. 23 Pigments and pheophytins in the water column statistics in March, 2018. 130
Table IV. 24 Results of nutrients, total organic carbon and pigments in water column in the mouth take in November 2017. 131
Table IV. 25 Results of nutrients, total organic carbon, pigments and pheophytins in water column in the mouth take in March 2018. 131
Table IV. 26 Analytical methods for the determination of organic compounds in water. 132
Table IV. 27 Metals concentration in water (mg/L) determined in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons. 136
Table IV. 28 Metals concentration in water (mg/L) determined in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons. Continued 137
Table IV. 29 Descriptive statistics on metals concentration in water (mg/L) in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons 138
Table IV. 30 . Descriptive statistics on metals concentration in water (mg/L) in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons. Continued 139
Table IV. 31 Analytical methods for determining hydrocarbons in sediment. 145
Table IV. 32 It summarizes different international sediment quality criteria for saline and brackish water systems. 146
Table IV. 33 Individual PAH concentration by assessed coastal lagoon. 148
Table IV. 34 Biomarkers identified in the Mecoacan lagoon (ME18) 149
Table IV. 35 Metals concentration in surface sediment of el Carmen, Machona, Tupilco, Zorro and Mecoacan lagoons. 152
Table IV. 36 Metals concentrations descriptive statistics in surface sediment in complete lagoons system and per lagoon. 153
Table IV. 37 Metals Enrichment Factors (EF) in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons. 155

Table IV. 38 Geo accumulation indices (Igeo) for metals in Machona, Tupilco,el Zorro and Mecoacan lagoons. I_{geo} < 1 uncontaminated or moderately contaminated (green); I_{geo} between 1-2 moderate contamination (yellow). 157
Table IV. 39Sampling areas most representative species relative density (%). 174
Table IV. 40 Vegetation in the Project Area (Hokchi Plant) Part “A” and “B” 175
Table IV. 41 Vegetation in the Project Area (Metering Station) 176
Table IV. 42 Mangle registered outside the Project area and its status in NOM-059-SEMARNAT-2010 177
Table IV. 43 Faunistic composition present in Project SAR 178
Table IV. 44 Richness and abundance per taxonomic group at sampling points 181
Table IV. 45 Shannon-Wiener (H') diversity indices and similarity per polygon. 182
Table IV. 46 Some birds present in the SAR reproductive seasons 184
Table IV. 47 Reproductive seasons of some mammals recorded in the SAR 186
Table IV. 48 Species in the SAR (NOM-059-SEMARNAT-2010) 188
Table IV. 49 Migratory species present in the SAR 188
Table IV. 50 Species of hunting interest for the state of Tabasco, 2015-2016 190
Table IV. 51 Species of commercial value according to CITES-2018 191
Table IV. 52 Wildlife species with local use in the SAR 193
Table IV. 53 Fauna identified as noxious within the SAR 196
Table IV. 54 Marine fauna under protection status of NOM-059-SEMARNAT 204
Table IV. 55 Landscape Assessment with the Muñoz-Pedreros Qualifying Scale and the Scale of Universal Purpose Values 212
Table IV. 56 Landscape rated value and numerical value 213
Table IV. 57 Muñoz-Pedreros’ (2004) Visual Frailty Factors and Project Area Landscape Frailty Values 216
Table IV. 58 Recommended uses according to quality and visual frailty (Muñoz-Pedreros 2004) 217
Table IV. 59 Municipality total population and by sex 219
Table IV. 60 Population indicators of the municipality 219
Table IV. 61 Population distribution aged 3 and over in the municipality 220
Table IV. 62 Indigenous population indicators 221
Table IV. 63 Indigenous languages spoken in the municipality 221
Table IV. 64 Municipality economically active population, 2010 221
Table IV. 65 Occupancy and distribution according to sector 222
Table IV. 66 Working population and its percentage distribution by occupational division 222
Table IV. 67 Housing and poverty indicators 225
Table IV. 68 Municipality total population and by sex 228
Table IV. 69 Population indicators of the municipality 229
Table IV. 70 Population distribution aged 3 and over in the municipality 230
Table IV. 71 Indigenous population indicators 230
Table IV. 72 Indigenous languages spoken in the municipality 230
Table IV. 73 Municipality economically active population, 2010 231
Table IV. 74 Occupancy and distribution according to sector 232
Table IV. 75 Working population and its percentage distribution by occupational division 232
Table IV. 76 Housing and poverty indicators 236
Table IV. 77 Total population and by sex municipality 239
Table IV. 78 . Population indicators of the municipality 239
Table IV. 79 Population distribution aged 3 and over in the municipality 241

Table IV. 80 Indigenous population indicators 241
Table IV. 81 Indigenous languages spoken in the municipality 241
Table IV. 82 Municipality economically active population, 2010 242
Table IV. 83 Occupancy and distribution according to sector 242
Table IV. 84 Working population and its percentage distribution by occupational division 243
Table IV. 85 Housing and poverty indicators 245
Table IV. 86 Total population and by sex municipality 248
Table IV. 87 Population indicators of the municipality 248
Table IV. 88 Population distribution aged 3 and over in the municipality 250
Table IV. 89 Indigenous population indicators 250
Table IV. 90 Indigenous languages spoken in the municipality 250
Table IV. 91 Municipality economically active population, 2010 251
Table IV. 92 Occupancy and distribution according to sector 251
Table IV. 93 Working population and its percentage distribution by occupational division 251
Table IV. 94 Housing and poverty indicators 254

IV. REGIONAL ENVIRONMENTAL SYSTEM (SAR) DESCRIPTION AND TRENDS DEVELOPMENT AND REGION DETERIORATION DESIGNATION.

Overview

The inventory to be carried out in this Chapter aims to carry out a geographical space characterization where its abiotic and biotic elements prevail environmentally homogeneous (climatic phenomena, vegetation, fauna, hydrology, soils, etc., and even socio-economic activities), which will be described and analyzed in a comprehensive manner the Regional Environmental System components where the project called **"Hokchi Area Development Plan Execution"** could interact with these environmental elements. For this purpose, are considered the planning guidelines of the previous chapters, information from reliable sources such as INEGI, CONAGUA, CONABIO, among others, as well as field work carried out for the Project Area and Direct Influence Area characterization.

In this Chapter, is also considered information from the Environmental Baseline, which was previously submitted by Hokchi Energy S.A. de C.V., to the appropriate authorities.

For environmental characterization in the local context, it is necessary to define the Project Area and the Project Area of Direct Influence thereof on environmental variables.

Definition of the Project Area (AP) and Area of Direct Influence (AID)

In order to achieve the established goals by the LGEEPA and its Regulations on the subject matter of Environmental Impact Assessment, the geographical space categories identified during the Environmental Impact Assessment procedure and which must be characterized in the local geographical scope both in the project area and the influence thereof in its surroundings are:

- The Project Area (**AP**). This is the geographical space occupied by both marine and land facilities defined in **Chapter II** of this document.

- Project's Direct Influence Area (**AID**). It is the area where both negative and positive impacts derived from Project different works and activities in its different stages that could have a significant and direct interaction with marine and land environmental elements such as: air, hydrology, soil, vegetation and fauna, waste management and disposal and socio-economic impacts, the AP and AID are shown below with a schematic line See Figure IV.1.

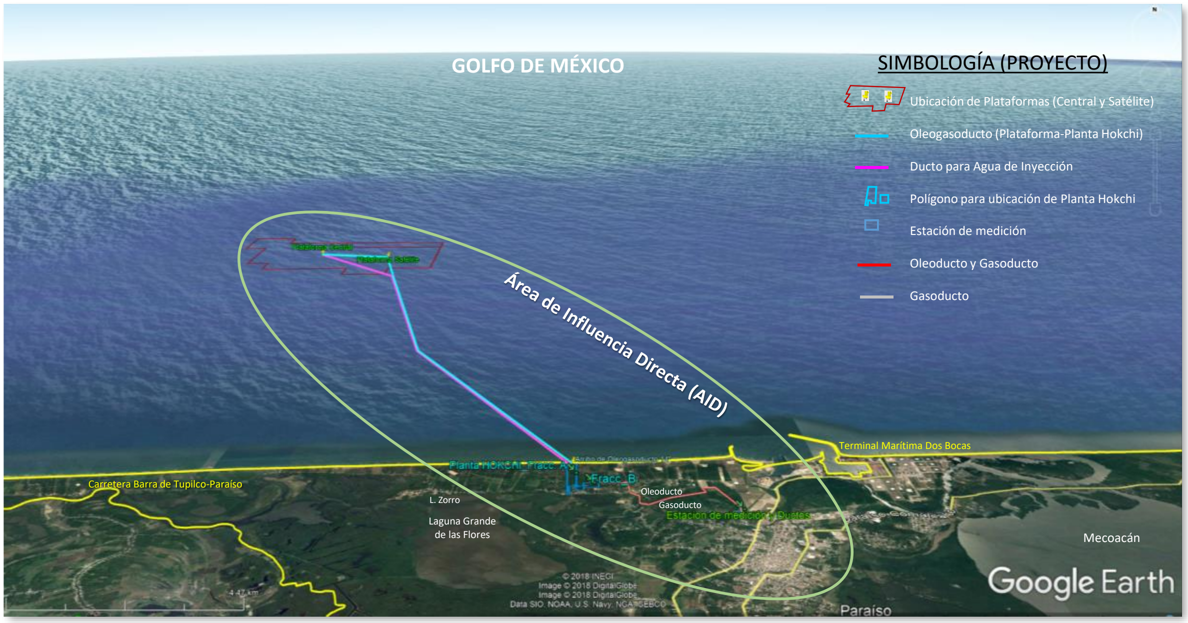


Figure IV. 1 Project Area (Platforms, Pipelines, Plant and Metering Station), Direct Influence Area (AID)

For this Project's AID, considers that mainly the municipal capital of Paraíso will be influenced; as well as in the land facilities surroundings, specifically the beach area to the North, the Ranchería Las Flores 2a Seccion to the South, Southwest and Southeast, which will be influenced directly by housing, lodging, food, transport (sea, land), leisure, etc. demand. As well as in the marine area where direct and local impacts could gain greater relevance and significance even though being temporary impacts originated by this Project during some of the stages, from site preparation, construction, operation/maintenance and until its abandonment.

Regional Environmental System (SAR)

The Regional Environmental System (**SAR**) should be understood as the finite Space defined based on the interactions between the abiotic, biotic and socio-economic environments of the region where the project is intended to be established, generally formed by a set of environmentally homogeneous ecosystems as the interaction result of its various components, whose delimitation derives from their uniformity and continuity, where an analysis of environmental and exploitation problems, constraints and potential will be applied.

The Environmental System in the regional context where the Project could interact with environmental elements was delimited ranging from Hokchi Field contractual area where marine installations will be located to the coastal area of the municipalities of: Cardenas (from the mouth of the Tonala River) on the Southwest side; to the South with the coastal area of Comalcalco; as well as the coastal area of the municipality of Paraíso and to the East of future land facilities the coastal area of the municipality of Centla (see Figure IV. 2.

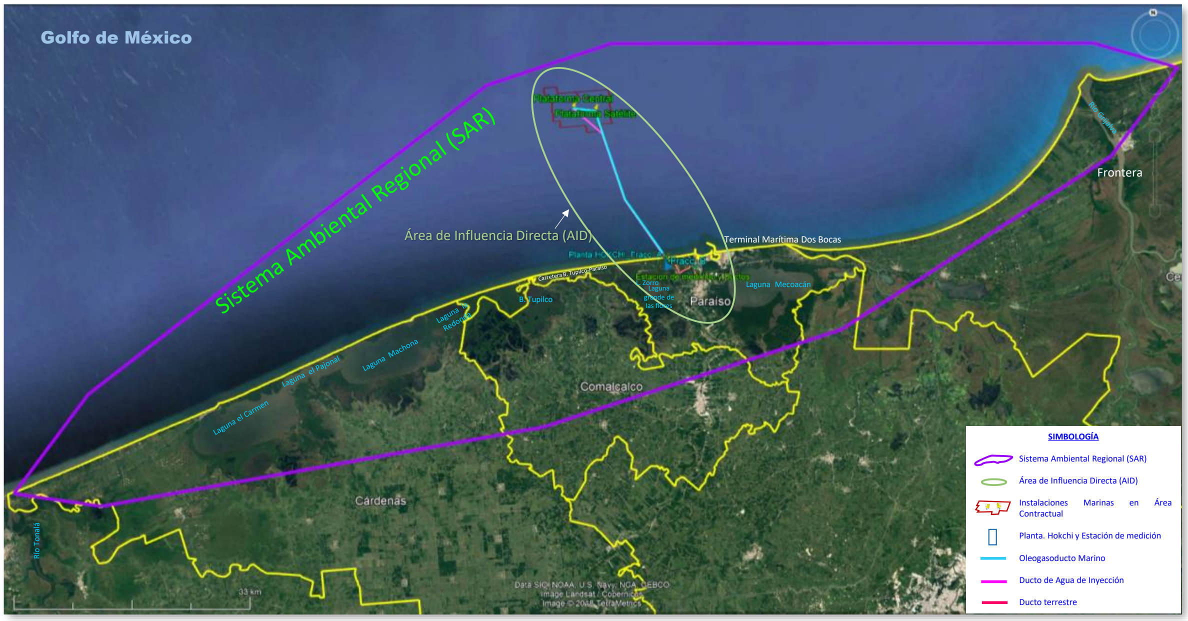


Figure IV. 2 Regional Environmental System (SAR), includes AP and AID

This Regional Environmental System was defined following the criteria and the use of simulation models described below:

IV.1 Delimitation and justification of the Regional Environmental System (SAR) where the project intends to be established.

In order to make a correct project SAR delimitation called **"Hokchi Area Development Plan Execution",** it is very useful to use tools for predicting hydrocarbons trajectories and dispersion at sea, pollutant plume monitoring to know the air quality at regional level, the results of which will provide more precisely the Project's scope possible interactions with the environmental elements making up the Environmental Management Units (**UGAs**) involved at regional level. Subsequently, the identified UGAs that could have interaction with project potential significant spills, will be analyzed under planning criteria as established by the applicable Ecological Management Programs, characterizing and analyzing in a comprehensive way their environmental elements, as well as their development and diagnosis showing trends in environmental development and degradation prior to the Project establishment.

The tools and Ecological Regulations considered for SAR delimitation are as follows:

IV.1.1. Numerical Simulation of Hydrocarbons Spill at Sea
IV.1.2. Regional Air Quality (land) monitoring and sulfur dioxide (marine) global plume monitoring
IV.1.3. General Territorial Ecological Regulatory Program (POEGT) Biophysical Environmental Units
IV.1.4. Environmental Management Units for Marine and Regional Ecological Regulatory Program of the Gulf of Mexico and the Caribbean (POEMRGMyMC)
IV.1.5. Environmental Management Units of the Ecological Regulatory Program of the State of Tabasco (POEET)

Once the justifying information is integrated and analyzed for SAR delimitation, both for simulation tools use and Environmental Management Units (UGAs) of the existing Environmental Management, as well as the project location and dimensions; works distribution and activities to be carried out both main, associated and interim ones; sites for waste disposal, populations social factors that could be influenced, geomorphological, edaphological, surface and underground hydrology characteristics, regional meteorology and vegetation types among others; as well as characteristics, distribution, uniformity and continuity of environmental units, sociocultural factors and allowed land uses by local, state and federal competent authorities.

The resulting SAR will allow an environmental, social and economic information inventory in the Project area and its environment, which will allow to establish significant impacts to the environment analysis generated during the stages of: Site preparation, Construction, Operation/Maintenance and Project Abandonment. This will allow preventive measures application to mitigate environmental impacts and thus ensure the development of a project in a sustainable manner.

IV.1.1. Numerical Simulation of Hydrocarbons Spill at Sea

Major accidents due to hydrocarbons leaks or spills in the sea and the consequent water, marine and coastal flora and fauna pollution; as well as possible impacts on touristic, recreational or economic activities of nearby towns, this potential for environmental damage that could give rise to these accidents within project areas of influence, makes it necessary to know the dispersion of hydrocarbons scope considering the variables by which they are influenced such as: wind speed and direction, direction and temperature of marine surface currents, etc., and some reliable model of spills predicting trajectories in the sea.

GNOME is an interactive environmental simulator designed for pollutants rapid modeling such as oil in the marine environment. To configure a spill scenario, this allows incorporating: the pollutant type spilled and its location through geographic coordinates or UTM; vector maps delimiting the marine area and land area (coastline) that allow tracing oil stains that have detained on the beach; mobility variables such as ocean circulation and diffusion models, wind speeds and direction in the area of interest, etc. Simulator result consists of graphics, videos or data files allowing further processing with other programs such as the Geographic Information System (GIS) or Google Earth, where the trajectory and dispersion is observed step by step following the spill influenced by ocean and weather conditions until its arrival on the coast.

As an additional criterion to UGAs or as a support tool, for planning and dimensioning purposes of the **Regional Environmental System**, the hypothetical scenarios of hydrocarbons leakage or spill in the 14” Ø marine oil pipeline (Satellite Platform, intermediate stretch and before the coastal arrival at land facilities) identified in risk analysis, scenarios consider prevailing and dominant winds. It should be noted that these spill scenarios would be the most significant due to their rapid dispersion reaching large areas, because they are strongly influenced by environmental variables such as: wind speed and direction, surface currents mainly; as well as water surface temperature and swell. These scenarios are described below:

In order to know the greater reach of hydrocarbons dispersion in the sea, the most critical conditions of wind speed and direction were taken, as well as speed and direction of marine currents.

Details of these simulations can be found in the study “Dispersion of hydrocarbons spills at sea” located in Annex No. 11 of the Environmental Risk Study.

Scenario A and B.- A (Prevailing Northeast Winds), B (Dominant North Winds) Simulation of a spill of 14,123 barrels of crude oil (29° API) on the 25.58 km long and 14” Ø oil pipeline on the Satellite Platform, making the following considerations:

1. Catastrophic leakage of the volume contained in the oil pipeline 25.58 km long and 14” Ø (14,123 barrels), considering a time of 10 min for the blockage of the section valves on the marine platform and on the arrival to the Paraiso coast.
2. Vanishing point at the following coordinates: Satellite Platform (18°37'31.04" N 93°19'41.63" W); Oil and gas pipeline Intermediate Point (18°30'51.01" N, 93°17'56.98" W); and Coastal Arrival (18°26'23.02" N, 93°15'6.40" W) North latitude and West Longitude respectively.
3. It is considered all hydrocarbon contained in the oil and gas pipeline is released in one day with a simulation time of around 120 hours (5 days), sufficient time to observe the arrival and dispersion of the oil spots along the coast.
4. Prevailing and dominant wind speed of 6.5 and 15 m/s (23.4 and 54 km/hr), respectively, with prevailing direction from the Northeast and North (in real accidents, changing winds should be considered in real time).
5. Oceanographic maps for modeling were obtained through the GNOME map generating tool known as GOODS (GNOME Online Oceanographic Data Server), see figures IV.3 and IV.4.

Below are the maps obtained with the GNOME simulator, showing the trajectories and reach of the spill of these scenarios towards the coastal area at the above mentioned conditions:

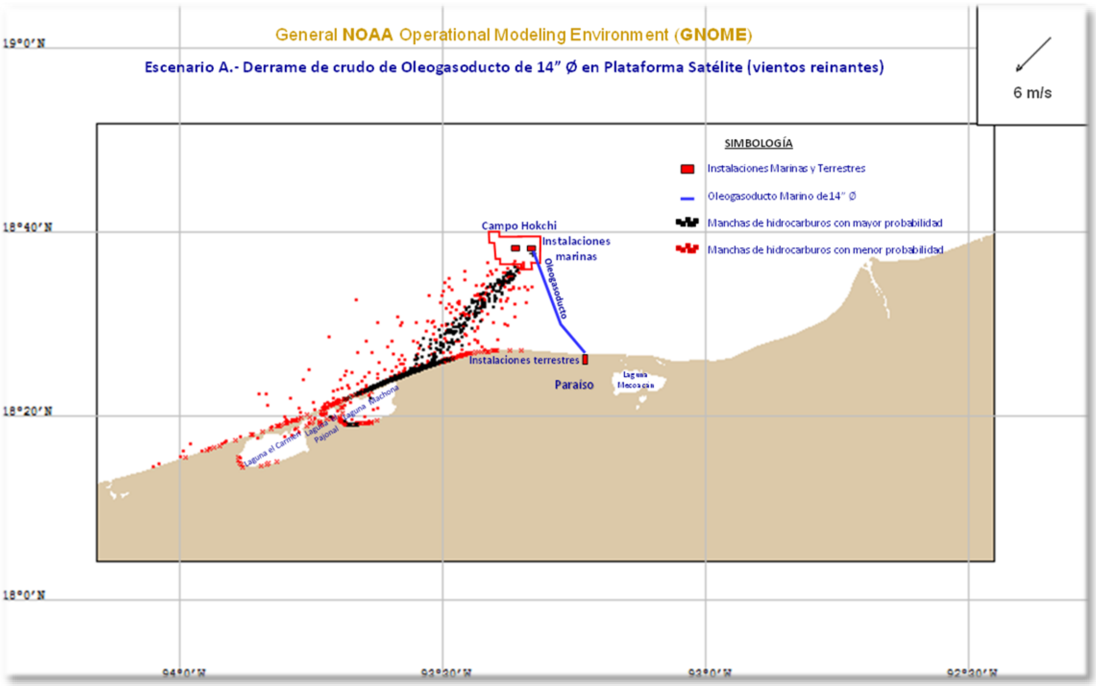


Figure IV. 3 Hydrocarbon dispersion to coastal area, Prevailing Winds (NE) Source: "Hydrocarbons Dispersion Study in the Hokchi Field Transport Pipeline", June 2018

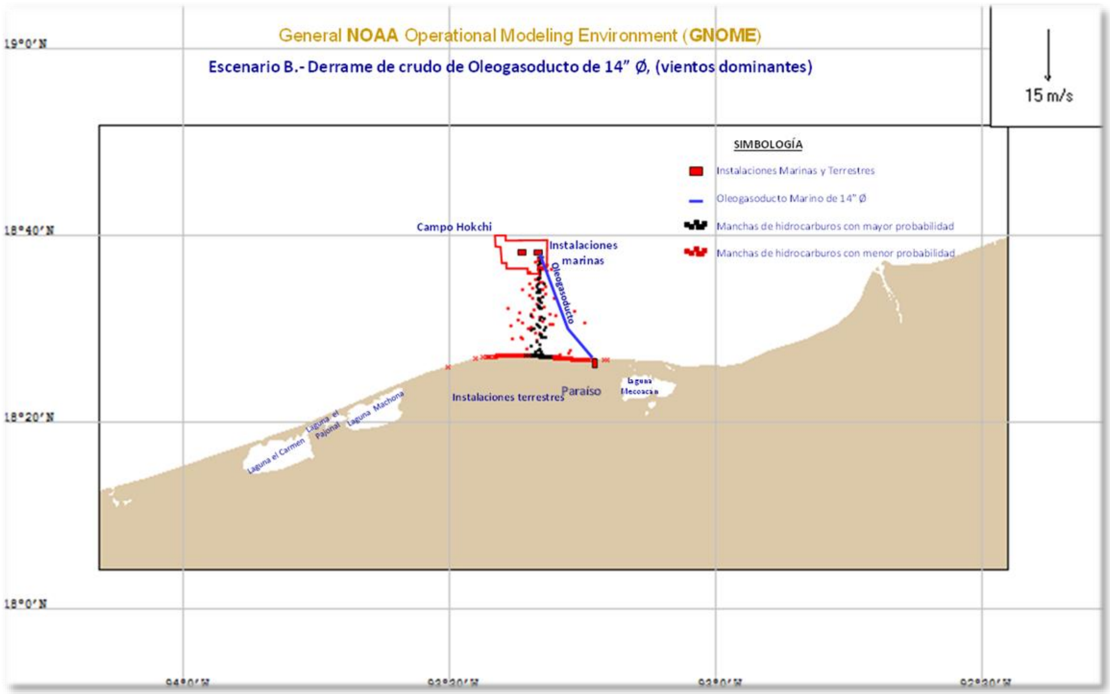


Figure IV. 4 Hydrocarbon dispersion to coastal area, Dominant Winds (N) Source: "Hydrocarbons Dispersion Study in the Hokchi Field Transport Pipeline ", June 2018

Results of modeling with GNOME

Once modelled on GOODS maps with coordinates at sea leakage points or oil spill at local weather conditions, it is observed that oil stains could reach coastal areas where the consequences could extend to sensitive areas from the Tonala River, Lagunas el Carmen, el Pajonal and la Machona, reaching up to 70 km on the southwest side of the marine installations and 72 km along the coasts in front of the aforementioned lagoons. For the oil pipeline leakage scenario before its arrival in the coastal area, the sea currents influence, direction and speed of the dominant winds on oil stains, make dispersion in the first instance to be to the Southwest of the vanishing point and subsequently the spots continue to disperse more slowly with a Westward direction along 15 km along the coastline, indicating that the influence of the stranding or arrival of hydrocarbon on the beach make the liabilities be minor and to not reach Lagunas el Carmen, el Pajonal and la Machona, where there are better preserved flora and fauna and where there are economic activities of fishing and oyster cultivation among others (see Figure IV.3 and IV.4).

In scenario B, it is observed that at the conditions of wind direction coming from the North and with dominant wind speeds, the possible trajectories they would follow would be heading South with possible affectations towards the barra de Tupilco and off the coast of the municipality of Paraíso.

IV.1.2. Regional Air Quality Monitoring and Global Sulphur Dioxide Plume Monitoring

Air quality monitoring was carried out in order to know if atmospheric pollutants influence from existing marine facilities exists in the coastal region of Paraíso and its surroundings, which will serve as a reference once this Project enters into operation to comply with the provisions of the Regulations of the General Law on Ecological Balance and Environmental Protection in the Subject Matter of Atmospheric Pollution Prevention and Control (Article 17, Part V) and Mexican Official Environmental Health Standards. The result will be obtained by comparing the concentrations obtained for the monitored standardized pollutants against the permissible limits set in the Environmental Health Standards mentioned in Table IV.1.

Table IV. 1 Mexican Official Standards and Periods for Evaluating Each Atmospheric Pollutant

POLLUTANT CRITERION	PERIOD	PERMISSIBLE LIMIT	OFFICIAL MEXICAN STANDARD
Ozone (O_3)	Maximum average of 1 hour	0.095 ppm	NOM-020-SSA1-2014
	Average of 8 mobile hours	0.07 ppm	
Carbon monoxide (CO)	Average of 8 mobile hours	11.0 ppm	NOM-021-SSA1-1993
Sulfur dioxide (SO_2)	Average 24 hours	0.11 ppm	NOM-022-SSA1-2010
	Average of 8 mobile hours	0.20 ppm	
Nitrogen dioxide (NO_2)	Maximum average of 1 hour	0.21 ppm	NOM-023-SSA1-1993
Particles less than 10 microns (PM_{10})	Average 24 hours	75 µg/cubic meters	NOM-025-SSA1-2014
Particles less than 2.5 microns ($PM_{2.5}$)		45 µg/cubic meters	

The concentration of gaseous atmospheric pollutants is expressed in units of the International System (µmol/mol). The µmol/mol unit is equivalent to parts per million (ppm). The particle concentration (PM_{10} and $PM_{2.5}$) is expressed in micrograms per cubic meter (µg/m^3). The above Standards apply to the entire national territory and are established as a protection measure to human health.

In order to classify air quality, the Metropolitan Air Quality Index (IMECA) was used as a reference, which establishes 5 classifications as shown in Table IV.2.

Table IV. 2 Classification of air quality in terms of IMECA (*)

IMECA INTERVALS	AIR QUALITY
0 – 50	GOOD
51 – 100	REGULAR
101 – 150	BAD
151 – 200	VERY BAD
>200	EXTREMELY BAD

(*) Environment Secretariat: www.sma.df.gob.mx
Environmental Standard NADF-009-AIRE-2006 published in the Official Gazette of the Federal District Government on April 29, 2006.

The monitoring and sampling points location was carried out according to the prevailing wind field at the time of year, the emission sources and the area of interest. Additionally, it was considered a reference point located near the population of Frontera, Tabasco.

Figure IV.5 shows the location of air quality monitoring sites and Table IV.3 shows the geographical location in UTM coordinates.

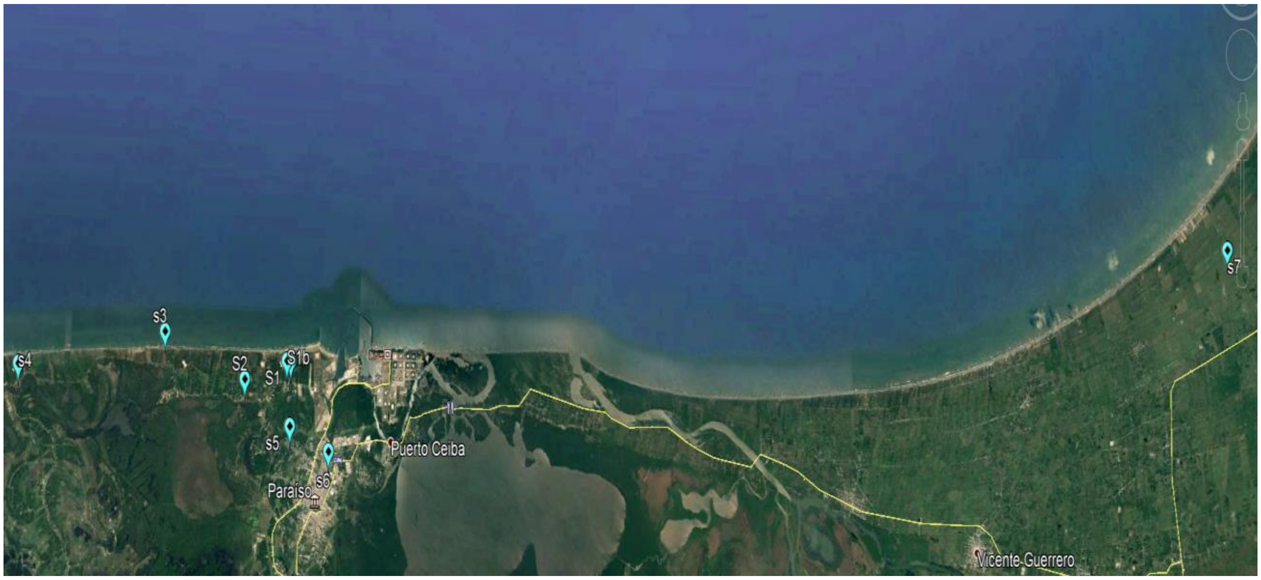


Figure IV. 5 Location of air quality monitoring points in the Paraíso, Tabasco, region. Source: own IMP.

Table IV. 3 Air quality monitoring points geographical location.

SITE	NAME	UTM X	UTM Y
S1a	"PARQUE INDUSTRIAL RANCHERIA LAS FLORES"	475994	2038195
S1b	SPHERES AREA FOR NITROGEN	475764	2037768
S2	"ESC. PRIM. JOSE COFFIN SANCHEZ"	473699	2037226
S3	"FRACCIONAMIENTO MAR DE PLATA"	469482	2038462
s4	"CENTRO DE SALUD LA UNIÓN 2ª SECCIÓN"	462017	2037164
s5	"IGLESIA NAC. PREBISTERIANA EBEN-EZER"	475962	2035594
s6	"HOTEL PLAZA BLANQUITA"	478072	2034758
s7	"RANCHO "MESA DORADA"	523993	2042712

UTM: Universal Transverse Mercator

Monitoring the sulfur dioxide global plume

The goal of this monitoring is to determine the sulfur dioxide global plume generated by emissions from oil facilities located in the Gulf of Mexico in the vicinity of where marine installations of this Project will be located. Sulfur dioxide monitoring will provide information on air quality in the project area, the area of influence at regional level with which the Project will be able to comply with the provisions of the General Law on Ecological Balance and Environmental Protection and its Regulations on atmospheric pollution prevention and control, taking prevention and control measures of emitting equipment from the design stage and during operations development.

The methodology to determine the extent and amplitude of the global sulfur dioxide plume generated by emissions from oil facilities located in the Gulf of Mexico, is based on the application of optical technology called Mini-DOAS, which was applied during the oceanographic campaign to collect environmental information for this Project.

Mini-DOAS is a method for determining trace gas concentrations by measuring their narrowband absorption structures in the spectral regions of UV and visible light. The DOAS technique uses spectral characteristics of trace gas absorption and aerosol extinction processes to separate broadband and narrowband spectral structures into an absorption spectrum and thus isolate specific band absorptions. Uses differential optical absorption spectroscopy (DOAS) technology to identify and quantify trace gases using their specific band absorptions.

It is an instrument based on a passive method using a mini-spectrophotometer, to obtain information on the vertical profile of SO_2 present in troposphere, by analyzing the spectrum of scattered sunlight. The instrument can be used from a mobile platform, configuring a mobile DOAS system; or it can also be used from a fixed platform, performing horizon to horizon scans. Where gases absorb radiation at certain wavelengths specific to the molecular structure of the gas; the radiation absorbed is used to excite energy levels, vibrational and rotational, or a combination of these. In monoatomic gases, energy levels tend to follow sequences that produce absorption lines (Finlayson-Pitts & Pitts, 2000).

Monitoring of the global sulfur dioxide plume from oil facilities was performed with the Mini-DOAS optical system, which uses Ultra Violet radiation during periods of greater solar incidence. Sulfur dioxide measurements are stored with date, time and geo positioning for results processing, analysis and interpretation.

Figure IV.6 presents the trajectory of the oceanographic cruise in the area of influence of the Project where the marine installations will be located carried out in November 2017.

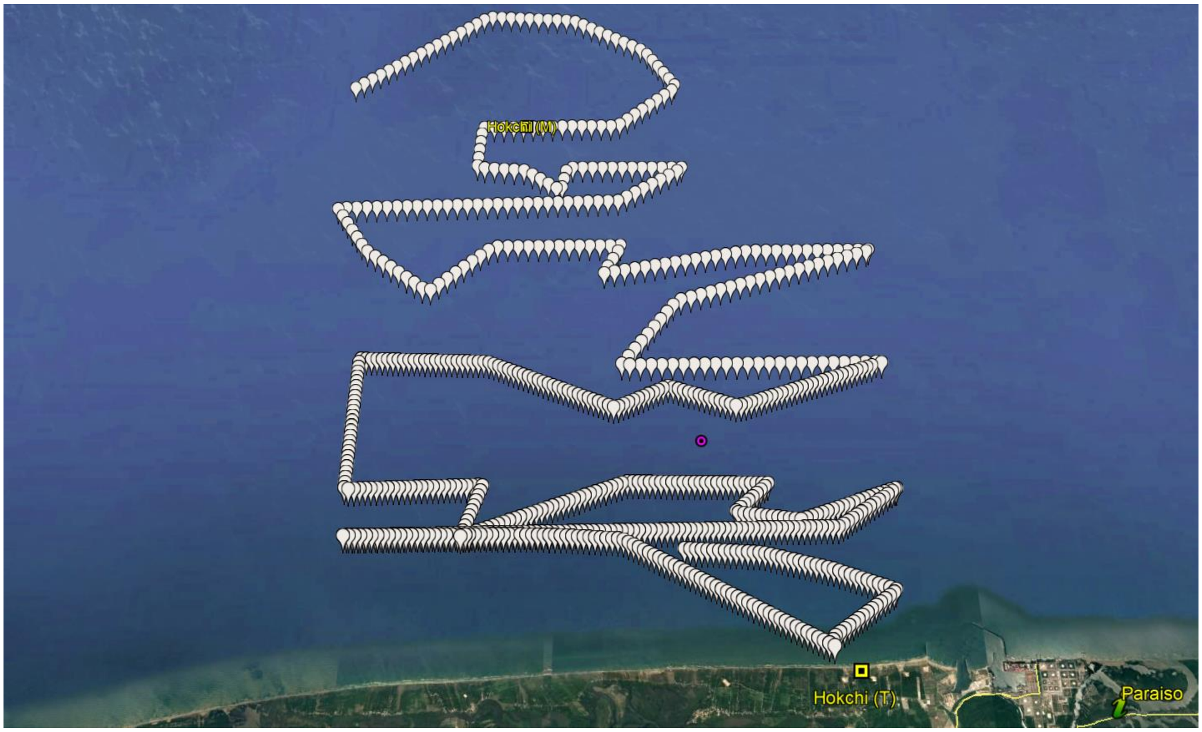


Figure IV. 6 The trajectory followed for SO2 measurement during the oceanographic campaign in the area of influence of the Hokchi Project off the coast of Paraíso, Tabasco. Source: own IMP.

Results of air quality monitoring and global monitoring of sulfur dioxide (SO2)

The results obtained from air quality monitoring carried out on February 22 to March 1, 2018 in the Paraíso, Tabasco, region, and up to 45 km east of the area where the land facilities of the Project will be located.

Sulfur dioxide concentrations found were very low (0.002 ppm) at all sites and at various hours, slightly higher values were found at site S1 (0.01 ppm) during noon and afternoon, at which time convective movements are generated that can cause emissions to interact with surface at shorter distances, which is due to being closer to the Terminal de Dos Bocas; it should be noted that although slightly higher, this value is 10% below the standard value.

In general, for Ozone, Carbon Monoxide, Nitric Oxide (NO), Nitrogen Dioxide (NO_2) and Nitrogen Oxides (NOx) the values found are below the air quality standard. Similarly, hydrosulphuric acid concentrations (California reference value is 0.02 ppm of H_2S) found were very low in the order of 0.001 to 0.006 ppm in the West, Southwest directions of the

Terminal Marítima Dos Bocas, which is associated with fugitive emissions from crude storage or anaerobic digestion process of matter.

According to the analysis of air pollutants concentration measurements criterion, there are no values exceeding health regulations in the region, which do not represent a health problem for the population.

The results obtained from the miniDOAS database show there are very low SO_2 concentrations in the atmosphere from the area where the marine installations will be located and their surroundings to the coastal region under study where land facilities will be located in the municipality of Paraíso. Therefore, it can be said these low SO_2 concentrations are mainly due to emission sources higher density (existing oil platforms) located more than 70 km from the Project and the defined SAR, as well as due to the good atmospheric dispersion existing in the region.

The good dispersion prevailing in the region is due to the recorded wind speeds ranging from 2 to 4 m/s and gusts of up to 10 m/s, these factors help to ensure air quality in the region under study is good in terms of pollutants criterion. Stating that such dispersion is also influenced by ambient temperatures ranging from 22 to 31°C, as well as relative humidity ranging from 40 to 90% in the monitored region.

Models results for predicting hydrocarbon spills trajectories at sea and regional atmospheric pollutant monitoring as supporting tools provide sufficient information to form a convincing criterion for selecting the number of Environmental Management Units that could interact directly or indirectly with the Project and the environmental elements involved. The next step is the review of other environmental policy instruments such as the Ecological Regulations applicable in the study area with which UGAs involved in the environmental characterization of SAR will be identified.

IV.1.3. General Territorial Ecological Regulatory Program (POEGT) Biophysical Environmental Units

According to the General Territorial Ecological Regulatory Program published in the Federal Official Gazette on September 07, 2012, the areas where land facilities will be located are immersed in the Ecological Regions (REG) 5.32 and 18.3, which correspond to Biophysical Environmental Units (UAB) 76 "Fluvio deltaic plains of Tabasco" and 135 "Alluvial plains of Western Tabasco" respectively.

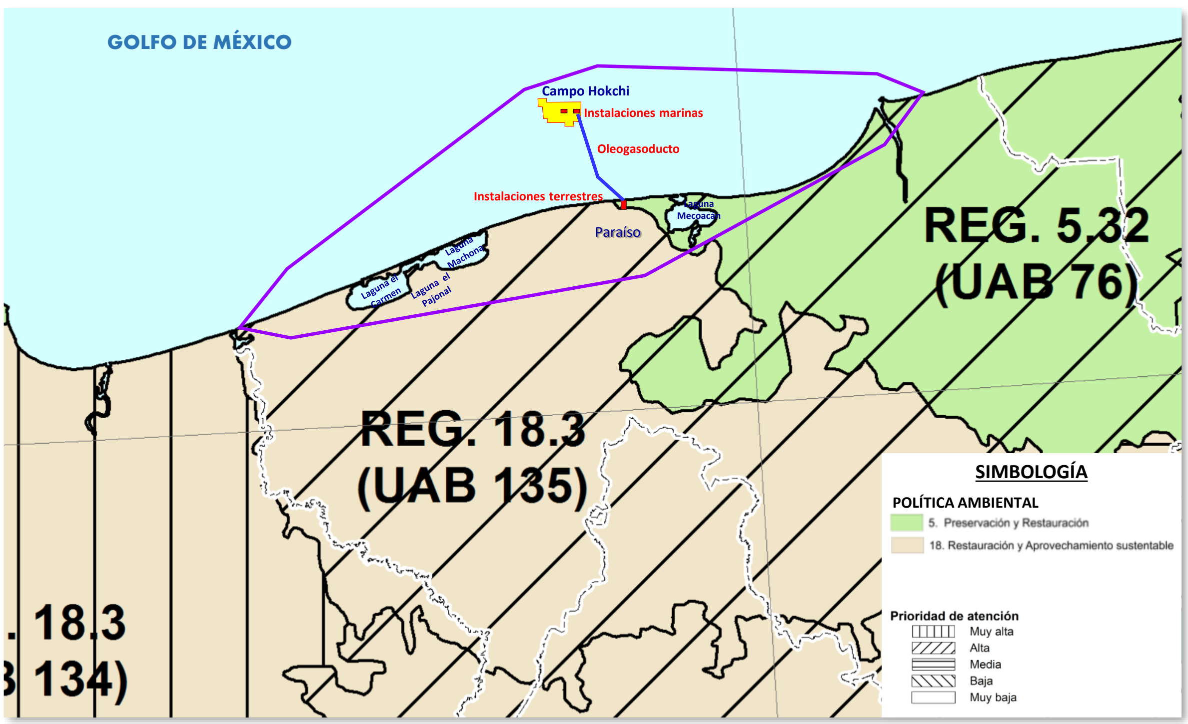


Figure IV. 7 Project Location, Ecological Regions and Biophysical Environmental Units

In REG 5.32, it corresponds to an Environmental Policy of preservation and restoration with a high attention priority, where the guiding axis of the UAB is flora and fauna preservation; and REG 18.3, its Environmental Policy is restoration and sustainable exploitation with high attention priority and the guiding axis of said UAB is agriculture, social development and animal husbandry with development coadjuvant activities such as the oil industry.

It should be noted that the area where land facilities will be located (Hokchi Plant), is currently of agricultural use; for the installation of oil and gas pipeline to the metering station, the use of the existing right of way will be used; and the area where the metering station will be installed, although classified as agricultural use, it was confirmed it is currently used by livestock (See Annex No. 5 Photographic Memory)

IV.1.4. Environmental Management Units for Marine and Regional Ecological Regulatory Program of the Gulf of Mexico and the Caribbean (POEMRGMyMC)

An analysis of the Marine and Regional Ecological Regulatory Program of the Gulf of Mexico and the Caribbean Sea (published in the DOF on November 24, 2012) was carried out and considering the forecasting modeling of oil spills trajectories at sea results, it was identified Environmental Management Units (UGAs) with which the project could have interaction with some of its environmental elements are:

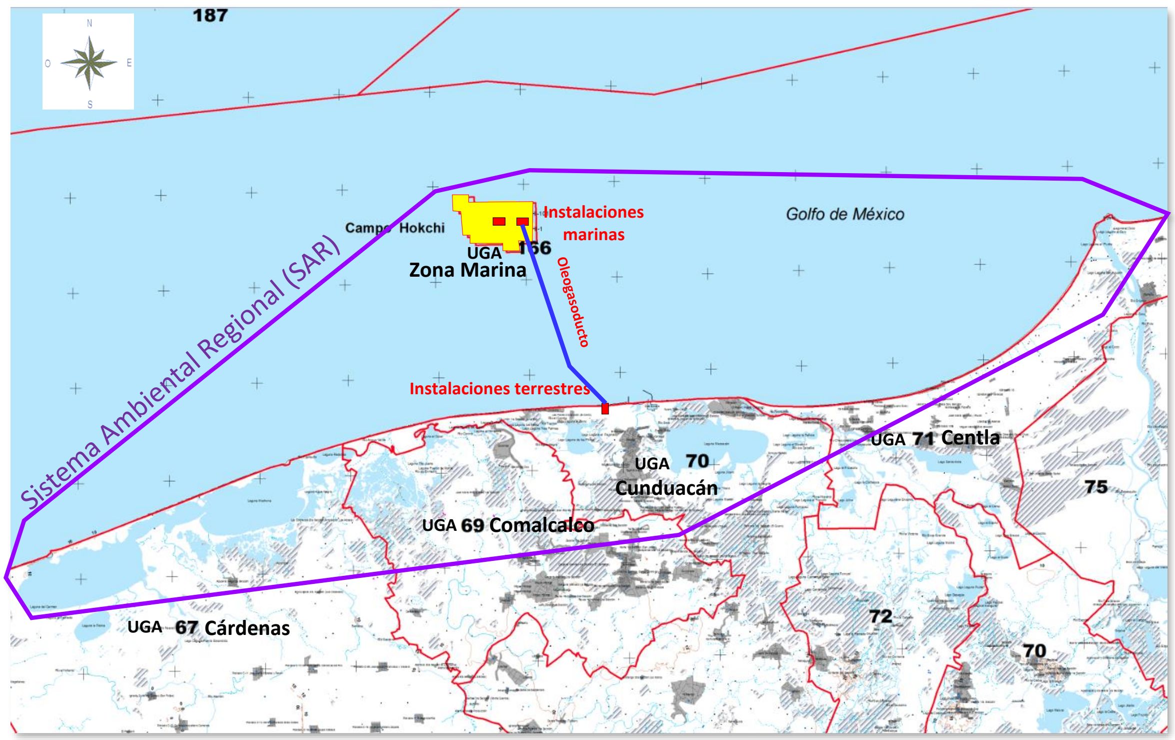


Figure IV. 8 SAR (UGA-67, UGA-69, UGA-70, UGA-71 and UGA-166) and Project location

On the Southwest side of the marine installations with UGA-67 (Cárdenas), on the South with UGA-69 (Comalcalco) and UGA-70 (Cunduacan); and on the East-Southeast side with UGA-71 (Centla), which are governed by the criteria of coastal zones with general and specific applicable actions; and on the North side of these UGAs in marine zone with the UGA-166 (marine area of federal competence) which includes oil exclusion areas and it is in the latter UGA that the two platforms will be located, production wells, injection wells, equipment, interconnections; as well as the oil and gas pipeline, injection and umbilical water pipelines that will interconnect with land facilities to be located in the municipality of Paraíso, Tabasco.

Land facilities part of this Project will be located specifically in the municipality of Paraíso, which is immersed in UGA-70 called “Cunduacan”, where the specific actions and criteria (A-028), do not exclude infrastructure installation of public benefit priority projects such as Oil facilities and CFE.

IV.1.5. Environmental Management Units of the Ecological Regulatory Program of the State of Tabasco (POEET)

The Ecological Regulation of the State of Tabasco published in the Official Gazette of December 20, 2006 and its respective amendment on December 22, 2012, establishes its Environmental Management Units by municipalities. In this same context, the Environmental System where land facilities will be located and their possible interaction of their different activities with environmental elements will be bordered in the coastal zone by the following municipalities:

Environmental Management Units of the Municipality of Cárdenas

Environmental Management Units of the Municipality of Comalcalco

Environmental Management Units of the Municipality of Paraíso

Environmental Management Units of the Municipality of Centla

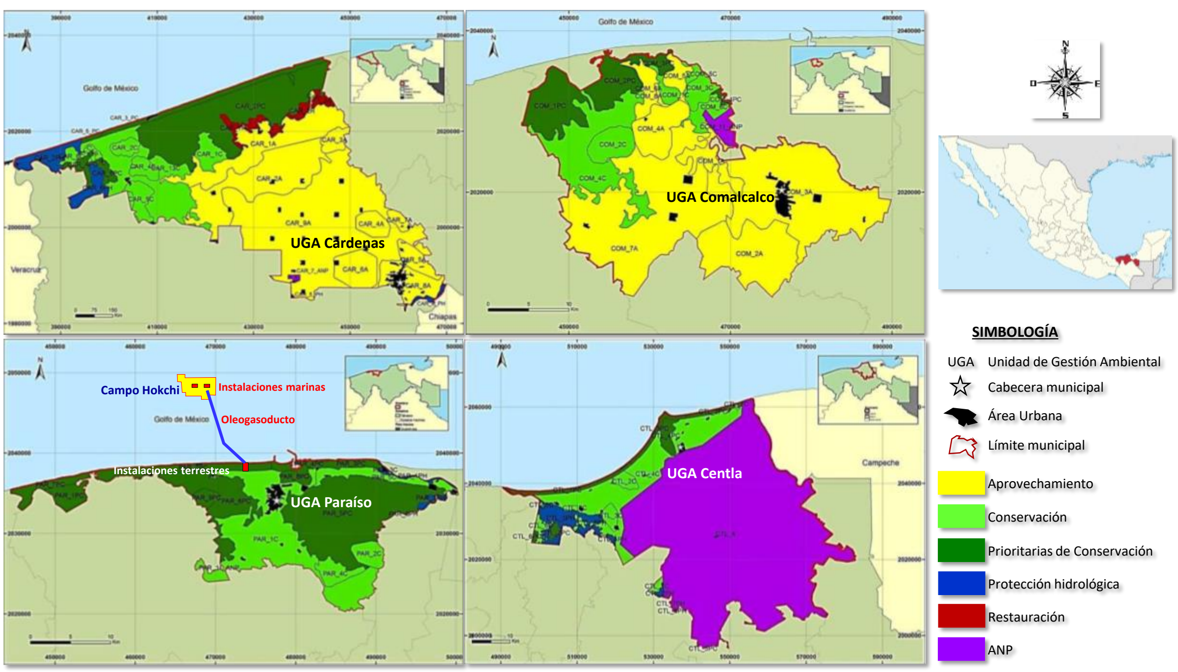


Figure IV. 9 Location of the Project and UGAs of the POE of the State of Tabasco

Where the general, specific ecological criteria and their strategies are aimed at protecting native species, reducing productive activities and infrastructure impacts, reducing the loss of forest cover, resources rational use; as well as adequate waste management in accordance with current regulations in order to avoid soil contamination, surface water and groundwater, among others.

Within these SAR areas, it is established that for the laying of pipelines, discharge lines and oil infrastructure, preventive, restoration and compensation measures should be established to maintain ecosystem health, runoffs and biological connectivity, using controlled directional drilling when pipelines or discharge lines cross rivers, bodies of water, mangrove vegetation or jungles, giving preference to the use of low-impact or already impacted areas.

Regional Environmental System Delimitation Summary

Due to the large marine and land areas covering UGAs where the Project could have interactions with environmental elements, for delimiting the Regional Environmental System (SAR) modelling was performed with GNOME (*General NOAA Operational Modeling Environment*) which is a prediction simulator of route or trajectories that could follow spilled oil stains from its inception in the exploitation area to its arrival on the coast.

This prediction tool is useful for the development of emergency response plans and thus anticipate measures and procedures for mitigating potential environmental damages both at sea and in the coastal area. However, effective emergency response measures should prioritize preventive measures preventing the most dangerous events from materializing before any other corrective action or apply appropriate mitigation measures in the event such events have occurred.

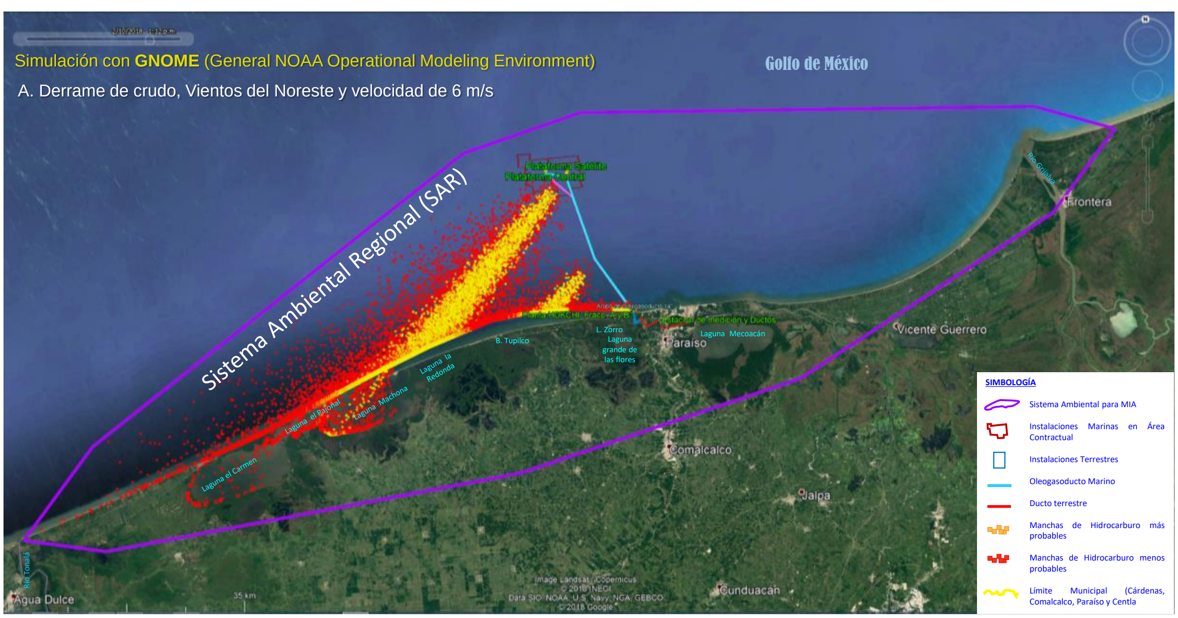


Figure IV. 10 SAR Delimitation by Hydrocarbons Dispersion at Sea, Prevailing Winds (NE)

Considering both hydrocarbon dispersion trajectories (more likely yellow dots and less likely red) in the marine area for each of the scenarios, it is observed that if rapid and effective emergency response actions were not taken during a significant spill, the areas that could be affected would be from coasts of the municipality of Paraíso to Lagunas la Machona, el Pajonal and el Carmen; as well as possible affectations on marine and land flora and fauna, and recreational and economic activities taking place in the coastal area of the municipalities of Cárdenas, Comalcalco and Paraiso, delimited in the SAR both by UGAs with support from hydrocarbons spills modeling in the marine environment with GNOME.

It should be noted that SAR delimitation also included possible affectations in the northerlies season with dominant winds towards the coasts of Paraíso, as well as the Eastern side of the Project was considered in order to carry out a more comprehensive environmental characterization and analysis covering the coastal area of the municipality of Centla (see figure IV.11).

Figure IV. 11 SAR Delimitation by Hydrocarbons Dispersion in the Sea Dominant Winds (N)

With regard to monitoring pollutant gases emissions, it was found that in the region or project area of influence, air quality is currently good because in general, for Ozone, Carbon Monoxide, Nitric Oxide (NO), Nitrogen Dioxide (NO_2) and Nitrogen Oxides (NO_x) values found are below air quality standard. Similarly, sulphydric acid concentrations were found below reference values, these values were associated with hydrocarbon storage activities in land areas and/or organic matter anaerobic digestion process.

Once the marine and land extensions have been analyzed with the tools already mentioned, the results give us the guideline to establish an imaginary line (purple) both in the marine and land areas to delimit the Regional Environmental System (SAR). In this way, the collection, analysis and characterization of environmental information will be more convincing about the Environmental Management Units (UGAs) the Project could involve.

In summary, the following ecological regions, biophysical units and environmental management units of both federal and state competence were identified for characterization and analysis and thus arrive at a good SAR diagnosis:

⇒ From the General Territorial Ecological Regulatory Program (DOF 24-11-2012), the Ecological Regions where the project will be located are: REG-5.32 and REG-18.3; as well as the Biophysical Environmental Units UAB-76 Pluviodeltaic Plains of Tabasco" and UAB-135 "Alluvial Plains of Western Tabasco" with Environmental Policies of preservation and restoration and sustainable use with development coadjuvant activities such as the oil industry.

⇒ Of the Marine and Regional Ecological Regulatory Program of the Gulf of Mexico and Caribbean Sea (DOF 24-11-2012), UGAs are: UGA-67 (Cardenas), UGA-69 (Comalcalco), UGA-70 (Cunduacan) specifically the coastal zone of the municipality of Paraíso, UGA-71 (Centla), and UGA-166 (federal marine area) on the Northern side of the municipality of Paraíso in the marine area.

⇒ From the Ecological Regulatory Program of the State of Tabasco (DOF 20-12-2006), modified (DOF 22-12-2012), municipal Environmental Management Units established in this regulation are: Cárdenas, Comalcalco, Paraiso and Centla.

In general, in the SAR delimited for this Project, the policies, ecological criteria and environmental strategies at the three levels of government **do not prohibit** the development of oil sector productive activities and infrastructure, they only guide and promote the protection of flora and fauna species, with aim to reduce such activities impacts; as well as to reduce forest cover loss, promote resources rational use; waste proper management in accordance with current regulations leading to the avoidance of soil, surface and groundwater pollution, etc. As well as the use of technologies promoting productive activities development and good performance using best practices and preventive measures, both restoration and compensation to maintain ecosystems health, runoffs, and biological connectivity.

It should be noted that risk scenarios at land facilities were not considered for SAR delimitation because they do not exceed 200 meters around the vanishing points. However, these scenarios would be largely immersed in the defined SAR and even within the project direct area of influence as shown in the figure showing the project direct area of influence at the beginning of this Chapter.

IV.2 Environmental system characterization and analysis

The integral analysis presented below includes: elements of the biotic and abiotic physical, social, economic and cultural environment, as well as the analysis of the different land and water uses present in the study area. Seasonal variability of environmental components, which reflect behavior and trends, will also be considered.

Evidence such as maps and images for the development, description and analysis of environmental aspects of the following sections is presented in Annex No. 2.

IV.2.1 Abiotic aspects

a) Climate

According to INEGI's state climates chart of Tabasco state with Köppen classification criteria, modified by Enriqueta Garcia (1981), the climate type in the Environmental System (municipalities of Cardenas, Comalcalco, Paraiso and Centla in land area) where the project will be located and its surroundings, belongs to an *Am(f)* climate corresponding to a humid warm climate with year-round rainfall where the rainfall of the driest month is less than 60 mm.

This climate is characterized by its average mean annual temperatures above 18°C, occurring in the study area the annual mean ranging from 24 to 28°C, with the highest mean annual temperature of 27.4°C and the lowest 26.2°C in the last five years.

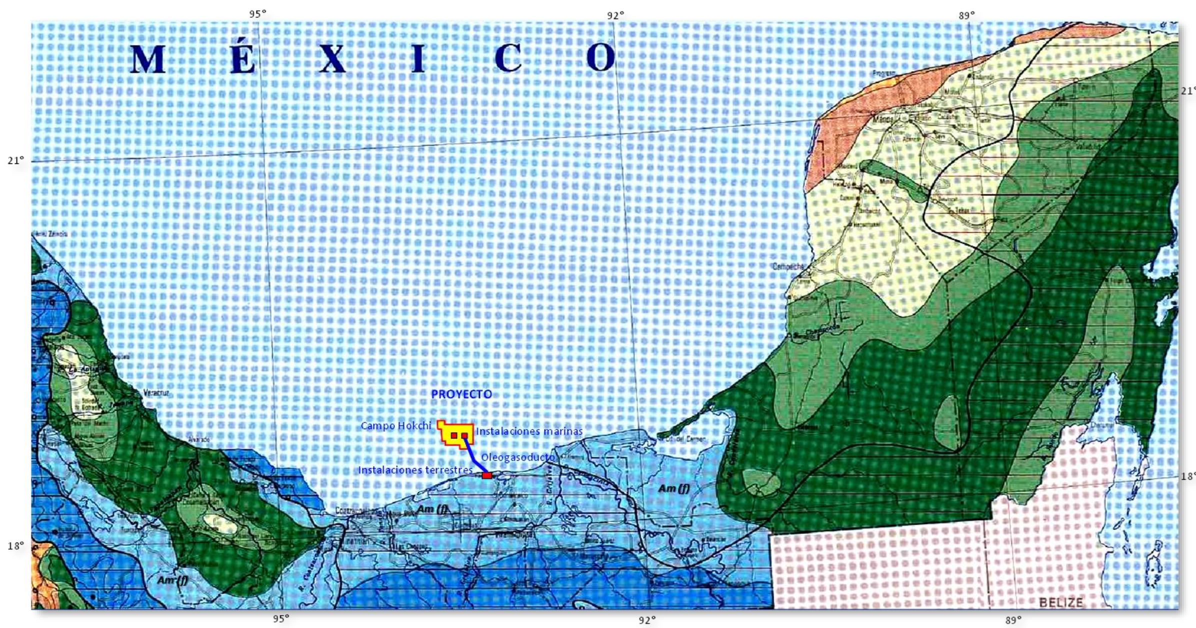


Figure IV. 12 Climate according to Köppen's classification, modified by E. Garcia. Source: Institute of Geography - UNAM, April 1989.

Because the Environmental System (SAR) is located on the Southern bank of the Gulf of Mexico whose land extensions are formed by plain areas, the invasion of maritime air masses is direct and causes much of the total annual precipitation, which oscillate by 1500 mm and increase as they move away from the coastal area heading South.

The location of this SAR in the tropical area and its low elevation relative to sea level determine warm climates development with maritime influence and the variation in temperature is moderate, as described below.

Temperature

From the climatological stations of CONAGUA's National Meteorological Service with data 1951-2010, the climate in the municipalities comprising the Environmental System (Cardenas, Comalcalco, Paraiso, Centla and the marine area) are as follows:

⇒ Weather station 27013, located at la Encrucijada in the municipality of Cardenas, the average annual temperatures are: 31.8°C, 26.6°C and 21.4°C, maximum, mean and minimum, respectively. Presenting average annual rainfall of 1982 mm.

⇒ Weather station 27009, located in Comalcalco, the average annual temperatures are: 31.4°C, 26.3°C and 21.3°C, maximum, mean and minimum, respectively. Average annual rainfall of 1848 mm.

⇒ Weather station 27034, located in Paraiso, the average annual temperatures are: 31.4°C, 26.5°C and 21.7°C, maximum, mean and minimum, respectively. Average annual rainfall of 1769 mm.

⇒ Weather station 27016, located in Frontera A, Obregon, Centla, average annual temperatures are: 33.6°C, 27°C and 20.4°C, maximum, mean and minimum respectively. Average annual rainfall of 1494 mm.

⇒ Weather station 4005, located in Cayo Arcas, Insular Campeche, the average annual temperatures are: 30.2°C, 27.6°C and 25°C, maximum, mean and minimum, respectively. Average annual rainfall of 356 mm.

In climates analysis for the marine environment, data were obtained from the same source for Cayo Arcas, Campeche located to the Northeast of the Project of which it is observed that even being more than 235 km from the coasts of Paraíso, temperatures have little variability and oscillate in the same range, however so for precipitation.

Relative humidity and evaporation

From the Geographic Synthesis of the state of Tabasco, one has relative humidity for the area fluctuates between 80% and 86%. Specifically in the project area, the range goes from 75.5 to 78.3%, showing in January the highest average of 83.3% and 69.5% as the lowest average in April. This high humidity makes throughout the state remains cloudy much of the year causing low insolation.

During the day, marine environment remains humid, due to the influence of the sea as opposed to land environment, where relative humidity presents very marked and pronounced minimum values, reaching 50% around 15:00 hours, while in the marine environment in this period of time the relative humidity values holds above 70%.

At night, the huge mass of sea water emits the heat absorbed during the day into the air, maintaining a thermal exchange with the marine-coastal atmosphere, and the variation in relative humidity and air temperature remains almost constant; a similar heat exchange process occurs during the day.

Mean annual evaporation is another of the indispensable variables to know hydric balance of an aquifer or determined basin, in the coastal region of the municipality of Paraíso, mean annual evaporation ranges from 1400 to 1500 mm. Towards the East and West of the municipality of Paraíso, the average real evapotranspiration decreases between1300 - 1400 mm. However, by way of comparison, to the South of this SAR evapotranspiration increases, being more than 1500 mm.

Wind Speed

According to the Environmental Baseline Report of the region under study, mean annual intensity of the dominant wind in general ranges from 9 to 12 m/s (32.4 to 43.2 km/hr).

From the engineering information of equipment distribution plan for the project, the prevailing wind direction comes from the Northeast, the speed and direction of the winds are concentrated in the months of October, November and December, with speeds reaching 30 km/h (8.3 m/s), presenting in May and June the lowest, with speed of 21 km/h (5.8 m/s).

As can be seen, SAR is located in the area where the Northeast trade winds dominates, which originate at the Southern edge of the North Atlantic anticyclonic cell or Bermuda-Azores cell, which collect high humidity when crossing the Atlantic Ocean.

Climatological phenomena

Climatological phenomena obtained from Köppen's classification, modified by E. García, the most characteristic climatological phenomena occurring in these areas are: trade winds with Eastern waves (tropical waves) coming from the Atlantic and tropical cyclones in summer and autumn, North winds in winter with high and uniform temperatures whose mean oscillates between 24°C and 28°C; which influence strongly these climatological phenomena.

Hurricanes.

These meteorological phenomena, known as tropical cyclones, are low pressure systems with abundant rain and electrical activity whose winds rotate anticlockwise in the Northern hemisphere. A tropical cyclone with winds less than or equal to 62 km/h is called a tropical depression, when these reach speeds of 63 to 117 km/h, it is known as a tropical storm and, after exceeding 118 km/h, the tropical storm becomes a hurricane.

Monitoring of variable sea temperature is of paramount importance, because the formation of these meteors is from 26ºC. Temperature monitoring is a way of knowing the areas where cyclones can move while maintaining or increasing their intensity.

Figure IV.42 also shows six instants of sea surface temperature evolution throughout the year, from the Climatological Atlas of Tropical Cyclones in Mexico, CENAPRED, 2014. one has that from January to April the sea temperature near Mexico is lower than the rest of the year. From May there is an increase in sea temperature, with the most notable increase in July for the Gulf of Mexico. From November the sea temperature begins to decrease again, recalling that the tropical cyclone season begins on June 1 in the Atlantic Ocean and ends until November 30.

Below are maps of the probability of tropical cyclones formation (Tropical Depression, Tropical Storm or Hurricane) and their predominant trajectories in the Gulf of Mexico and Caribbean Sea from June to November.

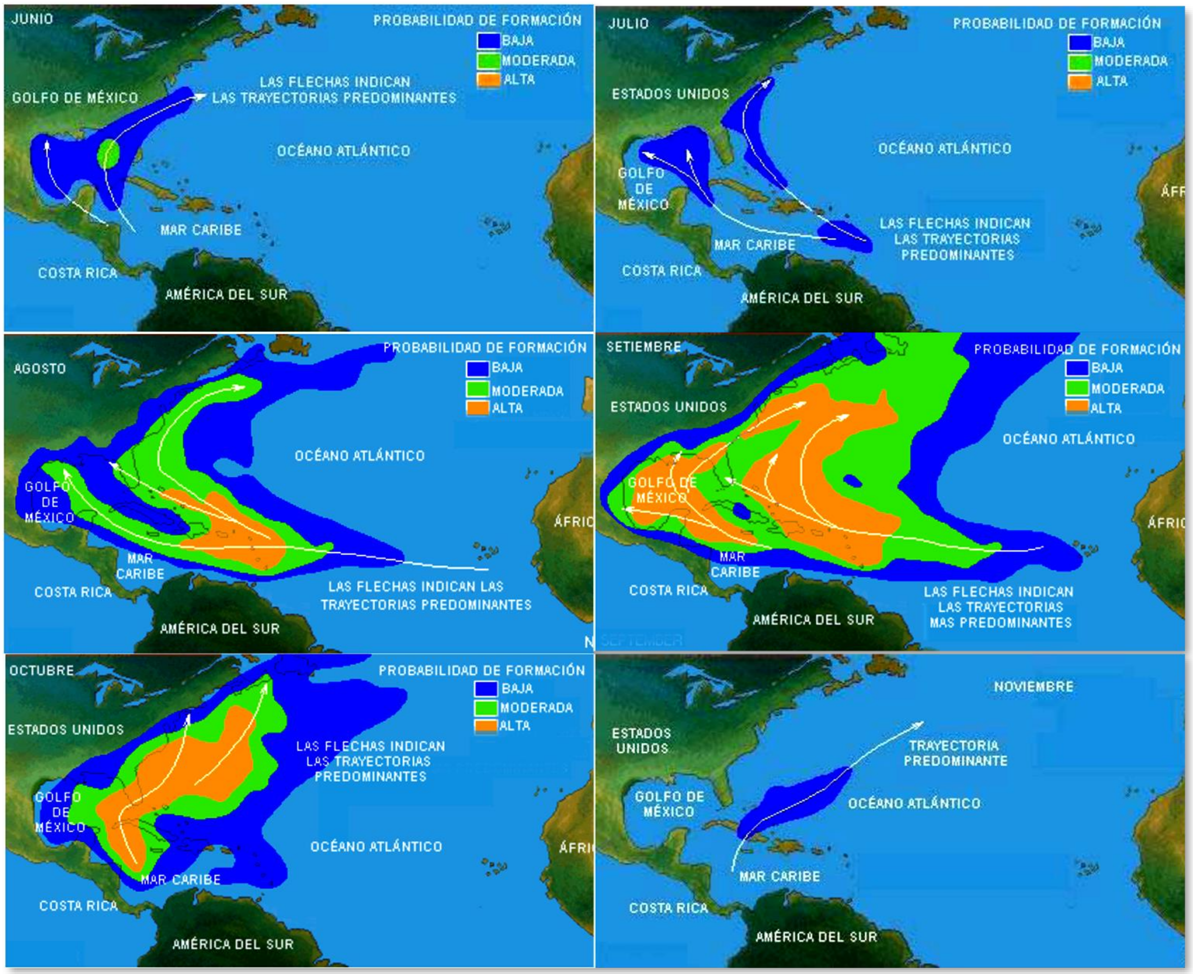


Figure IV. 13 Probability of tropical cyclones formation in the Gulf of Mexico and Caribbean Sea. Source: National Oceanic and Atmospheric Administration [NOAA].

As can be seen in these maps issued by NOAA, the probability of tropical cyclones formation in the Atlantic Ocean and Gulf of Mexico starts from June, reaching a critical point in the area where the Project will be located in September and decreasing in October until it dissipates in November. However, although in the area where the facilities will be located the probability of formation is zero in the months of June and July, and falls in the month of September to November, as is expected, the trajectories of tropical cyclones formed in the Caribbean Sea tend to the coastal plains of the Gulf of Mexico, so there is a possibility that the area will be affected by this meteorological phenomenon, as indicated in the following map of frequency of occurrence per year and the average direction that such meteors could follow in the Gulf of Mexico.

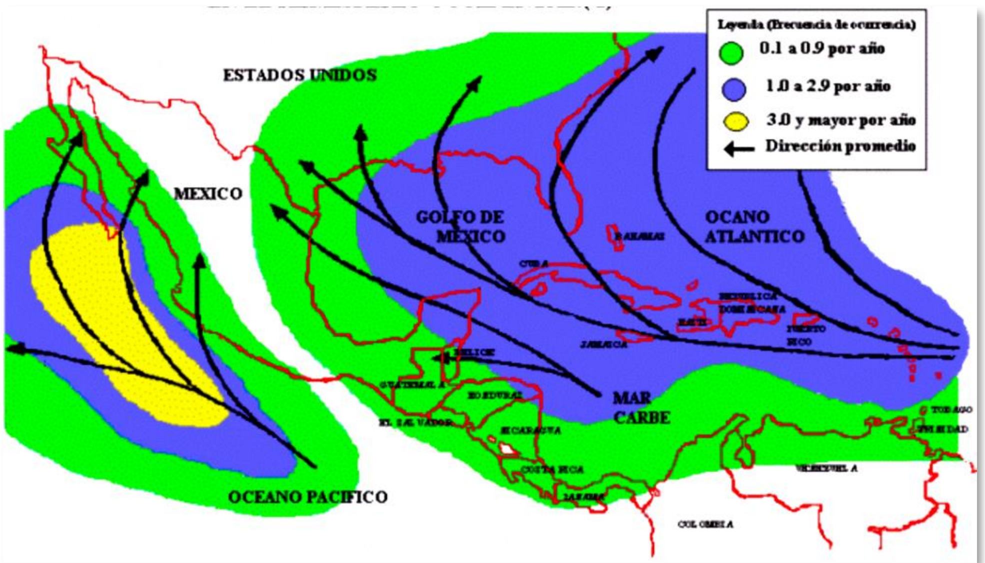


Figure IV. 14 Frequency of tropical cyclones occurrence in the Gulf of Mexico and Caribbean Sea. Source: Munchener Ruckversicherungs, "World Map of Nature Risks" Munich, Fed. Rep. of Germany, 1988.

These disturbances, depressions, storms and/or hurricanes when they occur, can occur from June to October and even November; the most important effects are flooding that can occur in the region.

From de National Risks Atlas from the National disasters Prevention Center (CENAPRED) it is understood that since 1851 to 2014, in the study area from Laguna el Carmen to the mouth of the Grijalva River in the municipality of Centla, there have been only tropical depressions, tropical storms and only one level 1 hurricane that entered Paraíso municipality becoming a tropical storm before reaching the municipality of Comalcalco (see figure IV.14).

Figure IV. 15 Figure IV.14. Tropical Cyclones (1851-2014) in the Environmental System. Source: CENAPRED, "Atlas of Hazards by Natural Phenomena of the State of Tabasco".

Similarly, derived from other analyses of meteorological information carried out on the environment, it can be said that in the region under study there is a possibility of tropical storms activity up to hurricanes. Figure IV.16 presents the trajectories of Hurricanes, Depressions and Tropical Storms (H, TS and TD respectively) recorded on the coast of Tabasco in the period 1990 to 2016 and the year of incidence shown in figure IV.17.

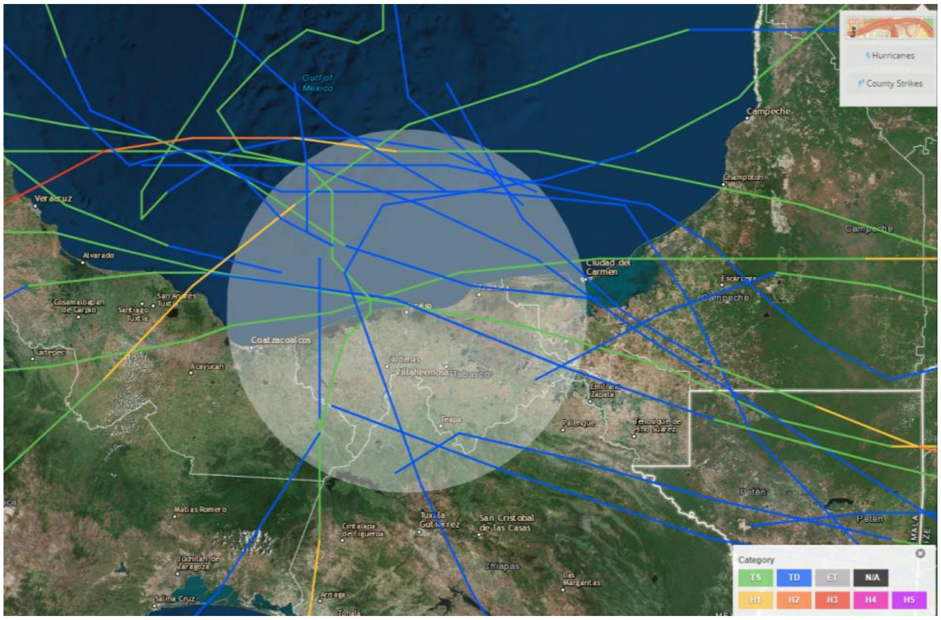


Figure IV. 16 Figure IV.16.- Hurricanes, Depressions and Tropical Storms Trajectories 1990-2016 (coast of Tabasco) Source: Meteorology Historical Analysis, IMP.

Figure IV.16 shows the number of hurricanes per year, recorded on the coast of Tabasco in the period from 1990 to 2016, where it can be observed that the highest number of hurricanes was in 2005. The most frequent number of hurricanes ranges from 1 to 3 per year as can be seen in the following graph.

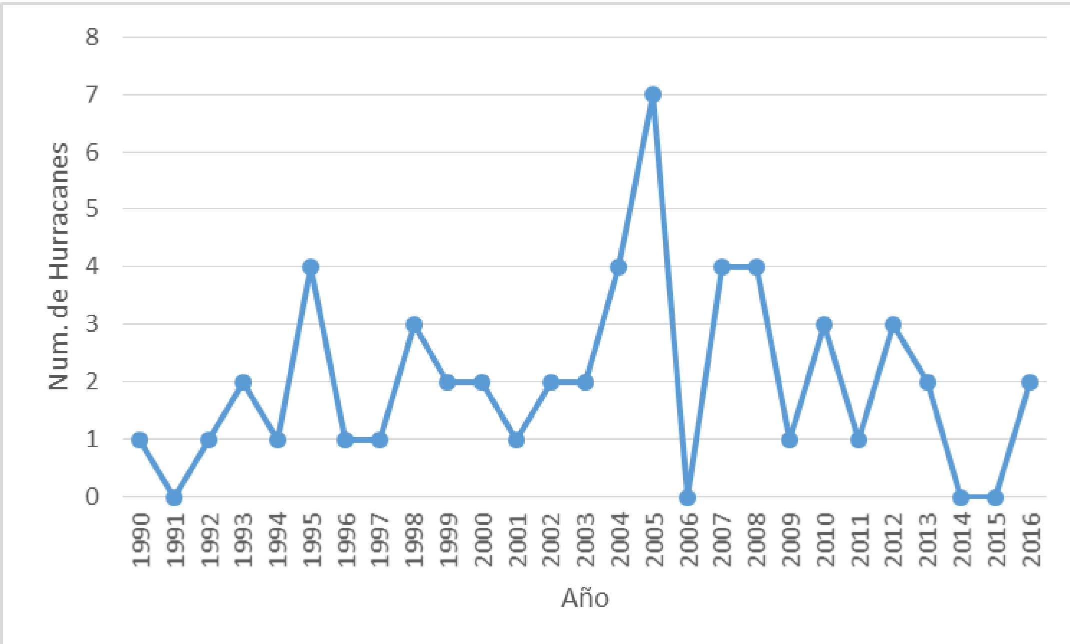


Figure IV. 17 Tropical storms and hurricanes recorded on the coast of Tabasco from 1990 to 2016. Source: Meteorology Historical Analysis, IMP.

Droughts

From the Geographic Synthesis of the state of Tabasco, it is the understanding for the study area, the dry season occurs in the months of March and April, where the mean volume of precipitation in this period is 40 mm, the precipitation in summer and early autumn is caused by the convective processes of the hot and humid air masses invading the area, while in the months of October to March, such rainfall is the result of cold fronts originating from the Northerlies that usually manifest in the form of drizzle during this period.

There is a probability of a “short” dry period starting on October 27, rising even further to reach values very close to 1 (0.999) between March 10 and April 22. The dry periods occurring last between six and seven weeks, with a return period of twenty years, the least likely periods of droughts are in the months of August to October.

The degree of drought hazard (CENAPRED) in the project area is “medium” and in the surroundings where the project can influence environmental factors is “low” (see figure IV.18).

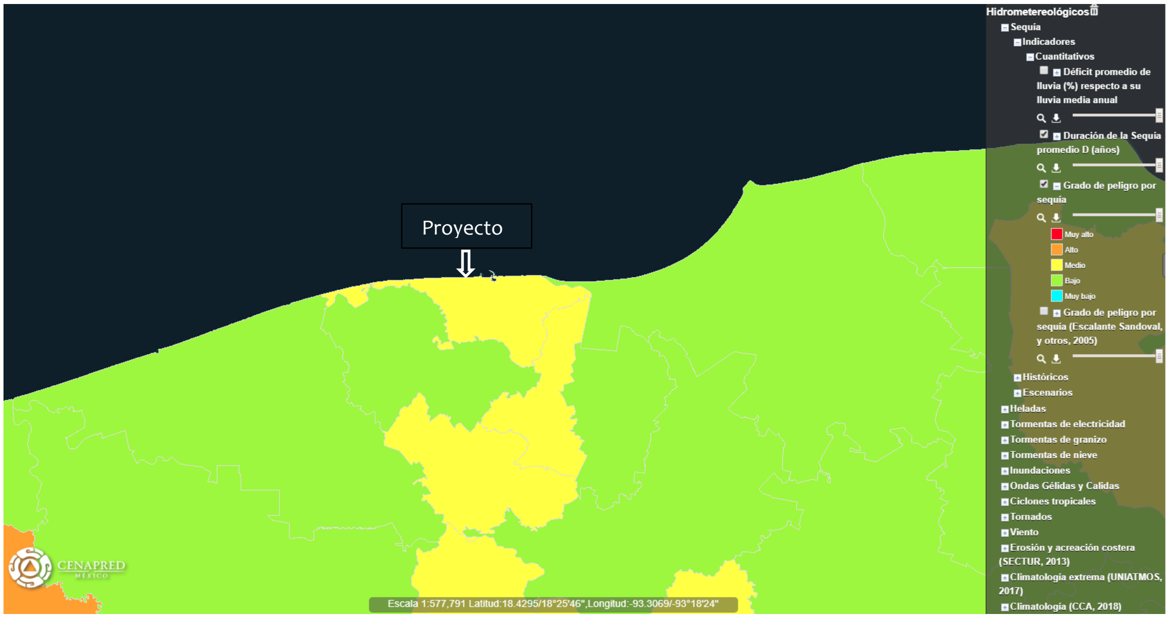


Figure IV. 18 Drought hazard in the Project Area and SA. Source: CENAPRED, "Atlas of Hazards by Natural Phenomena of the State of Tabasco".

An important aspect is that between July 9 and 22, in general, intra-summer drought occurs, which is nothing more than days with high temperatures and low rainfall within a wet season, the highest increase in probability occurs in Paraíso, where dry periods occur in nine out of ten years.

Northerlies

With regard to cold fronts or northerlies, these occur more than 25 between the months of November and February and cause sudden decreases in temperature for short periods, although they do not cause considerable disturbance; that is, the incidence of frost and hail is practically zero in the region due to slight variations in the temperature throughout the year. However, from CONAGUA information, the effect of these cold fronts is reflected in offshore maritime activities and oil activities in the Gulf of Mexico.

b) Geology and geomorphology

Lithological characteristics of the area

From the "Synthesis of Geographic Information of the State of Tabasco, 2001", in this North-Northwest portion of the state of Tabasco included in the SA that comprise the coastal area of the municipalities of Cardenas, Comalcalco, Paraiso and Centla; as well as the marine area adjacent to these municipalities, structural geology is shaped mainly by sedimentary rocks such as limestones, sandstones and evaporite deposits, which were subjected to severe compression efforts, which caused the more plastic rocks to fold and the more tenacious ones to fracture, generating positive structures similar to pillars (Horst) and negative structures similar to a pit (Graben) delimited by two normal failures that led to the formation of traps where hydrocarbons and natural gas were accumulated. Hydrocarbons generating rocks are considered of Tithonian, Middle Jurassic and Superior Jurassic age, which are rich in organic matter, mainly of algae that gave rise to these hydrocarbons.

Figure IV. 19 Land Geology of SA (coastal area of Cardenas, Comalcalco, Paraiso and Centla). Source: INEGI, Geological Chart of the State of Tabasco and Mexican Geological Service - CG Mineria-Economy Secretariat

These structures of the subsoil are associated with different tectonic stages whose evolution is summarized in three major events: a first stage of compressive stress that folded sedimentary rocks deposited during the Jurassic, which resulted in the geoforms represented by anticlines and elongated synclines with Northwest and Southeast heading at altitudes ranging from 200 to 900 masl; later there was the intrusion of saline masses towards the upper layers through fault planes and anticlines axes generating domic type deformation; finally there was a stage of tectonic relaxation during the Upper Miocene-Pleistocene, this distensive tectonic affected pre existing geoforms and generated lateral displacements associated with the Polochic-Motagua system of Miocene-Pliocene age which gave rise to a relief in the form of blocks that superficially define tectonic valleys (grabens). This led to the formation of the Macuspana and Comalcalco basins where large thicknesses of terrigenous sediments were deposited.

In the marine area, the presence of these pits and pillars caused that the basins developed isolated from each other, with particular characteristics, in some of them there were conditions of shallow seas with abundant organic matter that in the end will form hydrocarbons generating rocks and other basins with water breakthrough more shallow that allowed the formation of evaporite basins where large thicknesses of gypsum and salts that are currently known as domes were deposited, see following figure.

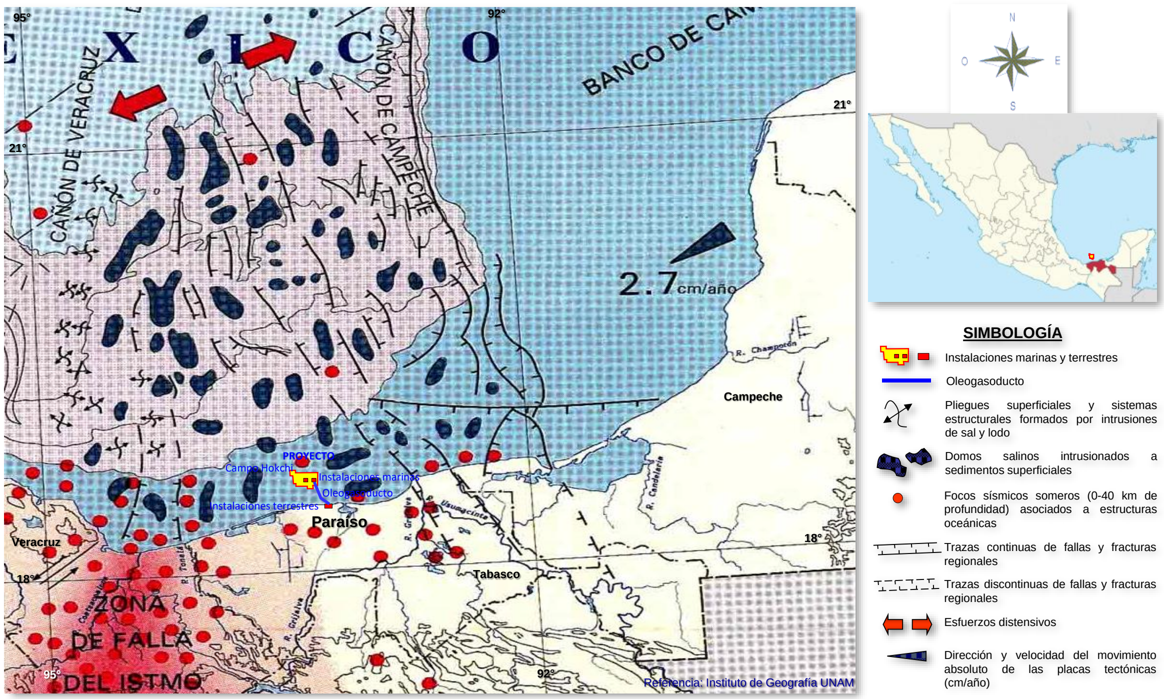


Figure IV. 20 Marine Geology. Source: Geographic Information Systems, Institute of Geography, UNAM, October 1991

This marine area where the platforms will be located is characterized by the presence of sedimentary deposits belonging to the Quaternary. The average thickness of this sequence is between 550 meters and 650 meters according to what was reported by (C&C Technologies and Oceaneering, 2016). The predominant geological features during the Holocene correspond to reef formations on carbonated sediment strata and the presence of paleocanals, resulting from eustatic changes in sea level during glaciation events. Different authors who have studied the Gulf of Mexico indicate that tectonic and sedimentary evolution was characterized by a slow subsidence that began in the middle Jurassic and continues today.

From more recent geotechnical studies (C&C Technologies and Oceaneering, 2016) for the areas where the Satellite Platforms and Central Platform will be located, and in order to determine the maximum load capacity and these platforms foundations behavior review, the study was conducted at a depth of 120 m under the seabed, where the following aspects were defined:

- Determination of the load curve — penetration.
- Determination of supports penetration final depth once performed the preload.
- Possibility of failure due to sudden penetration (punch — through) during preload operations.

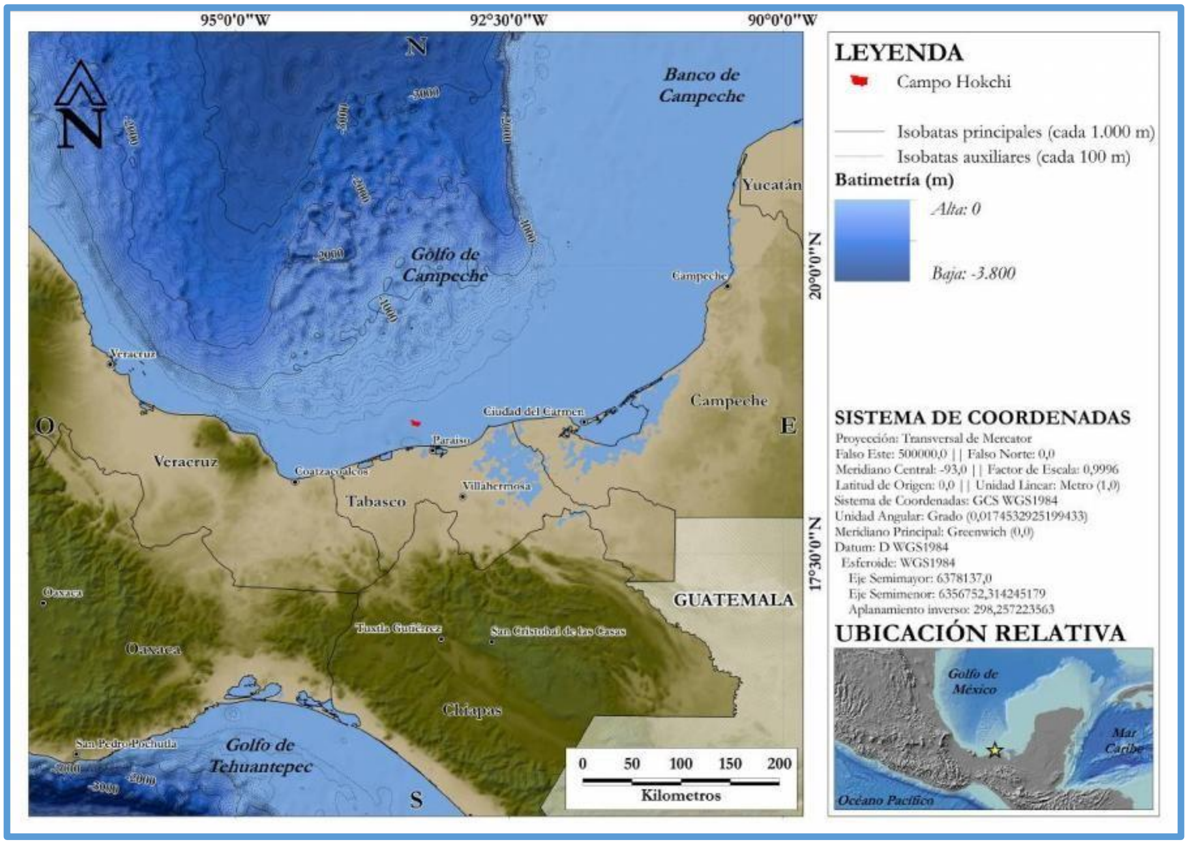


Figure IV. 21 Hokchi Field where the Central and Satellite Platforms (Marine Installations) will be located. Source: Report of the "Hokchi Geotechnical Survey Service" 2016

Regional geology

The marine and land facilities will be located within the Oil Province called "Southeastern Basins", which is located in the Coastal Plain of the Gulf of Mexico and the Continental Shelf of Southeastern Mexico, including a land and marine portion of shallow water, this province in its land part covers the South of the State of Veracruz, Northern Chiapas, almost all of the State of Tabasco and the far South West of the State of Campeche; the marine portion occupies part of the exclusive economic area in the Gulf of Mexico, from the 500 m isobath to the coastline, comprising the following basins:

- Isthmus Saline Basin.
- Comalcalco basin.
- Macuspana Basin.
- Reforma-Akal Pillar Basin.

The Southeastern Basins is the most prolific oil producer in the whole country. Exploratory activities began in 1979 and over the last 30 years more than 300 exploratory wells have been drilled, which have made possible the discovery, evaluation and production of hydrocarbon deposits in the carbonate Cretaceous and the clastic Tertiary of the sedimentary column.

Figure IV. 22 Location Map of Mexico's Oil Basins. Source: Report of the "Hokchi Geotechnical Survey Service" 2016

The study area is characterized by the presence of sedimentary deposits belonging to the Quaternary. The average thickness of this sequence is between 550 meters and 650 meters according to what was reported by (C&C Technologies and Oceaneering, 2016).

The predominant geological features during the Holocene correspond to reef formations on carbonated sediment strata and the presence of paleocanals, resulting from eustatic changes in sea level during glaciation events.

Stratigraphy

The project area in the land area and the delimited Environmental System that could be influenced by its environmental elements are located within the physiographic province "Coastal Plain of the Southern Gulf" and the sub province "Tabasco's Plains and Swamps" bordering the Southern portion of the Gulf of Mexico. It is a sedimentary composition plain whose origin is related to the regression of the Atlantic Ocean initiated from the Lower Tertiary; as well as the gradual filling of the ocean basin in the marine part of this Environmental System where until today large volumes of detrital material are accumulated dragged by the bodies of epicontinental water to its mouth.

Continuous rejuvenation of the coastal platform has allowed subsequent erosion of Tertiary age marine and continental deposits, which manifest with few low-rise knolls made of limestones and sandstones, representing an almost flat relief as it approaches the Gulf of Mexico. Within the Sub-province "Tabasco's Plains and Swamps", rivers have had unstable courses, which is due to the accumulation of recent alluvial material covering much of the plain mainly on the Eastern side of the municipality of Paraíso towards Centla and in a lesser proportion to the West of the same towards the municipalities of Comalcalco and Cardenas.

Stratigraphically, in the beach areas and coastal bars of the Southern Gulf Coastal Plain, the soils are of the Litoral type along the coastline from Laguna el Carmen, El Pajonal, La Machona, La Redonda, Barra de Tupilco, Playa El Limon, Laguna Barra Chiltepec, Playa Azul, Playa Pico de Oro, Playa Miramar, among others, up to mouth of the Grijalva river in the municipality of Centla. The soils in these areas are formed by sand accumulation reworked by the waves and distributed along the coastline. Adjacent to the Southern part to these soils Litoral type are Lacustrine and Palustre types composed by silty, clayey sediments and lenticular bodies characteristic of these floodplains.

In these areas the oldest rocks are also of sedimentary origin and were deposited in marine, lagoon and deltaic environments, where limestones, evaporites and conglomerates were formed respectively, of these the oldest are of Cretaceous age.

The geological factors that have influenced the deposit of lithostratigraphic units in the area have been tectonism, mainly manifested in the area by the filling of marine and lake basins with contributions of land materials, transported by a complex network of surface currents, which constitutes the response to a distensive younger event developed in the region, characterized by the occurrence of large syndepositional growth failures, of possible Late Miocene and Pliocene-Pleistocene age.

The lithostratigraphic column of the area is constituted mainly of sequences of consolidated and unconsolidated soils and rocks of Quaternary and/or Recent age. The lithology characterizing this sequence, is represented predominantly by sands, with some gravel and clays, accumulated within the last 10 000 years, and whose origin is related to processes mainly of fluvial nature.

Towards the basal part there are deposits of Pleistocene age, which lithologically is characterized as a sequence of sandstones, arranged forming lenticular bodies, and lutites, with occasional bodies of conglomerates, gravel and sand, which are associated developed within transitional environments of deltaic and paludal type, and even sporadically continental, under fluvial conditions.

Lithologically, the Pliocene is characterized by a monotonous alternation of fossiliferous lutites of blue gray color, which are the most predominant and sandstones, the latter, in parts have a clay-calcareous matrix, with some inter-stratifications of bentonite horizons and occasionally present some clay mudstone, towards the North of the study area there is a slight tendency to sandstones predominance.

(In Annex No. 2 is included the geology and physiography map)

Relief Morphology and Features

The SAR and the area where the project will be located in the land area, falls within the "Coastal Plain of the Southern Gulf", specifically in the sub-province called "Tabasco's plains and swamps" which comprise the municipalities of Cardenas, Comalcalco, Paraiso and Centla in the coastal area; as well as other municipalities included within this Plain, limited to the North by the Gulf of Mexico and to the South by the province "Sierras of Chiapas and Guatemala".

This sub-province, in its central portion, joins the lower basins of the Grijalva and Usumacinta rivers, whose currents converge south of Frontera in the place called Tres Brazos to finally flow into the Gulf of Mexico.

In this coastal plain, the riverbeds have been unstable, which makes the area regularly covered by recent alluvial material in most of the plain. The area where land facilities will be located and its surroundings close to the coastal area, are considered low-flooding areas, however to the East of the municipality of Paraíso where there are large flooding areas.

Geomorphologically in this part of the sub-province predominates the coastal plain, with very low and few knolls, where topoform systems are constituted by bars, which separate the marine waters from the lagoon systems waters el Carmen, el Pajonal and la Machona; as well as constituted by dune systems located in the Northwestern part of the state of Tabasco between the mouth of the Tonala River and el Carmen Lagoon and in the central part of the SAR under study, between el Cocal Lagoon and Mecoacan. Within these geomorphological characteristics, the barrier plains constituted by beaches that range from the Mecoacan lagoon to the boundaries with the state of Campeche to the east of the Project are also highlighted.

Geomorphology in the marine study area corresponds to the trait of coastal plain, soft relief with small elevations. The report presented by (C&C Technologies and Oceaneering, 2016) identifies level differences of the order of 0.5 meters for this sector.

The predominant deposition environment corresponds to deltaic deposits that in turn form submarine fans in the proximal part of the continental slope. The predominantly terrigenous sediments are the result of transportation of the Grijalva, Usumacinta, San Pedro rivers and the mouth of the Laguna de Terminos due to their abundant river currents. The material is transported and distributed on the seabed accompanied by sands. Close to the coast where sea movement is turbulent, fine sands are deposited, as it advances in depth, the flow behaves in a laminar way and at low speed allowing clay type fines materials to be deposited.

From the final report of the "Hokchi Geotechnical Survey Service" 2016, the geomorphology at regional level on the northeast side of the project is the so-called broad Platform known in literature as the Yucatan Platform or the Campeche Bank, which has a depth of -100 meters between the coastline to the limit of the underwater canyon. A variety of underwater topographies associated with geological evolution of the Gulf of Mexico are shown in this region, identifying the following regional morphological features:

1. Wide platform (Bank of Campeche).
2. Submarine canyon (Campeche Canyon).
3. Saline mounds.
4. Deep plain.
5. Narrow platform.

See next figure.

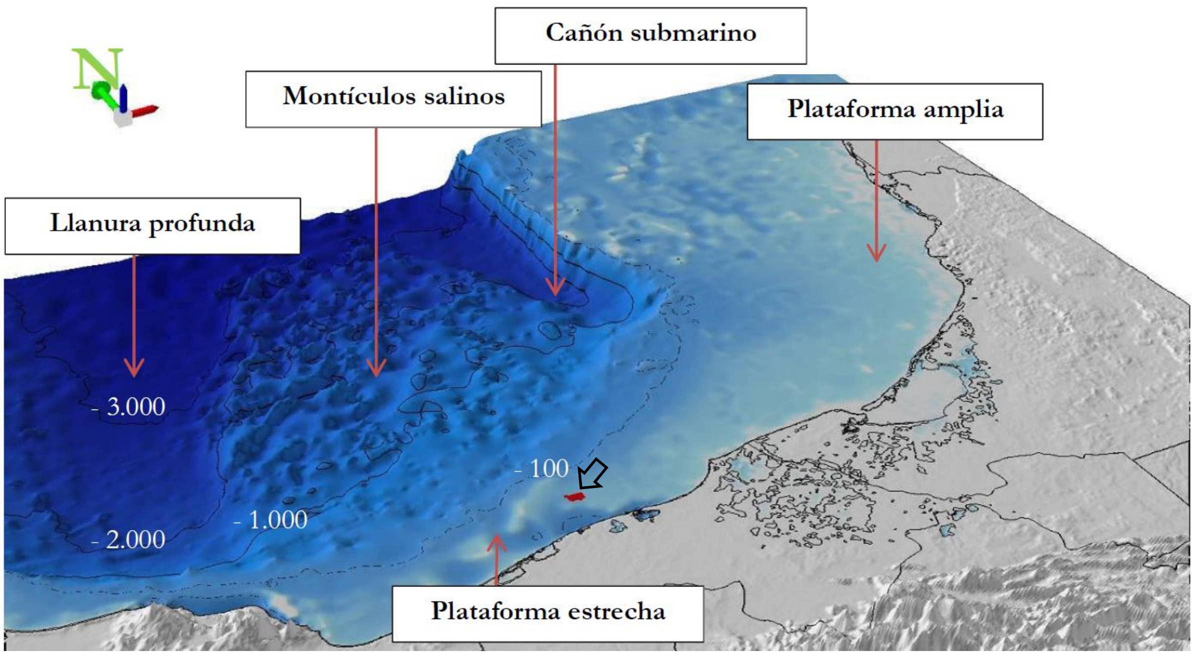


Figure IV. 23 Figure IV.23.- Regional morphology and bathymetry in the project area. Source: Report of the "Hokchi Geotechnical Survey Service" 2016

As can be seen in the previous figure, the project will be located in the narrow Platform, which is located North of the coastline of the municipalities of Centla, Paraiso, Comalcalco and Cardenas in the state of Tabasco; as well as South of the salt mounds with depth of up to -100 meters, where slopes do not exceed 3% until possibly 50 kilometers away from the break of the continental shelf and the coastline.

In general, both on the Wide Platform and on the Narrow Platform the slopes of the area do not exceed 3% so the geometries of the area can be defined as a wide and narrow underwater plain respectively with relatively low depths.

(In Annex No. 2 is included the Geology and Physiography map)

Faults and fractures

As for the structural geology where the Project will be located, structures associated with different tectonic stages have been detected in the state whose evolution is summed up in three major events: a first stage of compressive stresses that folded the sedimentary rocks deposited during the Jurassic, resulting in the formation of geoforms represented by anticlinals and elongated synclines facing Northwest Southeast; subsequently, saline masses intrusion into the upper layers through fault planes and anticlinals axes generating deformation domic type irregularly distributed; finally, there was a tectonic relaxation stage during the upper Miocene and Pleistocene whose distensive tectonics affected preexisting geoforms and generated lateral displacements that gave rise to the faults and basins of Macuspana and Comalcalco (see figure below), which the latter extends towards the continent with a Northeast-Southwest direction of the Project and are the ones that govern the physiographic province (Asociación Mexicana de Geólogos Petroleros, A. C., March, 2006).

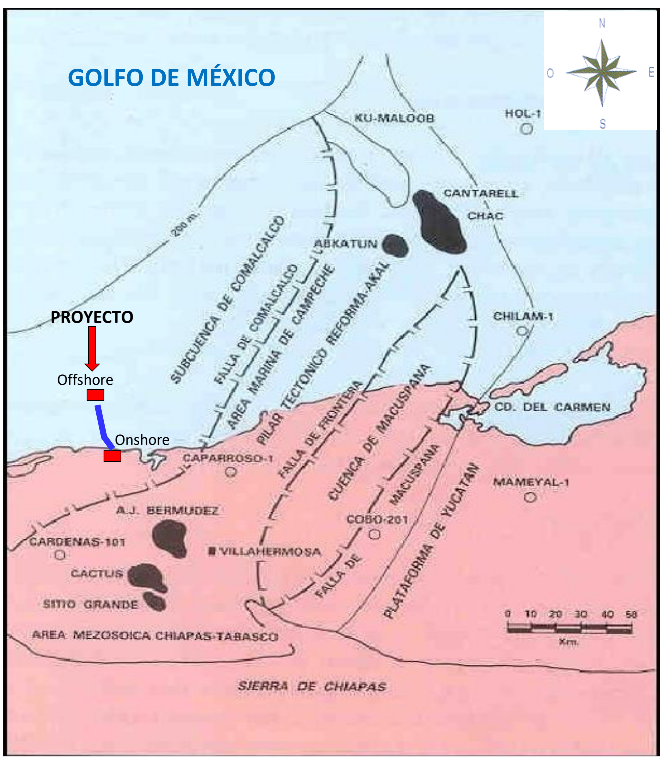


Figure IV. 24 Faults and fractures in project area and surroundings. Source: Geología Marina, Asociación Mexicana de Geólogos Petroleros, A. C., March, 2006.

According to geophysical seismology studies (Fugro McClelland, 1996) suggest that the area of marine influence is a tectonically stable area.

Regional tectonism in the marine area where the facilities will be located, are immersed in the Southeast Basins, where the following tectonic activity is presented that has led to its formation:

Isthmus Saline Basin.

Mesozoic and paleogenic rocks are affected either by folding and faulting or by rotating layers on the pedestals of saline diapirs; in the Tertiary there are dome type structures associated with saline masses, lystric faults with Northwest inclination affecting even the Mesozoic and counter-regional lystric faults.

Macuspana Basin.

Characterized by early Miocene-Pliocene lystric faults of NE-SW orientation and NE inclination with rollover anticlines associated with the evacuation of Oligocene clays. In the marine portion these faults break and displace to the Northwest the Mesozoic rocks with a raft system bringing Jurassic salt into contact with Oligocene sediments. Towards its Western edge there are lystric faults of Late Pliocene-Pleistocene with Northeast-Southwest orientation and Southeast inclination and elongated and tight anticlines of Plio-Pleistocene associated with faults inversion during Miocene. In its marine portion, in this basin different oil prospects are recorded, as a continuation of the producer alignment of the land area.

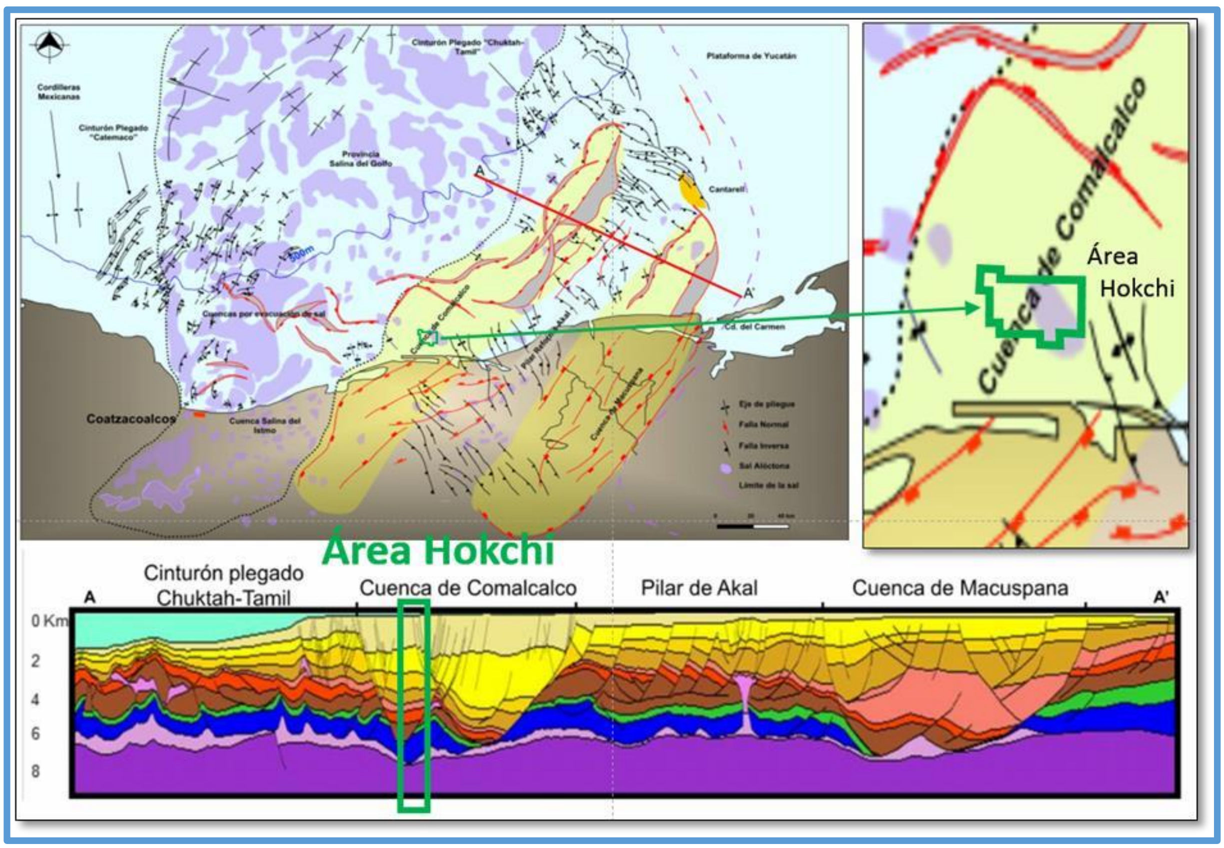


Figure IV. 25 Structural framework (Tectonism) of the Southeast Basins. Source: Report of the "Hokchi Geotechnical Survey Service" 2016

Akal Basin Pillar.

Three tectonic events comprising regional structural framework are distinguished. Initially an extensional event associated with the opening of the Gulf of Mexico in the Middle Jurassic, represented by a series of normal faults as a result of distensive efforts with the consequent formation of pits and pillars in the basement, followed by a compressive event characterized by a series of high to regular relief structures, oriented in a general manner NW-SE. They are affected on their flanks by a number of reverse faults with different inclinations, as well as thrusts. Finally, a final extensional event during the Neogene large growth faults that, in some cases, are associated with clay and/or salt intrusions.

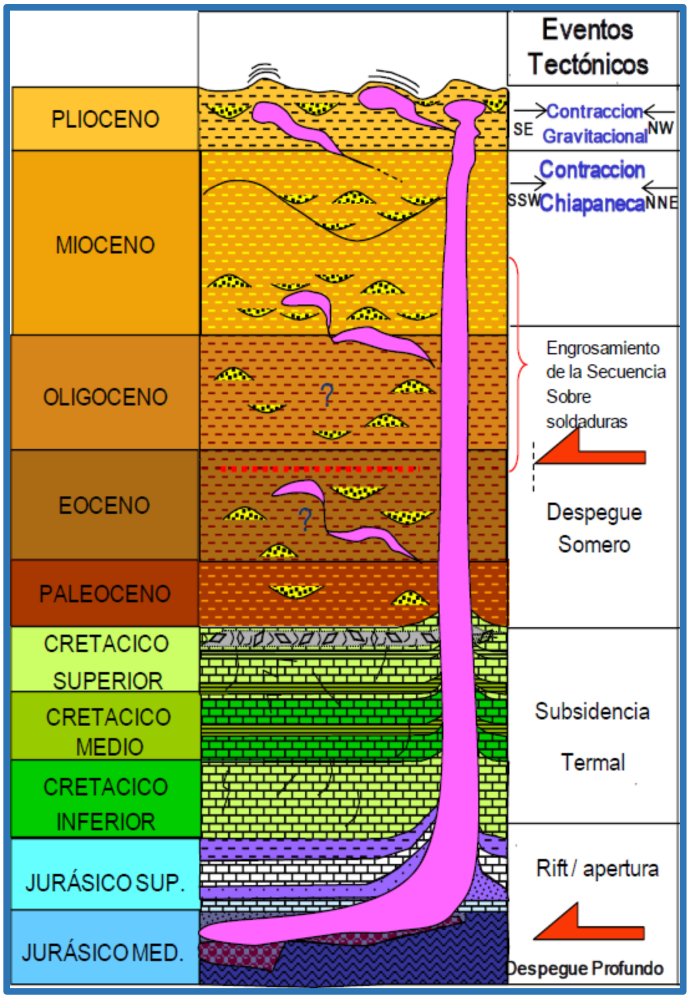


Figure IV. 26 Tectonic events in the Southeast Basins

Source: Report of the "Hokchi Geotechnical Survey Service" 2016

Seismicity

Historically, the state has been affected by earthquakes usually originating in the state of Chiapas and Oaxaca. For the purposes of industrial facilities anti-seismic design, reference is taken from the Civil Works Design Manual of the Federal Electricity Commission, which for its preparation used earthquake catalogues of the Mexican Republic since the beginning of the century, where there are historical records of soil accelerations including the great earthquakes that occurred in many decades. Below is a map showing the Seismic Regions of the Mexican Republic.

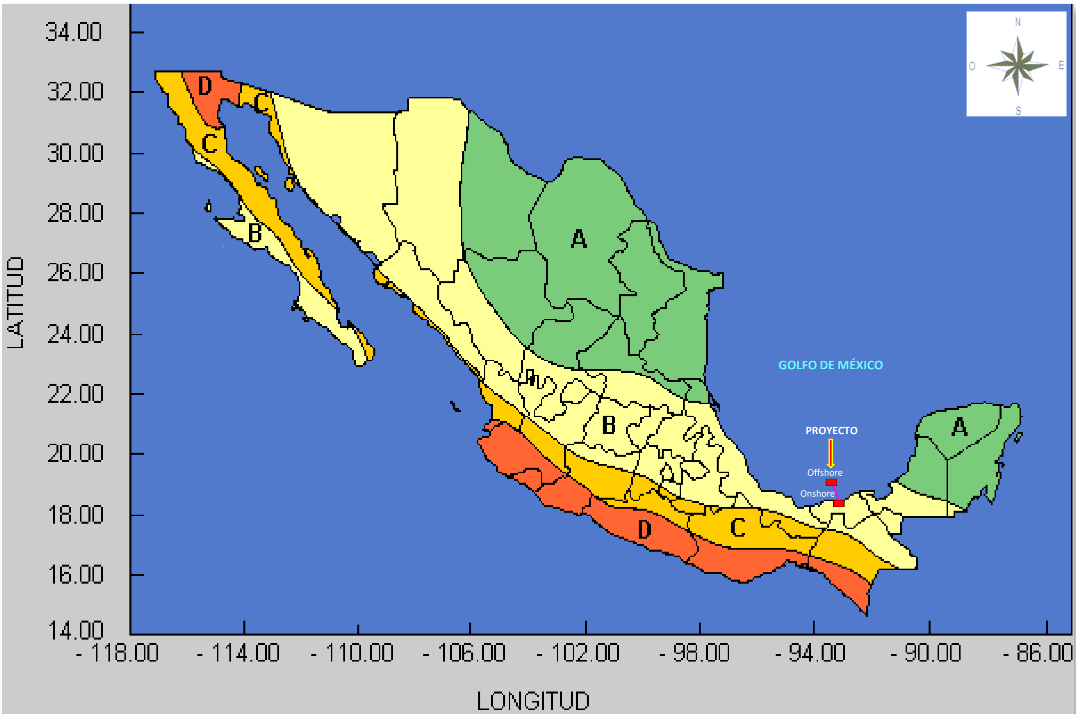


Figure IV. 27 Seismic areas in the Mexican Republic

Source: National Meteorological Service, CFE's Manual on the Design of Civil Works per Seism.

According to the map of seismic regions of the National Seismological Service (figure IV.27), the Area where the land facilities of the Project and its surroundings will be located is classified according to the Manual on the Design of Civil Works per Seism of the Federal Electricity Commission as **seismic area B**, which means it is an intermediate zone where earthquakes are not so frequently recorded or are areas affected by high accelerations but do not exceed 70% of soil acceleration. The four seismic areas in which the Mexican Republic was divided was carried out for the purpose of anti-seismic design, for which catalogues of major earthquakes and soil acceleration records of some of the great earthquakes that occurred in the Mexican Republic since the beginning of the century were used. These zones reflect how frequent earthquakes are in the various regions and the maximum acceleration of the soil to expect during a century. In the area of interest, the telluric movements that have been felt so far have their epicenter in the states of Chiapas and Oaxaca.

From the Atlas of Natural Phenomena Hazards of the State of Tabasco of the Mexican Geological Service, the region that includes the SAR, the seismic hazard is medium and high, according to the seismic intensity model, with ranges of levels 7 and 8 of the Mercalli scale. The seismic intensity in the municipalities of Cardenas and the Western side of Comalcalco are of intensity VII and in the Southeastern part of Cárdenas, East of Comalcalco, Paraiso and Centla of intensity VIII, in a North-South distribution, along an inferred geological fault area called “Tehuantepec Fracture”; in the Western portion of lagoon system comprising Laguna el Carmen and el Pajonal, the earthquake hazard is low. However, the lack of data in the region has long been the subject of debate and is due to the lack of data since there are no exposed rocks on the surface showing the characteristics of the fault zones, for which we only have the correlation with respect to the total magnetic field image, where the area of greatest intensity is spatially related to the highest magnetic field values (see Figure IV.28).

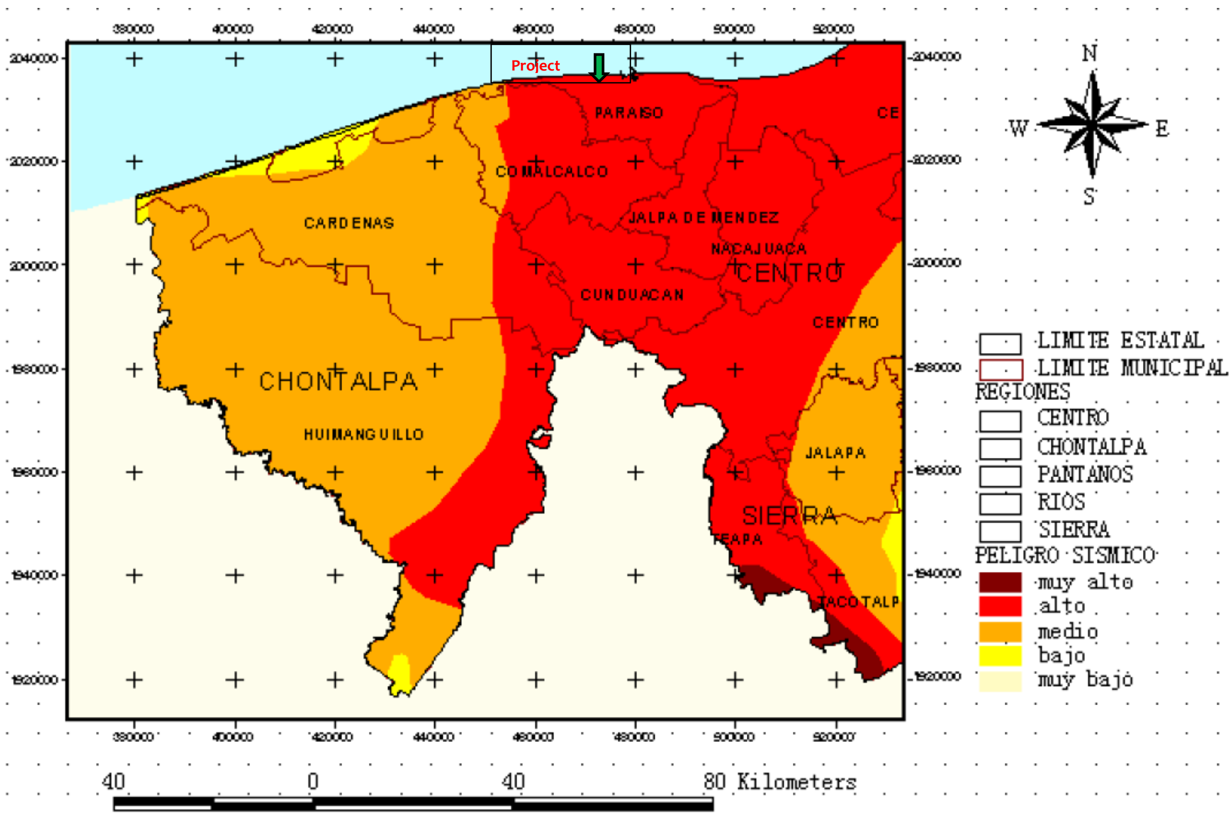


Figure IV. 28 Seismic hazard in the Project’s SAR

Source: CENAPRED: “Atlas of Hazards by Natural Phenomena of the State of Tabasco”

Landslides, cave ins and other earth or rock movements.

The area of interest where the Project will be located belongs to the physiographic province called “Southern Gulf Coastal Plain” constituted by very few knolls with gentle slopes, so there are no risks due to landslides, slips or other similar phenomena both in the area and its surroundings.

Floods and Vulnerability before Climate Change

According to information from CENAPRED, municipalities comprising the SAR (Cardenas, Comalcalco, Paraiso and Centla) in the coastal area and that could be influenced by the Project in case of extraordinary events, present “medium”, “high” and “very high” vulnerability due to flooding in the areas close to the lagoon system from the laguna el Carmen up to the laguna Mecoacan, is the most sensitive area to these events. The following figure shows how the sea has gained ground and invaded crops and other land infrastructure.

Figure IV. 29 Most vulnerable areas, heading to the lagoon system el Carmen-la Machona. Fuente IMP

In the area where land facilities will be located to the west of the Terminal de Almacenamiento Dos Bocas (see brown and red respectively in figure IV:30), there is "high" vulnerability.

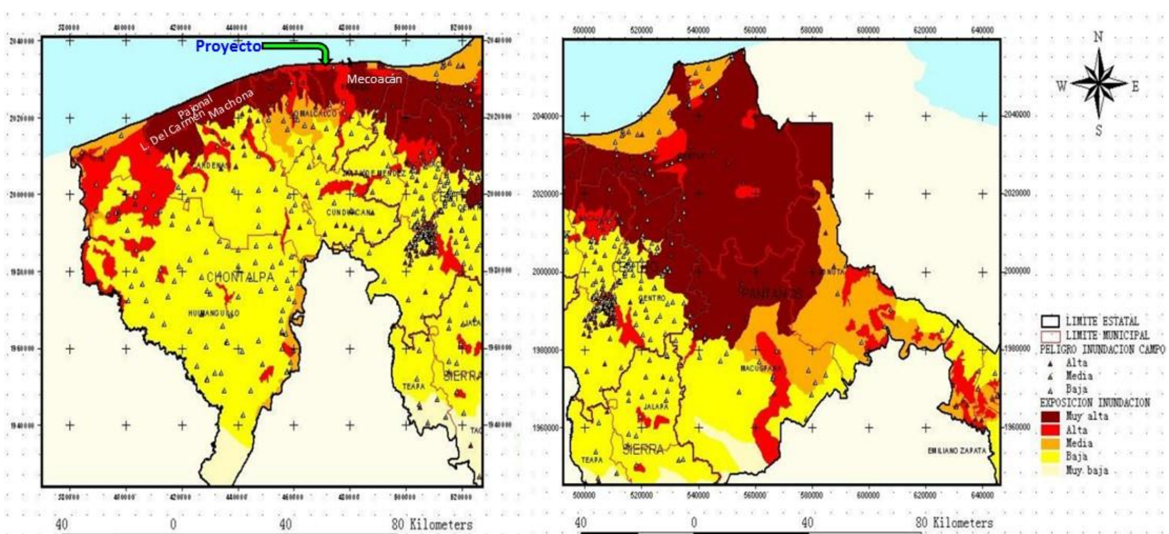


Figure IV. 30 Flood hazard

Source: CENAPRED, "Atlas of Hazards by Natural Phenomena of the State of Tabasco".

However,

towards the East of the Storage Terminal, the vulnerability is "medium" in the coastal area of the municipality of Centla (see figure IV.30), the same low vulnerability occurs from Laguna el Carmen towards the mouth of the river Tonala.

The Tabasco Coastal Vulnerability Index (Geographical Research, Bulletin of the Institute of Geography, Issue 91, December 2016), indicates that sea level rise is an extreme event that will seriously impact low-lying coastal areas, such as the coastal region of Tabasco.

At the national level, the Tabasco coast is one of the most vulnerable sites before such an event, so the indices reported here are the product of studies carried out by the Institute of Geographical Research of the UNAM, where it considers that for this local index using the methodology of the Coastal Vulnerability Index using Geographical Information Systems. This model was adjusted to local conditions of the Tabasco coast on the variables integrating its methodology (waves, tides, sea level, coastal slope, erosion rates and geomorphology) available and with local data on vulnerability degree found of the coast.

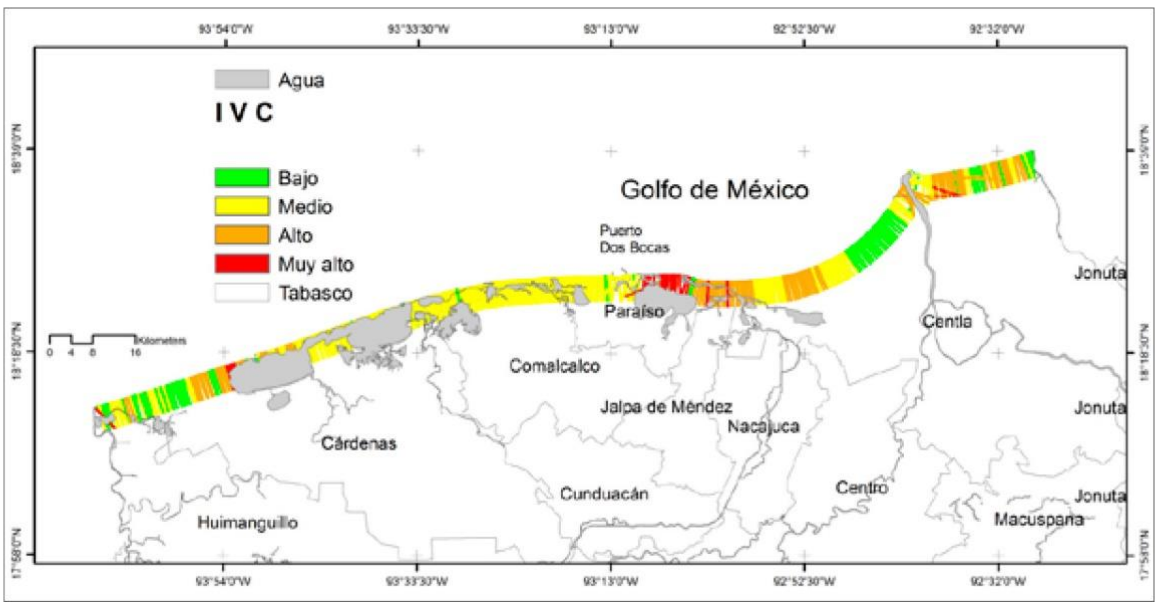


Figure IV. 31 Figure IV.31.- Coastal vulnerability index of the Tabasco coast

Source: Geographical Research Institute, Geography Institute Bulletin, Volume 2016, Issue 91, December 2016

From the same source, it was obtained that the most vulnerable sectors are located precisely in front of the most important coastal lagoon systems in the state, Carmen-Pajonal Machona and Mecoacan, the latter with a higher degree of vulnerability. As shown in the following figure, where it is noted the erosion caused by the sea near the Barra de Tupilco where much of the road has been affected and even crops adjacent to the sea.

Figure IV. 32 Erosion caused by waves near Barra de Tupilco

Source: IMP

It is important to note that the entire coastal area from the Tonala River to the mouth of the Grijalva River included in this SAR is influenced by anthropic activities (agriculture, livestock and oil activities and populations, among others).

Figure IV. 33 North side of the property where the Hokchi Plant will be located

Source: IMP

Specifically, in the project area the coastal vulnerability index **is medium**. Considering both results of these studies, land facilities will have to make all necessary arrangements before an index that goes from median to high according to the information obtained. Currently there is still a beach width of approximately 35 m and a width with coastal vegetation of approximately 60 m that functions as erosion mitigator caused by waves and coastal wind on the North side of the property, vegetation that could be conserved to continue its natural function.

Possible volcanic activity.

In the land area, the nearest volcano is 120 km from the facilities and is known as Chichón or Chichonal, it is located southeast of Ostuacán and Southwest of Ixtacomitán in the state of Chiapas with an altitude of 1260 meters above sea level, it rises on Sedimentary rocks of the Tertiary. This volcano is formed by augite andesite and andesitic tuffs. After manifesting with incipient fumaroles during the first months of 1982, el Chichón entered into violent activity from March 28, April 3 and 4 of the same year. The eruptive columns rose to more than 17 km, generating a large dispersion of light particles, and the heavier ones generated an ash layer that reached up to 15 km round. The lighter particles formed a thick cloud that stayed in the atmosphere for up to several weeks.

From the Atlas of Natural Phenomena Hazards of the state of Tabasco, the level of danger due to volcanic activity is very low in the area under study (Cardenas, Comalcalco, Paraiso and Centla) and is mainly due to the fall of ash of pyroclastic materials if it occurs when winds to the north, under these conditions, the drop of volcanic material would be about 4 cm thick (see figure IV.34).

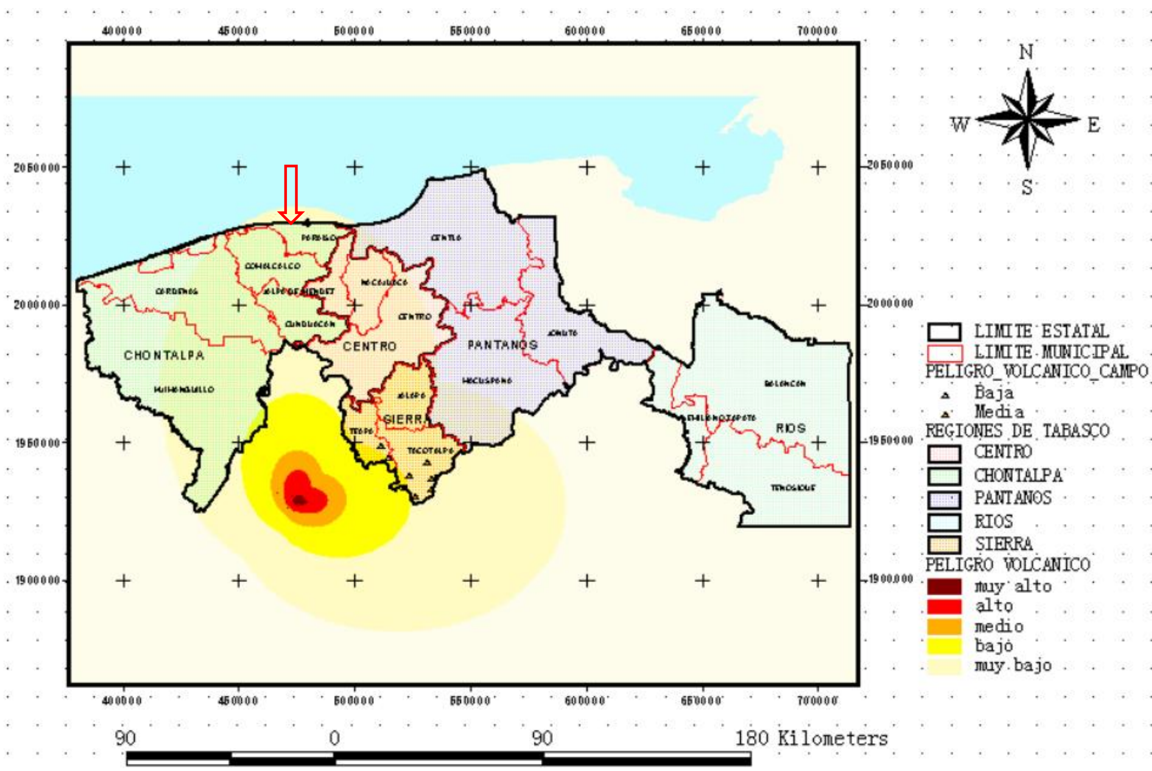


Figure IV. 34 Figure IV.34.- Danger due to volcanic activity

Source: CENAPRED, "Atlas of Hazards by Natural Phenomena of the State of Tabasco".

From historical data recorded near this volcano, on April 6 of that same year an earthquake of 5.8 degrees on the Richter scale was added to the explosions, which was felt as far as Villahermosa and Cardenas. The ash cloud extended to the states of Chiapas, Campeche, Tabasco and Oaxaca, temporarily disabling airports in the region and in turn causing damage to crops.

It should be clarified that due to the physical characteristics of the soil and the topoforms of very soft slopes in the area where the facilities will be located, this earthquake did not cause land displacements or affectations.

c) Soils

Land types on the project site and SAR (FAO-UNESCO and INEGI)

Soils in the SAR according to FAO-UNESCO and INEGI classification, from the Tonala River, along the coastal area along the coastline to the mouth of the Grijalva River, predominate Regosols; which are layers of loose material with little development and therefore do not have very differentiated layers among themselves, in general they are clear or poor in organic matter, are shallow soils, their fertility is variable and productivity is conditioned to depth. These Regosols, have calkaric type subunits rich in lime and nutrients for plants, distric soils with acidic characteristics, rich in nitrogen, but poor in other important nutrients for plants such as calcium, magnesium and potassium and eutric that are slightly acidic to alkaline and more fertile than distric soils. Generally these soils have a slightly alkaline (6.5) to neutral pH, Regosol of the bars presents predominantly rainfed agriculture with permanent crops of coconut trees, cultivated grassland and to a lesser extent rainfed agriculture with annual crops and its fertility ranges from moderate to high and presents a susceptibility of moderate to high erosion. It has a severe limitation for its use and management due to its high drainage.

Regosol of the beaches and dunes, has very low fertility and very high susceptibility to erosion due to sea waves movement and winds that prevail over the coast.

As in the coastal flood plain, from the mouth of the Tonala River to the mouth of the Grijalva River, soil types are associated with Glaysol molic, Solonchak gleyic, and Fluvisol Gleyic, these soils are originated by marsh and clay materials with a high content of organic matter decomposing in such a way that sometimes presents a fetid odor, the accumulation of these materials takes place in the lowest parts that are flooded most of the year, except in the dry season; as well as they contain significant amounts of soluble salts, which causes their electrical conductivity to be between 4 and 16 mmhos/cm. These soils are usually located in warm humid climate with abundant rainfall in summer.

The almost permanent flooding condition allows the growth of aquatic vegetation as popal-tular in the lower parts of the relief, also allows the growth of cultivated and induced grasslands. In many areas due to drainage deficiency or marine influence, there is a process of salts accumulation, in the same way, organic matter accumulation, promotes the darkening or melanization of soil surface layer, this soil formation process characterizes horizon A.

Gleysols are usually soils located to the South in the flooding zones, these superficially present a layer characterized for having an average thickness of 18 centimeters, contain organic matter greater than 1% and high nutrients content. The textural class of the surface

30 cm is medium and in the rest of its thickness is thin, this type of soil is located in small very local areas of this great flood plain, for this reason this soil is not dominant in these plains and is associated with Eutric Gleysol and Vertic Gleysol, soil originated from alluvial materials and marsh. Fertility for agricultural use of these soils varies from moderate to high, the most severe constraint for their use and management is the water table existing within 50 cm with low internal drainage.

The Edaphology map according to the FAO-UNESCO and INEGI classification, is in Annex No. 2.

Land area characterization

As part of the Project area characterization and its direct influence area; as well as to determine if there is presence of contaminated soils associated with the oil industry, some strategic points were defined and sampled (see figure IV.35) in order to verify the current state of the soil mainly in the area of direct influence of the Project where the ground facilities and their surroundings will be located.

Environmental analysis along the coastal strip was also considered to define sampling points, as well as physiography and land uses, where it was observed that due to the environmental situation of rural areas in Southeastern Mexico suffers an accelerated and progressive deterioration of primary vegetation, which translates into the loss of natural resources, ecological potentials and environmental quality, which are necessary to support the entity inhabitants development. Problems related to the sustainable use and long-term conservation of renewable natural resources are becoming increasingly complex, both due to traditional activities such as agriculture, livestock and the disorderly growth of population centers, in addition to industrial activities mainly exploration and oil extraction.

Having knowledge of the environment where the facilities will be located, the following sampling points were defined:

Figure IV. 35 Soil sampling points in the Area where the Hokchi Plant will be located, Metering Station and its surroundings, Paraíso, Tabasco.

Sampling and analysis purpose is to identify possible soil contamination with hydrocarbons light fraction (HCfL), hydrocarbons mean fraction (HCfm) and hydrocarbons heavy fraction (HCfp), as well as the determinations of benzene, toluene, ethyl-benzene and xylenes (BTEX) and polycyclical or polynuclear aromatics (HAP) in the evaluated area in soil samples according to the guidelines of NOM-138-SEMARNAT/SSA1-2012 emphasizing the stratification of hydrocarbons concentrations.

Other possible contaminants to be determined were: Total Organic Matter (MOT) content, PCBs, organochlorinated compounds and heavy metals according to NOM-147-SEMARNAT/SSA1-2004.

For the local location of the sampling points, it was determined based on the terrain physiography, hydrology and material of which the soil is constituted, since according to the type of geological deposit, the nature and its composition can vary rapidly in small spaces both horizontally and vertically. Soils are often altered by the action of man; therefore, the type of pollutants can show a great variability depending on the activities that have been carried out thereon. This work was carried out following the technical specifications for sampling NOM-138-SEMARNAT/SSA1-2012, NOM-147-SEMARNAT/SSA1-2004, NMX-AA-132-SCFI-2006 and ASTM D1452-80 method.

For the integration and correlation of information obtained in the field (sampling and environmental description, among others) and analytical determinations, specialized software was used, as well as an analytic-deductive methodology for its interpretation.

The equipment used in these work for sampling was with manual sampling equipment (Hand Auger and nucleator) whose use depended on the depth and texture of the sampling point; the method consists in taking the sample by inserting the equipment into the soil from the surface manually and after reaching the depth desired, the tube with the core material that will form the sample is removed; all this in accordance with what is specified in NOM-138-SEMARNAT/SSA1-2012, NOM-147-SEMARNAT/SSA1-2004, NMX-AA-132-SCFI-2006 and ASTM D1452-80 method. A systematic random sampling was performed, which consisted of collecting simple samples at varying depths depending on the physical characteristics of the material (soil).

Figure IV. 36 Sampling at the points indicated in Figure 35

Those located in the figure above correspond to the coordinates indicated in the following table:

Table IV. 4 Location in UTM (Datum WGS84) coordinates of the site quadrant and sampling points.

X (UTMs)	Y (UTMs)	Fecha	Hora	Punto	Observaciones
476720	2033963	27-mzo-2018	13:15	REFERENCIA	Arcilla obscura con olor a descomposidón
476503	2038610	27-mzo-2018	08:55	Suelo1	Arena fina gris daro (playa) sin olor
474583	2038542	26-mzo-2018	15:40	Suelo2	Arena fina gris daro (playa) sin olor
472680	2038109	26-mzo-2018	13:00	Suelo3	Arena fina gris daro (playa) sin olor
471114	2038524	26-mzo-2018	11:38	Suelo4	Arena café claro húmeda sin olor
469276	2038487	26-mzo-2018	10:20	Suelo5	Arena café claro húmeda sin olor
476613	2037736	26-mzo-2018	17:00	Suelo6	Arena fina combinada café clara y obscura húmeda sin olor
474653	2037876	26-mzo-2018	16:30	Suelo7	Arena fina café obscuro húmeda sin olor
472817	2037736	26-mzo-2018	12:20	Suelo8	Arena café claro húmeda sin olor
471081	2037891	26-mzo-2018	11:00	Suelo9	Arena fina café daro húmeda sin olor
473876	2038723	26-mzo-2018	15:15	SueloA1	Arena fina gris claro (playa) ligeramente húmeda sin olor
473404	2037383	26-mzo-2018	14:05	SueloA2 ⬅	Arena fina café obscuro húmeda sin olor
473120	2037426	26-mzo-2018	13:34	SueloA3	Arena fina café húmeda sin olor
473370	2038754	27-mzo-2018	09:40	SueloA4	Arena fina gris daro (playa) sin olor
473566	2037977	26-mzo-2018	14:45	SueloA5 ⬅	Arena fina café sin olor
477137	2036376	27-mzo-2018	10:45	SueloB11	Ardilla obscura sin olor
477182	2035865	27-mzo-2018	12:10	SueloB12	Arena fina café húmeda sin olor
477017	2035846	27-mzo-2018	12:35	SueloB13	Ardilla obscura sin olor
476595	2036201	27-mzo-2018	11:40	SueloB14	Ardilla obscura sin olor
476979	2036098	27-mzo-2018	11:17	SueloB15 ⬅	Arena-Ardilla

Results of soil characterization

From the previous table, it is observed that the points sampled with keys SA_2 and SA_5 correspond to the area where the Hokchi Plant will be located, which presented physical characteristics of dark brown and light brown respectively. The sampling point identified as SB_{15} is the soil where the metering station will be located, which presented clay sand characteristics because it is a little further away from the coastline. The other sampling points presented similar physical characteristics (odorless) and in terms of color, the points near the beach presented fine light gray sand. Only the reference point presented the smell of decay,

Cationic Exchange Capacity

It can be observed in these results that soil samples near the coastline mostly presented as Medium Soil Class with a cationic exchange capacity between 5 and 10 Cmol (+) Kg^{-1} for Calcium, 1.3 to 3.0 Cmol (+) Kg^{-1} for Magnesium and Very Low Class for Potassium with lower results 0.2 Cmol (+) Kg^{-1}. While soils with less marine influence including the Reference have a High Class for Calcium with a cationic exchange capacity greater than 10 Cmol (+) Kg^{-1}. Most of these soils are presented as Middle Class and High Class for Magnesium and Low Class for Potassium.

Organic matter.

From baseline data and results obtained from all cases, organic matter content is less than 4%, so it is considered that all sampled soils are classified as very low soil class in terms of organic matter.

Hydrocarbons in soils.

The following results are presented from the Mexican Official Standard NOM-138-SEMARNAT/SSA1-2012, which establishes the maximum allowable levels of hydrocarbons in soils and guidelines for sampling in characterization and specifications for remediation.

According to hydrocarbon concentrations records shown in Table IV.5, the presence of hydrocarbons mean fraction is only observed at some soils sampling points near the coastline, as well as the reference point, it should be noted that these observed hydrocarbons should not be found naturally, however, they display well below limit concentrations (1200 mg/kg Dry base for Agricultural, Forestry, Livestock and Conservation soil).

Table IV. 5 Results of hydrocarbons in soils analysis.

IDENTIFICACIÓN	HIDROCARBUROS FRACCION PESADA	HIDROCARBUROS FRACCION MEDIA	HIDROCARBUROS FRACCION LIGERA	BENCENO	ETILBENCENO	TOLUENO	m+p-XILENO	o-XILENO
	mg/kg B.S.	mg/kg B.S.	mg/kg B.S.	mg/kg B.S.	mg/kg B.S.	mg/kg B.S.	mg/kg B.S.	mg/kg B.S.
SUELO 1	<266	<8.69	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO 2	<266	28.394	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO 3	<266	10.328	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO 4	<266	13.958	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO 5	<266	10.076	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO 6	<266	12.598	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO 7	<266	<8.69	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO 8	<266	26.448	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO 9	<266	16.052	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO A1	<266	30.095	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO A2	<266	16.378	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO A3	<266	10.544	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO A4	<266	<8.69	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO A5	<266	19.862	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO B11	<266	<8.69	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO B12	<266	<8.69	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO B13	<266	<8.69	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO B14	<266	<8.69	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
SUELO B15	<266	<8.69	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086
REFERENCIA PARAISO	<266	14.565	<3.22	<0.1032	<0.0967	<0.1567	<0.2133	<0.1086

Polycyclic aromatic hydrocarbons in soils.

Polycyclic aromatic hydrocarbons (HAPs) are organic compounds derived from organic material combustion, mainly containing at least two aromatic rings; 16 of them are called “priority pollutants” by the United States Environmental Protection Agency due to their wide distribution in the environment and by its mutagenic, carcinogenic and teratogenic properties (Zhang et al. 2006; Morrillo et al. 2008).
HAPs are classified according to their origin in: biogenic, petrogenic and pyrogenic. Petrogenic HAPs are petroleum derivatives, their main compounds include alkylated analogous (with radicals) and unsubstituted (parent compounds) of naphthalenes, fluorenes, phenanthrenes, dibenzothiophenes and chrysines (Johnsen & Karlson 2007).

Of the results obtained, in no soil sample in the study area records of polycyclic aromatic hydrocarbons were found.

HAPs concentrations in these soils seem to indicate an association with the amount of organic matter in the soil with natural vegetation (coconut and wetland vegetation), values found in ranges less than 0.01 to 0.07 mg/kg including all points sampled both those soils for agricultural use (coconut trees) and those that have changed to agricultural use (see sampling points), these obtained values are comparative with that reported by R Ortiz-Salinas, et al, 2012 (Polycyclic aromatic hydrocarbons in coastal soils of Tabasco).

What can be said, HAPs presence in agricultural soils can probably also be increased by the deposit due to the burning of organic material for agricultural purposes, as well as oil facilities in the coastal strip.

Polychlorinated biphenyls in soils.

In accordance with the Official Mexican Standard NOM-133-SEMARNAT-2015, Environmental Protection-Polychlorinated Biphenyls (PCBs) -Management specifications, the following results of recorded concentrations for twenty soil samples are presented.

Analysis results did not show concentrations of these compounds in any soil sample carried out in the study area.

Metals in soils.

According to Mexican Official Standard NOM-147-SEMARNAT/SSA1-2004, which establishes criteria for determining remediation concentrations of soils contaminated by arsenic, barium, beryllium, cadmium, hexavalent chromium, mercury, nickel, silver, lead, selenium, thallium and/or vanadium, the following concentrations results recorded for twenty soil samples are shown.

Because metals can be present in the soil naturally and sometimes in concentrations such that they may pose a risk to human populations or ecosystems health, it is important to establish criteria for determining anthropogenic pollution in soils and, where appropriate, remediation concentrations.

The results for Arsenic, Beryllium, Mercury, Silver, Selenium and Thallium did not show concentrations in the sampled soils of the study area. Cadmium in A3 soil sample showed concentrations below the maximum allowable established in NOM-147-SEMARNAT/SSA1-2004 for agricultural/residential/commercial soils.

Based on the reference concentrations presented in the table above and analyzing the results for Barium, Hexavalent Chromium, Nickel and Total Lead (table below). It can be said that even if these metals are present in the sampled soils of the study area, concentrations found do not exceed the reference limits.

However, in the case of Vanadium, a single sample of point called Soil A4 (15.99 mg/kg) exceeds the permissible limit for soils for agricultural/residential/commercial use.

Table IV. 6 Statistical data on metals presenting results in soils.

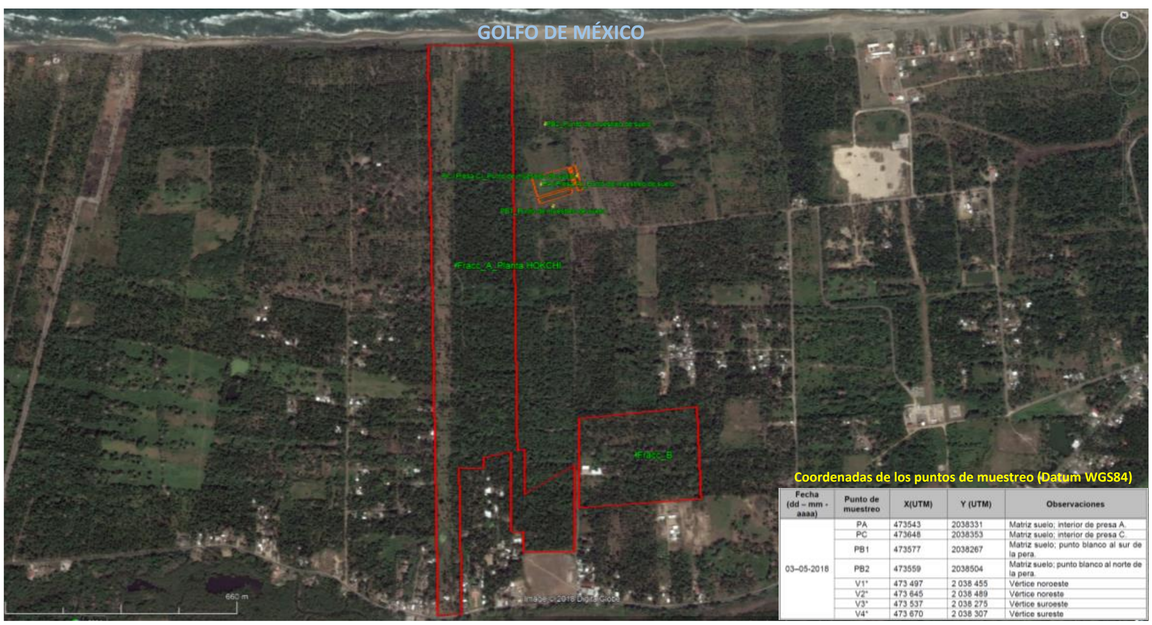
	BARIO TOTAL	CROMO HEXAVALENTE	NIQUEL TOTAL	PLOMO TOTAL	VANADIO TOTAL
MAX	642.4	0.908052	125.9	28.82	**79.55**
MIN	5.174	0.265793	12.5	3.866	12.35
Media	52.13	0.40	24.78	6.92	29.51
Desviacion Estandar	176.71	0.24	30.82	6.27	16.89
No de datos	20	6	20	17	20
Maximo Permisible	**5 400**	**280**	**1600**	**400**	**78**

In general, the presence of some hydrocarbon traces found at specific points near the coastline may be an indication of pollution by deposits of natural emanations or possible hydrocarbon spills in offshore installations, which with the passage of time and marine dynamics of both waves, winds and sea currents, have influenced their arrival in the coastal area. Although they do not exceed the maximum allowed values so far, they are indicative of potential cumulative effects if there would be incidents mainly at marine facilities.

Soil sampling in identified dams near the Property

Soil sampling was also carried out on the Northeast side very close to the Property where the Hokchi Plant will be located; this area was identified during field work where a location or “Pear” was identified with its respective dams that presumably were used in the past for storage or containment of drilling cuttings. Due to its proximity to the property's polygon, the decision was made to carry out soil sampling in these dams in order to determine the presence of hydrocarbons in the soil or sediment that could have impacted the shallow water table at the boundaries of the property.

In this area, four probes identified as PA, PC, PB1 and PB2 were carried out in order to take equal number of samples from the soil matrix to a stratum for the different analytical determinations. All samples were obtained by signatories and analyzed by accredited laboratories before EMA and approved by PROFEPA. In soil samples light fraction hydrocarbons (HCfl), mean (HCfm), heavy (HCfp), monoaromatic specific hydrocarbons (benzene, toluene, ethyl-benzene and xylenes (BTEX) concentrations were determined: and Polycyclic or Polynuclear Aromatic (HAP) and compare them with the maximum allowable limits established in NOM-138-SEMARNAT/SSA1-2012.



Fecha (dd – mm - aaaa)	Punto de muestreo	X(UTM)	Y (UTM)	Observaciones
03–05-2018	PA	473543	2038331	Matriz suelo; interior de presa A.
	PC	473648	2038353	Matriz suelo; interior de presa C.
	PB1	473577	2038267	Matriz suelo; punto blanco al sur de la pera.
	PB2	473559	2038504	Matriz suelo; punto blanco al norte de la pera.
	V1*	473 497	2 038 455	Vértice noroeste
	V2*	473 645	2 038 489	Vértice noreste
	V3*	473 537	2 038 275	Vértice suroeste
	V4*	473 670	2 038 307	Vértice sureste

Figure IV. 37 Soil sampling points near the Area where Hokchi Plant will be located

Results

It was determined there is hydrocarbons presence close to the area where the Hokchi Plant will be located, since the results of analytical determinations for hydrocarbons heavy fraction and mean fraction the sample coming from dam A and labeled as PA resulted in 24,399.49 and 53,543.60 ppm respectively, values exceeding maximum allowable limit for agricultural and industrial soil use (see figure IV.37).

The evaluated area is approximately 25 000,00 sq.m (2.5 hectares) and although it is located outside the property, due to its proximity to the site (approximately 50 m from the main dam and 30 m from the pear or location), there could be pollution to the shallow water table.

The results of this assessment has the purpose only to provide corresponding technical elements for the environmental authority to provide guidance to follow on the administrative procedures to whom it may concern.

The above is due to the possibility of pollution of the shallow aquifer in the vicinity of the Property where the Hokchi Plant will be located.

d) Surface and underground hydrology

Hydrological resources located in the study area.

In general, regarding surface hydrology: the Regional Environmental System (SAR), the Direct Influence Area (AID) and the Project Area (PA) specifically, marine installations will be located in the Southern portion of the Gulf of Mexico off the coast of the municipality of Paraíso, Tabasco, and the land facilities will be immersed in hydrological regions known as: Hydrological Region 29 called “Coatzacoalcos” (RH29) and Hydrological Region 30 “Grijalva-Usumacinta” (RH30).

It should be noted that Project land facilities will be located within Basin **A** “Tonala River and Coatzacoalcos Lakes”, as well as within sub-basin **a** “Lagunas el Carmen and Machona”, belonging to Hydrological Region RH29.

Surface hydrology in coastal area

The hydrology comprising the SAR defined above, on the West side of the Project towards the lagoon system el Carmen, el Pajonal, la Machona, la Redonda, Laguna Grande de las Flores, are located in a plain formed from the delta of the river Tonala to the Dos Bocas port and belongs to the Hydrological Region 29 called “Coatzacoalcos”, covering in the coastal area the entire lagoon system of the municipalities of Cardenas, Comalcalco and part of the municipality of Paraiso, in the state of Tabasco.

The SAR on the West side is delimited by the Tonala River, which is the main stream limiting the states of Veracruz and Tabasco; this river begins its passage from the state of Chiapas and the main rivers Zanapa, Blasillo and Chicozapote until its mouth into the Gulf of Mexico.

On the East side, approximately 4 kilometers from the property where the Hokchi Plant will be located, the Hydrological Region to which it belongs is RH 30 known as “Grijalva-Usumacinta” and comprises from the Dos Bocas port to the mouth of the San Pedro River, 23 kilometers to the West of the mouth of the Grijalva River. In the lagoon system on the East side of the project, there are mainly: the Mecoacan Lagoon, Juliva, La Tinaja, El Eslabon, Pomposu, Pucte, Troncon, El Provecho, El Desague, El Espino, El Cerco and

Laguna Santa Anita, until their mouth in the Barra de Chiltepec, municipalities of Paraíso and Centla, towards Eastern coastal area of the SAR delimited up to the Grijalva River Delta.

Topography in the study area is almost flat where predominating slopes oscillate around 5% with few depressions where the altitude varies from 2 to 17 meters above sea level. Moisture is almost homogeneous throughout the system for most of the year, which is the result of the shallow water table that varies between fifty centimeters and four meters deep.

El Carmen, Pajonal and La Machona lagoons are considered among the most important lagoons in the region; these lagoons are on the Northwest flank of the Mezcalapa River Delta and are linked by the El Pajonal Lagoon (see SAR figure). These lagoons are the remnants of a larger lagoon body parallel to the current coastline, of which were part the La Redonda and La Palma lagoons (Javier Bello et al., Eduardo Ramirez, University of the Sea, May 2014).

The lagoons are isolated from the Gulf of Mexico by a narrow coastal barrier formed by ancient beach lines, and active or stabilized dunes. The communication with the Gulf is carried out by means of two mouths: the first is natural and is located Northwest of El Carmen lagoon on the side of the settlement Sanchez Magallanes, which is subjected to intense sedimentation due to the dynamics of the Gulf of Mexico; the second is artificial and is located Northeast of La Machona lagoon, which is exposed to marine erosion. The coastal barrier separating the El Carmen, Pajonal and La Machona lagoons from the Gulf of Mexico has a length of approximately 35 kilometers with measurements between 300 and 600 meters wide, with an elevation of between one and six meters above sea level. In the South-Southeast portion with a tendency to the East of the lagoon system, there are extensive mangrove swamps.

This lagoon system has communication with the sea from which it receives the main volume of water, the supply of fresh water to la Machona Lagoon depends essentially on the Santa Ana River which pours its flow into the Northeast portion of the lagoon, while El Carmen lagoon receives contributions from the San Felipe and Naranjillo rivers in its Northwest end. These currents present very short trajectories and carry rain runoffs from inland where land uses are currently strongly influenced by anthropogenic activities such as cultivation, livestock, oil activities and human settlements, among others.

Within the SAR, the Mecoacan lagoon system is also included, this lagoon presents a transition environment between the marine and the limnetic environment, is also characterized by its high biological productivity, annual hydrological conditions are influenced by seasonal variation in atmospheric conditions and presents a salinity lower than the open sea, which indicates an estuarine behavior caused by the continuous supply of fresh water from the continent's runoffs to an intense rainfall regime. It can also be said that the supply of numerous nutrients is the product of the mangrove forest that surrounds it, as well as the secondary vegetation of the environment of this lagoon system.

The bathymetry of the lagoon system is presented in the section of Coastal Area and Lagoon System.

Water use

Hydrological Region 30, Grijalva-Usumacinta, is located within the “Southern Border” Administrative Region of the National Water Commission and collects runoffs from the tropical forests of Tabasco and Chiapas, although its seat is located in Guatemalan territory. Comprises a territorial extension of 102 465 sq. km, and is located in one of the greater rainfall areas of the country, with an annual average of 1 903 mm. This results in an average runoff of 73 647 cubic hectometers. In the plains of the Grijalva and Usumacinta rivers a volume of water equivalent to one third of the country's runoffs is poured into the Gulf of Mexico.

The Grijalva River originates from numerous streams and rivers that descend from the Cuchumatanes mountain range in Guatemala and takes the name of Grijalva from the confluence of the San Gregorio and San Miguel rivers. It crosses the Chiapas Valley under the name of the Grijalva River or Rio Grande de Chiapas. Its waters are stored and its regime regularized in the Nezahualcoyotl dam, which was built downstream from the confluence of the La Venta river. The Grijalva changes its course direction from the Northwest to the North until it enters the coastal plain of the Gulf of Mexico, where it begins to be called Mezcalapa River. It bifurcates twice: first in the Rompido de Samaria, where the direction of its course changes to the East, and then when dividing it forms the river Carrizal on the left bank and the Viejo Mezcalapa on the right bank.

Later on it receives on its right bank the contributions of the Pichucalco River and the rio de la Sierra. Downstream from the confluence of these rivers is located the hydrometric station Gaviotas II.

The Usumacinta River is one of the most important currents in Mexico; it is formed by the confluence of the La Pasion and Chixoy or Salinas rivers, both coming from Guatemalan territory. On the left bank, the Lacantun River flows into it and passes through Boca del Cerro before receiving the flow of the San Pedro River. It crosses the state of Tabasco and before reaching the Gulf of Mexico it is divided into three arms. The Western arm will join with the Grijalva; the central arm is called San Pedro y San Pablo, and flows directly into the Gulf of Mexico; the Eastern arm, called Palizada, flows into the laguna de Terminos through the mouth called Chica.

Vulnerability of surface water bodies

In the Northern part of the route of the Tonala River near its mouth, the detritus material of the entire drainage network in the area is of a Palustre and alluvial type; the presence of dunes, bars and estuaries of the coast, are favored by the type of river mouths, as well as the large lagoon systems integrating this lagoon systems, owe their origin to marine regression phenomena and dynamic fluvio-terrestrial sedimentation processes due to tidal effects, ocean currents and waves. In this same context, due to water bodies uses since their origin in the states of Chiapas and the entire route through the state of Tabasco; as well as the land uses throughout the SAR coastal plain, there are possible anthropogenic type threats, which are mainly due to:

- Hydrocarbons pollution due to activities, both hydrocarbon exploration and extraction throughout the region defined as SAR for this project; as well as storage and transport thereof throughout the coastal region.
- Pollution by fecal coliforms due to municipal wastewater discharged by the locality of Cardenas and other populations upstream into water bodies.
- Alteration of physicochemical characteristics (salinity) of lagoon bodies and their flooding zones by the opening of the mouth of Panteones.

- Contamination through nutrients carried by agricultural runoffs
- Pressure on some species of fishing importance, such as oyster in El Carmen, Pajonal and La Machona lagoons.
- On the West side of the project where the Mecoacan lagoon system is located up to the mouth of the Grijalva River, surface water main uses are for communication routes, supply to populations and smaller scale for industrial use.

• Water quality analysis

The surface water quality, according to water quality data from the Energy, Natural Resources and Environmental Protection Secretariat (SERNAPAM) of the state of Tabasco, the water quality in the SAR delimited to the North of the state, from the river Tonala to the river Grijalva is as follows:

From station 52, Laguna el Carmen, at the height of La Villa De Sanchez Magallanes, the water quality is:

- Total Suspended Solids SST 116 mg/L, indicating it is within an acceptable range of water quality according to water quality classification scale. This parameter measures the amount of material (solid) suspended in water and cannot be dissolved.
- Biochemical Oxygen Demand BOD_5 3 mg/L, indicates it is in excellent quality condition. This parameter measures the amount of organic matter degraded by biological processes (biodegradable)
- Chemical Oxygen Demand (DQO) is a parameter measuring organic matter amount degraded by chemical means (has no values).
- Coliforms 240,000 NMP/100 ml, which indicates is strongly contaminated. The presence of coliforms in water is an indication it may be contaminated with sewage or other decomposing waste.

From station 69, La Machona next to Puente Boca de Panteones, Ejido “el Alacran”, the water quality is:

- Total Suspended Solids SST 80 mg/L, indicating it is within an acceptable range of water quality according to water quality classification scale. This parameter measures the amount of material (solid) suspended in water and cannot be dissolved.
- Biochemical Oxygen Demand BOD_5 5 mg/L, indicates it is of good quality. This parameter measures the amount of organic matter degraded by biological processes (biodegradable)
- Chemical Oxygen Demand (DQO) is a parameter measuring organic matter amount degraded by chemical means (has no values).
- Coliforms 240,000 NMP/100 ml, which indicates is strongly contaminated. The presence of coliforms in water is an indication it may be contaminated with sewage or other decomposing waste.

From data from the same source (SERNAPAM), the water quality of the Mecoacan Lagoon reports from 2016 station 47 located on the puente del "Bellote" by the Paraiso-Chiltepec highway:

- Total Suspended Solids SST 88 mg/L, indicating it is within an acceptable range of water quality according to water quality classification scale. This parameter measures the amount of material (solid) suspended in water and cannot be dissolved.
- Biochemical Oxygen Demand BOD_5 2 mg/L, indicates it is of good quality. This parameter measures the amount of organic matter degraded by biological processes (biodegradable)
- Chemical Oxygen Demand (DQO) is a parameter measuring organic matter amount degraded by chemical means (has no values).
- Coliforms 24,000 NMP/100 ml, which indicates it is strongly contaminated. The presence of coliforms in water is an indication it may be contaminated with sewage or other decomposing waste.

The water quality for the Grijalva river data station 3 is:

- Total Suspended Solids SST 28 mg/L, indicating it is in a good quality range according to water quality classification scale. This parameter measures the amount of material (solid) suspended in water and cannot be dissolved.
- Biochemical Oxygen Demand BOD_5 6 mg/L indicates it is found acceptable. This parameter measures the amount of organic matter degraded by biological processes (biodegradable)
- Chemical Oxygen Demand COD 25 mg/L is in the acceptable range, this is a parameter measuring the amount of organic matter degraded by chemical means (does not present values).
- Coliforms 54,000 NMP/100 ml, which indicates is heavily contaminated. The presence of coliforms in water is an indication it may be contaminated with sewage or other decomposing waste.

Underground hydrology

As for underground hydrology, throughout the SAR delimited by the Southwest side, from the mouth of the Tonala River to the Dos Bocas Maritime Terminal, including project land facilities will be located on the 2702 aquifer known as "La Chontalpa" from which water could be supplied for all its facilities. The analysis of this aquifer is made due to the possible interactions related to exploitation use and exploitation as utility water for these facilities will come from this aquifer.

From geographical information synthesis of the state of Tabasco from INEGI, geohydrology shows favorable climatic geological conditions in the study area, where the hydrological cycle dynamism is high rainfall and high frequency throughout the SAR and even throughout the state. In addition to the above, the coastal plain is made up of sand-clayey granulometry material with very good permeability characteristics, which makes this geohydrological cycle dynamics favor aquifer recharges.

In fact, throughout the SAR for the land part, the aquifer has fairly shallow saturation levels reflected by the presence of lakes and lagoons making up the surface even beyond the delimited SAR.

Aquifer 27-02 "La Chontalpa"

This aquifer comprises the Northwest end of the state of Tabasco, to the North it borders with the Gulf of Mexico and to the West with the state of Veracruz. This aquifer presents a flat topography or very gentle slopes hindering rapid runoffs of surface rainwater, which causes infiltration and an annual recharge making possible its exploitation and use by settled populations and industrial uses of the area, as well as for agricultural use.

The hydraulic behavior of this aquifer indicates static levels are at depths ranging from 5.0 to 1.0 m, with the deepest being recorded in the Southern part of the aquifer, gradually ascending to the coastline where they become more shallow reaching about a meter in depth.

Water quality in the aquifer

This aquifer water quality is contained in small thickness alluvial materials and tertiary sandstones forming thicknesses of up to 1500 m, in the first 500 m they report fresh water, while at greater depth the amount of dissolved solids increases as well as salinity until sometimes water is found completely salty.

Depth of the aquifer, in these area, two aquifers are distinguished: one free or surface within the first 20 m of depth and a second semi-confined or confined by clay layers located between 50 and 400 m of depth.

The direction of the groundwater flow runs from South to North until reaching the Gulf of Mexico as final destination.

As for pollution, it is said (National Water Commission, DOF: 20 April 2015) that pollution occurs in said aquifer due to the following human activities:

1) Oil industry facilities (Petrochemical, batteries and compressors) along the length and width of this aquifer.

2) Domestic wastewater discharges from villages.

3) Sugar Industries South of the delimited Regional Environmental System

4) Agriculture with extensive agrochemicals application (cultivation of lemon, orange, pineapple, rice, sorghum, sugarcane, papaya, etc.).

Median Annual Groundwater Availability

The median annual groundwater availability according to publications in force in the Federal Official Journal is as follows:

Agreement by which is updated the median annual groundwater availability of 653 aquifers in the United Mexican States (DOF: Monday, April 20, 2015), which are part of hydrological and administrative regions Frontera Sur. In said agreement is established La Chontalpa (27-02) aquifer has an availability of 1580,863,690 million cubic meters per year to grant concessions or allocations to maintain it in sustainable conditions and there is no resource deficit.

On the basis of these available data, it is considered the Federal Water Authority will have no objection to granting the concession to the Project for its exploitation, use and water development.

Aquifer 27-04 "Centla"

This aquifer comprises the Eastern portion of the delimited SAR, which is located in the Northern part of the state of Tabasco with almost flat physiography, bordering with the Gulf of Mexico composed of vast areas susceptible to flooding the material constituting the areas and floodplains as well as the aquifers are old sediments of quaternary age, sandy granulometry and clayey intercalations made up of a mixture of tertiary age gravel, sands and clays.

In this part of the state, aquifers are of free type and semi-confined by lenses or clay layers, which are exploited by wells and water wheels intended for public and industrial use, which still has availability of the resource.

The hydraulic behavior of this aquifer is similar to La Chontalpa aquifer, as well as its depth from South to North towards the coastline ranging from 14 m to 4 m as it approaches the Gulf of Mexico.

The regional flow direction of this aquifer runs from South to North towards the Gulf of Mexico coastline.

Groundwater quality (National Water Commission, DOF: April 20, 2015), goes from sweet to tolerable and presents a median permeability in unconsolidated material throughout the area.

Median Annual Groundwater Availability

For the case of Median Annual Groundwater Availability of the Centla aquifer (2704) according to the same document mentioned above, by which is updated median annual groundwater availability of the 653 aquifers of the United Mexican States (DOF: Monday, April 20, 2015), which are part of South Frontier hydrological and administrative regions. In said agreement is stated the Centla aquifer (27-04) has an annual availability of 829,236,336 million cubic meters to grant concessions or allocations to maintain it in sustainable conditions and there is no resource deficit.

However, this aquifer analysis is done to cover the SAR delimited to the East part of the future land facilities, which due to its distance, there is no need for its exploitation by the project.

Coastal area and lagoon system

Physiography; bathymetry and marine currents.

In the marine area, current velocity vectors in the SAR defined for the project, is presented as an example simulations results using a hydrodynamic model of the Mexican Petroleum Institute, where in the first instance the bathymetry in the vicinity of where the marine installations were located within the Hokchi field and subsequently the velocities of sea currents are presented in the same SAR defined for the Project.

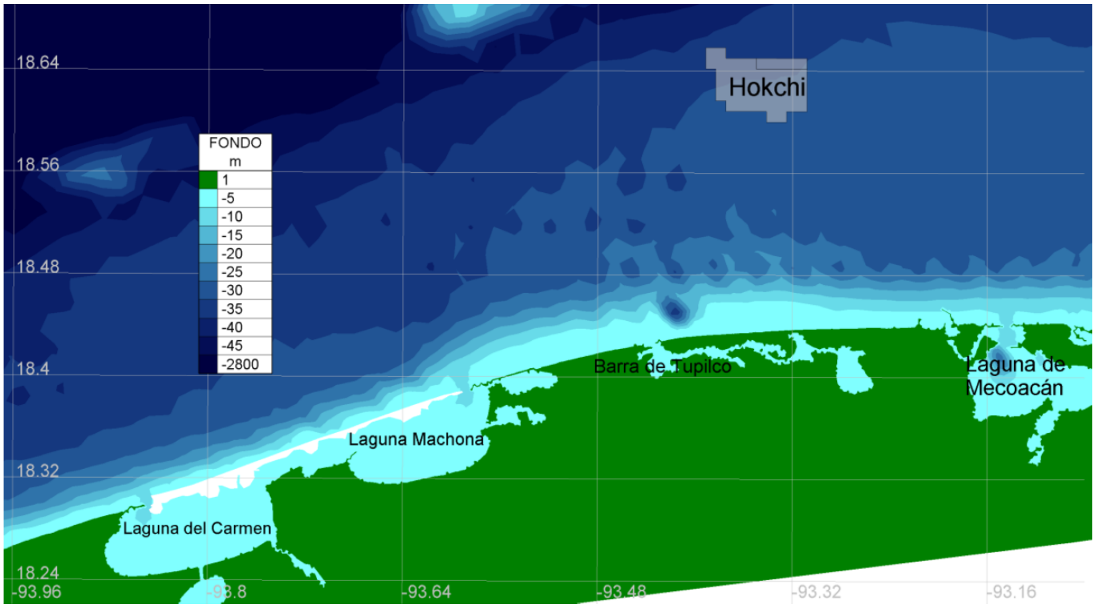


Figure IV. 38 Bathymetry in SAR defined for the project. Source: IMP, "Study of hydrocarbon spill dispersion Field Hokchi"

Marine platforms included in the Project, will be installed within the Hokchi Field in the range between 25 to 30 meters deep, which is indicated on the map at approximate coordinates 18.64° and 93.32° approximately, the coordinates in detail are found in Chapter II of this study.

Below is also a bathymetric map, indicating the Project location.

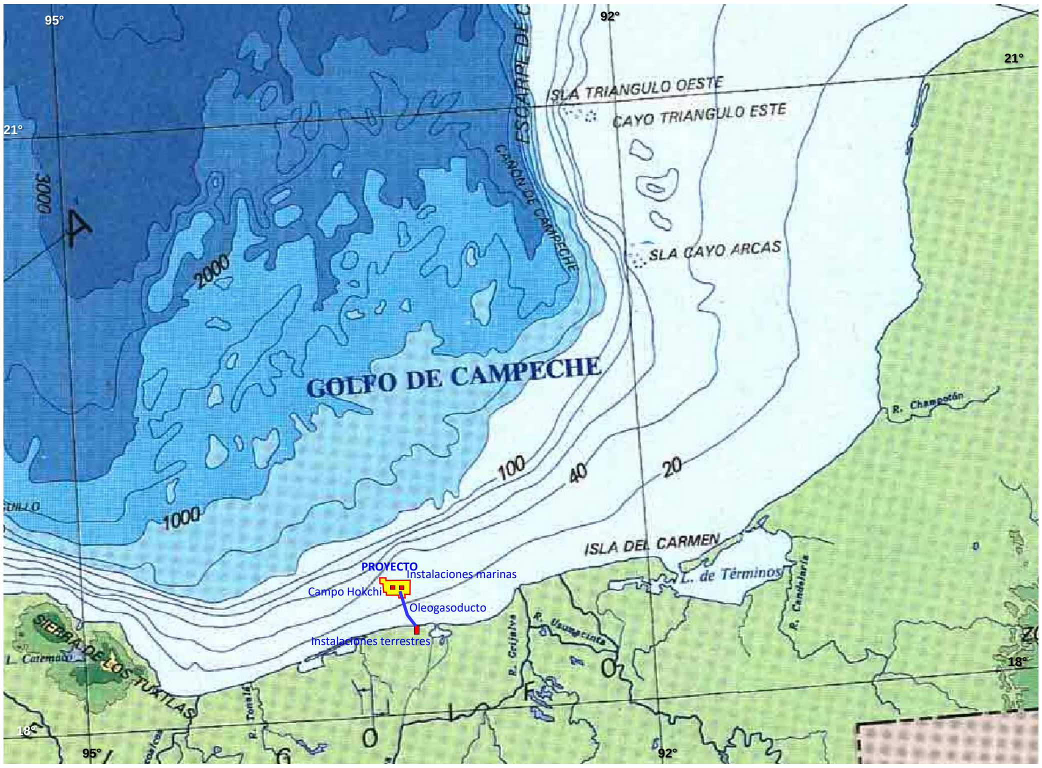


Figure IV. 39 Bathymetry and project location (30 m) in the marine part. Source: Institute of Geography of the UNAM map

As for current velocities, Figure IV.40 shows that in the area where marine platforms and installations will be located and in the entire SAR delimited in the coastal area up to Laguna el Carmen, they oscillate between 0.1 meters per second.

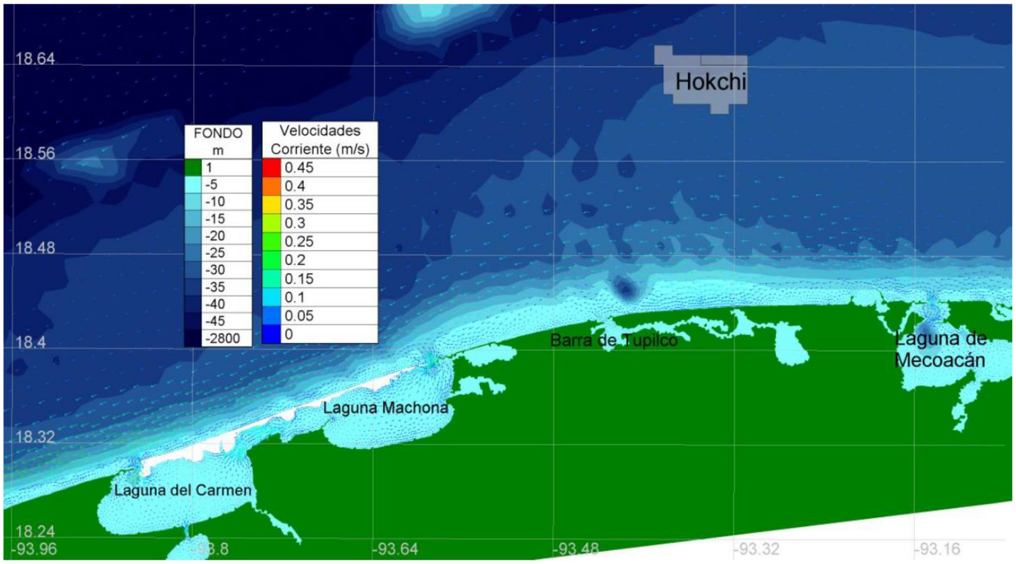


Figure IV. 40 Bathymetry in SAR defined for the project. Source: IMP, "Study of hydrocarbon spill dispersion Field Hokchi"

The hydrodynamic behavior of the area is characterized by water bodies movements towards the Southwest with direction changes (towards the SE) caused by the encounter of ocean currents coming mainly from the Yucatan Peninsula and the Northern Gulf of Mexico.

The swell has an average significant height of 0.6 m, a period of 6.53 s and a prevailing incident direction of 33.82° (NE). Swells occur during northerlies times causing sea level increases generating erosion in the coastal area. The bathymetry is shallow with a gentle slope from 30 m in the platforms area to the wave breaker area on the coast opposite Dos Bocas. Marine currents have an average value of 0.25 m/s with reigning direction of propagation towards the SW. Currents would lead to a probable dispersion of products generated by industrial activities towards the Laguna el Carmen, Pajonal, Machona system mainly.

Coastal circulation; coastal transport system, salinity and water bodies temperature with their seasonal variations are as follows:

In the Gulf of Mexico (Zavala Hidalgo et al., 2003) winds on the continental shelf are particularly relevant. The wind direction and the concave shape of the gulf cause regions to exist where seasonal currents go clockwise, while others go in the opposite direction. This means that during autumn and winter (October-March) currents along the coast of Tabasco are Westward with slight tendencies Northeast along the mouth of the Tonala River clockwise.

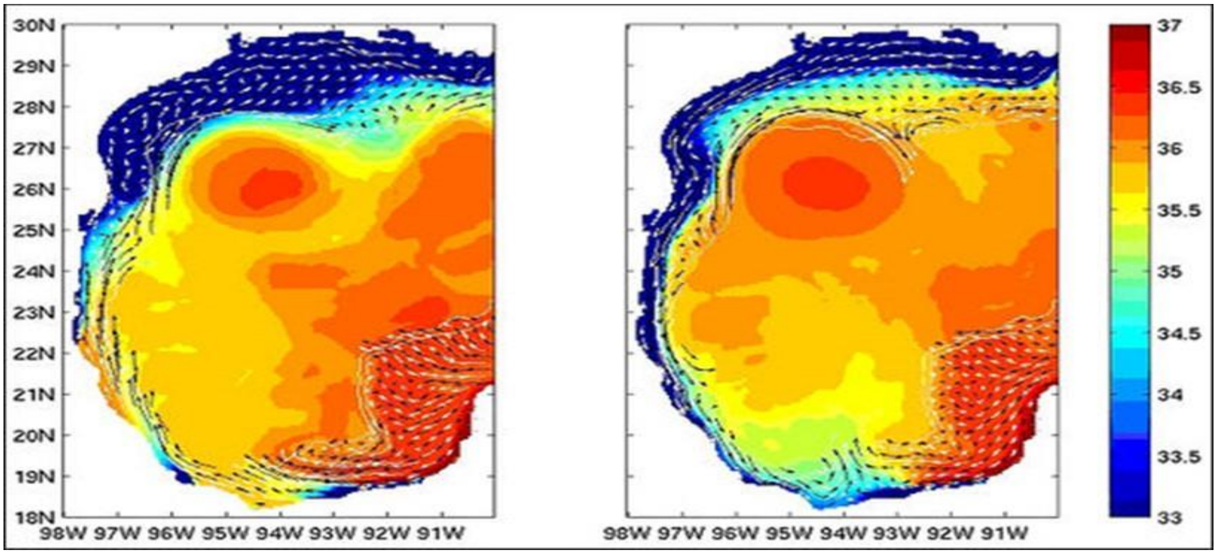


Figure IV. 41 Average circulation and surface salinity in the Gulf of Mexico (April-July, left) and (September-March, right). Sources: "Characterization and Regionalization of Oceanographic Processes in Mexican Seas ", (Zavala Hidalgo, et. al., 2003), CONABIO.

This causes currents to converge at the Southern end of the Gulf of Mexico producing flows perpendicular to the coast, from the platform area to the oceanic area, which are important because they are accompanied by high organic matter content and low salinity waters (Figure IV.41).

Salinity in the project area relating to the previous map in the month of April-July, is in the range of 33 to 34 and for the months of September to March they are slightly above this range.

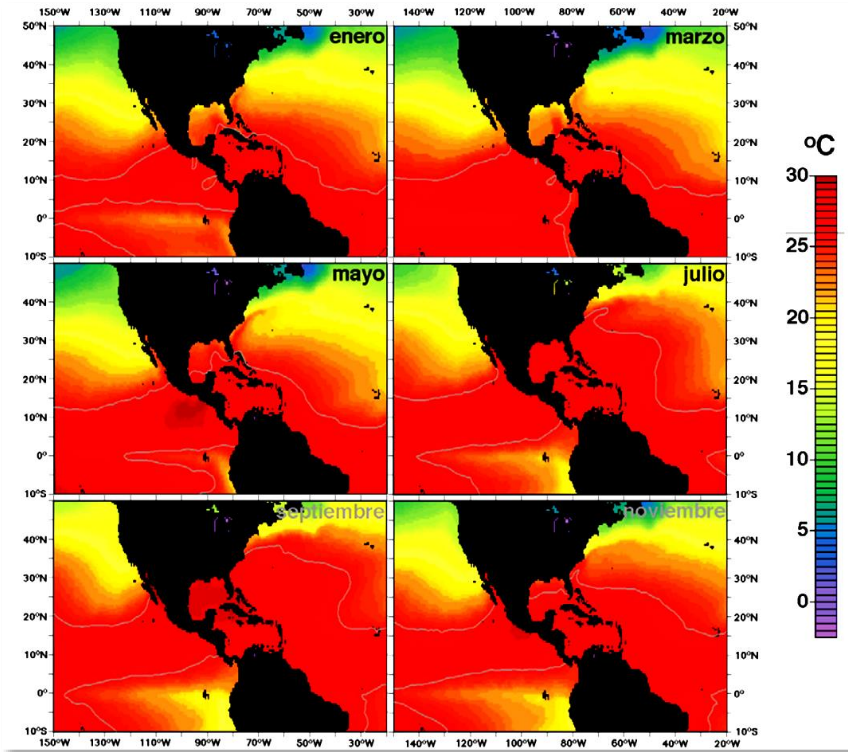


Figure IV. 42 Sea surface temperature throughout the year (°C) Source: Climatological Atlas of Tropical Cyclones in Mexico, CENAPRED, 2014

The surface temperature in SAR delimited in the Gulf of Mexico part ranges from 24 to 26°C according to information obtained from the Climatological Atlas of Tropical Cyclones in Mexico from the National Disaster Prevention Center.

Water bodies circulation in the Gulf of Mexico is determined by two semi-permanent characteristics: 1) Lazo current in the Eastern part and 2) Anticyclonic circulation cell on the Western border.

1) The Lazo stream moves from the Caribbean Sea to the Gulf of Mexico with an estimated volume of 29-33 Sv (1sv = 106 cubic meters/s) and the Anticyclonic Cell moves into the Gulf of Mexico a volume between 8-10 Sv.
2) There is another very intense current called the West Centla Current or the Mexican Current towards the North on the West coast of the Gulf of Mexico, which is generated by the variation of the Coriolis force with the latitude, winds and water bodies flow through the Yucatan Canal. This current is generated by the detachment of an anticyclonic gyre of the Lazo Stream moving Westward and disintegrates when it comes into contact with the continental slope, generating cyclonic and anticyclonic gyres giving rise to common water mass of the Gulf.

Campeche Bay, adjacent to where the Hokchi marine installations will be located, is an area where cyclonic gyres occur with approximate diameters of 150 km and speeds of 30-40 cm/s generated by the cyclonic rotational wind stress, the encounter of the anticyclonic gyres with the slope, the formation of the great anticyclonic gyre and the coast geometry, influenced by an intrusion current heading South and the topography of the Campeche canyon.

In the continental shelf area of the Yucatan peninsula and the Campeche bank, surface currents move throughout the year in East-West direction directly responding to changes in wind force and direction, being the component of wind force along the coast the parameter defining in the greatest way marine currents dynamics in the Hokchi area.

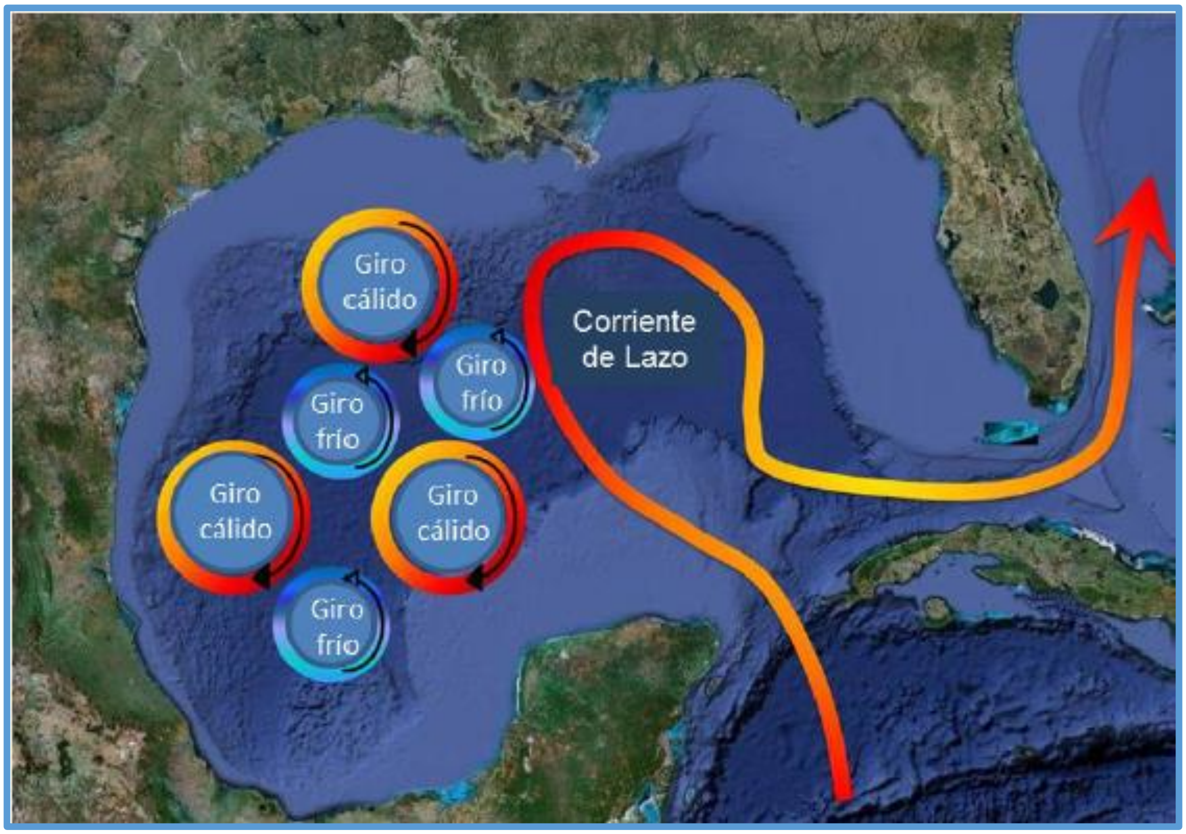


Figure IV. 43Lazo Current in the Gulf of Mexico. Source: Report of the "Hokchi Geotechnical Survey Service" 2016

Wind and marine currents direction and speeds

Low water season

Currents dynamics shown in the following figure is a currents rose diagram for each of the seasons characterizing the year such as: dry season between the months of March and June and refers to a period where precipitation is scarce, rainy season between July and October and refers to the period of greatest rainfall; and finally, the northerlies occurring between November and February and is a time corresponding to the arrival of cold fronts coming from the North in the area where marine platforms and installations will be located within the Hokchi Field.

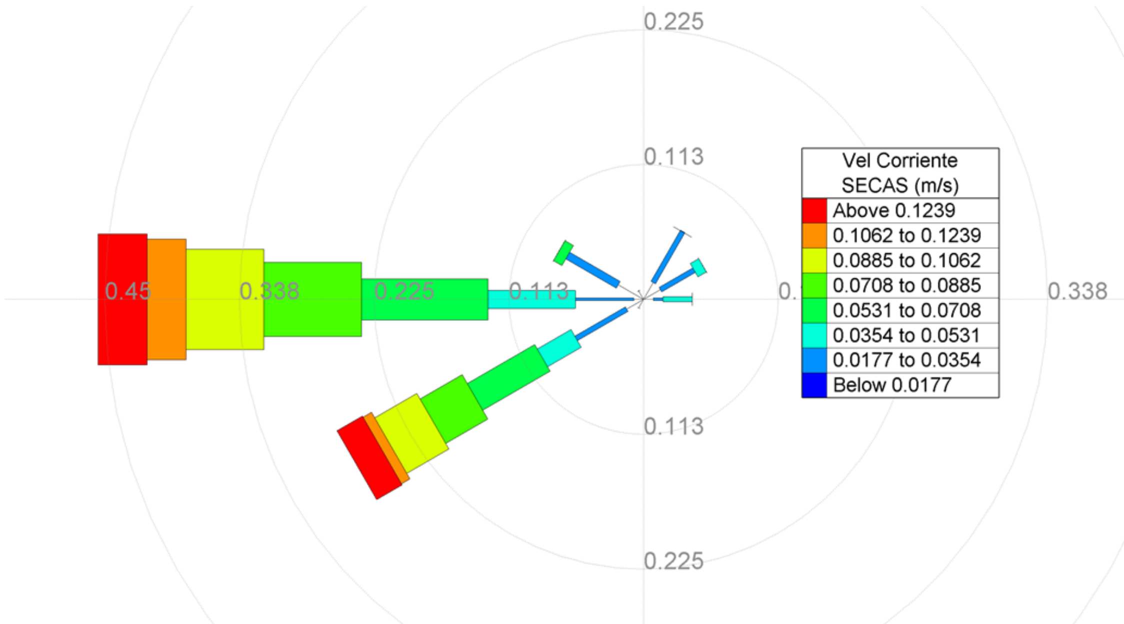


Figure IV. 44 .- Current velocities rose diagram in dry season. Concentric circles represent the probability in %. Source: IMP Hydrodynamic model.

It is important to note that the wind rose diagrams shown in this document define the direction of wind where it is headed, unlike the meteorologists convention which is where it comes from; As in the previous figure is observed prevailing currents propagation direction is 270 degrees corresponding to a Westward heading with average current velocities of 0.08 m/s. Color bars represent probabilities accumulation for each speed ranges.

From the following figure, the prevailing winds go with the propagation direction of 210 degrees heading towards West-Southwest (WSW) with mean velocities of 6.5 m/s and the dominant winds with propagation direction of 180 degrees heading towards the South and maximum velocities of 11 m/s. Concentric circles represent probability in % and colored bars represent the accumulation of probabilities for each of the velocity ranges as shown in the following figure.

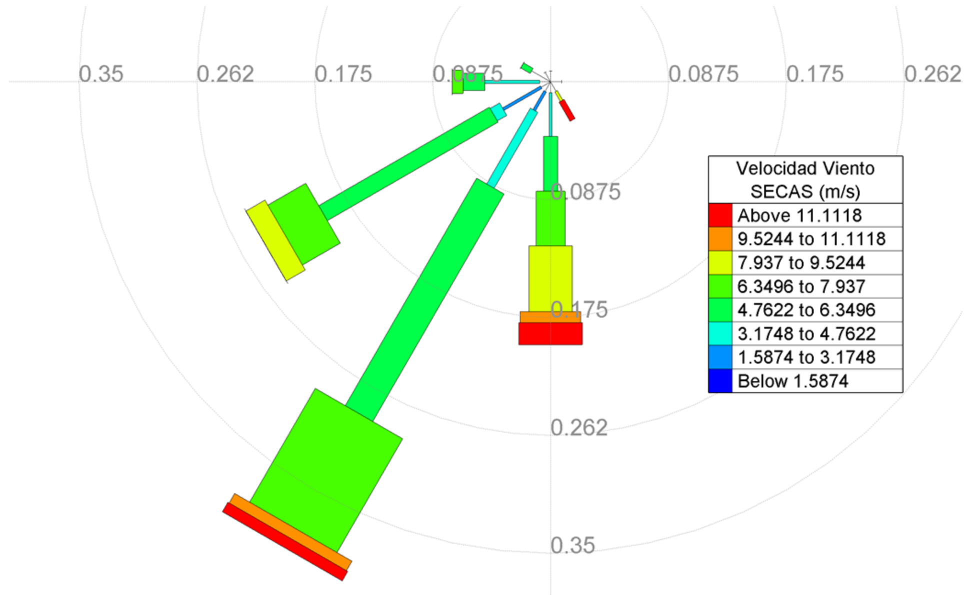


Figure IV. 45 Wind rose in dry times. Source: IMP Hydrodynamic model.

Rainy Season

During the rainy period, propagation directions of prevailing currents are 240 degrees heading towards West-Southwest (WSW) with average current velocities of 0.10 m/s. The concentric circles represent the probability in % and the bars represent probabilities accumulation of each of the velocity ranges represented in different colors as shown in the following figure.

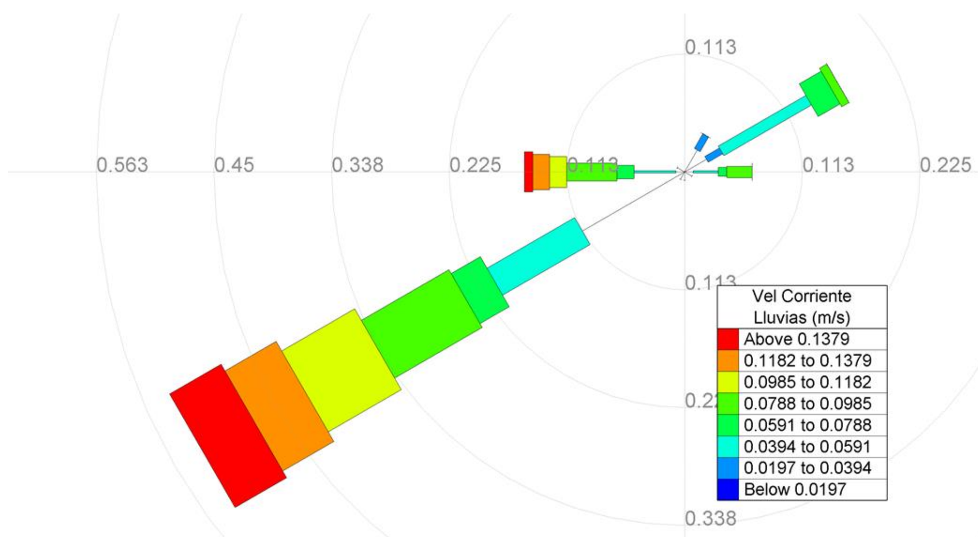


Figure IV. 46 Sea currents velocities direction rose in rainy season Source: IMP Hydrodynamic model.

As well as prevailing winds propagation direction average of 225 degrees heading West-Southwest (WSW) with average velocities of 5 m/s, there are also propagation directions dominant winds of 180 degrees heading South with maximum velocities of 9.5 m/s as shown in the following figure. Concentric circles represent the probability in %. Color bars represent probabilities accumulation for each speed ranges.

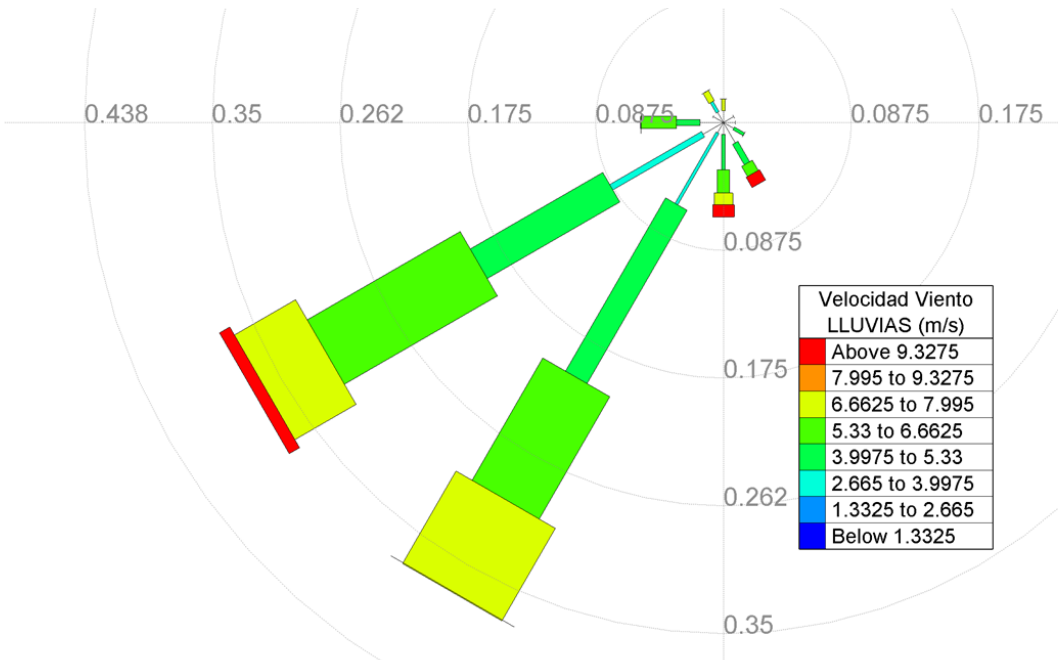


Figure IV. 47 Wind rose speeds in rainy season. Source: IMP Hydrodynamic model.

Northerlies season

During the northerlies season,prevailing sea currents propagation direction is 255 degrees heading West-Southwest (WSW) with average current velocities of 0.16 m/s. In this case, prevailing and dominant currents directions coincide. Concentric circles represent probability in %, colored bars represent probabilities accumulation for each of the velocity ranges as shown below.

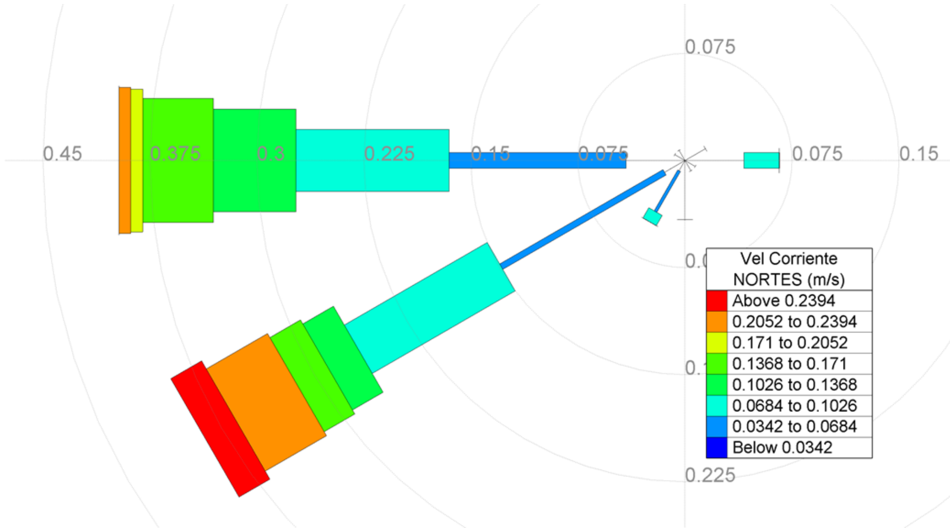


Figure IV. 48 Current velocities rose in northerlies season. Source: IMP Hydrodynamic model.

In the following figure, the prevailing wind propagation direction is 210 degrees West-Southwest (WSW) with average speeds of 6.5 m/s and the maximum (dominant) speeds of 15 m/s go with 180 degrees South heading. Concentric circles represent the probability in %. Color bars represent probabilities accumulation for each speed ranges.

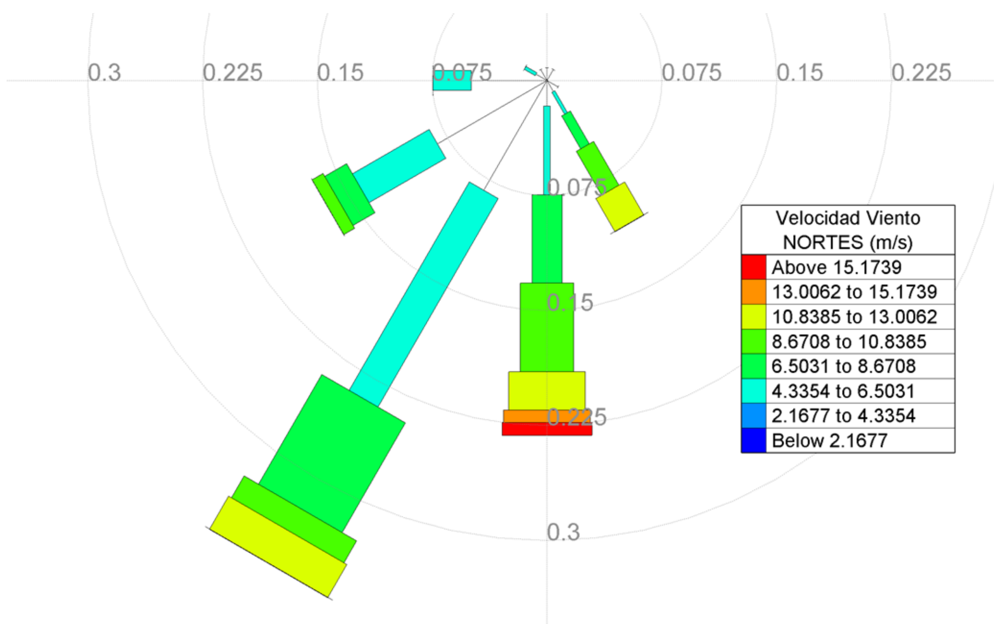


Figure IV. 49 Wind speeds rose in northerlies season. Source: IMP Hydrodynamic model.

Marine environment assessment

Project Oceanographic Campaign

The marine ecosystem corresponding to the Hokchi project area and the area of influence towards the coastline was characterized by an oceanographic campaign aboard the Oceanographic Ship Justo Sierra of UNAM from November 26-30, 2017. The course consisted of 50 stations with the distribution detailed in Figure IV.50. The sampling scheme followed the operational context of the field which will locate a pipeline from its location to the coast and follows the following pattern:

17 Points within the area in the project area and area of influence that formed the LBA study conducted in the northerly season in 2016 as reference and control points in order to monitor environmental variability.

21 Stations on 5 km grid for the analysis of the area of influence of industrial development and stations 1km away on both sides of the pipeline line preliminary projected from the field to Dos Bocas, Tabasco, according to information provided by Hokchi Energy.

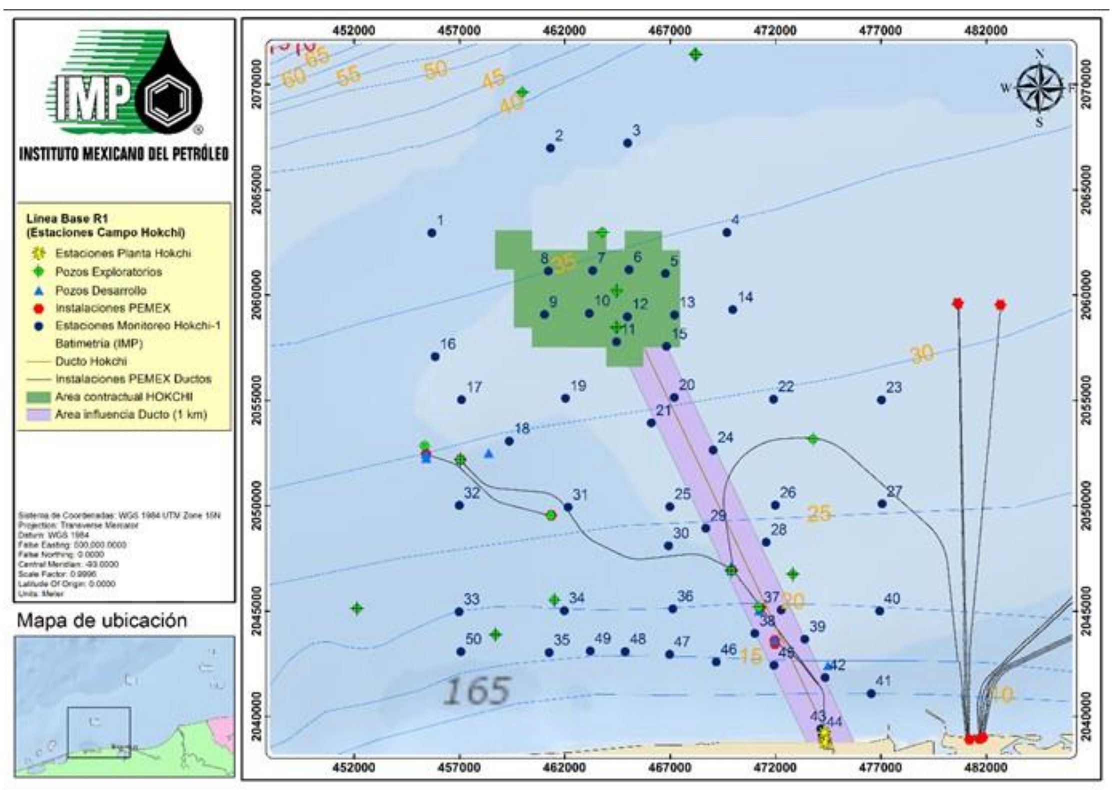


Figure IV. 50 Campaign sampling stations in the project area and influence area

Two coastal stations at a distance of 500 and 200 m offshore from the coastline for water quality assessment for industrial use purposes (Figure IV.51).

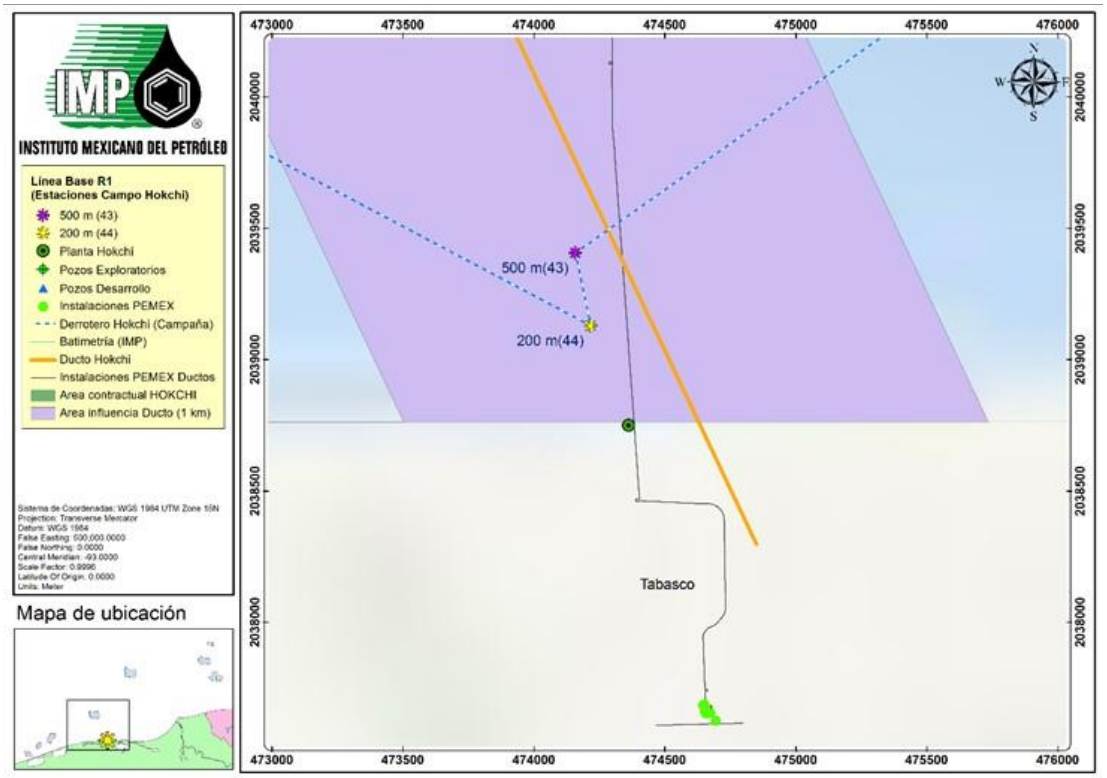


Figure IV. 51 Coastal stations for water quality assessment for in-process use.

Marine environment characterization was integrated with the assessment of different water, sediment and biological quality parameters considered in the "Guide to the Development of the Environmental Baseline Prior to the Start of Marine Hydrocarbons Exploration and Extraction Activities" issued by ASEA as summarized in Table IV.7. Two levels were located in the water column: 1) 0-5 m and 2) greater than 5 m deep and up to 2 m from the bottom. Sediments were collected within the first 20 cm of the sea bed.

Table IV. 7 Characterization study scope

TOPIC	Marine Environment Compartment	Study element	Effort in the study area
Climate and meteorology	Atmosphere	Mean temperature, mean precipitation, relative humidity, mean evaporation, average cloudiness, extreme weather events, wind speed and direction, atmospheric pressure	17 replica stations of Hokchi Block ELBA, 14 stations around the projected pipeline, 20 stations in grid between the block and the coastline and 2 intake stations.
Hydrodynamics and bathymetry	Water column	Currents speed and direction depending on depth Suspended particles dispersion pattern Swell Bathymetry	Currents speed and direction measurements during the course of the oceanographic campaign. Swell and total depth in 50 stations
Air Quality	Atmosphere	Temperature, Ozone, NO, NO_2, SO_2, PM_{10}	Meteorological stations in Paraiso
Water Quality	Water column	a) Salinity, Temperature, Dissolved Oxygen, Fluorescence b) Total suspended solids, nutrients (NH_4, NO_2, NO_3, PO_4, SiO_4) (c) Hydrocarbons (HTP, HAP, BTEX) (d) Metals (Fe, Zn, Cd, Pb, Cu, Cr, Hg, Ni, V, Sn, Ba)	a) Complete profiles of water column in 48 stations. b, c, d) 50 stations at two depth levels: surface and bottom
Sediment quality	Sediment	a) Redox potential, apparent characteristics, sediment type b) Granulometry and Sedimentary Texture c) Organic matter, total organic carbon d) Hydrocarbons: HTP. HAP e) Metals: Fe, Zn, Cd, Pb, Cu, Cr, Hg, Ni, V, Ag, Ba, Mn, Mo, Se, Sn) f) Characteristics of the sedimentary profile through SPI image analysis	48 stations: 17 replica stations of the Hokchi Block ELBA, 14 stations around the projected pipeline, 20 stations in grid between the block and the coastline
Biota	a) Phytoplankton biomass and chlorophylls. b) Zooplankton biomass c) Hydrocarbonoclastic and heterotrophic bacteria.	a, b) Abundance c) Colony forming units, abundance d) Abundance, wealth and diversity	a, b, c) 48 stations on two levels: surface and bottom. d) surface sediment

TOPIC	Marine Environment Compartment	Study element	Effort in the study area
	d) Benthic infauna		

Pre-existing influence sources

The relevant marine oil installations that can be considered a source of pollution by previous operations to the Hokchi area and its surrounding environment are the location of different offshore platforms and the Dos Bocas Marine Terminal, as well as the 36-inch diameter pipeline network transporting production water and crude oil.

In Dos Bocas, production water is separated from crude oil, treated and then returned by submarine pipelines to the ocean or re-injected into an isolated aquifer at the facility. Crude is temporarily stored in tanks and can be mixed with Maya crude or super light Olmeca crude produced inland. The crude oil is then loaded to ships from the offshore buoys of Dos Bocas or sent through pipelines to the Western coast, where it is transported by vessel to other locations in Mexico (IMP, 2002).

In Southeastern Mexico, production waters are treated at the Dos Bocas facility, and then discharged into the sea by means of two submarine sources. These past practices could cause potential environmental problems, as has been observed elsewhere in the Gulf of Mexico and the North Sea (EPA 1996, Gerard et al. 1999). Production waters contain aliphatic and polyaromatic hydrocarbons PAHs, volatile organic compounds VOCs and a variety of heavy metals, including Ni, V, Ba, Fe, Mn, Zn and Pb.

At all stages of the offshore oil life cycle, during exploration, production and processing, accidental discharges of crude oil and production water can occur. Oil spills and congenital waters release PAHs, salts and heavy metals into the environment. In the sea, a part of the hydrocarbons is separated and dissolved in the sea water, while the heavier and less soluble fractions remain on the surface due to their lower specific gravity. Sea water dissolves salts and heavy metals. Gas and crude combustion (in condensate pits and by burnt spills) releases large amounts of PAHs contained in crude oil, while incomplete combustion generates PAHs of higher molecular weight than those normally found in crude oil. This type of high molecular weight PAHs have high carcinogenic potential, while PAHs predominating in crude and production waters have lower potential. The release of these chemicals into the environment can damage land and aquatic ecosystems as well as human beings.

Table IV.8. The potential pollutants representing risk due to industrial activity are summarized. The ecosystem state description through monitoring these pollutants will allow us to define the presence and magnitude of potential impacts.

Table IV. 8 Pollutants associated with oil and gas offshore operational sources

Operations	Potential risk pollutants					
Burners	SOx	NOx	CO	VOC	H_2S	PAH
Sludge and solids	Cr	Ba	Salinity	TPH	VOC	PAH
Congenital water	Cr	V	Salinity	TPH	VOC	PAH
Spills	Cr	V	Salinity	TPH	VOC	PAH
Hazardous waste	Pb	VOC	PAH	TPH	Solvent	PCB
Diesel/Gas Exhaust	SOx	NOx	CO	VOC		
Sewage	Bacteria	PO4				

SOx- sulfur oxides, NOX- nitrogen oxides, CO- carbon monoxide, VOC-volatile organic compounds, H2sS-hydrogen sulfide, PAH-polyaromatic hydrocarbons, TPH-total petroleum hydrocarbons, PCB-polychlorinated biphenyls, PO4-phosphates

Water quality characterization (marine and land)

Total Petroleum Hydrocarbons (HTP)

Total petroleum hydrocarbons were not detected in water samples collected in Hokchi Field. The analytical method used was EPA 1664A-1999 with detection limit 5.0 mg/L for the heavy fraction and EPA8015B-2007 with detection limit of 0.03 mg/L for the light fraction. The results are consistent with what was observed in the Round 1 Regional Environmental Baseline study of Shallow Water Fields.

Polynuclear polycyclic aromatic hydrocarbons (HAP)

No HAPs were identified in Hokchi Field water samples. The analytical method used was EPA8310 1986, with different detection limits depending on the compound to be analyzed (Table IV.9). HAPs were not detected in studies conducted in the Gulf of Mexico by the Mexican Petroleum Institute (Round 1 Regional Environmental Baseline of Shallow Water Fields).

Table IV. 9 Analytical methods used for the determination of polycyclic aromatic and monoaromatic hydrocarbons in water column

Compound	Method	Detection Limit	Units
Acenaphthene	US EPA 8310 1986	7.70E-06	mg/L
Acenaphthylene	US EPA 8310 1986	0.00000738	mg/L
Anthracene	US EPA 8310 1986	0.00000344	mg/L
Benzo (a) anthracene	US EPA 8310 1986	0.00000113	mg/L
Benzo (a) pyrene	US EPA 8310 1986	0.00000579	mg/L
Benzo (b) fluoranthene	US EPA 8310 1986	0.00000594	mg/L
Benzo (g, h, i) perylene	US EPA 8310 1986	0.00000515	mg/L
Benzo (k) fluoranthene	US EPA 8310 1986	0.00000462	mg/L
Chrysene	US EPA 8310 1986	0.00000104	mg/L
Dibenzo (a, h) anthracene	US EPA 8310 1986	0.00000378	mg/L
Phenanthrene	US EPA 8310 1986	0.0000145	mg/L
Fluoranthene	US EPA 8310 1986	0.00000462	mg/L
Fluorene	US EPA 8310 1986	0.0000103	mg/L
Indene (1,2,3, c-d) pyrene	US EPA 8310 1986	0.0000104	mg/L
Naphthalene	US EPA 8310 1986	0.00000864	mg/L
Pyrene	US EPA 8310 1986	0.00000671	mg/L
Benzene	US EPA 8260C 2006	0.12	ug/L
Ethylbenzene	US EPA 8260C 2006	0.14	ug/L
M+p-xylene	US EPA 8260C 2006	0.22	ug/L
O-xylene	US EPA 8260C 2006	0.21	ug/L
Toluene	US EPA 8260C 2006	0.12	ug/L

Oil biomarkers (BMK)

No oil biomarker compounds were identified in water samples in Hokchi Field. In the Regional Environmental Baseline study performed by the Mexican Petroleum Institute in Shallow Water Fields of Round 1, biomarkers were not found in water; in studies carried out in other parts of the Gulf (Environmental Monitoring of the Gulf of Mexico, Oceanographic Campaign Ueyatl 1) biomarkers were identified (in concentrations of ng/l) at a single sampling point located near the Yucatan platform. The most abundant biomarkers were hopane, however it was not possible to identify the origin of these compounds due to limited information.

BTEX Monoaromatic hydrocarbons

Monoaromatic compounds benzene, ethylbenzene, xylenes and toluene (BTEX) were not detected in water samples in Hokchi Field. Reports from previous studies also do not indicate the quantifiable presence of BTEX, which is attributed in part to its rapid evaporation from the water surface and therefore generally do not represent environmental risk. BTEX are abundant in oil discharges operations, so their concentrations can reach important values in these sites and pose a toxic risk to organisms inhabiting nearby.

Metals

Metals concentrations in study polygon water column were low, detectable only for aluminum, iron and mercury, while nickel, chromium, tin and zinc were detected only in 2 sites. Additionally, most concentrations of these metals were found below the limits determining chronic or acute environmental effects according to criteria of the US National Oceanic and Atmospheric Administration (NOAA) and published by Buchman (2008). Aluminum showed a concentration interval of 0.02-0.12 mg/L on the surface and a little wider at the water column bottom, where it recorded an interval of 0.01-0.17 mg/L. In previous campaigns aluminum was detected in similar concentrations, so one can infer it is an element with little variability in the area. Naturally, aluminum concentrations are low in marine environment and are only increased by untreated discharges from the mining industry. The analytical method detection limit was 0.0006 mg/L.

Iron presented a minimum water surface concentration of 0.013 mg/L, average 0.043 mg/L and maximum of 0.356 mg/L. The maximum value was recorded at site 1, at the Northwest end of the Influence Replica area. Said concentration is higher than the concentration causing acute effects (0.300 mg/L); however, the 75th percentile of Fe concentrations in surface water is considerably lower (0.041), so it could be an isolated event. Previous studies have found this metal in higher concentration, even higher than the maximum value to avoid environmental damage, which would entail an environmental risk.

Mercury was found in 18 surface sites with a minimum concentration of 3.0E-05 mg/L, an average of 1.0E-04 and a maximum of 1.33E-04 mg/L. With the exception of site 6 located in the Field Replica area, all values were below the established limit to avoid chronic damage (9.4E-04 mg/L). At the bottom of the water column, a smaller number of sites were detected with values higher than the analytical method detection limit (MDL) 2.7E-05 mg/L, with all values lower than 2.99E-04 mg/L.

Nickel levels were low, only in two sites could be detected at concentrations higher than MDL (0.00015 mg/L). Nickel is reported at low concentrations (several times below MDL) and with high uncertainty in most previous studies; however results of this study are still lower.

Similar results were found for chromium, since it was only identified in two sites of surface samples (MDL = 0.00031 mg/L), one of them coinciding with nickel. Chromium is an element found in low concentrations, particularly in the Southern Gulf of Mexico, lower levels than MDL are reported in most cases.

Tin was detected in two sites at the water column bottom (MDL = 0.00024 mg/L). Few studies have included tin, and when included it has not been detected at concentrations higher than the detection limit of the method used.

Zinc, with MDL = 0.0003 mg/L, was identified in two sites on the surface and one on the bottom, being the latter with highest concentration (0.011 mg/L) and corresponding to the Duct area. However, even the maximum concentration does not represent environmental risk according to the criteria established to avoid chronic damage (0.081 mg/L). According to previous studies, zinc is usually found in higher concentrations in deep and ultradeep waters of the Gulf of Mexico.

The values found for each element are found in Table IV.10, which also includes the limits to avoid chronic or acute damage.

In summary, metal concentrations in water were low, in all cases lower than MDL for arsenic, barium, cadmium, cobalt, copper, lead and vanadium. For chromium, nickel, tin and zinc, only two samples were found with detectable concentrations at sites other than the Hokchi Field. Aluminum had lower concentrations than those representing chronic or acute environmental effects, while iron had some concentrations (8 in total) higher than chronic effect (0.05 mg/L) and one higher than acute effect (0.30 mg/L). It is suggested to monitor iron variation to verify if the observed peak concentration is an isolated event or represents a trend in concentrations.

Table IV. 10 Metals concentration in water column surface and bottom (mg/L) in Hokchi.

		Al		Tot Cr	Fe		Hg		Ni	Sn	Zn	
Area	Site	surface	bottom	surface	surface	bottom	surface	bottom	surface	bottom	surface	bottom
Field Replica 2016/2017	5	0.04	0.02		0.031	0.016	0.0001					
	6	0.04	0.02		0.028	0.010	0.0013					
	7	0.04	0.02		0.025	0.014						
	8	0.04	0.02		0.029	0.016	0.0001	0.0001				
	9	0.04	0.02		0.028	0.014						
	10	0.07	0.04		0.151	0.024	0.0001				0.005	
	12	0.05	0.06		0.027	0.029						
	13	0.06	0.08		0.029	0.036						
Influence Replica 2016/2017	1				0.356	0.017	0.0001					
	2	0.02			0.024	0.009						
	3	0.02	0.01		0.013	0.006	0.00004					
	4	0.04	0.04			0.034	0.00005					
	14	0.07	0.05		0.033	0.035	0.00003					
	16	0.04	0.04		0.023	0.024		0.00028				
	18	0.07	0.05		0.0420	0.032						
	30	0.06	0.04		0.026	0.022						
	35	0.07	0.05		0.041	0.034						
Grid Stations 2017	17	0.05	0.06		0.024	0.039						
	19	0.09	0.06		0.043	0.025	0.00004					
	22	0.06	0.05		0.028	0.027	0.00004					
	23	0.07	0.06		0.031	0.053	0.00007					
	25	0.08	0.07		0.037	0.034	0.00021					
	26	0.06	0.04		0.042	0.031		0.00030				
	27	0.05	0.05	0.0133	0.078	0.045		0.00005	0.0052			
	31	0.05	0.05		0.045	0.033	0.00005	0.00003				
	32	0.05	0.03		0.030	0.019				0.0105	0.005	
	33	0.06	0.05		0.033	0.028						
	34	0.06	0.04		0.034	0.026						
	36	0.04	0.04		0.022	0.023						
	40	0.07	0.06		0.046	0.036						
	41	0.07	0.08		0.046	0.061						
	46	0.07	0.05		0.026	0.027						
	47	0.08	0.08		0.038	0.043						
	48	0.07	0.06		0.037	0.033	0.00003					
Pipeline Stations 2017	11	0.09	0.07	0.0006	0.030	0.032	0.00003					
	15	0.06	0.05		0.024	0.026	0.00005					
	20	0.06	0.04		0.033	0.020	0.00003					
	21	0.07	0.06		0.034	0.028		0.00008		0.0073		
	24	0.08	0.07		0.039	0.033			0.0013			
	28	0.04	0.05		0.035	0.032						
	29	0.05	0.05		0.029	0.026						
	37	0.05	0.07		0.026	0.044						
	38	0.05	0.05		0.026	0.039						0.0114
	39	0.06	0.08		0.031	0.061						
	42	0.12	0.17		0.064	0.071		0.00003				
	45	0.08	0.09		0.044	0.039	0.00004					
Plant Stations 2017	43	0.08	0.07		0.036	0.045		0.00003				
	44	0.09	0.09		0.040	0.051						
No effect		---		---	≤0.050		≤0.00094		≤0.0082	---	≤0.081	
Chronic Effect		---		---	>0.050		>0.00094		>0.0082	---	>0.081	
Acute Effect		---		---	≥0.300		≥0.00180		≥0.0740	---	≥0.090	

Sediment quality

Granulometry

Grain size distribution in surface sediments showed sand dominance in virtually the entire study polygon. In some seasons, a significant silts percentage was observed, while clays remained in all cases with proportions less than 9% (Figure IV.52). These results differ from previous studies in which fines fraction dominated sediments composition.

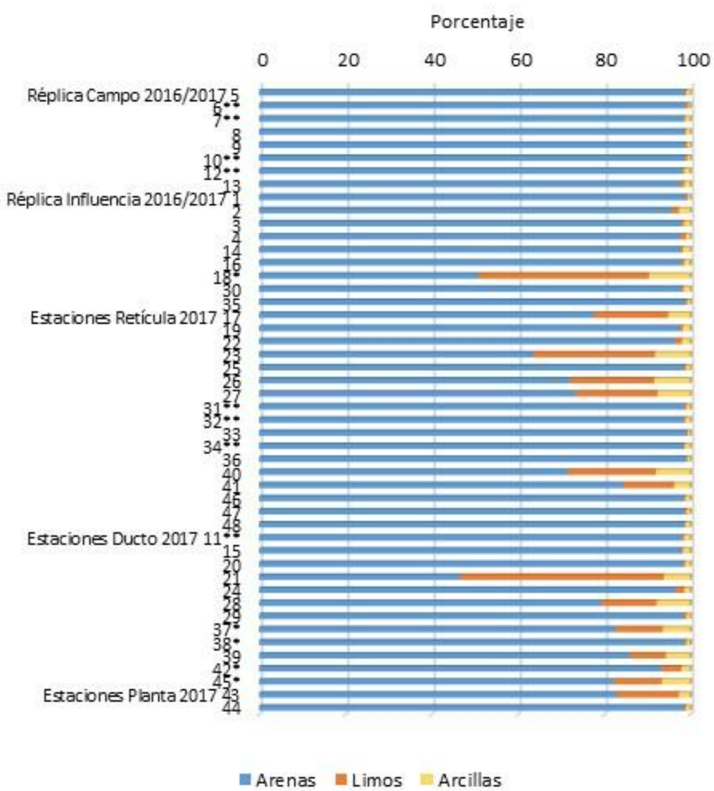


Figure IV. 52 Percentage of sands, silts and clays in surface sediment samples at Hokchi Field Oceanographic Campaign sites. Sites marked with * represent proximity to exploratory oil wells; ** to developing oil wells

Pollutants adsorption capacity is determined by grain size, basically the smaller the size increases adsorption, as has been shown in studies where pollutants concentration and grain size show direct relation. Based on the results found, study area sediment would have limited influence on metals concentration, which was confirmed by correlation results, which were moderate to low for most metals except aluminum and copper (Table IV.11).

Table IV. 11 Determination coefficient (R2) between grain size (sands, silts, clays) and metals concentration in Hokchi Camp

	Al	As	Ba	Cu	Co.	Fe	Mn	Ni	Pb	V	Zn	Cr
Sands	0.81	0.26	0.35	0.84	0.58	0.49	0.04	0.55	0.21	0.45	0.68	0.45
Limes	0.75	0.24	0.34	0.81	0.53	0.44	0.03	0.48	0.24	0.41	0.62	0.39
Clays	0.84	0.26	0.26	0.75	0.63	0.59	0.06	0.68	0.07	0.51	0.74	0.56

Potential RedOx

Rust reduction potential (RedOx) of marine sediment is a characteristic related to various sediment conditions, highlighting material depositation degree, organic matter flow, benthic fauna activity and oxygen concentration at the water column bottom. Several studies around the world report redox potential in marine environments usually presents variations that in turn modify oxygen flow and alternatively mobilizes and precipitates Fe and other associated metals. These oscillations in the redox potential are mainly due to the interaction of macrofauna and meiofauna with sediment through processes such as bio-irrigation and bio-disturbance. Oxid-reduction potential values in Hokchi Field showed an interval of -58.2 to 242.6 mV, with negative values in 42 of 48 samples. The sites with positive potential were located in the North of the study polygon, in the areas of Influence Replica and Field Replica (Figure IV.53). The result indicates during the study reducing conditions prevailed and theoretically an increase in organic matter occurs due to a low decomposition rate.

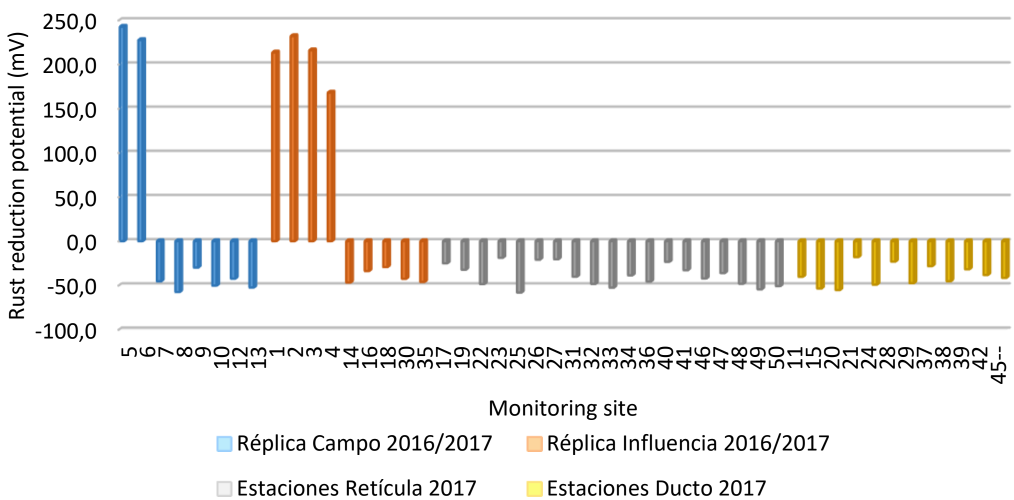


Figure IV. 53 Oxidation-reduction potential values in surface sediments of Hokchi Field.

Total Petroleum Hydrocarbons (HTP)

No detectable amounts of HTP were found in surface sediments of Hokchi Field. HTPs were also not found in the Round 1 Regional Environmental Baseline Studies of Shallow Water Fields, nor in the Gulf of Mexico Environmental Monitoring, Ueyatl 1 Oceanographic Campaign, recently conducted by the Mexican Petroleum Institute in 2014.

Polynuclear polycyclic aromatic hydrocarbons (HAP)

HAPs in Hokchi Field surface sediment did not reach the minimum detectable concentration in any of the samples taken during the cruise. Some authors agree that HAP identification and its sources requires a comprehensive analysis that can be complicated since HAPs are subject to both atmospheric and fluvial dispersion processes, where environmental parameters such as particle size, currents, temperature, physical and chemical conditions, among others, determine their accumulation or dispersion from a given place. Botello et al. (2015) determined HAP in sediments off the coast of Tamaulipas, finding that spatial distribution of these compounds showed influence of river discharge in this part of the Gulf of Mexico. HAPs with the highest abundance were acenaphthene, fluorene, anthracene, chrysene, phenanthrene and dibenzo (a, h)anthracene. The main source of HAP was pyrolytic, and to a lesser extent fossil fuel combustion. Concentrations fluctuated from 0.01-0.07 µg/g, representing low environmental risk according to international sediment quality criteria.

Oil biomarkers (BMK)

No oil biomarker compounds were identified in sediment samples in Hokchi Field. In the Regional Environmental Baseline study conducted by the Mexican Petroleum Institute in Shallow Water Fields of Round 1, BMK were found in concentrations of the order of ng/g. In this study, some chemical indices could be calculated to compare them with those of light and heavy crude extracted from the Sonda de Campeche. The results indicated similarity with those of the Mayan heavy crude oil.

Metals

Surface sediment samples were analyzed to determine the concentration of 16 metals. Cadmium was not detected in any of the samples (MDL was 0.5593 mg/kg), while mercury (MDL = 0.038 mg/kg), selenium (MDL = 3.48 mg/kg) and tin (MDL = 3.51 mg/kg) were detected in few sites (2, 3 and 9 respectively). In general, remaining metals concentration in decreasing order was: Mn > Ba > Zn > V > Cr > As > Ni > Sn > Cu > Co > Pb. This order is consistent with what was observed in other studies in the Southern Gulf region, where manganese and barium were also the most abundant metals in sediment.

Table IV.12 shows metals concentrations (mg/kg) at sampling sites indicating the area to which they belong: Field Replica 2016/2017, Influence Replica 2016/2017, Grid Stations 2017, Pipeline Stations 2017 and Plant Stations 2017. On May 28, 2018, a modification to the pipeline location was reported, now with sites 10, 11, 12, 15, 20, 21, 25, 29, 38 and 45 which were initially classified in Grid 2017 or Pipeline Stations 2017 area. The analysis on sediment quality by metals is based on the original pipeline layout (Pipeline Stations 2017), broadening the discussion if any metal presented a change in its behavior due to the modification in the location of the pipeline.

At the bottom of Table IV.12 are the TEL (threshold effect level) and PEL (probable effect level) criteria establishing the association between the concentration of a specific metal and the adverse biological effect resulting from exposure. The lowest concentration, TEL, represents the concentration below which biological effects are expected to occur rarely. The higher value, PEL, defines the level above which negative effects are frequently expected. Considering this information, three concentration intervals can be defined: 1) the minimum effect interval, in which the effects are rarely expected (concentration lower than TEL, cells in green color in Table IV.12, the possible effect interval, in which negative impacts are expected occasionally (metal concentration greater than TEL but less than PEL, yellow cells); and 3) probable effect interval in which effects will occur frequently (concentration higher than PEL, red cells).

Aluminum showed concentrations from 1.41 to 8.15 mg/kg with a general average of 3.60 mg/kg in Hokchi Field. A trend of increasing concentrations towards the East of the 2017 Grid Stations and in general in the sites located along the pipeline was observed, so that in these areas aluminum concentrations were found higher than the general average mentioned. The stations of the Field Replica 2017 showed the lowest concentrations, as well as the lowest variation (CV =7.46) compared to the remaining areas. For this element there are no limit values establishing negative effects and the results found in the Hokchi Field are in the interval of other studies carried out in the Southern Gulf of Mexico area. With the new location of the pipeline, concentrations average for the 2017 Grid area increased and decreased for the 2017 pipeline, as the highest aluminum concentrations, but the trend of maximum levels in these areas is preserved.

Iron presented in minimum concentrations of 0.09 mg/kg, average 11.06 mg/kg and maximum 19.31 mg/kg and variation coefficient of 36.6 indicating a moderate variation. Iron highest concentrations occurred in several of the sites located in the Pipeline, in the Grid and in one of the coastal sites (site 43). There are also no environmental criteria for iron as it is another abundant element in the earth's crust and its origin is mainly natural. Iron behavior did not change significantly with the new pipeline layout, a modification similar to that presented by aluminum was observed.

Arsenic was recorded in concentrations of 3.72-24.27 mg/kg with an average of 11.21 mg/kg. As shown in Table IV.12, most sampling sites exceeded TEL concentration (7.2 mg/kg). It was observed that stations of the Influence Replica and the Field Replica presented the highest concentrations, exceeding said criterion in all cases, which means that environmental effects may present moderately. The sites located along the Pipeline showed variable concentrations of this metal (3.72-22.60 mg/kg), while the two sites located in the Plant (coastal) showed levels lower than the overall average for Hokchi Field. Arsenic concentrations observed in other studies have been half of that found in Hokchi Field, so it is advisable to closely monitor the variation of its levels to avoid increasing environmental risk. Arsenic maintained this behavior even with the new layout of the pipeline.

The barium was found in concentrations from 2.71 mg/kg to 347.20 mg/kg, with an average of 47.85 mg/kg and CV of 159.18. The maximum values of this metal (347.20 mg/kg and 159.3 mg/kg) corresponded to a site located in the Influence Replica and one of the pipeline. With the exception of these two sites, barium concentrations were lower than the TEL criterion (130 mg/kg), so the environmental risk is minimal. The concentrations found in this study are lower than previously reported, with a maximum of 438.2 mg/kg. However, this study results and the previous ones agree that the frequency of barium levels higher than TEL is low. With the new pipeline layout, the second highest concentration is classified within the Grid area.

The average Cu concentrations were 4.74 mg/kg, with a minimum of 2.2 mg/kg and maximum of 12.34 mg/kg. The highest levels of copper were found in the stations near the Pipeline, however, in no case was exceeded the concentration indicated in >TEL (18.7 mg/kg), so copper does not represent environmental risk in the Hokchi Field. With the new pipeline layout, the average concentration of this metal in the area of the Grid increased slightly and decreased in the pipeline.

Cobalt showed a concentration interval of 2.44-7.43 mg/kg in the Hokchi Field. It was observed that some of the highest values were measured at the stations located along the Pipeline, showing an interval of 2.91-7.43 and an average of 5.09 mg/kg, although it was not a definite distribution pattern. With the new pipeline location, it was observed that concentrations decreased (average of 4.30 and maximum of 7.35 mg/kg) and those of the Grid increased, in both cases the change was minimal. For cobalt there is no criterion establishing a maximum concentration to avoid environmental damage.

Manganese fluctuated within the interval of 60.28 mg/kg to 431.2 mg/kg, with an average of 192.96 mg/kg. The lowest values and with the lowest variation were observed in the 2016/2017 Field Replica area, while the highest and more variable values corresponded to the Grid sites. With the new pipeline layout, minimal changes were observed, following the same trend. There are no maximum environmental protection values for this metal.

Nickel presented a minimum concentration of 4.16 mg/g, a maximum of 19.37 mg/kg and an average of 9.07 mg/kg throughout the field of study. Concentrations of this metal exceeded TEL value (15.9 µg/g) in half of the sites in the Pipeline area, in two sites in the 2017 Grid and one in the (coastal) Plant. Nickel's behavior taking into account the new pipeline layout presented the same modification as previous metals, i.e., a slight decrease in the average of pipeline sites and an increase in the Grid. Mexican oil is characterized by being rich in nickel (along with vanadium); moreover, nickel is used as a catalyst in oil refining, so its concentrations are directly related to activities of the oil industry.

Lead was recorded in a minimum concentration of 1.78 mg/kg and a maximum concentration of 22.37 mg/kg, with an overall average of 3.93 mg/kg which are levels observed in previous studies. Most of the concentrations were kept below 5 mg/kg and the highest were recorded in Pipeline sites. None of these values were higher than the criterion considered safe for the environment and human health (TEL = 30.24 mg/kg). The new pipeline layout slightly modified this behavior, increasing the concentrations in the Grid, however, the maximum lead observed at site 21 remains in the area of influence of the new pipeline.

Tin was only detected in 9 sites, with a minimum of 4.01 mg/kg, an average of 5.04 mg/kg and a maximum of 6.15 mg/kg, the latter corresponded to site 24. With the new pipeline layout, this site was classified within the Grid so the average for this area increased. Tin does not have a maximum allowable concentration for environmental protection.

Vanadium concentrations showed an interval of 4.18-23.09 mg/kg with an average of 13.21 mg/kg. The maximum value was found at site 43 (coastal), in the Grid and along the pipeline, while in the remaining areas variable concentrations were measured. The new pipeline layout slightly modified concentrations interval observed along the pipeline and increased that of the Grid, especially for sites 39 and 37 that were originally classified in the pipeline area.

Zn showed a concentration interval of 6.79-32.23 mg/kg with an average of 16.35 mg/kg. The maximum occurred at a Grid site and several of the highest concentrations were observed at sites located along the pipeline, followed by a coastal site (station 43). There is no environmental risk due to zinc in the area, considering that the TEL and PEL criteria were not exceeded anywhere. The new pipeline layout did not significantly modify this behavior.

Total chromium fluctuated in concentrations from 4.41 mg/kg to 34.13 mg/kg with an average of 12.84 mg/kg. The highest concentrations were present in the sites corresponding to the Pipeline and one of the coastal areas; this was a behavior observed in several metals. The concentration criterion established to ensure environmental health (52.3 mg/kg) was never exceeded in any case. The new pipeline layout implied the maximum concentration was no longer located in one of the pipeline sites, but in the Grid area.

Table IV. 12 Metals concentration in sediment (mg/kg) during the Hokchi oceanographic campaign in the Gulf of Mexico. The color code corresponds to the toxicity criteria established by NOAA for each metal. Concentrations lower to TEL represent a minimum risk, higher than TEL but lower than PEL represent a possible risk and higher concentrations than PEL, a probable risk.

Area	Site	Al	As	Ba	Cu	Co.	Fe	Hg	Mn
Field Replica 2016-2017	5	2789	17.61	4.33	4.51	3.76	10400	n.d.	194.20
	6	2534	10.61	n.d.	4.80	3.36	10680	n.d.	121.50
	7	2806	10.28	n.d.	2.88	3.80	9767	n.d.	117.60
	8	3156	11.90	n.d.	3.83	2.65	7906	n.d.	118.70
	9	2877	11.35	n.d.	3.75	3.19	9412	n.d.	123.60
	10*	2779	7.63	n.d.	4.30	3.27	9184	n.d.	117.30
	12*	2799	6.24	7.90	2.45	3.75	9974	n.d.	110.20
	13	2483	15.84	n.d.	2.60	4.03	10830	n.d.	132.40
Influence Replica 2016-2017	1	2497	9.98	n.d.	5.38	n.d.	8206	n.d.	186.90
	2	2580	22.09	3.19	3.08	3.34	11180	n.d.	194.70
	3	2052	20.59	n.d.	4.57	3.62	9464	n.d.	303.10
	4	2695	10.53	n.d.	4.01	3.89	11530	n.d.	107.50
	14	2775	11.90	2.71	4.51	3.95	10190	n.d.	145.50
	16	2443	12.78	n.d.	2.36	2.58	9085	n.d.	236.60
	18	8154	9.42	347.20	9.96	5.05	16330	0.068	206.50
	30	2032	19.08	n.d.	2.35	3.49	9356	n.d.	431.20
	35	2051	14.01	6.92	2.36	3.99	8789	n.d.	148.40
Grid Stations 2017	17	5850	n.d.	46.35	7.32	6.68	16760	n.d.	336.80
	19	2501	11.16	n.d.	5.38	3.50	94.68	n.d.	90.15
	22	3101	10.95	5.87	4.65	6.10	11930	n.d.	175.60
	23	7588	5.07	43.48	9.00	7.20	17300	n.d.	201.60
	25*	1776	16.58	3.10	3.99	4.45	8205	n.d.	376.70
	26	6550	3.83	44.37	8.83	6.60	15430	n.d.	211.80
	27	7095	4.15	26.06	8.36	6.62	16350	n.d.	214.50
	31	1744	9.32	n.d.	n.d.	2.83	7942	n.d.	66.89
	32	2250	24.06	n.d.	2.56	3.98	9616	n.d.	405.00
	33	1811	18.72	n.d.	3.38	4.02	8726	n.d.	258.00
	34	2067	14.62	n.d.	2.61	4.66	10190	n.d.	167.50
	36	1827	13.80	n.d.	3.94	3.67	8724	n.d.	172.30
	40	6294	7.28	37.55	7.78	6.46	18180	0.052	202.00
	41	5679	n.d.	13.27	5.69	5.19	11480	n.d.	234.60
	46	1550	7.80	n.d.	2.27	2.44	4104	n.d.	60.28
	47	1406	8.53	n.d.	2.41	2.83	4748	n.d.	73.67
	48	1856	10.90	n.d.	2.71	2.93	6111	n.d.	199.40
Pipeline stations 2017	11	2557	9.49	n.d.	4.14	3.42	9306	n.d.	132.80
	15*	2757	11.98	3.40	3.81	3.42	10590	n.d.	184.70
	20*	2055	10.78	n.d.	3.77	2.90	8851	n.d.	165.50
	21*	7762	3.72	91.48	12.34	7.35	14470	n.d.	182.80
	24	1920	10.24	4.49	4.18	4.45	7152	n.d.	210.90
	28	7269	6.98	56.04	9.34	7.43	15620	n.d.	250.90
	29*	2075	22.60	n.d.	2.96	3.86	10270	n.d.	224.10
	37	5678	7.11	78.86	6.34	6.10	18090	n.d.	275.80
	38*	2649	8.62	n.d.	2.20	4.59	13720	n.d.	147.20
	39	5490	8.91	87.97	7.05	6.85	16900	n.d.	201.40
	42	4847	7.25	159.30	4.19	4.79	12050	n.d.	185.60
	45*	7908	5.07	16.53	5.86	5.95	17900	n.d.	224.90
Plant Stations 2017	43	6893	6.17	10.08	5.45	7.27	19310	n.d.	297.40
	44	2484	8.26	n.d.	2.68	4.16	8819	n.d.	135.50
> TEL		*	< 7.2	< 130	< 18.7	*	*	< 0.13	*
TEL < [ ] > PEL		*	7.2 < [ ] > 41.6	> 130	18.7 < [ ] > 108	*	*	0.13 < [ ] > 0.7	*
[ ] > PEL		*	> 41.6		> 108	*	*	> 0.7	*

[“] is the metal concentration (mg/kg).

The sites marked with * are the sites located in the area of the pipeline notified on 05/28/2018

Table IV. 13 Metals in sediment concentration (mg/kg). Continued

Area	Site	Ni	Pb	Se	Sn	V	Zn	Cr
Field Replica 2016-2017	5	6.65	n.d.	n.d.	n.d.	11.41	11.22	8.44
	6	5.56	n.d.	n.d.	n.d.	11.82	10.34	7.02
	7	6.25	n.d.	n.d.	n.d.	11.89	11.77	9.74
	8	5.84	2.22	n.d.	n.d.	7.00	9.86	6.57
	9	6.31	2.03	n.d.	n.d.	10.34	12.19	8.71
	10*	6.80	2.40	n.d.	n.d.	11.99	12.42	8.93
	12*	7.13	2.55	n.d.	n.d.	11.90	13.11	10.70
	13	6.56	2.18	n.d.	n.d.	14.02	11.78	7.94
Influence Replica 2016-2017	1	6.69	4.59	n.d.	n.d.	8.19	9.86	9.71
	2	6.28	3.52	n.d.	n.d.	10.43	9.90	7.99
	3	5.53	2.35	n.d.	n.d.	11.28	11.63	7.12
	4	6.78	2.07	n.d.	n.d.	17.04	17.59	11.43
	14	7.12	1.78	n.d.	n.d.	12.33	12.73	10.85
	16	5.22	2.49	n.d.	n.d.	9.99	15.02	5.74
	18	12.66	5.09	5.56	n.d.	18.26	27.93	16.88
	30	5.42	18.54	3.71	5.68	11.78	12.61	6.67
	35	7.74	2.33	n.d.	n.d.	9.44	10.99	7.69
Grid Stations 2017	17	19.37	3.20	n.d.	n.d.	18.64	32.23	25.88
	19	6.13	2.24	n.d.	n.d.	11.58	11.14	7.98
	22	11.32	2.38	n.d.	n.d.	16.50	16.13	26.46
	23	14.62	2.82	n.d.	n.d.	20.91	28.58	20.84
	25*	5.62	n.d.	n.d.	n.d.	11.20	11.14	7.21
	26	14.26	3.37	n.d.	n.d.	19.43	27.11	22.50
	27	14.44	2.80	n.d.	n.d.	17.13	25.45	18.81
	31	4.16	n.d.	n.d.	4.01	9.69	9.33	5.08
	32	6.28	2.84	n.d.	n.d.	10.65	10.90	7.60
	33	6.56	2.26	n.d.	n.d.	10.36	9.19	5.67
	34	8.00	3.33	n.d.	n.d.	14.85	14.59	12.89
	36	7.10	n.d.	n.d.	n.d.	8.38	9.04	10.89
	40	15.97	4.01	n.d.	n.d.	19.36	27.65	21.08
	41	12.82	3.40	n.d.	n.d.	11.47	25.35	17.83
	46	4.34	n.d.	n.d.	n.d.	4.18	8.23	4.41
	47	4.29	n.d.	n.d.	n.d.	5.14	6.79	5.14
	48	5.80	n.d.	n.d.	n.d.	6.08	8.52	5.46
Pipeline stations 2017	11*	5.98	1.87	n.d.	n.d.	11.63	13.83	8.62
	15*	7.39	2.45	n.d.	n.d.	13.71	13.02	10.11
	20*	5.53	2.58	n.d.	n.d.	10.72	9.23	5.76
	21*	14.42	22.37	n.d.	5.90	18.94	28.97	21.76
	24	4.91	n.d.	4.26	6.15	7.39	9.53	7.04
	28	17.35	10.31	n.d.	5.86	18.82	27.37	34.13
	29*	5.88	2.08	n.d.	4.72	12.39	11.11	7.14
	37	18.54	3.99	n.d.	4.57	20.30	27.05	23.95
	38*	6.89	2.02	n.d.	n.d.	19.73	16.48	12.41
	39	16.93	3.31	n.d.	n.d.	19.65	27.44	23.77
	42	12.03	2.82	n.d.	n.d.	15.13	22.32	18.34
	45*	18.45	3.21	n.d.	4.33	18.78	31.82	25.56
Plant Stations 2017	43	18.62	3.08	n.d.	n.d.	23.09	30.91	31.41
	44	6.96	2.37	n.d.	4.10	9.15	13.22	8.62
> TEL		< 15.9	< 30.24	*	*	*	< 124	< 52.3
TEL < [ ] > PEL		15.9 < [ ] > 42.8	30.24 < [ ] > 112	*	*	*	124 < [ ] > 271	52.3 < [ ] > 160
[ ] > PEL		> 42.8	> 112	*	*	*	> 271	> 160

[ ] is the metal concentration (mg/kg).

The sites marked with * are the sites located in the area of the pipeline notified on 05/28/2018

Metals general distribution showed the highest concentrations occurred in the sites located along the Pipeline, followed by the Grid area, particularly copper, cobalt, iron, nickel, lead, vanadium, zinc and chromium showed this behavior. Minimum concentrations of vanadium, chromium, manganese, cobalt, nickel, aluminum and zinc were most frequently observed in the Southern area of the Grid (sites 46 and 47). It is also observed metals concentrations in the 2016/2017 Replica Field area generally showed the most stable concentrations (lower CV) compared to the other areas of the Hokchi Field. Figure IV.54 describes measured concentrations of nickel in Hokchi Field: intermediate and stable concentrations in the Replica Field area, followed by the Influence Replica area. In the Grid area variability in the concentration increases, reaching TEL criterion at the pipeline sites the highest concentrations were presented more frequently, as well as in one of the coastal sites. This behavior was observed for copper, zinc, cobalt, chromium and aluminum.

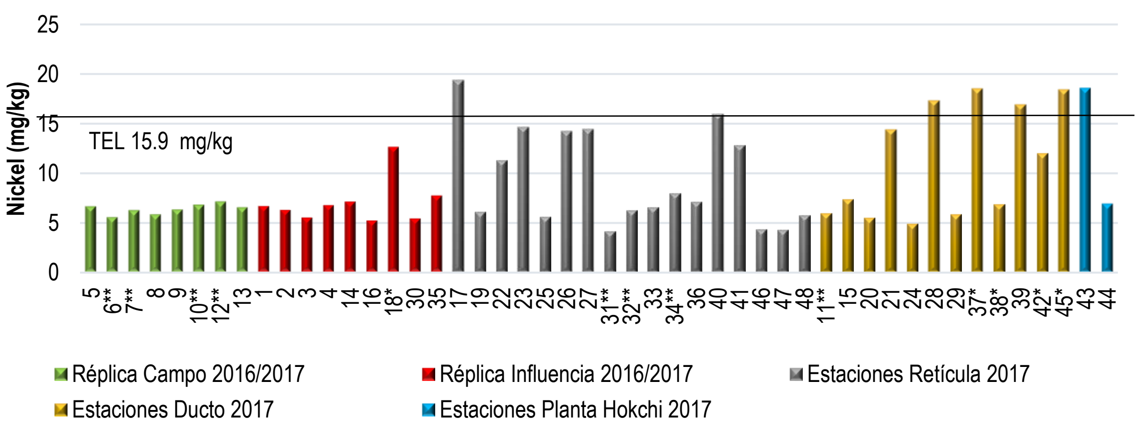


Figure IV. 54 Nickel concentration (mg/kg) in surface sediment determined in Hokchi Field. Sites marked with * represent proximity to exploratory oil wells; ** to developing oil wells.

Several Metals concentrations showed variation with the area, being higher in the Grid areas and in Pipeline 2017. The new pipeline layout modified this behavior, as some of the highest concentrations fell outside the initial layout and were classified at Grid sites. The metal presenting concentrations higher than the environmental protection criterion (7.2 mg/kg) was arsenic, exceeding this criterion in 80% of the samples. Another observed aspect was oil wells influence on metals concentration; in general, the highest concentrations were found in sites near exploratory wells. This was observed for aluminum, barium, copper, iron, nickel, vanadium, zinc and chromium.

Note that arsenic did not present this behavior, suggesting it has a different source than that related to wells. Table 14 summarizes elements concentration descriptive statistics in the areas described above and in sites near exploratory wells and developing wells.

Table IV. 14 Table IV.14. Descriptive statistics of metal concentrations in sediments (mg/g) divided into zones in the Hokchi study area

Area		Al	As	Ba	Cu	Co.	Fe	Mn
Field Replica 2016-2017	Min	2483.00	6.24	4.33	2.45	2.65	7906.00	110.20
	Avg	2777.88	11.43	6.12	3.64	3.48	9769.13	129.44
	Max	3156.00	17.61	7.90	4.80	4.03	10830.00	194.20
	CV	7.46	33.26	41.28	24.71	12.81	9.74	20.80
Influence Replica 2016-2017	Min	2032.00	9.42	2.71	2.35	2.58	8206.00	107.50
	Avg	3031.00	14.49	90.01	4.29	3.74	10458.89	217.82
	Max	8154.00	22.09	347.20	9.96	5.05	16330.00	431.20
	CV	64.08	33.43	190.52	56.07	18.76	23.46	45.04
Grid Stations 2017	Min	1406.00	3.83	3.10	2.27	2.44	94.68	60.28
	Avg	3585.00	11.12	27.51	5.06	4.71	10346.51	202.75
	Max	7588.00	24.06	46.35	9.00	7.20	18180.00	405.00
	CV	64.01	50.91	65.38	48.89	34.17	49.87	50.00
Pipeline stations 2017	Min	1920.00	3.72	3.40	2.20	2.91	7152.00	132.80
	Avg	4413.92	9.40	62.26	5.52	5.09	12909.92	198.88
	Max	7908.00	22.60	159.30	12.34	7.43	18090.00	275.80
	CV	53.38	50.85	86.15	52.80	31.33	28.96	20.83
Plant Stations 2017	Avg	4688.50	7.22	10.08	4.07	5.72	14064.50	216.45
Exploratory wells stations	Min	2649.00	5.07	16.53	2.20	4.59	12050.00	147.20
	Avg	5847.20	7.49	150.47	5.71	5.30	15618.00	208.00
	Max	8154.00	9.42	347.20	9.96	6.10	18090.00	275.80
Wells in development stations	Min	1744	6.24		2.45	2.83	7942.00	66.89
	Avg	2442	11.53		3.39	3.63	9582.38	154.85
	Max	2806	24.06		4.80	4.66	10680.00	405.00
		Ni	Pb	Se	Sn	V	Zn	Cr
Field Replica 2016-2017	Min	5.56	2.03			7.00	9.86	6.57
	Avg	6.39	2.28			11.30	11.59	8.51

Area		Al	As	Ba	Cu	Co.	Fe	Mn
	Max	7.13	2.55			14.02	13.11	10.70
	CV	8.00	8.88			17.79	9.30	15.92
Influence Replica 2016-2017	Min	5.22	1.78			8.19	9.86	5.74
	Avg	7.05	4.75	4.64		12.08	14.25	9.34
	Max	12.66	18.54			18.26	27.93	16.88
	CV	32.14	111.51			28.19	39.97	36.54
Grid Stations 2017	Min	4.16	2.24			4.18	6.79	4.41
	Avg	9.48	2.97			12.68	16.55	13.28
	Max	19.37	4.01			20.91	32.23	26.46
	CV	51.18	18.64			41.69	53.79	60.16
Pipeline stations 2017	Min	4.91	1.87		4.33	7.39	9.23	5.76
	Avg	11.19	5.18		5.26	15.60	19.85	16.55
	Max	18.54	22.37		6.15	20.30	31.82	34.13
	CV	50.29	119.09		15.21	27.89	42.66	55.99
Plant Stations 2017	Avg	12.79	2.73		4.10	16.12	22.07	20.02
Exploratory wells stations	Min	6.89	2.02		4.33	15.13	16.48	12.41
	Avg	13.71	3.43		4.45	18.44	25.12	19.43
	Max	18.54	5.09		4.57	20.30	31.82	25.56
Wells in development stations	Min	4.16	1.87			9.69	9.33	5.08
	Avg	6.27	2.60			11.80	12.04	8.82
	Max	8.00	3.33			14.85	14.59	12.89

Enrichment Factors (EF) and Geo accumulation Index (Igeo)

Enrichment Factors (EF) of each metal were calculated to estimate whether there is an anthropic contribution or, on the contrary, it is about concentrations that can be considered natural for the study area. The calculation includes metal concentration normalization taking as reference sediment local characteristics, following the formula:

$$FE = \frac{\left(X_{sed}/Fe_{sed}\right)}{\left(X_{cor}/Fe_{cor}\right)}$$

where EF is the Enrichment Factor, X_{sed} and Fe_{sed} are the observed concentrations, and X_{cor} and Fe_{cor} are the reference concentrations.

There is a classification according to the value obtained from EF, which indicates that if the EF of a metal is less than 1, it is considered there is no enrichment, i.e., the presence of the metal in the study area is mainly due to natural processes. However, when EF value is greater than 1 and as it increases it means metal concentration has an anthropogenic contribution. Thus, the categories are: 1) natural origin for EF values < 1; 2) minimum enrichment for cases where 1 < EF < 3; 3) moderate enrichment for EF values between 3-5; 4) severe moderate for 5 ≤ EF < 10; 5) severe for 10 ≤ EF < 25; 6) very severe for 25 ≤ EF < 50 and 7) extremely severe for EF ≥ 50.

The results obtained for metals in the study polygon are presented in Table IV.15. Values were less than 1 for aluminum, vanadium, chromium, cobalt, nickel and copper. In the case of lead, barium, zinc and manganese, some EF values were found to indicate a slight contribution from anthropic sources. It is noteworthy that the monitoring site 19 recorded an extremely low iron concentration (94 mg/kg), which was reflected in EF values obtained for metals. However, it is considered to be an isolated case and not representative of the study area, so it will not be discussed further.

EF values for arsenic and tin suggest that concentrations of these metals are due to human activities. Arsenic factors presented 18 sites with severe enrichment classification, 17 with very severe enrichment and 1 with the highest classification, extremely severe. The highest EF values were observed in the Field Replica, Influence and Grid areas. Tin also showed high EF values, most corresponded to severe moderate enrichment classification. Table IV.15 contains the EF values obtained for the metals of the studied polygon.

To supplement the EF results, geo accumulation indexes, I_{geo}, were also calculated, which are based on reference concentrations of each metal. The formula for calculating I_{geo} is as follows:

$$I_{geo} = log_2 \left({}^{X}/_{1.5Bn} \right)$$

where *X* is the metal concentration, Bn is the metal reference concentration and factor 1.5 is applied to correct the lithogenic effects. Like EF, I_{geo} has 7 classes: if I_{geo} value is less than 0, it is said there is no pollution; if $I_{geo} < 1$ is considered as uncontaminated or moderately contaminated; if I_{geo} has a value between 1-2, contamination by that metal is moderate; if I_{geo} is 2-3, indicates moderate contamination; if I_{geo} reaches values between 3-4 it is strongly contaminated; for I_{geo} values between 4-5 it is a strong contamination; between 5-6 it indicates strong to very strong contamination; and if it is greater than 6 it is considered highly contaminated.

The analysis of I_{geo} values supports results found with EF and are consistent (i.e., the higher EF values also corresponded to those of I_{geo} and vice versa). Arsenic was the only metal with I_{geo} values indicating influence from non-natural sources. However, in none of the sites were reached indices greater than 2, so the contamination according to this index is moderate (Table IV.16).

In summary, both EF and I_{geo} values indicate arsenic has anthropic origin in virtually the entire study polygon, while other metals may have mainly natural origin.

Cuadro IV. 15 Factores de Enriquecimiento para los metales en el campo Hokchi

Área	Sitio	Al	V	Cr	Mn	Co	Ni	Cu	Zn	As	Sn	Ba	Pb	Hg
Réplica de Campo 2016/2017	5	0.12	0.29	0.29	0.71	0.52	0.31	0.28	0.55	33.87		0.04		
	6	0.10	0.30	0.24	0.43	0.45	0.25	0.29	0.50	19.87				
	7	0.13	0.32	0.36	0.46	0.56	0.31	0.19	0.62	21.05				
	8	0.17	0.24	0.30	0.57	0.48	0.35	0.32	0.64	30.10			0.81	
	9	0.13	0.29	0.33	0.50	0.49	0.32	0.26	0.67	24.12			0.62	
	10	0.13	0.35	0.35	0.48	0.51	0.36	0.31	0.70	16.62			0.75	
	12	0.12	0.32	0.39	0.42	0.54	0.34	0.16	0.68	12.51		0.07	0.74	
	13	0.10	0.35	0.26	0.46	0.54	0.29	0.16	0.56	29.25			0.58	
Réplica de Influencia 2016/2017	1	0.13	0.27	0.43	0.86		0.39	0.43	0.62	24.32			1.61	
	2	0.10	0.25	0.26	0.66	0.43	0.27	0.18	0.46	39.52		0.02	0.91	
	3	0.09	0.32	0.27	1.21	0.55	0.28	0.32	0.63	43.51			0.72	
	4	0.10	0.39	0.36	0.35	0.49	0.28	0.23	0.78	18.27			0.52	
	14	0.12	0.32	0.38	0.54	0.56	0.34	0.29	0.64	23.36		0.02	0.50	
	16	0.12	0.29	0.23	0.99	0.41	0.28	0.17	0.85	28.13			0.79	
	18	0.22	0.30	0.37	0.48	0.45	0.37	0.40	0.88	11.54		1.80	0.90	1.87
	30	0.10	0.34	0.26	1.75	0.54	0.28	0.16	0.69	40.79	10.93		5.71	
	35	0.10	0.29	0.31	0.64	0.65	0.42	0.18	0.64	31.88		0.07	0.76	
Estaciones Retícula 2017	17	0.15	0.30	0.56	0.76	0.57	0.55	0.29	0.99			0.23	0.55	
	19	11.55	32.62	30.34	36.08	53.19	31.08	37.19	60.51	2357.41			68.14	
	22	0.11	0.37	0.80	0.56	0.74	0.46	0.26	0.70	18.36		0.04	0.57	
	23	0.19	0.32	0.43	0.44	0.60	0.41	0.34	0.85	5.86		0.21	0.47	
	25	0.09	0.36	0.32	1.74	0.78	0.33	0.32	0.70	40.41		0.03		
	26	0.19	0.34	0.52	0.52	0.62	0.44	0.37	0.90	4.96		0.24	0.63	
	27	0.19	0.28	0.41	0.50	0.58	0.42	0.33	0.80	5.08		0.14	0.49	
	31	0.10	0.33	0.23	0.32	0.51	0.25		0.60	23.47	9.09			
	32	0.10	0.30	0.28	1.60	0.60	0.31	0.17	0.58	50.04			0.85	
	33	0.09	0.32	0.23	1.12	0.66	0.36	0.25	0.54	42.91			0.75	
	34	0.09	0.39	0.46	0.62	0.66	0.38	0.17	0.74	28.69			0.94	
	36	0.09	0.26	0.45	0.75	0.61	0.39	0.30	0.53	31.64				
	40	0.15	0.28	0.42	0.42	0.51	0.42	0.28	0.78	8.01		0.17	0.64	1.29
	41	0.22	0.27	0.56	0.77	0.65	0.54	0.32	1.14			0.10	0.85	
	46	0.17	0.27	0.39	0.56	0.86	0.51	0.36	1.03	38.01				
	47	0.13	0.29	0.39	0.59	0.86	0.43	0.33	0.74	35.93				
	48	0.13	0.27	0.32	1.24	0.69	0.46	0.29	0.72	35.67				
Estaciones Ducto 2017	11	0.12	0.33	0.33	0.54	0.53	0.31	0.29	0.76	20.40			0.58	
	15	0.11	0.35	0.34	0.66	0.47	0.33	0.24	0.63	22.63		0.03	0.67	
	20	0.10	0.32	0.23	0.71	0.47	0.30	0.28	0.54	24.36			0.84	
	21	0.23	0.35	0.54	0.48	0.73	0.48	0.56	1.03	5.14	7.34	0.54	4.45	
	24	0.12	0.28	0.35	1.12	0.90	0.33	0.38	0.69	28.64	15.48	0.05		
	28	0.20	0.32	0.79	0.61	0.69	0.53	0.39	0.90	8.94	6.75	0.30	1.90	
	29	0.09	0.32	0.25	0.83	0.54	0.27	0.19	0.56	44.01	8.27		0.58	
	37	0.14	0.30	0.48	0.58	0.49	0.49	0.23	0.77	7.86	4.55	0.37	0.64	
	38	0.08	0.38	0.33	0.41	0.48	0.24	0.10	0.62	12.57			0.42	
	39	0.14	0.31	0.51	0.45	0.58	0.48	0.27	0.84	10.54		0.44	0.56	
	42	0.18	0.33	0.55	0.58	0.57	0.48	0.23	0.95	12.03		1.12	0.67	
	45	0.19	0.28	0.51	0.48	0.48	0.49	0.21	0.91	5.66	4.35	0.08	0.52	
Estaciones Planta 2017	43	0.16	0.32	0.59	0.58	0.54	0.46	0.18	0.82	6.39		0.04	0.46	
	44	0.12	0.28	0.35	0.58	0.68	0.38	0.20	0.77	18.73	8.37		0.77	

Código de clasificación							
	(verde)	origen natural	(naranja)	enriq. moderado	(rojo)	enriq. severo	(morado) e. extremadamente severo
	(amarillo)	enriq. mínimo	(rosa)	enriq. mod-severo	(azul)	enriq. muy severo	

Cuadro IV. 16 Índices de geoacumulación (Igeo) para los metales en el campo Hokchi.

	Sitio	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sn	Ba	Pb	Hg
Réplica de Campo 2016/2017	5	0.00	0.02	0.02	0.01	0.00	0.05	0.02	0.03	0.03	1.53		0.00		
	6	0.00	0.02	0.02	0.00	0.00	0.05	0.02	0.03	0.03	1.26				
	7	0.00	0.02	0.02	0.00	0.00	0.05	0.02	0.02	0.03	1.25				
	8	0.00	0.01	0.02	0.00	0.00	0.04	0.02	0.02	0.03	1.32			0.06	
	9	0.00	0.02	0.02	0.00	0.00	0.04	0.02	0.02	0.03	1.30			0.05	
	10	0.00	0.02	0.02	0.00	0.00	0.05	0.02	0.03	0.03	1.09			0.07	
	12	0.00	0.02	0.02	0.00	0.00	0.05	0.03	0.02	0.04	0.98		0.00	0.07	
	13	0.00	0.02	0.02	0.00	0.00	0.05	0.02	0.02	0.03	1.48			0.06	
Réplica de Influencia 2016/2017	1	0.00	0.01	0.02	0.01	0.00		0.02	0.03	0.03	1.23			0.12	
	2	0.00	0.02	0.02	0.01	0.00	0.05	0.02	0.02	0.03	1.65		0.00	0.10	
	3	0.00	0.02	0.02	0.01	0.00	0.05	0.02	0.03	0.03	1.62			0.07	
	4	0.00	0.02	0.02	0.00	0.00	0.05	0.02	0.02	0.04	1.26			0.06	
	14	0.00	0.02	0.02	0.01	0.00	0.05	0.03	0.03	0.03	1.32		0.00	0.04	
	16	0.00	0.02	0.02	0.01	0.00	0.04	0.02	0.02	0.04	1.36			0.07	
	18	0.00	0.02	0.03	0.01	0.00	0.06	0.03	0.04	0.05	1.20		0.01	0.13	-32.32
	30	0.00	0.02	0.02	0.01	0.00	0.05	0.02	0.01	0.03	1.58	0.84		0.22	
	35	0.00	0.02	0.02	0.01	0.00	0.05	0.03	0.02	0.03	1.41		0.00	0.07	
Estaciones Retícula 2017	17	0.00	0.02	0.03	0.01	0.00	0.07	0.04	0.03	0.05			0.01	0.09	
	19	0.00	0.02	0.02	0.00	0.00	0.05	0.02	0.03	0.03	1.29			0.06	
	22	0.00	0.02	0.03	0.01	0.00	0.07	0.03	0.03	0.04	1.28		0.00	0.07	
	23	0.00	0.02	0.03	0.01	0.00	0.08	0.03	0.04	0.05	0.87		0.01	0.08	
	25	0.00	0.02	0.02	0.01	0.00	0.06	0.02	0.02	0.03	1.50		0.00		
	26	0.00	0.02	0.03	0.01	0.00	0.07	0.03	0.04	0.05	0.72		0.01	0.09	
	27	0.00	0.02	0.03	0.01	0.00	0.07	0.03	0.04	0.04	0.76		0.01	0.08	
	31	0.00	0.02	0.02	0.00	0.00	0.04	0.02		0.03	1.19	0.67			
	32	0.00	0.02	0.02	0.01	0.00	0.05	0.02	0.02	0.03	1.70			0.08	
	33	0.00	0.02	0.02	0.01	0.00	0.05	0.02	0.02	0.03	1.57			0.06	
	34	0.00	0.02	0.02	0.01	0.00	0.06	0.03	0.02	0.04	1.43			0.09	
	36	0.00	0.02	0.02	0.01	0.00	0.05	0.03	0.02	0.03	1.40				
	40	0.00	0.02	0.03	0.01	0.00	0.07	0.04	0.04	0.05	1.06		0.01	0.11	-35.54
	41	0.00	0.02	0.03	0.01	0.00	0.06	0.03	0.03	0.04			0.01	0.09	
	46	0.00	0.01	0.01	0.00	0.00	0.03	0.02	0.01	0.03	1.10				
	47	0.00	0.01	0.02	0.00	0.00	0.04	0.02	0.02	0.03	1.15				
	48	0.00	0.01	0.02	0.01	0.00	0.04	0.02	0.02	0.03	1.28				
Estaciones Ducto 2017	11	0.00	0.02	0.02	0.00	0.00	0.05	0.02	0.02	0.04	1.20			0.05	
	15	0.00	0.02	0.02	0.01	0.00	0.05	0.03	0.02	0.04	1.33		0.00	0.07	
	20	0.00	0.02	0.02	0.01	0.00	0.04	0.02	0.02	0.03	1.27			0.07	
	21	0.00	0.02	0.03	0.01	0.00	0.08	0.03	0.04	0.05	0.70	0.85	0.01	0.24	
	24	0.00	0.01	0.02	0.01	0.00	0.06	0.02	0.03	0.03	1.24	0.87	0.00		
	28	0.00	0.02	0.03	0.01	0.00	0.08	0.04	0.04	0.05	1.04	0.85	0.01	0.18	
	29	0.00	0.02	0.02	0.01	0.00	0.05	0.02	0.02	0.03	1.67	0.75		0.06	
	37	0.00	0.02	0.03	0.01	0.00	0.07	0.04	0.03	0.05	1.05	0.73	0.01	0.11	
	38	0.00	0.02	0.02	0.01	0.00	0.06	0.02	0.01	0.04	1.15			0.05	
	39	0.00	0.02	0.03	0.01	0.00	0.07	0.04	0.03	0.05	1.17		0.01	0.09	
	42	0.00	0.02	0.03	0.01	0.00	0.06	0.03	0.03	0.04	1.06		0.01	0.08	
	45	0.00	0.02	0.03	0.01	0.00	0.07	0.04	0.03	0.05	0.87	0.70	0.01	0.09	
Estaciones Planta 2017	43	0.00	0.02	0.03	0.01	0.00	0.08	0.04	0.03	0.05	0.97		0.01	0.09	
	44	0.00	0.02	0.02	0.00	0.00	0.05	0.02	0.02	0.04	1.13	0.68		0.07	
			no contaminado				moderadamente cont				fuertem cont			muy contaminado	
			no a moderadamente cont				mod a fuertemente cont				muy fuertem cont				

Organic compounds (total petroleum hydrocarbons, polycyclic aromatic and monoaromatic compounds, biomarkers) were not detected in water or sediment of Hokchi Field. These results are consistent with studies conducted in the Southern Gulf of Mexico, in which few compounds have been identified and in low concentrations.

Of the 16 metals analyzed in sediment, cadmium was not detected anywhere, while mercury, selenium and tin were identified in few sites. In general, remaining metals concentration in decreasing order was: Mn > Ba > Zn > V > Cr > As > Ni > Sn > Cu > Co > Pb. The result is similar to what was observed in other studies in the Southern Gulf region, where manganese and barium were also the most abundant metals in sediment.

With regard to the possible environmental effect, arsenic was the only metal exceeding TEL criterion in 80% of sites within Hokchi Field, so it is recommended to monitor its concentrations evolutions. Analysis of enrichment factors and geo-accumulation indices for arsenic indicated their concentrations are highly influenced by human activities, showing in most cases severe and very severe enrichment.

Bathymetry of the lagoon system

Lagoon system El Carmen, Pajonal and La Machona

El Carmen, Pajonal and La Machona lagoons, as well as the Mecoacan lagoon system, are of average depth referred to the mean sea level ranging between 0.90 m and maximum values of 10.0 m in the mouth of Panteones (see next figure). The lagoon bed is sensibly flat and its geomorphic features are distinctive natural tidal channels poorly developed and located in the lagoon mouths, oyster banks abound, the artificial canal is dredged from the mouth of Santa Ana to the estuary of La Redonda, which communicates with the rivers San Felipe and Santa Ana, see lagoon system in the SAR delimitation figure.

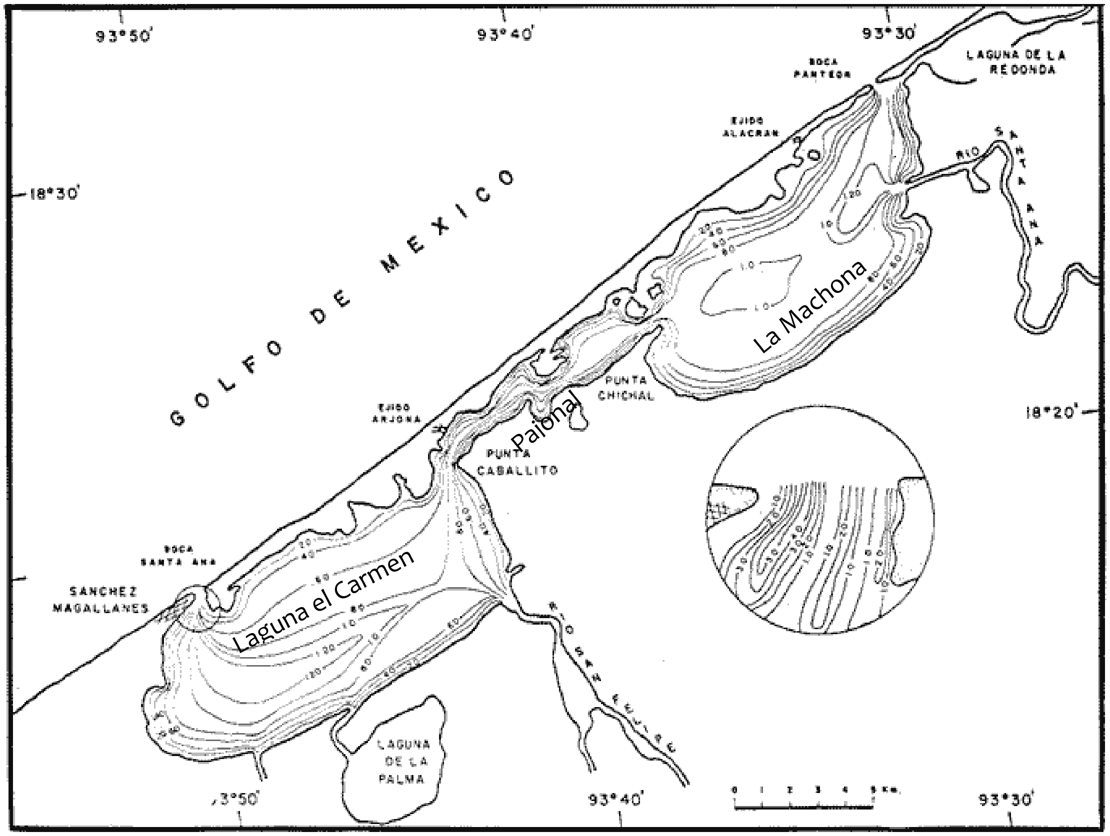


Figure IV. 55 Bathymetric map of Laguna el Carmen, Pajonal and la Machona Source: Institute of Marine Sciences and Limnology-UNAM

Main geomorphic units are: a Gilbert-Beaumont type sandy Litoral barrier, formed by ancient beach lines and sandy dunes; large mangrove swamps developed preferably towards the barrier leeward; a coastal plain formed by fluvio-deltaic sediments, with lagoon remnants and abandoned meanders; and two rivers and several streams that drain into the South bank of the lagoons.

The coastal stream, with an average speed of 25 cm/sec towards the Southwest (SW), brings a lot of sand towards the lagoons. The rate of sandy sedimentation is considerable in lagoon mouths with clear marine influence.

The advanced evolutionary state of the lagoons has been increased by the artificial opening of the Panteones mouth.

Currents velocity and direction correspond to the tidal flow and the wind regime, with a variation range between 0 and 200 cm/s. The highest velocities are observed in the mouths of Santa Ana and Panteones as the tide descends. During storms, water entering the lagoons flows with speeds of up to 150 cm/s, through the two lagoon mouths.

Mecoacan lagoon system

The Mecoacan and Dos Bocas lagoons are related to the terrigenous sedimentation processes of the Mezcalapa river delta. The communication between the lagoons and the Gulf of Mexico is through a wide mouth limited by two Litoral barriers formed by ancient beach cords and dunes. The Mecoacan lagoon is elongated, with its main axis parallel to the coast; the average depth was 1.20 m with maximum values of up to 3.0 m in the Dos Bocas bar and 5.0 m in the El Bellote natural channel. The lagoon floor is noticeably flat and has abundant organic banks. The Dos Bocas lagoon is small, consists of two natural channels surrounding Morelos Island formed with terrigenous sediments (A. Galaviz S. et al, Inst. of Marine Sciences and Limnology.

The Western canal is the deepest, 5.0 m and is the natural communication between the Dos Bocas bar, the Seco River and the Mecoacan Lagoon through another natural channel called El Bellote, in which the average depth was 8.0 m.

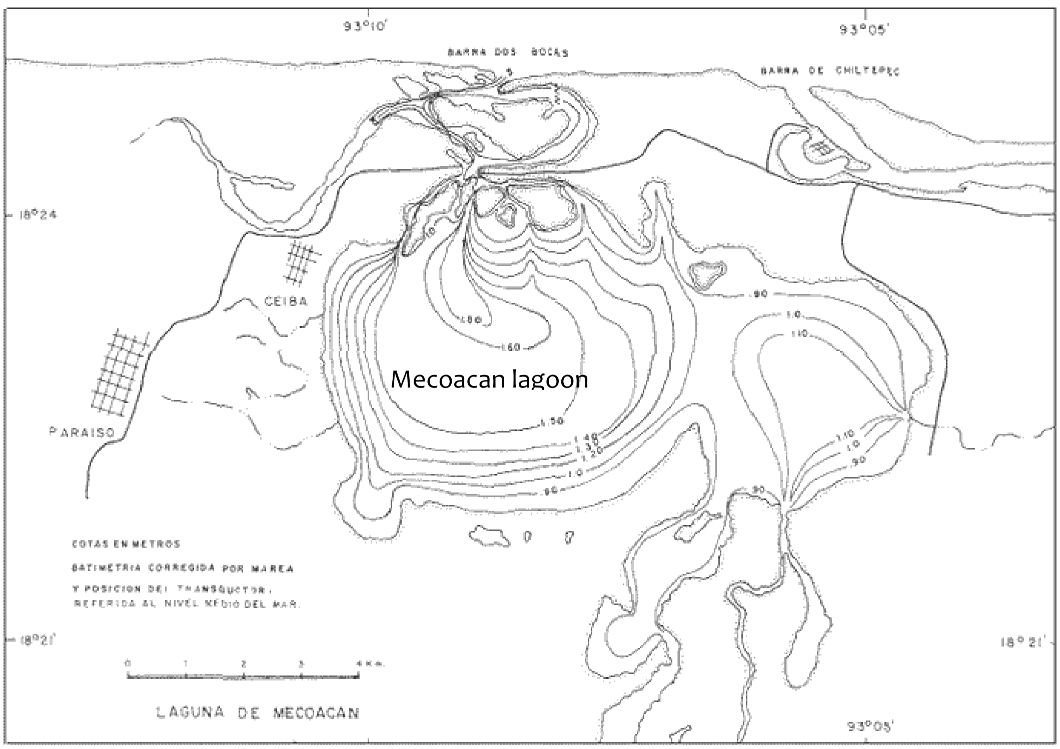


Figure IV. 56 Bathymetric map of the Mecoacan lagoon Source: Institute of Marine Sciences and Limnology-UNAM

The tidal flow is clear on the Dos Bocas bar being quickly damped by friction inward. Its amplitude ranged from 0.7 m in Dos Bocas to 0.05 m in the ensenada del Castro. The velocity of the current ranged between 2 and 90 cm/sec according to the tide and with wind coming from the Northeast (NE). The general movement of lagoon water was almost circular, from West to East. Tide inversions were determined and the tide delay between Dos Bocas and Los Angeles lagoon was 6 hours. Lagoon sediments are terrigenous, mostly sandy-silty, with smaller amounts of clay; they are poorly and very poorly classified. Its lithological distribution is related to water dynamics and the existence of oyster cultivation banks. The average sedimentation rate was 1.5 cm/year with maximum values of 2.0 cm/year. Water visibility fluctuated between 1.20 m in Dos Bocas, 1.00 m in Boca Grande and 0.20 m in most part of the Mecoacan lagoon. The evolutionary state varies from intermediate in the Dos Bocas lagoon to advanced in the Mecoacan lagoon.

This coastal lagoon system is associated with river deltaic systems produced by irregular sedimentation or surface subsidence causing compaction of load effects. They were formed and several have changed over the past 5,000 years; some others are very geologically young (hundreds of years). Sandy barriers are quickly formed, enfolding very shallow marginal or intra-deltaic depressions; low sediment input deltas that can be shallow and often ephemeral, lagoons elongated between beach mounds. It presents typical sandy barriers; runoff can be direct or river water can enter the lagoons through inlets; modifications in shape and bathymetry occur rapidly; energy is usually low, except in canals and inlets; there is typically low salinity, but may show seasonality and short variations in time (A. Galaviz S. et al, Inst. of Marine Science and Limnology).

Water quality in SAR Coastal Lagoon Systems (SLC)

In order to evaluate water quality in sensitive areas where the Project could interact with environmental elements in the delimited SAR for characterization, physicochemical parameters and contaminants of the lagoon system were measured (Laguna el Carmen, La Machona, Barra de Tupilco, Laguna Grande de las las Flores and Mecoacan) in the coastal area of the state of Tabasco that have direct communication with the Gulf of Mexico. In this sense, it can be said that the Project could interact with these ecosystems established there only in the event of an undesired event (leakage, spill or release of hazardous substances) and without taking the relevant actions included in the Emergency Response Plan. Sampling goals were to evaluate the following physicochemical parameters:

- Temperature, dissolved oxygen, pH to determine water quality of these ecosystems.
- Nutrients concentration (nitrites, nitrates, orthophosphates and silicates), as well as suspended solids to establish water quality.
- Compare results obtained with the allowable limits on the protection of aquatic life, published in the Federal Official Journal on December 31, 1998.
- Non-standardized variables at the national level will be compared with international criteria.

One third of Mexico's fresh water is in Tabasco, there are shallow lagoon systems that are part of the entire hydrographic system of the State. Coastal lagoons are Litoral aquatic bodies that have, for the most part, permanent or ephemeral communication with the sea and are the result of the encounter between two bodies of water of various characteristics.

The aforementioned causes peculiar phenomena in their physical, chemical and biological behavior, with consequent ecological patterns. They are the result of three fundamental characteristics: nutrients supply from rivers, organisms penetration by sea and organic matter supply by mangroves, presenting a high potential productivity; receiving a considerable energy subsidy, coupled with fundamental ecological processes in these systems, the available energy is clearly higher compared to that of other aquatic ecosystems, therefore any alteration of these components results in the modification of ecosystem properties (Contreras, 1991).

They represent one of the most productive ecosystems in the country (Contreras and Zavalegui, 1988). These systems show a marked individuality; however, they are governed by some factors “common” to all of them, such as the mixture of freshwater and marine water, resulting in their high primary productivity (Contreras, 1991). Coastal lagoons represent an excellent recruitment and growth habitat for a significant number of commercially important species, whose life cycle includes estuarine and marine phases (De la Lanza, 1991).

In Mexico, el Carmen-Machona and Mecoacan lagoons in Tabasco stand out for their size and productivity.

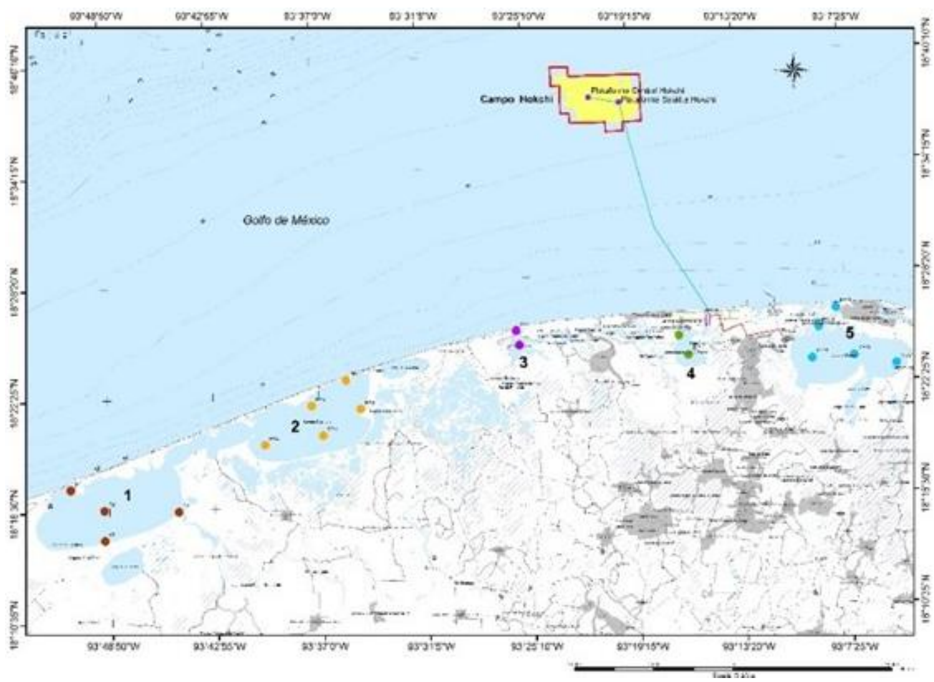


Figure IV. 57 Location map of sampling points of the Lagoon System

Thus, during the month of March of this year, water and sediment sampling was carried out in the main lagoon systems where they could be affected by the activities to be carried out by the Project.

In SAR, phenomena cause and influence physical, chemical and biological behavior and their consequent ecological patterns are the result of three fundamental characteristics:

Nutrients supply from rivers, organisms penetration by sea and organic matter supply by mangroves, presenting a high potential productivity; receiving a considerable energy subsidy, coupled with fundamental ecological processes in these systems, the available energy is clearly higher compared to other aquatic ecosystems, therefore, any alteration of these components results in ecosystem properties modification (Contreras, 1991).

They represent one of the most productive ecosystems in the country (Contreras and Zavalegui, 1988). These systems show a marked individuality; however, they are governed by some factors “common” to all of them, such as the mixture of freshwater and marine water, resulting in their high primary productivity (Contreras, 1991). Coastal lagoons represent an excellent recruitment and growth habitat for a significant number of commercially important species, whose life cycle includes estuarine and marine phases (De la Lanza, 1991).

In Mexico, el Carmen-Machona and Mecoacan lagoons in Tabasco stand out for their size and productivity. Table IV.17 presents a summary of the physicochemical variables evaluated in the field and analyzed in the laboratory of five lagoon systems.

Table IV. 17Results of basic physicochemical parameters to determine water quality of some lagoon systems in Tabasco, Mexico, March 2018.

Sistema Lagunar	ESTACIÓN	OXIGENO		pH		SALINIDAD		TEMPERATURA		TURBIEDAD		SOLIDOS SUSP.	
		SUP.	FONDO	SUP.	FONDO	SUP.	FONDO	SUP.	FONDO	SUP.	FONDO	SUP.	FONDO
Del Carmen	C1	7.44	7.33	6.5	7.9	38.3	37.9	28	28	0.45	0.4	<10	26
	C2	7.38	4.51	8	7.9	21.75	24.2	28	28	1.1	2.6	20	12
	C3	8.34	8.25	8	8.2	21.48	21.49	30	30	2.4	7.1	45	38
	C4	7.2	6.5	7.8	7.8	18.02	19.53	30	30	4.3	6.6	23	77
	Promedio	6.94	10.66	6.65	11.07	24.89	25.78	29.00	29.00	2.06	4.18	29.33	38.25
	D. Est.	3.74	13.16	3.81	12.83	9.10	17.45	13.77	13.67	11.00	18.66	23.12	39.09
	Mínimo	0.81	3.57	0.68	3.39	18.02	19.53	28.00	28.00	0.45	0.40	20.00	12.00
	Máximo	10.72	46.31	9.21	45.64	38.30	37.90	30.00	30.00	4.30	7.10	45.00	77.00
	N	9	9	9	9	4	4	4	4	4	4	3	4
Machona	MA5	7.19	7.14	8	8	2.71	2.77	29	28	16	22	39	40
	MA6	6.96	7.01	7.2	7.8	5.23	5.16	27	28	36	37	119	81
	MA7	7.64	*	8.3	*	2.96	*	28	*	28	*	50	*
	MA8	8.2	8.4	7.8	8	2.22	2.67	29	29	38	25	49	58
	MA9	7.97	7.18	8.1	8	3.36	3.3	28	28	18	20	42	49
	Promedio	7.11	10.69	7.08	11.19	3.30	3.48	28.20	28.25	27.20	26.00	59.80	57.00
	D. Est.	2.35	10.92	2.26	10.58	1.16	1.85	0.84	12.64	10.06	13.37	33.42	29.70
	Mínimo	0.81	3.57	0.68	3.39	2.22	2.67	27.00	28.00	16.00	20.00	39.00	40.00
	Máximo	10.72	46.31	9.21	45.64	5.23	5.16	29.00	29.00	38.00	37.00	119.00	81.00
	N	14	13	14	13	5	4	5	4	5	4	5	4
Tupilco	T10	6.93	*	6.7	*	**	*	28	*	13	*	15	*
	T11	7.03	6.95	7.7	7.6	**	**	31	31	29	23	30	31
	Promedio	6.98	6.95	7.20	7.60	#¡DIV/0!	#¡DIV/0!	29.50	31.00	21.00	23.00	22.50	31.00
	D. Est.	0.07	4.91	0.71	5.37	0.00	0.00	2.12	21.92	11.31	16.26	10.61	21.92
	Mínimo	6.93	6.95	6.70	7.60	0.00	0.00	28.00	31.00	13.00	23.00	15.00	31.00
	Máximo	7.03	6.95	7.70	7.60	0.00	0.00	31.00	31.00	29.00	23.00	30.00	31.00
	N	2	1	2	1	0	0	2	1	2	1	2	1
El Zorro	Z12	8.32	7.45	8.1	8.1	**	**	27	27	16	18	22	21
	Z13	7.62	7.45	8.2	8.2	**	**	27	27	18	22	28	31
	Promedio	7.97	7.45	8.15	8.15	#¡DIV/0!	#¡DIV/0!	27.00	27.00	17.00	20.00	25.00	26.00
	D. Est.	0.49	0.00	0.07	0.07	0.00	0.00	0.00	0.00	1.41	2.83	4.24	7.07
	Mínimo	7.62	7.45	8.10	8.10	0.00	0.00	27.00	27.00	16.00	18.00	22.00	21.00
	Máximo	8.32	7.45	8.20	8.20	0.00	0.00	27.00	27.00	18.00	22.00	28.00	31.00
	N	2	2	2	2	0	0	2	2	2	2	2	2
Mecoacán	ME14	8.31	8.44	8.1	8.1	30.9	33.3	26	26	8	21	69	124
	ME15	7.07	6.96	6.6	6.7	20.65	19.94	28	29	4	6.5	25	34
	ME16	7.07	6.64	6.9	6.8	14.16	14.37	27	29	7	13	31	29
	ME17	6.89	*	7.4	*	9.92	*	27	*	7	*	26	*
	ME18	8.64	8.8	8.1	8.1	30.9	35.9	25	26	12	24	68	124
	Promedio	7.60	7.71	7.42	7.43	21.31	25.88	26.60	27.50	7.60	16.13	43.80	77.75
	D. Est.	0.81	3.57	0.68	3.39	9.56	14.65	1.14	12.39	2.88	9.95	22.66	57.89
	Mínimo	6.89	6.64	6.60	6.70	9.92	14.37	25.00	26.00	4.00	6.50	25.00	29.00
	Máximo	8.64	8.80	8.10	8.10	30.90	35.90	28.00	29.00	12.00	24.00	69.00	124.00
	N	5	4	5	4	5	4	5	4	5	4	5	4

* no se tomó muestra — SUP.= Nivel de superficie — UNT = unidad nefelométrica de turbidez

** <2 partes por mil — FDO.= Fondo

El Zorro or L. Grande de las Flores

Also are included a temporal and spatial distribution graphical representation of the reported concentrations product of sampling in each lagoon system; in addition, and, depending on the parameter in question; it is important to mention that for this report it was based on the same criteria used by the then INE (National Institute of Ecology of 2007) in its extensive study on “Water quality in coastal ecosystems in Mexico” where a comparison is made, first with NOM-001 (1969, Ecological Criteria for Water Quality (1989) and Regulations for Water Contamination Prevention and Control (1973) established and in force by Mexican environmental authorities.

In the event parameters are not included because there is no regulatory framework in question, bibliographic references of previous studies within the area or similar or equivalent systems at national and international level were consulted, in this way for:

Salinity

It is a conservative property and its variations in lagoon systems are mainly due to the influx of rivers, rains or evaporation, with respect to this parameter it was decided to analyze al Carmen-Machona lagoon system separately, the Western (W) section of the lagoon identified as El Carmen, of the Eastern (E) part identified as Machona, due to the following data behavior:

In the El Carmen section the surface average was 24.89 ppmil with intervals between 18.02 and 38.30 ppmil; in bottom the average concentrations were 25.78 ppmil with intervals between 19.53 and 37.90 ppmil. As for what was found in Laguna Machona the average surface values were an order of magnitude lower compared to the previous body, with an average of 3.30 ppmil with an interval between 2.22 to 5.23 ppmil, in bottom an average concentration of 3.48 ppmil and minimum and maximum values of 2.67 to 5.16 ppmil, respectively.

In both laguna de Tupilco and el Zorro (Laguna Grande de las Flores) values detected in all seasons reported values < 2 ppmil.

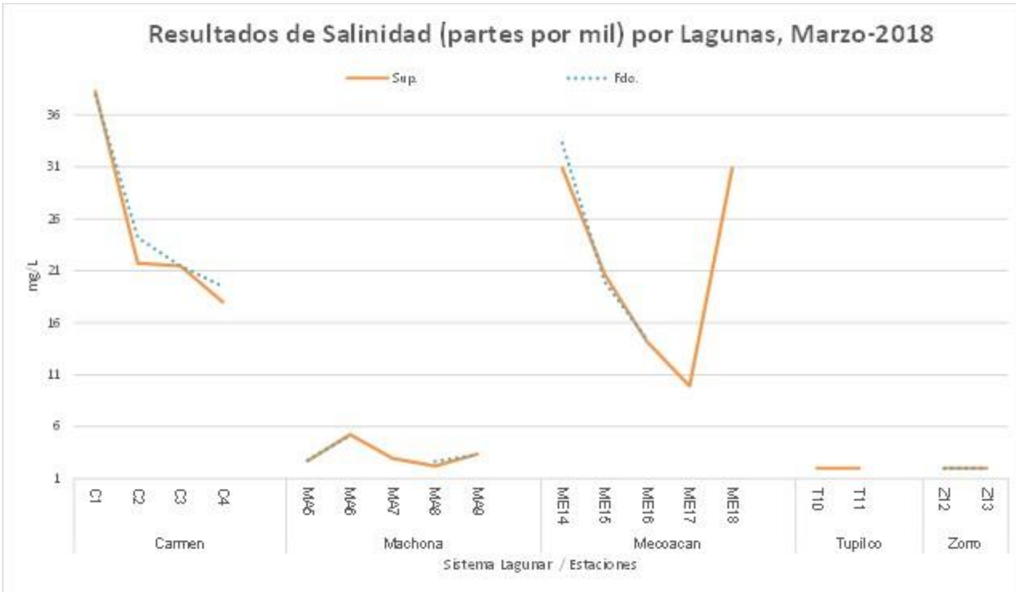


Figure IV. 58 Distribution of sampling stations in Tabasco lagoon systems, sampled in March 2018.

According to Gonzalez et al., 2017, system behavior is strongly influenced by sea dynamics through the mouth (Boca Santa Ana) connecting the system with the sea, salinity behavior found in el Carmen-Machona system, according to the reference author simulations, would correspond to the rains season reported for 1974, where the Eastern part of the system (La Machona) presents salinities less than 3.9 G/l, and the Western one, salinities, especially near the mouth of Santa Ana, of a marine system, Figure IV.59.

Data obtained in the March sampling of this year presented this behavior, where Laguna el Carmen is the most salinized of the two, so it could suggest it is a behavior already reported in the system and therefore is a natural condition of this parameter in that system.

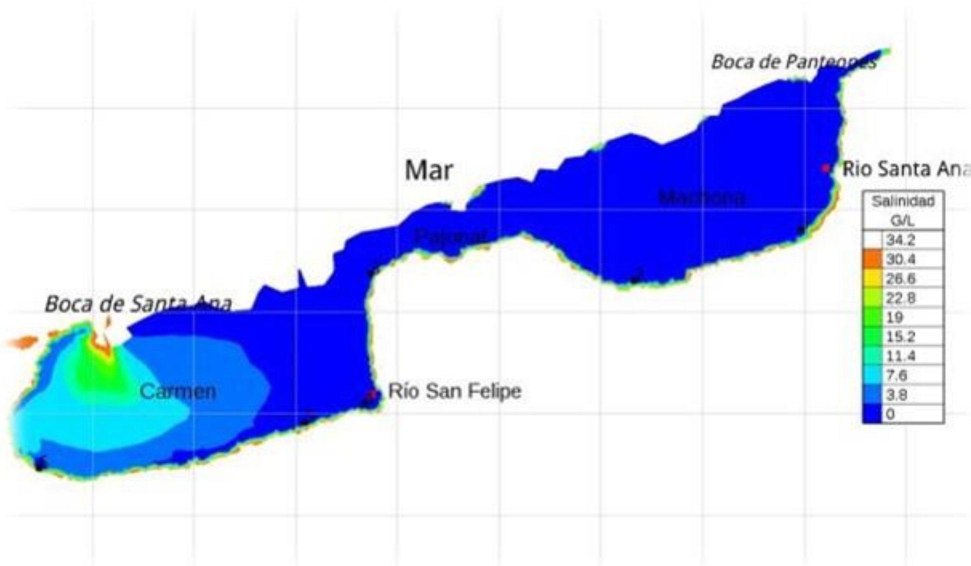


Figure IV. 59 Salinity distribution in rainy season in October 1974, taken from Gonzalez et al., 2017.

With regard to the lagoons in Tupilco and Laguna Grande de las Flores (El Zorro), taking as an example the previous system, by having no contact with the sea salinity is not affected, explains low salinity values and would also represent a natural condition of the system.

Meanwhile, in the Mecoacan Lagoon the average surface values were 21.31 ppmil and intervals between 9.92 and 30.90 ppmil.

Of this latter system, studies conducted in Mecoacan by García-Cubas,1989 throughout the year show wide variations differing in the Eastern and Western portions of the main lagoon basin, mainly related to rainfall contributions and currents circular movement. Galaviz-Solís et al. (1987) indicate salinities of 8 to 16% in the winter; for the summer the Eastern part shows low values ranging from 9 to 15% and contrast with those of the Western portion of the lagoon which vary from 19 to 28%; for autumn, they indicate values of 6 to 15%.

In this way, what was found in March 2018 is reasonably adjusted to the aforementioned variations and therefore, values found in March 2018, would represent natural conditions of the system are clearly influenced by the ebb of tide at the site near the mouth of Santa Ana and the lowest values of water lagoon with fluvial influence in the vicinity of rivers within the lagoon, while in waters without marine or fluvial influence (station C2) there are intervals between 21 and 24 ppmil.

Hydrogen potential (pH)

In el Carmen-Machona lagoon system, surface values were reported with a central measurement of 7.74 pH units (UpH) within an interval of 6.50 to 8.30. In the background, the average obtained was 7.95 with an interval between 7.80 and 8.20 UpH.

In the Tupilco lagoon, average surface values of 7.20 UpH were reported at intervals of 6.70 to 7.70 UpH; in the bottom, only one season was possible to determine and the value was 7.60 UpH.

On the other hand, in Laguna del Zorro the surface and bottom values in both cases were the same where average values of 8.15 UpH with intervals of 8.10 to 8.20 UpH.

The lagoon de Mecoacan system on average surface 7.42 UpH with 6.60 to 8.10 UpH interval, in the background the average was 7.43 UpH with an interval between 6.70 to 8.10 UpH.

Figure IV.60 generally shows the highest average values were presented at bottom level in all systems, however, it should be highlighted that all reported values are within the allowed range in NOM-001-ECOL-1996 for wastewater discharges in water and national assets, which is 5 to 10 UpH, so for this parameter does not represent any risk and its variations are due to climatic conditions pertaining to the season in all lagoon systems evaluated.

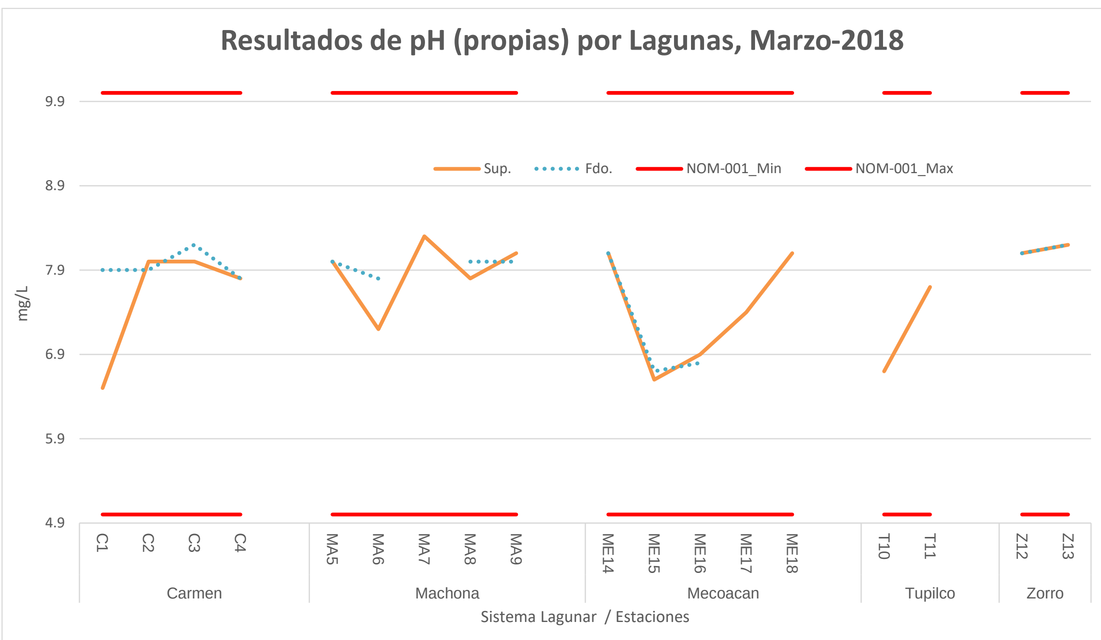


Figure IV. 60 pH Results (UpH) in surface and bottom of the water column, sampled in March 2018 in 5 lagoon systems of Tabasco.

Water temperature

Figure IV.61 shows the results of surface and bottom temperature in the water column sampled in March 2018 in the 5 lagoon systems of Tabasco.

The temperature in the Carmen-Machona system at surface level presented as central measurement an average of 28.56°C with intervals between 27 and 30°C. On the other hand, an average of 28.63 °C and intervals from 28 to 30°C were detected at bottom level.

In the Tupilco lagoon system the surface average was 29.5°C and intervals from 28 to 31°C, at bottom level there is only one station recording a 31°C value.

In laguna del Zorro, on the other hand, stable temperature values of 27°C were detected at both surface and bottom level.

Finally, in the Mecoacan lagoon, surface average was 26.60°C and intervals from 25 to 28°C, meanwhile, at bottom level the average detected was 27.5 with intervals of 26 to 29°C.

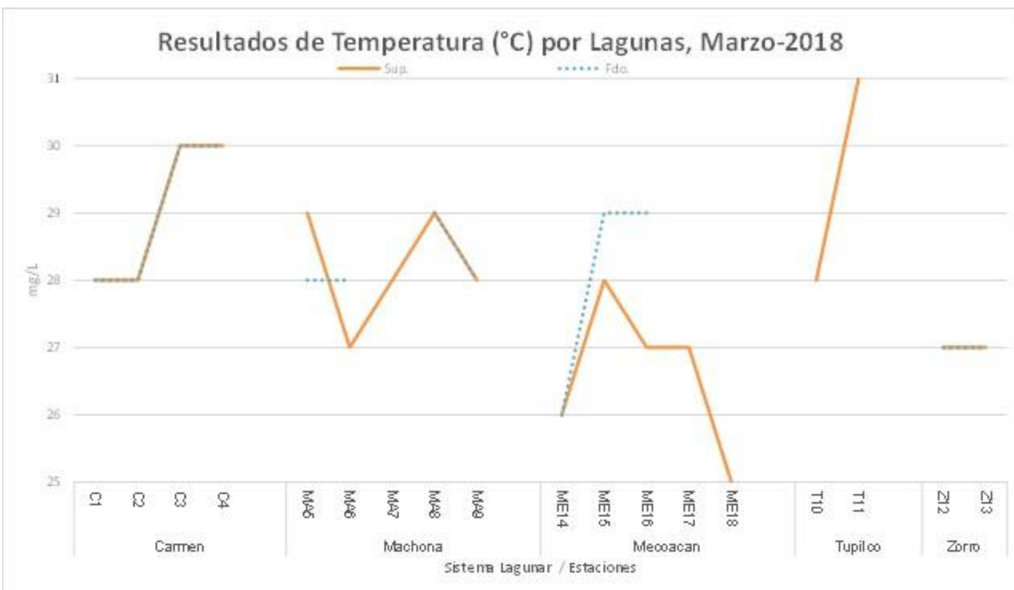


Figure IV. 61 Results temperature (°C) in surface and bottom of the water column, sampled in March 2018 in 5 lagoon systems in Tabasco.

For the Carmen-Machona Galaviz lagoon system, 1980 reported quality temperatures in lagoon water with mean values of 30°C in the mouth of the lagoons the temperature varied from temperate (25°C) to warm (33°C), in the reflux. Surface drainage provided warm water at intervals from 29 to 33°C, towards the southern portion of the lagoons. Insolation and mixing processes resulted in water temperature in lagoon areas without fluvial or marine influence will vary from 27 to 32°C.

On the other hand, García-Cubas, 1990, reported in the Mecoacan lagoon, in turn, likewise, warm waters with an average of 28°C and an annual variation of around 7°C during most of the year. The minimum temperatures are recorded in winter, coinciding with the "Northerlies" season (24-25°C) and the highest temperatures in early autumn (28.5 to 32°C). CECODES 1981, reported for the month of March temperatures vary within the lagoons between 28 and 28.5°C; between 29 and 30°C for the month of June; between 28.5 and 32°C in October and the lowest are recorded in the month of January, with variations from 23.9 to 24°C.

In conclusion, temperatures of all lagoon systems sampled in March 2018 follow the patterns mentioned in specialized literature, with a tendency to be identified as warm lagoons and their behavior corresponds normally to dry seasonality.

Dissolved Oxygen

For the waters of the Carmen-Machona lagoon system, surface values with central measurement of 7.59 mg/L were reported within an interval of 6.96 to 8.34 mg/L. In the bottom, average obtained was 7.04 with an interval between 4.51 and 8.40 mg/L.

In the Tupilco lagoon, surface average values were reported in the lowest of the 5 systems with 6.98 mg/L with intervals of 6.93 to 7.03 mg/L; in the bottom, only one season was possible to determine and the value was 6.95 mg/L.

In laguna del Zorro the highest average value of all lagoons for surface with 7.97 mg/L with an interval of 7.62 to 8.32 mg/L, meanwhile, at bottom level the representative value, having the same readings was 7.45 mg/L.

Finally, the lagoon system of Mecoacan in surface found an average of 7.60 mg/L with 6.89 to 8.64 mg/L interval, in the bottom the average was 7.71 mg/L and a minimum and maximum intervals of 6.64 to 8.80 mg/L, respectively.

Figure IV.62 shows in general a relatively homogeneous behavior in all systems, the highest concentrations at surface level, however, when considering a minimum allowable limit established in the Ecological Criteria, 1989, which is 5 mg/L (for the protection of aquatic life in freshwater and marine water) most (17 of 18 data) is within the limit established by the Mexican environmental authority and only one does not meet such criteria; in this case, said phenomenon presented at C2 station (4.51 mg/L) of Laguna el Carmen at bottom level.

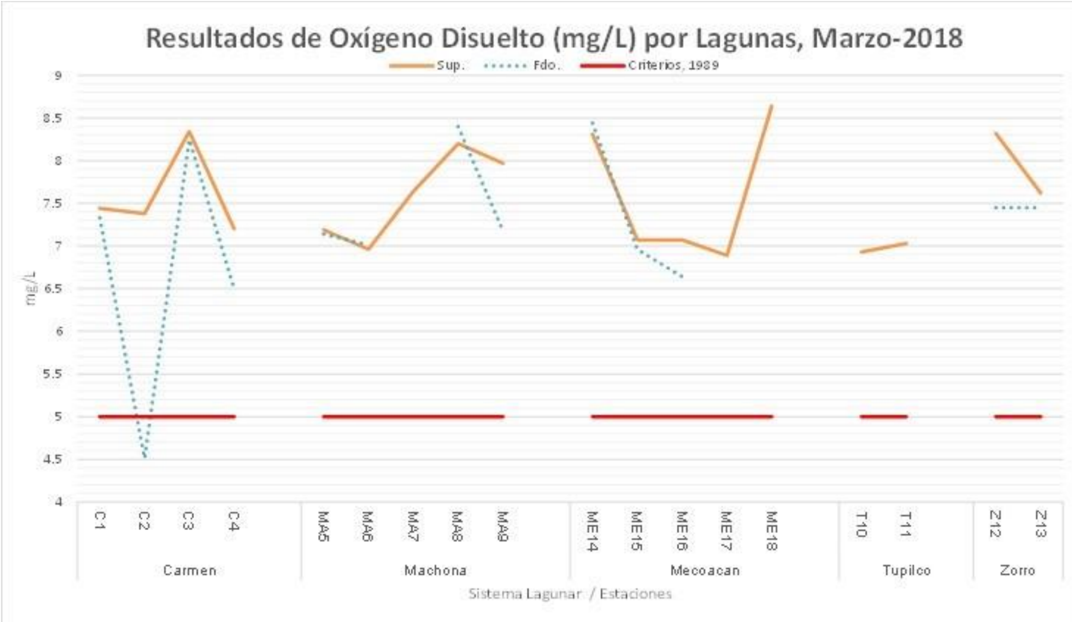


Figure IV. 62 Dissolved oxygen results (mg/L) in surface and bottom of the water column, sampled in March 2018 in 5 lagoon systems in Tabasco.

Station C2 is located practically in the center of the lagoon, apparently away from direct influences of the mouth tide and the fluvial inputs of the rivers that flow into it. Therefore, the reference result reflects a phenomenon of hypoxia at that point (which would require its comparison with other variables to explain this behavior), but the immediate consequence for these oxygen concentrations, according to literature is the disappearance of sensitive organisms and species.

Total Suspended Solids (SST)

Figure IV.63 shows the results of total suspended solids (SST) in surface and bottom in the water column sampled in March 2018 in the 5 lagoon systems of Tabasco.

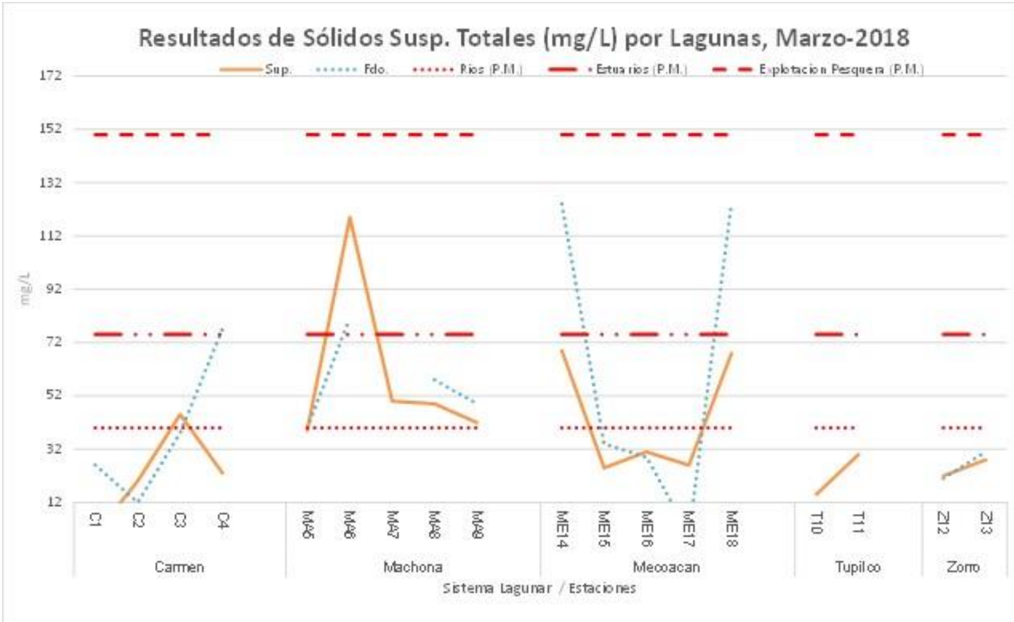


Figure IV. 63 Results of total suspended solids (SST) in surface and bottom of the water column, sampled in March 2018 in Tabasco's 5 lagoon systems.

Just like salinity in el Carmen-Machona lagoon system, SST will be analyzed separately, per Western (W) Laguna El Carmen and Eastern (E) Machona section, due to the following data behavior:

In el Carmen lagoon, the average surface presented values with central measurement of 29.33 mg/L and intervals from 20 to 45 mg/L; in the bottom, average concentrations were 38.25 mg/L with intervals between 12 to 77 mg/L. On its part, in Laguna Machona average surface values were 59.80 mg/L and intervals from 39 to 119 mg/L, in bottom an average of 57 mg/L was reported, with intervals between 40 and 81 mg/L.

In the case of Tupilco lagoon values were as follows; surface average was 22.50 mg/L with intervals of 15 to 30 mg/L, for bottom level it was reported only in one season, the detected value was 31 mg/L.

In Laguna del Zorro, on its part, average values were 25 mg/L and intervals from 22 to 28 mg/L, in bottom the average values detected were 26 mg/L with intervals of 21 to 31 mg/L.

Finally, the Mecoacan lagoon presented a surface level in an average of 43.80 mg/L and intervals from 25 to 69 mg/L, at bottom level the average detected was 77.75 mg/L with a wide interval of 29 to 124 mg/L.

Figure IV.63 includes, together with values obtained in the March 2018 sampling, maximum allowable limits (monthly average) for basic contaminants in wastewater discharges into water and national assets related to: Aquatic life protection in rivers (40 mg/L) and coastal waters with estuaries (75 mg/L) and fishing exploitation (150 mg/L), included in NOM-001-ECOL-1996.

Therefore, from this reference we can conclude that: averages of SST concentrations in Laguna el Carmen, Tupilco and Laguna del Zorro are the only lagoon systems with all their surface and bottom values below all reference limits. Let us remember that in graph 7.2.5.7 it represents net values obtained in each sample, so that only some point values come out from this behavior, for example in station C3 (Surface) and C4 (Bottom).

In the same order of ideas, the Machona and Mecoacan lagoons except for three stations (MA6, ME14 and ME18) which are > 100 mg/L, their reported values are below the average of 75 mg/L allowed estuaries.

Finally, none of the lagoon systems exceeds the fishing exploitation limit of 150 mg/L.

Therefore, it is concluded for this parameter values detected in lagoon systems assessed they do not represent a pollution problem in the water column for the development of aquatic life.

Turbidity

Figure IV.64 shows the results of surface and bottom turbidity in water column sampled in March 2018 in the 5 lagoon systems of Tabasco.

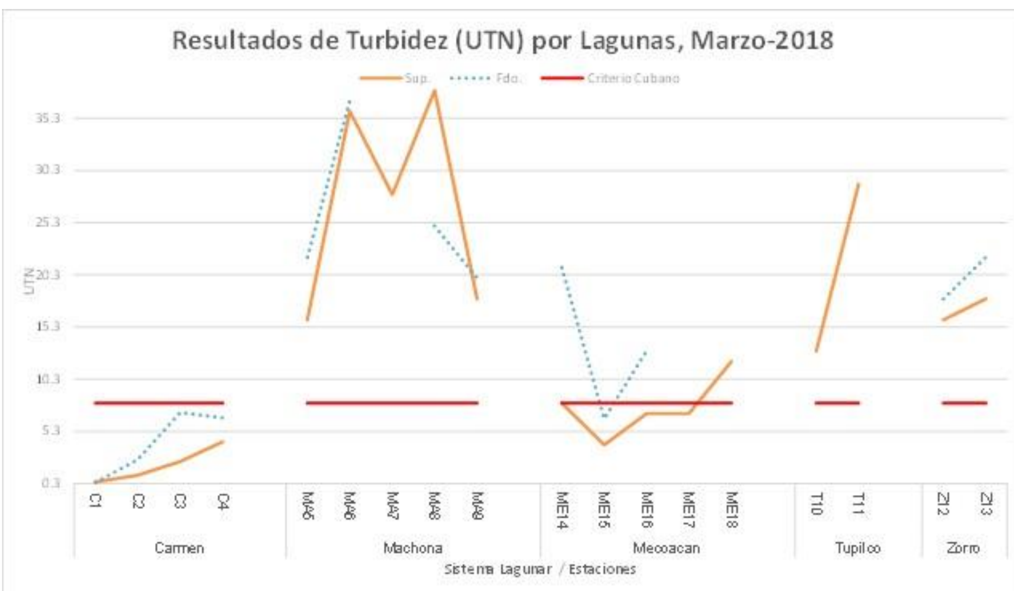


Figure IV. 64 Turbidity (UTN) results on surface and bottom of the water column, sampled in March 2018 in Tabasco's 5 lagoon systems.

Just like salinity and total suspended solids, in the lagoon el Carmen-Machona system turbidity will be analyzed separately, by Western (W) Laguna el Carmen and Eastern (E) Machona section, due to the following data behavior:

In el Carmen lagoon, surface average showed values with a central measurement of 2.06 UTN and intervals from 0.45 to 4.30 UTN; in bottom, average concentrations were 4.18 UTN with intervals between 0.40 to 7.10 UTN. On its part, in Laguna Machona, average surface values were 27.20 UTN and intervals from 16 to 38 UTN, in bottom, an average of 26 UTN was reported, with intervals between 20 and 37 UTN.

Galaviz, 1980, identified particularly in el Carmen - La Machona lagoon system, water turbidity in the Santa Ana mouth, had a transparency of up to 2.20 m approximately. Towards the South and East (E) of La Machona lagoon, turbidity was 0.50 m.

Decrease in transparency, explains the reference, was due to the mixing of marine waters with those inside the lagoon and those coming from the Santa Ana river, which are abundant in suspended solids. Another factor significantly influencing turbidity in this system is the removal of fine sediments from the lagoon floor, caused by wind waves, which increases water turbidity reducing visibility in an interval that can range from 20 centimeters to one meter.

Evidently, results of la Machona are significantly higher than those identified in el Carmen lagoon, this could be explained because the depth in this system, on average is lower, which facilitates various phenomena such as swell caused by winds favoring waters mixing, causing as a consequence removal of fine sediments.

In the case of Tupilco lagoon, values were as follows; the average surface was 21 with intervals of 13 to 29 UTN, for the bottom level it was reported only in one season, the detected value was 23 UTN.

In Laguna del Zorro, on its part, average values were 17 UTN and intervals from 16 to 18 UTN; in bottom, average values detected were 20 UTN with intervals of 18 to 22 UTN.

Finally, in the Mecoacan lagoon there was an average of 7.60 UTN at surface level and intervals from 4 to 12 UTN; at bottom level the average detected was 16.13 UTN with a wide interval of 6.5 to 24 UTN.

According to Betanzos, et al, 2011, turbidity has a direct relationship with water color and total solids, and inverse with transparency. It proposes turbidity intervals (Table IV.18.) determined can be used as quality indices for marine waters quality assessment for fishing use, identifying as good quality values less than five Turbidity Units (NTU).

Table IV. 18 Turbidity quality intervals obtained as a function of transparency, modified by Betanzos, et al., 2011.

Variable	Good	Doubtful	Bad
Turbidity (NTU)	0-5	5-8	>8
Transparency (%)	100-50	50-20	<20

Therefore, and taking as the appropriate proportion the reference, because it was determined in coastal sea water, we could say that: turbidity concentrations in el Carmen lagoon is the only lagoon system with all its “Good” values in surface and bottom, where turbidity is low, meaning water transparency is optimal for light penetration, would follow on this scale, the Mecoacan lagoon, where most surface values are good and few bottom are in “good” range.

Finally, the Tupilco lagoons, Laguna de las Flores (El Zorro) and La Machona, both in surface and bottom, have values higher than 8, classifying them as “bad” where turbidity is higher and water transparency bad, stands out from the last three systems la Machona with the highest turbidity values in all systems assessed.

Nutrients

In Table IV.19, nutrient statistics are presented, for the case of ammoniacal nitrogen the lowest values were presented in Laguna el Carmen and Mecoacan stations and the highest concentrations in Machona, Tupilco and el Zorro stations; however, in the five lagoons the values exceeded interval maximum value reported in water quality and literature criteria (Table IV.20).

Ammonium

Ammonium is a very common form in these ecosystems and its permanence is constant throughout the annual cycle, sometimes its decrease is related to greater photosynthetic activity or water higher oxygenation, although it is not a rule. In general, the amount of ammonium present in lagoon waters is closely related to biological processes with heterotrophic characteristics, both in the water column and in sediments (Contreras et al. 1996).

Nitrites

In the case of nitrites, a behavior similar to that of ammoniacal nitrogen was obtained with the lowest values in Laguna el Carmen and Mecoacan stations, and the highest in Machona, Tupilco and Zorro. In the entire study area values were below 0.024 mg/L, lower or equal to those reported in the water quality ecological criteria and those in literature of 0 .02 and 0.07 mg/L respectively (Table IV.20).

Nitrates

With regard to nitrates, lowest concentrations of this nutrient were found in el Carmen, Machona and Mecoacan lagoons. Tupilco and Zorro obtained values above 0.05 mg/L. El Carmen, Machona and Mecoacan lagoons did not exceed water quality concentrations ecological criteria and of literature of 0.036 and 0.04 mg/L respectively (Table IV.20).

Nitrates and nitrites average values tend to be lower compared to those of ammonium, often maximum are reached during the rainy season. Nitrogenated forms, the dominant is ammonium and whose relation to total inorganic nitrogen ranges from 60 to 98%, the aforementioned has a strong relationship with the presence and dominance with nanophythoplanktonic forms which manifest a considerable contribution to total biomass of phytoplankton, since as has been proven nanophythoplankton captures preferably regenerated nitrogen (ammonium), while microphytoplankton does it with new nitrogenated forms (nitrates), (Contreras et al., 1996).

Phosphates

The results in total phosphorus and total phosphates in lagoons were to obtain a behavior similar to that of ammoniacal nitrogen and nitrites with the lowest values in Laguna el Carmen and Mecoacan stations, and the highest in Machona, Tupilco and Zorro. Mecoacan lagoon stations, as well as two stations of Laguna el Carmen in surface and bottom showed total phosphorus values below the maximum value reported in literature of 0.14 mg/L. With respect to total phosphates, all sampling points in the five lagoons were above concentrations reported in the criteria and literature of 0.002 and 0.034 mg/L, respectively (Table IV.20).

Nutrients seasonal variations are wide. The highest concentrations are located after the rainy season, when in addition to the autochthonous elements, those coming from terrigenous dragging originated by rivers are added.

Minimum concentrations are detected after spring phytoplankton flowering but even in these months nutrients are detected in higher amounts than those available in the nearby marine area (Contreras et al., 1996).

Silica

Silicon dissolved in water (Si (OH_4) has a variable concentration (higher in inland waters) and is normally in excess with respect to nitrogen and phosphorus, except in areas of domestic discharges and in large diatom blooms. Dissolved silica is called reactive because it responds to colorimetric test with Molybdate, acquiring a typical blue color. In this way, reactive silica values in the five lagoons obtained values in an interval of 0.91 and 15.32 mg/L. The lowest concentrations were present in el Carmen and Mecoacan lagoon with a minimum value of 0.91 mg/L in surface water in el Carmen and a maximum of 10.2 mg/L in Mecoacan in surface water. On the other hand, the highest concentrations were in Machona, Tupilco and Zorro with a minimum value of 9.92 mg/L in bottom water in Machona lagoon and the maximum in el Zorro surface water with 15.32 mg/L. All obtained values are above the interval of 0.65-3.32 mg/L of silicates reported in literature (Table IV.19.).

Table IV. 19 Water column nutrient statistics in March 2018

Nutrients (mg/L)	Level	Carmen Resorts					Machona Stations					Tupilco Stations		
		min	max	average	n	CV	min	max	average	n	CV	min	max	n
Ammonia Nitrogen	AREA	0.013	0.032	0.022	4	35.8	0.156	0.334	0.255	5	25.2	0.211	0.231	2
	BOTTOM	0.007	0.039	0.022	4	64.1	0.181	0.214	0.201	4	7.1		0.156	1
Nitrite Nitrogen	AREA	0.004	0.009	0.007	4	30.5	0.010	0.021	0.014	5	31.9	0.023	0.024	2
	BOTTOM	0.004	0.007	0.005	4	28.6	0.009	0.018	0.012	4	32.9		0.013	1
Nitrate Nitrogen	AREA	0.003	0.007	0.005	4	32.9	0.002	0.036	0.012	5	129.8	0.055	0.062	2
	BOTTOM	0.003	0.006	0.004	4	37.4	0.002	0.023	0.010	4	105.8		0.069	1
Total Phosphorus	AREA	0.032	0.256	0.144	4	64.2	0.340	0.413	0.364	5	8.4	0.495	0.518	2
	BOTTOM	0.032	0.234	0.144	4	62.6	0.340	0.387	0.358	4	6.0		0.571	1
Total Phosphates	AREA	0.097	0.783	0.438	4	64.4	1.041	1.263	1.114	5	8.3	1.516	1.586	2
	BOTTOM	0.098	0.717	0.440	4	62.7	1.039	1.185	1.095	4	6.1		1.748	1
Reactive Silica	AREA	0.910	8.450	4.988	4	62.4	10.21	13.16	11.834	5	11.5	10.80	11.83	2
	BOTTOM	1.100	8.800	4.475	4	72.9	9.92	12.12	11.228	4	9.4		11.54	1

Continued...

Table IV.19. Water column nutrient statistics in March 2018

Nutrients (mg/L)	Level	el Zorro Stations			Mecoacan Stations				
		min	max	n	min	max	average	n	CV
Ammonia Nitrogen	AREA	0.193	0.243	2	0.009	0.067	0.035	5	70.5
	BOTTOM	0.170	0.179	2	0.018	0.023	0.021	4	11.6
Nitrite Nitrogen	AREA	0.014	0.017	2	0.003	0.007	0.005	5	40.0
	BOTTOM	0.014	0.017	2	0.003	0.010	0.006	4	56.5
Nitrate Nitrogen	AREA	0.096	0.153	2	0.002	0.020	0.007	5	121.8
	BOTTOM	0.083	0.145	2	0.002	0.019	0.007	4	111.6
Total Phosphorus	AREA	0.525	0.560	2	0.046	0.093	0.073	5	26.4
	BOTTOM	0.516	0.557	2	0.047	0.084	0.068	4	22.6
Total Phosphates	AREA	1.608	1.715	2	0.142	0.284	0.225	5	26.1
	BOTTOM	1.579	1.706	2	0.144	0.256	0.207	4	22.4
Reactive Silica	AREA	11.88	15.32	2	2.860	10.22	6.788	5	51.3
	BOTTOM	11.29	15.12	2	1.790	9.970	5.485	4	75.7

Parameters (mg/L)	Values obtained during the campaign	Values Reported in Literature. LAGUNAS Y BAHÍAS DEL GOLFO (LB/G), Herrera-Silveira *et al.* 2004 and Contreras *et al.* 1996
Ammonia Nitrogen	**Machona, Tupilco and el Zorro. 100 % Above the maximum value in literature and NOM 0.01**	Minimum value 0.07 mg/L. Maximum value 0.145 mg/L. Herrera-Silveira et al. 2004 NOM-001 of 0.01 mg/L
Nitrites	**The five lagoons 100% < at the upper interval of literature**	Minimum value 0.005 mg/L Maximum value 0.015 mg/L Herrera-Silveira et al. 2004 0.00014-0.07 mg/L (Contreras, 1996) 0.02 mg/L (CECA, 1989) nitrites
Nitrates	**Tupilco and el Zorro. 100 % Above the maximum value of literature and criteria.**	Minimum value 0.015 mg/L Maximum value 0.098 mg/L Herrera-Silveira et al. 2004 0.04 mg/L (CECA, 1989) nitrates
Total Phosphates	**The five lagoons Above the maximum value of literature and criteria.**	Minimum value 0.07 mg/L. Maximum value 0.14 mg/L (Contreras, 1996) 0.002 mg/L (CECA, 1989) Phosphates 0.005-0.034 mg/L Herrera-Silveira et al. 2004
Silicates	**The five lagoons Above the maximum value in literature.**	Minimum value 0.65 mg/L. Maximum value 3.32 mg/L Herrera-Silveira et al. 2004

Table IV. 20 Nutrient values reported in literature.

Total Organic Carbon

In the case of Total Organic Carbon (TOC), the lowest concentrations of this parameter were found in el Carmen and Mecoacan lagoons and the highest were for Machona, Tupilco and el Zorro. Table IV.21 shows average, minimum and maximum values as well as their variation coefficient for each lagoon.

This parameter, as its name implies, is the measure of organic compounds total carbon content present in water. It refers to both fixed and volatile organic compounds, natural or synthetic. It is the most correct expression of total organic content. One of the parameters indicating the amount of organic matter present in a water sample is obtained by analyzing the CO_2 generated through combustion of a water sample, to which carbonated inorganic compounds have been previously removed. Concentrations obtained in the five lagoons are generally higher than those obtained in the Gulf of Mexico shallow area.

Table IV. 21 Total organic carbon statistics in water column in March, 2018

Total Organic Carbon (mg/L)	Level	Carmen Resorts					Machona Stations					Tupilco Stations		
		min	max	average	n	CV	min	max	average	n	CV	min	max	n
TOC	AREA	0.90	6.60	4.80	4	54.8	8.0	19.3	11.62	5	38.7	12.0	12.8	2
	BOTTOM	1.10	7.10	4.95	4	53.7	8.8	11.9	10.30	4	12.4		12.1	1
Total Organic Carbon (mg/L)	Level	Mecoacan Stations					el Zorro Stations							
		min	max	average	n	CV	min	max	n					
TOC	AREA	1.40	3.80	2.84	5	38.0	11.2	11.2	2					
	BOTTOM	1.20	3.50	2.30	4	53.0	11.9	11.0	2					

Photosynthetic pigments: Chlorophylls a, b, c and pheophytins

Table IV.22 presents statistical values for photosynthetic pigments (Chlorophyll a, b and c) and pheophytins in surface and bottom water at lagoons sampled sites.

Regarding chlorophyll a in surface water, the highest values were presented in la Machona lagoon and in bottom water with values reaching a median of 26.487 mg/cubic meters and a maximum value of 54.535 mg/cubic meters, for surface water, median value was 17.511 mg/cubic meters and an extreme value of 49.456 mg/cubic meters. The other lagoons obtained values below 10 mg/cubic meters. In bays and lagoons such as Celestun, Laguna Chelem and Rio Lagartos according to (Herrera-Silveira et al., 2004), the median value for chlorophyll "a" was 3.8 mg/cubic meters and the lower and upper quartile was 2.2-6.0 mg/cubic meters, of the five lagoons sampled, el Carmen, Tupilco and el Zorro, chlorophyll "a" values were found within these intervals.

For chlorophyll b, average and median values in surface and bottom in general showed were lower than 3.0 mg/cubic meters, with the exception of an extreme value of 5.159 mg/cubic meters in surface water of the Machona lagoon (Table IV.22). Chlorophyll “b” is an accessory pigment present in plants and other complex photosynthetic cells; absorbs light of a different wavelength and transfers energy to chlorophyll “a”, which is in charge of transforming it into chemical energy, is a minority chlorophyll in chlorophyceae algae and higher plants, apparently is not found present in red and brown algae, diatoms or dinoflagellates (Gómez-Aguirre, 1971). The values recorded in this campaign coincide with the interval obtained in San Quintin Bay of 0.1 to 2.9 mg/cubic meters reported in literature (Millan-Nuñez, R. and S. Alvarez Borrego. 1978).

For chlorophyll c, behavior in the five lagoons did not present a homogeneous trend as in the case of chlorophyll “b”. Average and median values in surface and bottom in general were lower than 5.0 mg/cubic meters, with the exception of an extreme value of 8.681 mg/cubic meters in surface water of la Machona lagoon (Table IV.22). Chlorophyll “c” is present in all algae studied to date (86 species) in dinoflagellates and cryptophytae, is also an accessory pigment present in plants and other complex photosynthetic cells; absorbs light of a different wavelength and transfers energy to chlorophyll “a”, which transforms it in chemical energy, is a minority chlorophyll in chlorophyceae algae and higher vegetables, apparently not present in red and brown algae, diatoms or dinoflagellates (Contreras, 1985). The values recorded in this campaign coincide with the interval obtained in Estero de Punta Banda and Bahía San Quintin, reporting intervals of 0.1-2.6 mg/cubic meters and 0.2 to 10.5 mg/cubic meters respectively (Millan-Nuñez, R. and S. Alvarez Borrego. 1978).

With regard to pheophytins average and median values in surface and bottom were lower than 2.0 mg/cubic meters in the Tupilco, el Zorro and Mecoacan lagoons and for el Carmen lagoon less than 4.0 mg/cubic meters. La Machona lagoon was the one obtaining the highest concentrations of both the average, median and maximum values, with a maximum value in surface water of 20.311 mg/cubic meters and in bottom water of 14.812 mg/cubic meters (Table IV.22).

In general, relation between the amount of chlorophyll “a” and pheophytins is indicative of the physiological status of phytoplankton populations, a relative abundance of pheophytins indicates the presence of a population in decline, which was only shown in four seasons of the five sampled in la Machona lagoon. Intervals reported in literature in coastal lagoons go from 0.0 to 11.0 mg/cubic meters. Pheophytins presence is sometimes explained in terms of phytoplankton populations decay and degradation because they are in an advanced stage of succession, or in terms of grazing by zooplankton (Millan-Nuñez, R. and S. Alvarez Borrego. 1978).

Table IV. 22 Pigments and pheophytins in the water column statistics in March, 2018.

Pigments (mg/cubic meters)	Level	Carmen Resorts					Machona Stations					Tupilco Stations		
		min	max	average	n	CV	min	max	average	n	CV	min	max	n
Chlorophyll "a"	AREA	0.53	3.44	1.93	4	68.7	14.582	49.456	24.425	5	58.9	5.639	6.085	2
	BOTTOM	0.98	2.84	1.91	2	68.9	10.525	54.535	29.509	4	66.1		6.724	1
Chlorophyll "b"	AREA	0.40	1.39	0.86	4	61.4	1.035	5.159	2.277	5	73.2	0.660	0.997	2
	BOTTOM	0.74	2.23	1.49	2	70.9	0.158	2.250	0.950	4	106.0		1.257	1
Chlorophyll "c"	AREA	0.54	1.57	1.065	4	48.4	2.916	8.681	4.511	5	52.9	1.311	1.599	2
	BOTTOM	1.30	2.94	2.12	2	54.7	2.447	7.965	4.949	4	58.6		2.078	1
Pheophytinins	AREA	0.50	2.20	1.35	4	61.2	0.158	20.311	9.027	5	91.6	0.158	0.158	2
	BOTTOM	1.10	2.80	1.95	2	61.6	0.158	14.812	5.701	4	111.7		0.16	1

Table IV. 23 Pigments and pheophytins in the water column statistics in March, 2018.

Pigments (mg/cubic meters)	Level	el Zorro Stations			Mecoacan Stations				
		min	max	n	min	max	average	n	CV
Chlorophyll "a"	AREA	4.883	5.411	2	3.046	7.868	4.907	5	43.5
	BOTTOM	5.097	5.161	2	2.453	7.824	5.584	5	43.9
Chlorophyll "b"	AREA	0.984	1.152	2	0.497	1.275	0.919	5	39.6
	BOTTOM	1.129	1.449	2	0.393	1.209	0.859	5	38.2
Chlorophyll "c"	AREA	0.513	1.676	2	1.315	2.430	1.783	5	23.3
	BOTTOM	1.540	1,738	2	1.409	2.186	1.846	5	19.6
Pheophytinins	AREA	0.158	0.158	2	0.158	0.158	0.158	5	26.4
	BOTTOM	0.158	0.158	2	0.158	0.158	0.158	5	

Table IV. 24 Results of nutrients, total organic carbon and pigments in water column in the mouth take in November 2017.

PARAMETERS	BT-E-43-SUPERFICIAL	BT-E-43-MEDIUM	BT-E-43-BOTTOM	BT-E-44-SUPERFICIAL	BT-E-44-MEDIUM	BT-E-44-BOTTOM
	2018-03-27	2018-03-27	2018-03-27	2018-03-27	2018-03-27	2018-03-27
	15:30	15:15	14:30	14:00	13:40	13:00
Pigments						
CH-a (mg/cubic meters)	4.100		3.100	6.200		1.500
CH-b (mg/cubic meters)	0.394		0.181	0.821		0.158
CH-c (mg/cubic meters)	0.158		ND	0.158		ND
TOC	ND		ND			ND
Nutrients						
NITRATES+NITRITES mg/L	0.0231		0.0468	0.0097		0.0408
TOTAL REACTIVE PHOSPHOROUS (O-PO4) mg/L	0.013		0.017	0.01		0.019
TOTAL SILICA (SiO_2, FROM Si) mg/L	1.260	1.3		1.700		3.660
ND Not Detected, NA Not Applicable						

Table IV. 25 Results of nutrients, total organic carbon, pigments and pheophytins in water column in the mouth take in March 2018.

PARAMETERS	BT-E-43-SUPERFICIAL	BT-E-43-MEDIUM	BT-E-43-BOTTOM	BT-E-44-SUPERFICIAL	BT-E-44-MEDIUM	BT-E-44-BOTTOM
	2018-03-27	2018-03-27	2018-03-27	2018-03-27	2018-03-27	2018-03-27
	15:30	15:15	14:30	14:00	13:40	13:00
Pigments						
CH-a (mg/cubic meters)	2.513		2.092	1.537	1.730	7.155
CH-b (mg/cubic meters)	ND		0.271	0.252	0.224	1.758
CH-c (mg/cubic meters)	0.882		0.870	0.404	0.719	3.761
Pheophytines (mg/cubic meters)	0.577		ND	1.040	ND	ND
TOC	1.099	1.131	1.374	1.412	1.204	1.228
Nutrients						
NITRATES (NITROGEN DE) mg/L	0.01844	0.002124	ND	ND	0.008681	0.001817
NITRITES (NITROGEN DE) mg/L	0.018256	0.01758	0.023994	0.009512	0.009452	0.016442
TOTAL REACTIVE PHOSPHOROUS (O-PO4) mg/L	0.0244	0.0437	0.0617	0.0377	0.0728	0.0598
TOTAL SILICA (SiO_2, FROM Si) mg/L	0.644	0.7676	1.518	1.353	1.953	2.314
ND Not Detected, NA Not Applicable						

Total Petroleum Hydrocarbons (HTP)

Total petroleum hydrocarbons were not detected in water samples collected in el Carmen, Machona, Coral, el Zorro and Mecoacan lagoons. The analytical method used for the determination of mean fraction compounds was EPA8015C 2007, with MDL of 0.0396 mg/L.

Polynuclear polycyclic aromatic hydrocarbons (HAP)

Polycyclic aromatic hydrocarbons did not reach the minimum detectable concentration according to the methods employed (Table IV.26) in any of the water samples in the lagoons. Studies conducted in Mecoacan lagoon report the presence of some HAPs (acenaphthylene, anthracene, Benzo(a) anthracene, Benzo(a) pyrene, Benzo(g, h, i) perylene, Phenanthrene, Fluoranthene, naphthalene and Pyrene) at concentrations lower than 0.15 µg/L, which are lower to the ecological criteria established for the protection of marine aquatic life.

Table IV. 26 Analytical methods for the determination of organic compounds in water.

Compound	Units	method	MDL
Benzene	ug/L	US EPA 8260C 2006	0.12
Ethylbenzene	ug/L	US EPA 8260C 2006	0.14
Toluene	ug/L	US EPA 8260C 2006	0.12
M+p-xylene	ug/L	US EPA 8260C 2006	0.22
O-xylene	ug/L	US EPA 8260C 2006	0.21
Acenaphthene	mg/L	US EPA 8310 1986	0.0000077
Acenaphthylene	mg/L	US EPA 8310 1986	0.00000738
Anthracene	mg/L	US EPA 8310 1986	0.00000344
Benzo (a) anthracene	mg/L	US EPA 8310 1986	0.00000113
Benzo (a) pyrene	mg/L	US EPA 8310 1986	0.00000579
Benzo (b) fluoranthene	mg/L	US EPA 8310 1986	0.00000594
Benzo (g, h, i) perylene	mg/L	US EPA 8310 1986	0.00000515
Benzo (k) fluoranthene	mg/L	US EPA 8310 1986	0.00000462
Chrysene	mg/L	US EPA 8310 1986	0.00000104
Dibenzo (a, h) anthracene	mg/L	US EPA 8310 1986	0.00000378
Phenanthrene	mg/L	US EPA 8310 1986	0.0000145
Fluoranthene	mg/L	US EPA 8310 1986	0.00000462
Fluorene	mg/L	US EPA 8310 1986	0.0000103
Indene (1,2,3, c-d) pyrene	mg/L	US EPA 8310 1986	0.0000104
Naphthalene	mg/L	US EPA 8310 1986	0.00000864
Pyrene	mg/L	US EPA 8310 1986	0.00000671

Oil biomarkers

No petroleum biomarker compounds were identified in water samples in the studied system lagoons.

BTEX Monoaromatic hydrocarbons

Benzene, ethylbenzene, xylenes and toluene (BTEX) monoaromatic compounds were not detected in the lagoon system studied water samples. No history of measurement of these compounds has been found in aquatic study systems.

Metals

Water samples taken at the lagoons surface and bottom were analyzed to determine aluminum, arsenic, barium, cadmium, cobalt, copper, chromium, tin, iron, mercury, nickel, lead, vanadium and zinc concentration. Laboratory results indicated metals concentrations are low, undetectable for cadmium, with low detection frequency for copper (50%), mercury (27%) and tin (25%). Each study site individual concentrations are presented in Table IV.27, while descriptive statistics for each lagoon are summarized in Table IV.28 (for the Tupilco and el Zorro lagoons only have 2 data, so only the average is presented).

Aluminum concentrations fluctuated from 0.002 to 1.204 mg/L with average of 0.340 mg/L on surface and 0.001-1.112 mg/L with average of 0.392 mg/L in bottom, i.e., they showed a wide variation. The highest concentrations corresponded to la Machona lagoon, particularly to MA6 and MA8 sites. Aluminum is not covered by the Mexican standard NOM-001-ECOL-1996, establishing metals maximum limits in coastal waters for fishing, recreation and estuaries exploitation.

Arsenic showed minimum levels of 0.002 mg/L, average of 0.003 and maximum of 0.005 mg/L, with similar values for bottom. The highest surface concentration was found in el Zorro lagoon (Z12), while the T11 site, in Tupilco lagoon, showed the maximum bottom concentration. None of the reported concentrations reach the limits set in NOM001-ECOL-1996, as shown in Table IV.27, so arsenic does not pose an environmental risk. Buchman (2008) through the National Oceanic and Atmospheric Administration (NOAA) published the criteria to avoid chronic and acute effects on marine life in freshwater systems, which in this paper were taken for comparative purposes and in reserve for those metals not included in NOM-001. For total arsenic, the maximum allowable value to avoid chronic effects is 0.15 mg/L, while acute effects occur at concentrations equal to or greater than 0.34 mg/L. As can be seen in Table IV.27, in no case was any of the NOAA criteria exceeded, confirming that there is no risk from arsenic in the lagoons studied. In previous works

Barium fluctuated from 0.004 to 0.042 mg/L on the surface and from 0.004 to 0.035 mg/L on the lagoons bottom. The highest concentrations were observed in the Mecoacan lagoon. Barium is not included in Mexican standard NOM-001-ECOL-1996, however, international NOAA criteria specify that barium should have concentrations lower than 0.110 mg/L to avoid acute effects and 0.0039 mg/L to avoid chronic effects in marine life. Under these criteria, virtually all water samples exceed concentration to avoid chronic effects, so it is suggested to monitor barium concentrations in lagoons and identify the main source of this metal, since barium is a metal poorly studied in lagoon systems in the Southern Gulf of Mexico. Due to poor information, barium values only provide an overview of their concentrations in lagoon systems and further study is required.

Cobalt concentrations showed a minimum of 0.0002 mg/L, average of 0.0007 mg/L and maximum of 0.0015 mg/L. The highest concentrations corresponded to samples collected in la Machona lagoon (site MA6), both in the surface and in the bottom. According to NOAA's criteria, in no case were the values of protection to aquatic life exceeded. Cobalt is reported with a concentration of 0.00001-0.0011 mg/L in laguna de Terminos, Campeche (Botello, et al. 1996). Cobalt is not included in NOM-001, and values of 0.11 mg/L and 0.0039 mg/L are considered in NOAA's criteria to avoid acute and chronic effects, respectively.

Copper, an essential element for marine life, was found in a concentration range of 0.0013-0.0056 mg/L at the surface and 0.0027-0.0064 mg/L at the bottom. The highest concentrations were observed in la Machona lagoon, with higher values at the bottom of this lagoon (average 0.0053 mg/L), followed by the Tupilco lagoon. In the remaining lagoons copper was detected with low frequency. In all cases, metal concentrations were lower than the maximums established by NOM-001 (6 mg/L). In literature, a copper concentration interval of 0.2-6.6 µg/L is reported in laguna de Terminos, Campeche (Botello, et al. 1996), that is below the environmental criterion.

In the case of total chromium, a minimum of 0.0004 mg/L was found in surface and 0.0006 mg/L in bottom, average of 0.0025 and 0.0030 in surface and bottom respectively and maximum of 0.0082 and 0.0073 mg/L for the aforementioned sampling levels. This metal also reached the highest values in la Machona lagoon (average of 0.007 mg/L in surface and 0.0014 mg/L in bottom), with the maximum of the entire lagoon system at the MA6 site. However, these concentrations do not represent environmental risk as they are lower than those established in NOM-001. The average chromium concentration in el Carmen lagoon reported by Botello et al. (1996) was 9 µg/L, which is slightly higher than what was found in this study.

Tin was only found in la Machona lagoon, with the maximum in both surface and bottom at MA6 site, as has been the behavior of several metals. Tin is not included in NOM-001 and NOAA’s criteria, therefore it is not possible to establish whether these concentrations represent an overview of tin concentrations in lagoon systems.

Iron showed a general minimum of 0.008 mg/L (in bottom), average of 0.864 mg/L and maximum of 2.533 mg/L (in surface). The highs were also found in Laguna de la Machona, site MA6. Iron is not included in NOM-001, and in NOAA’s criteria only chronic effects are considered, for which there is a limit of 1 mg/L. according to this last data, the Machona lagoon exceeded in all cases this concentration, suggesting that chronic effects may occur due to this metal. In literature was found iron concentration reached maximum levels in laguna de Terminos (1.1-21.1 µg/L), but no values are reported for other lagoons in the state.

Mercury was found in concentrations higher than MDL (0.000027 mg/L) in la Machona lagoon and in C2 and C3 in el Carmen lagoon. The highest concentrations (0.0003 mg/L) corresponded to la Machona lagoon, at the bottom. NOM-001 sets a maximum level of 0.02 mg/L for fishing, recreation and estuaries activities, while NOAA specifies chronic effects can occur from a concentration of 0.00077 mg/L. In none of the cases any criteria were exceeded, so mercury does not pose an environmental risk in the analyzed system lagoons. Average concentrations reported for El Carmen, Mecoacan and Machona lagoons are 0.2, 0.4 and 0.3 µg/L (Botello et al., 1996), similar to those found in this study.

Nickel concentrations ranged from 0.001-0.01 mg/L with an average of 0.004 mg/L at the surface, and slightly lower at the bottom. This metal was also found in higher concentrations in la Machona lagoon (average 0.007 mg/L), and lowest concentrations in el Carmen lagoon (average 0.002 mg/L). Nickel concentrations are lower in all cases than values established in NOM-001 (4 mg/L) and even NOAA’s strictest values (0.47 for acute effects and 0.052 mg/L for chronic effects), so nickel does not represent environmental risk. In literature it is mentioned environmental studies including nickel are very scarce and only specific information is available for Laguna Madre (10.8 µg/L) and laguna de Terminos (0.1 µg/L).

Lead was found in a concentration interval from 0.002 to 0.022 mg/L, with an overall average of 0.009 mg/L. Like several of the metals described above, the highest concentrations were observed in la Machona lagoon (site MA8), while in the Mecoacan lagoon, this metal was practically not detected. Lead concentrations did not exceed NOM-001 criteria, however

NOAA is stricter and sets a value of 0.0025 mg/L to avoid chronic effects. According to this criterion, species that inhabit Machona, Tupilco and el Zorro lagoons could be at risk of negative lead effects. Previous environmental studies on the Gulf of Mexico coast found lead concentration in the state of Tabasco (el Carmen, Machona, Atasta and Terminos lagoons) fluctuated between 1.3-291 µg/L, that is, higher than those found in this LB study, indicating a significant decrease in concentrations of this metal.

Vanadium presented in higher concentrations in la Machona lagoon (0.0050 mg/L), followed by a site in the Tupilco lagoon (0.0049 mg/L). The lowest levels were observed in el Carmen lagoon. Vanadium is not considered in NOM-001, and NOAA sets values to avoid chronic and acute effects that were not reached in any of the water samples from the lagoons.

Zinc levels fluctuated widely from 0.004 to 0.0606 mg/L, with the highs at site MA6 of la Machona lagoon and the lows in el Carmen lagoon. The criterion for fishing and recreational activities established in NOM-001 is 20 mg/L, so zinc values in lagoons are well below these criteria and even those dictated by NOAA (0.12 mg/L), so this metal does not represent environmental risk. In literature, data on zinc concentration in the Gulf of Mexico are limited, although all coincide in they are relatively high (average of 15 µg/L) for Veracruz and lower for Tabasco (average of 3.0 µg/L). Values found in this study are higher than those reported in literature.

Table IV. 27 Metals concentration in water (mg/L) determined in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons.

	Aluminum		Arsenic		Barium		Cobalt		Copper		Chrome		Tin	
Site	surface	bottom	surface	bottom	surface	bottom	surface	bottom	surface	bottom	surface	bottom	surface	bottom
C1	0.002	0.001	0.0032		0.0039	0.0039	0.0009	0.001				0.0007		
C2	0.012	0.015	0.0017		0.0146	0.0119	0.0009	0.001			0.0008			
C3	0.072	0.264	0.0035		0.0162	0.0196	0.0010	0.001			0.0006	0.0014		
C4	0.061	0.345			0.0216	0.0265	0.0009	0.001		0.0057		0.0022		
MA5	0.638	0.623	0.0019		0.0208	0.0209	0.0008	0.001	0.0056	0.0061	0.0050	0.0062	0.0188	0.0160
MA6	1.204	0.97	0.0039		0.0227	0.0217	0.0015	0.001	0.0055	0.0059	0.0082	0.0073	0.0324	0.0345
MA7	0.721		0.0022		0.0210		0.0010		0.0050		0.0045		0.0156	
MA8	0.995	1.11		0.0016	0.0347	0.0305	0.0009	0.0008	0.0051	0.0064	0.0054	0.0068	0.0057	0.0094
MA9	0.657	0.72	0.0042		0.0200	0.0198	0.0007	0.0011	0.0054	0.0064	0.0048	0.0054	0.0111	0.0128
T10	0.183		0.0034		0.0259		0.0002		0.0050		0.0012			
T11	0.277	0.389	0.0026	0.0066	0.0270	0.0335	0.0007	0.0010	0.0033	0.0042	0.0015	0.0026		
Z12	0.252	0.235	0.0045	0.0016	0.0333	0.0288	0.0003	0.0002	0.0019	0.0027	0.0015	0.0019		
Z13	0.303	0.317	0.0041	0.0034	0.0229	0.0235	0.0004	0.0011	0.0034	0.0038	0.0025	0.0025		
ME14	0.182	0.265	0.0042	0.0063	0.0135	0.0093					0.0010	0.0014		
ME15	0.095	0.0885	0.0032	0.0020	0.0253	0.0247					0.0004	0.0006		
ME16	0.125	0.223	0.0034	0.0020	0.0322	0.0352		0.0004			0.0010	0.0013		
ME17	0.161		0.0029		0.0424				0.0013		0.0014			
ME18	0.185	0.312	0.0039	0.0020	0.0189		0.0002				0.0008	0.0016		
Maximum allowable limit NOM-001-ECOL-1996 (mg/L) in coastal waters														
To			0.2						6		1			
B			0.4						6		1.5			
C			0.2						6		1			
NOAA's environmental criteria (mg/L)														
D	0.75		0.34		0.11		1.5		0.013					
E	0.087		0.15		0.0039		0.003		0.009					

A: fishing exploitation; B: recreation; C: estuaries. D: limit concentration to avoid acute effects; E: limit concentration to avoid chronic effects

Table IV. 28 Metals concentration in water (mg/L) determined in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons. Continued

	Iron		Mercury		Nickel		Lead		Vanadium		Zinc	
Site	surface	bottom	Surface	bottom	surface	bottom	surface	bottom	surface	bottom	surface	bottom
C1	0.0118	0.0081			0.0010	0.0002					0.0014	0.0019
C2	0.0329	0.0418			0.0017	0.0015	0.0023	0.0024	0.0006	0.0004	0.0006	0.0124
C3	0.2054	0.6022		0.0000	0.0020	0.0035	0.0024	0.0041	0.0006	0.0017	0.0016	0.0032
C4	0.1614	0.8322	0.0001	0.0000	0.0022	0.0063	0.0045	0.0090	0.0005	0.0015	0.0008	0.0237
MA 5	1.2166	1.1684	0.0001		0.0054	0.0056	0.0141	0.0136	0.0040	0.0036	0.0371	0.0330
MA 6	2.5329	1.9919	0.0001	0.0001	0.0096	0.0086	0.0165	0.0146	0.0050	0.0040	0.0499	0.0518
MA 7	1.4513		0.0003		0.0061		0.0133		0.0039		0.0413	
MA 8	1.6709	1.9408	0.0000	0.0001	0.0068	0.0079	0.0223	0.0204	0.0046	0.0051	0.0211	0.0301
MA 9	1.2882	1.3793	0.0001		0.0055	0.0067	0.0125	0.0115	0.0042	0.0039	0.0255	0.0325
T10	0.4876				0.0038		0.0062		0.0050		0.0606	
T11	0.9883	1.5663			0.0046	0.0066	0.0061	0.0069	0.0046	0.0059	0.0083	0.0089
Z12	0.6496	0.6122			0.0042	0.0059	0.0065	0.0063	0.0035	0.0031	0.0053	0.0122
Z13	0.8475	0.8509			0.0059	0.0061	0.0062	0.0066	0.0037	0.0041	0.0047	0.0046
ME 14	0.3278	0.5186			0.0024	0.0034			0.0016	0.0019	0.0010	0.0021
ME 15	0.2571	0.2230			0.0023	0.0023			0.0015	0.0013		0.0034
ME 16	0.3482	0.6451			0.0023	0.0037			0.0017	0.0022	0.0004	0.0046
ME 17	0.4125				0.0036		0.0029		0.0020		0.0111	
ME 18	0.3635	0.5783			0.0027	0.0044			0.0016	0.0024	0.0004	0.0059
Maximum allowable limit NOM-001-ECOL-1996 (mg/L)												
To			0.02		4		0.4				20	
B			0.02		4		1				20	
C			0.02		4		0.4				20	
NOAA's environmental criteria (mg/L)												
D			0.0014		0.47		0.065		0.28		0.12	
E	1		0.00077		0.052		0.0025		0.019		0.12	

A: fishing exploitation; B: recreation; C: estuaries. D: limit concentration to avoid acute effects; E: limit concentration to avoid chronic effects

Table IV. 29 Descriptive statistics on metals concentration in water (mg/L) in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons

	Aluminum		Arsenic		Barium		Cobalt		Copper		Chrome		Tin	
	surface	bottom	Surface	bottom	surface	bottom	surface	bottom	surface	bottom	surface	bottom	surface	bottom
Lagoon System														
min	0.002	0.001	0.0017	0.0016	0.004	0.004	0.0002	0.0002	0.0013	0.0027	0.0004	0.0006	0.006	0.009
p25	0.090	0.223	0.0026	0.0017	0.018	0.018	0.0003	0.0008	0.0030	0.0039	0.0009	0.0013	0.008	0.010
average	0.340	0.392	0.0033	0.0032	0.023	0.022	0.0007	0.0009	0.0042	0.0052	0.0025	0.0030	0.017	0.018
p75	0.554	0.506	0.0040	0.0041	0.027	0.028	0.0009	0.0011	0.0053	0.0062	0.0046	0.0047	0.019	0.021
max	1.204	1.112	0.0045	0.0066	0.042	0.035	0.0015	0.0013	0.0056	0.0064	0.0082	0.0073	0.032	0.035
El Carmen														
min	0.002	0.001	0.0017	0.0000	0.004	0.004	0.0009	0.0008	0.0000	0.0057	0.0006	0.0007	0.000	0.000
average	0.037	0.156	0.0028		0.014	0.015	0.0009	0.0010		0.0057	0.0007	0.0014		
max	0.072	0.345	0.0035	0.0000	0.022	0.027	0.0010	0.0013	0.0000	0.0057	0.0008	0.0022	0.000	0.000
Machona														
min	0.638	0.623	0.0019	0.0016	0.020	0.020	0.0007	0.0008	0.0050	0.0059	0.0045	0.0054	0.006	0.009
average	0.843	0.857	0.0030	0.0016	0.024	0.023	0.0010	0.0010	0.0053	0.0062	0.0056	0.0064	0.017	0.018
max	1.204	1.112	0.0042	0.0016	0.035	0.030	0.0015	0.0013	0.0056	0.0064	0.0082	0.0073	0.032	0.035
Cocal														
average	0.230	0.389	0.0030	0.0066	0.026	0.033	0.0005	0.0010	0.0042	0.0042	0.0013	0.0026		
El Zorro														
average	0.278	0.276	0.0043	0.0025	0.028	0.026	0.0003	0.0006	0.0026	0.0033	0.0020	0.0022		
Mecoacan														
min	0.095	0.089	0.0029	0.0020	0.013	0.009	0.0002	0.0004	0.0013	0.0000	0.0004	0.0006	0.000	0.000
average	0.150	0.222	0.0035	0.0031	0.026	0.023	0.0007	0.0004	0.0013		0.0009	0.0012		
max	0.185	0.312	0.0042	0.0063	0.042	0.035	0.0015	0.0004	0.0013	0.0000	0.0014	0.0016	0.000	0.000

Table IV. 30 . Descriptive statistics on metals concentration in water (mg/L) in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons. Continued

	Iron		Mercury		Nickel		Lead		Vanadium		Zinc	
	surface	bottom	surface	bottom	surface	bottom	surface	bottom	surface	bottom	surface	bottom
Lagoon System												
min	0.012	0.008	0.00003	0.00004	0.001	0.000	0.002	0.002	0.001	0.000	0.0004	0.0019
p25	0.244	0.519	0.00004	0.00004	0.002	0.003	0.004	0.006	0.002	0.002	0.0009	0.0034
Avg	0.736	0.864	0.00010	0.00005	0.004	0.005	0.009	0.010	0.003	0.003	0.0159	0.0153
p75	1.160	1.274	0.00008	0.00005	0.005	0.006	0.013	0.013	0.004	0.004	0.0255	0.0269
max	2.533	1.992	0.00030	0.00006	0.010	0.009	0.022	0.020	0.005	0.006	0.0606	0.0518
El Carmen												
min	0.012	0.008	0.00005	0.00004	0.001	0.000	0.002	0.002	0.001	0.000	0.0006	0.0019
average	0.103	0.371	0.00005	0.00004	0.002	0.003	0.003	0.005	0.001	0.001	0.0011	0.0103
max	0.205	0.832	0.00005	0.00004	0.002	0.006	0.004	0.009	0.001	0.002	0.0016	0.0237
Machona												
min	1.217	1.168	0.00003	0.00005	0.005	0.006	0.013	0.012	0.004	0.004	0.0211	0.0301
average	1.632	1.620	0.00011	0.00006	0.007	0.007	0.016	0.015	0.004	0.004	0.0350	0.0368
max	2.533	1.992	0.00030	0.00006	0.010	0.009	0.022	0.020	0.005	0.005	0.0499	0.0518
Coral												
average	0.738	1.566			0.004	0.007	0.006	0.007	0.005	0.006	0.0345	0.0089
El Zorro												
average	0.749	0.732			0.005	0.006	0.006	0.006	0.004	0.004	0.0050	0.0084
Mecoacan												
min	0.257	0.223			0.002	0.002	0.003	0.000	0.002	0.001	0.0004	0.0021
average	0.342	0.491			0.003	0.003	0.003		0.002	0.002	0.0032	0.0040
max	0.413	0.645			0.004	0.004	0.003	0.000	0.002	0.002	0.0111	0.0059

Metals general behavior in water is exemplified in Figure IV.65-67. Aluminum, cobalt, copper, chromium, tin, iron, mercury, nickel and lead presented the highest concentrations in la Machona lagoon, while vanadium and zinc also had the highest values in the Tupilco lagoon. Arsenic and barium presented high values in the Tupilco and Mecoacan lagoons.

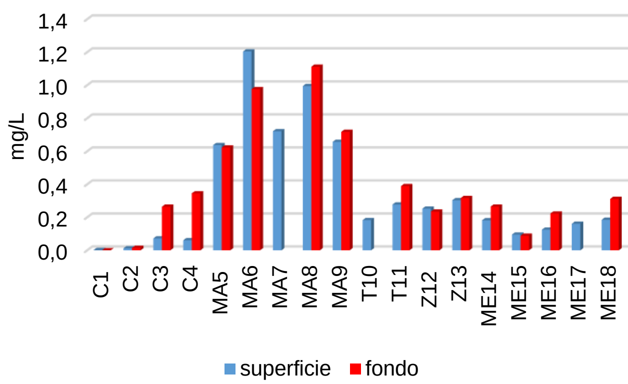


Figure IV. 65 Aluminum concentration in water (mg/L) in the lagoons el Carmen (C1-C4), Machona (MA5-MA9), Tupilco (T10-T11), el Zorro (Z12-Z13) and Mecoacan (ME14-ME18)

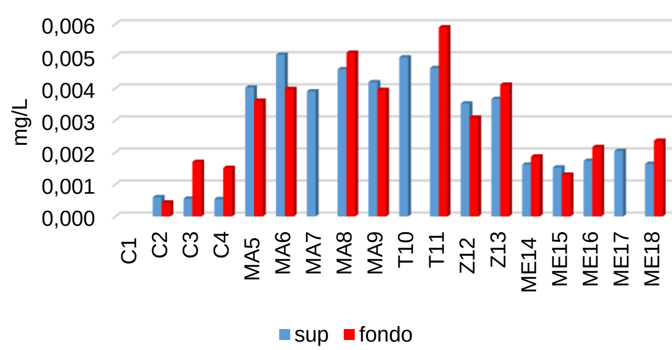


Figure IV. 66 Concentration of vanadium in water (mg/L) in el Carmen (C1-C4), Machona (MA5-MA9), Tupilco (T10-T11), el Zorro (Z12-Z13) and Mecoacan (ME14-ME18) lagoons

To corroborate the differences described in the previous paragraph, a factor analysis was used to metals concentration data. Analysis result (Figure IV.68) suggests arsenic and copper concentrations are governed by physical and chemical factors other than the remaining metals. Further research is required in order to understand these behaviors.

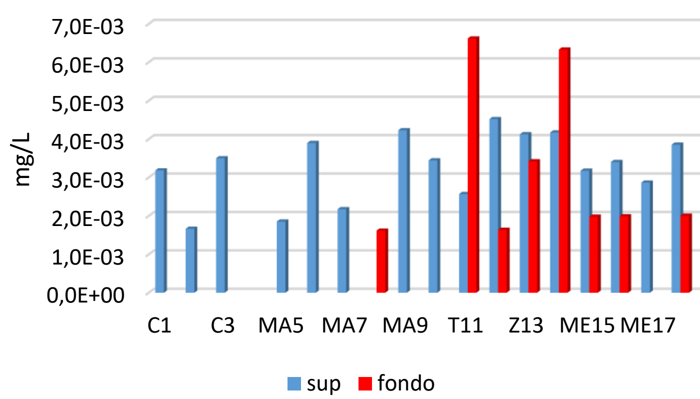


Figure IV. 67 Concentration of arsenic in water (mg/L) in el Carmen (C1-C4), Machona (MA5-MA9), Tupilco (T10-T11), el Zorro (Z12-Z13) and Mecoacan (ME14-ME18) lagoons

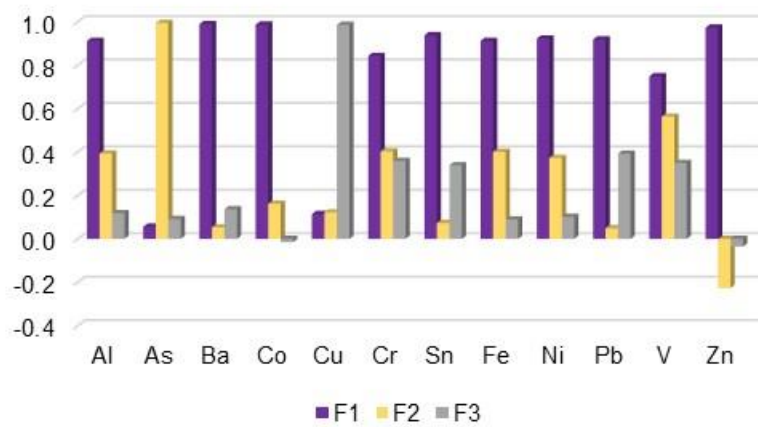


Figure IV. 68 Factors analysis result for metal concentrations in water in the studied lagoons.

Sediment quality

Granulometry

The surface sediment samples analyzed for each study site indicated el Carmen lagoon has sand dominance (72%), followed by the Tupilco lagoon. The Machona and Mecoacan lagoons had similar sands and silts percentages (close to 47%), and a smaller fraction of clays (3%). El Zorro lagoon presented the highest proportion of clays (17%). There are few studies reporting sediments grain size analysis, so this information provides a general idea of grain sizes distribution in the mentioned lagoons sediments. Figure IV.69 shows the percentages obtained for each lagoon.

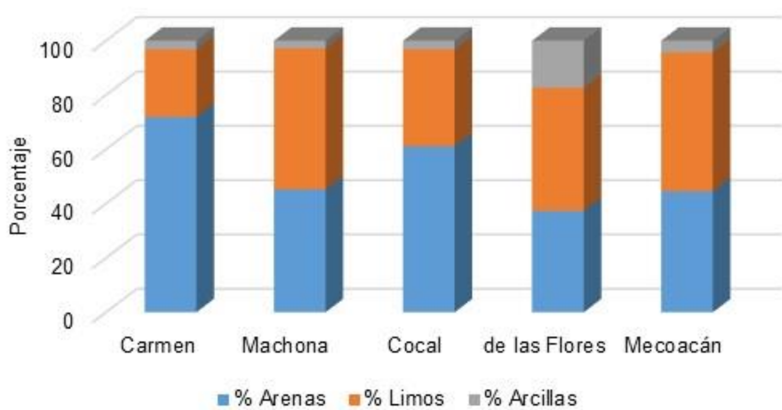


Figure IV. 69 Sediment gravimetric analysis results in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons.

Sediment texture

Based on the granulometric analysis, sedimentary textures of each sample were obtained per lagoon system. Figure IV.70 shows sedimentary texture Ternary diagram. Sediments varied primarily between Sand and Limo, only in Tupilco and el Zorro systems, the sediment was defined as Sandy Limo.

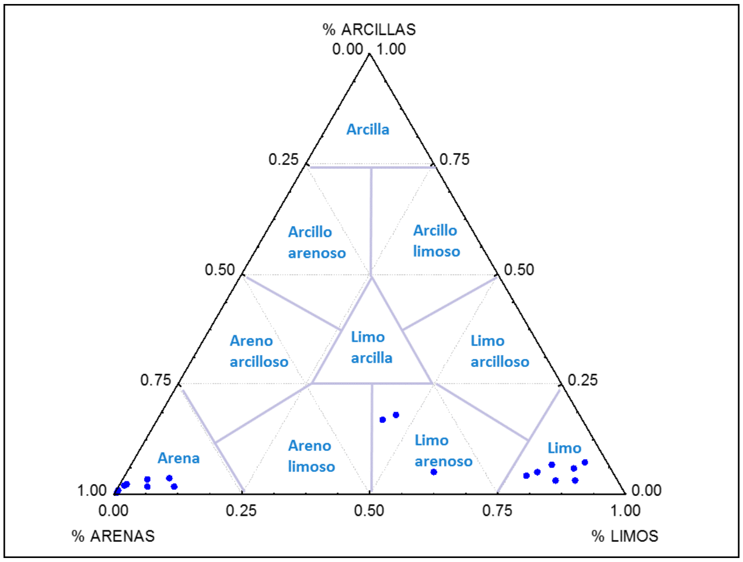


Figure IV. 70 Coastal lagoon system sedimentary texture

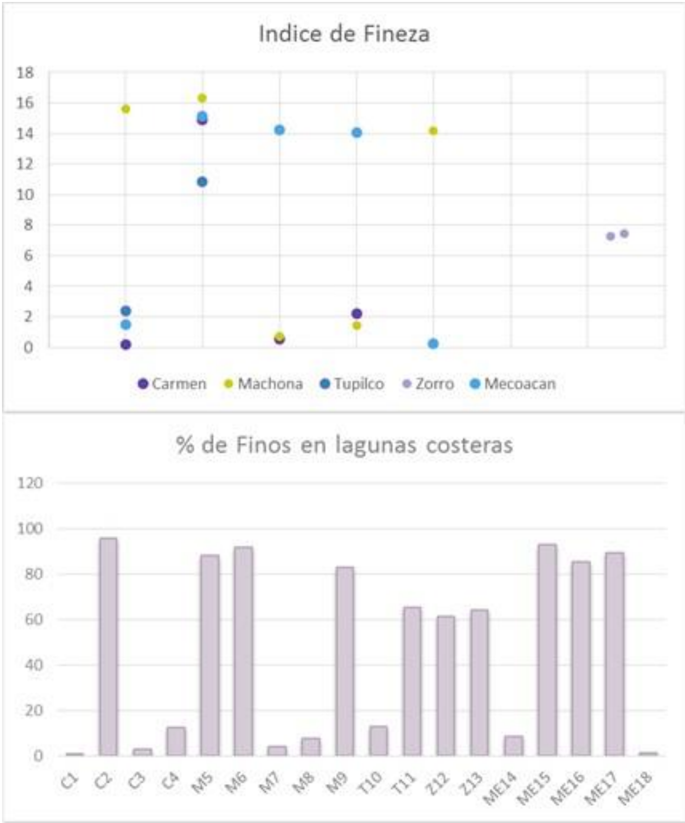


Figure IV. 71 Coastal lagoon system sedimentary texture

Figure IV.71 presents characteristics of lagoon systems sediment fines fractions. Sediments with the highest proportion of fines sediments were observed in the Mecoacan and Machona lagoons.

Fines sediments, because they provide greater adsorption area of contaminants may contain organic contaminants higher concentration compared to Sandy sediments, however, sediments of the evaluated lagoon system vary between the two fractions, sand and lime, such difference is related to sediment collection points whose textural distribution is related to hydrodynamics and deposit processes of particulate materials.

Total Petroleum Hydrocarbons (TPH)

Detectable amounts of TPH (mean fraction) were found in surface sediments of three sites, one in the Tupilco lagoon (63.06 mg/kg) and two in the Mecoacan lagoon (38.48 mg/kg and 46.21 mg/kg). In literature is reported hydrocarbons concentrations in el Carmen and Machona lagoon are 45 ppm, while for Mecoacan lagoon they were measured in a concentration of 88 ppm, however, the comparison should be taken with reserves because analysis methods may differ from one study to another.

The analytical methods employed for hydrocarbons in sediment are presented in Table IV.31, indicating the corresponding detection limit.

Table IV. 31 Analytical methods for determining hydrocarbons in sediment.

Compound	Units	Method	LD
Acenaphthene	mg/kg	US EPA 8270D 2007	0.0109
Acenaphthylene	mg/kg	US EPA 8270D 2007	0.0159
Anthracene	mg/kg	US EPA 8270D 2007	0.0141
Benzo(a)anthracene	mg/kg	US EPA 8270D 2007	0.0086
Benzo(a)pyrene	mg/kg	US EPA 8270D 2007	0.0122
Benzo(b)fluoranthene	mg/kg	US EPA 8270D 2007	0.0119
Benzo(g,h,i)perylene	mg/kg	US EPA 8270D 2007	0.0126
Benzo(k)fluoranthene	mg/kg	US EPA 8270D 2007	0.0099
Chrysene	mg/kg	US EPA 8270D 2007	0.0175
Dibenzo (a, h) anthracene	mg/kg	US EPA 8270D 2007	0.011
Phenanthrene	mg/kg	US EPA 8270D 2007	0.0153
Fluoranthene	mg/kg	US EPA 8270D 2007	0.0136
Fluorene	mg/kg	US EPA 8270D 2007	0.0179
Indene(1,2,3, c-d)pyrene	mg/kg	US EPA 8270D 2007	0.014
Naphthalene	mg/kg	US EPA 8270D 2007	0.0108
Pyrene	mg/kg	US EPA 8270D 2007	0.0146
Hydrocarbons light fraction	mg/kg	EPA 8015D-2003	3.834
Hydrocarbons mean fraction	mg/kg	EPA 8015D-2003	12.34
Hydrocarbons heavy fraction	mg/kg	EPA 1664A-1996/EPA 9071B-1996	300

Mendoza (2006) assessed aliphatic hydrocarbons concentration in 23 points of the Mecoacan lagoon in the climatic seasons of northerlies, dry season and rain through gas chromatography, observing similar values to observations in this evaluation. During the dry season, it determined a total aliphatic concentration in Mecoacan lagoon of 842.5 µg/g with an average concentration of 36.63 µg/g, in the northerlies season a total of 53.42 µg/g and an average of 2.28 µg/gm, and for the rainy season a total of 9.4 µg/g.

PAH in surface sediment of the lagoons studied were observed at concentrations higher than the minimum analytically detectable. Polyaromatic hydrocarbons are ubiquitous compounds of multiple origin such as coal combustion, fossil fuel emissions and organic material or fresh fossil fuels. In oceanic areas, these compounds, if found, are usually at very low or zero concentrations, although their origin is not easily determined. Coastal areas can be observed at high concentrations mainly in relation to oil-contaminated areas, spills, refinery wastes, petrochemicals, shipping and industrial discharges in general, as well as atmospheric emissions (Vives et al., 2002).

PAH identification can be complicated as they are subject to both atmospheric and fluvial dispersion processes, where environmental parameters such as particle size, currents, temperature, physical and chemical conditions, among others, determine the accumulation or dispersion of a given place.

Sediment quality criteria for different polyaromatic hydrocarbons compounds are based on their toxicity determined by compounds molecular weight, those with low molecular weight show their highest toxicity in an acute way, while those with high molecular weight, being more fat-soluble have carcinogenic and mutagenic potentials manifesting themselves in the long term.

Table IV. 32 It summarizes different international sediment quality criteria for saline and brackish water systems.

	TEL	ERL	PSDDA-SL	SQC-Chronic	SQO	LAET	T20	PEL	ERM	HAET	SQC-Acute	SLC	T50
Sediment (ng/g)	Acute Criteria							Chronic criteria					
Naphthalene	34.6	160	210	500	200	2100		391	2100	270	10500	414	
Biphenyl							17						73
Acenaphthylene	5.87	44	64		60	>560		128	640	130		47.4	
Acenaphthene	6.71	16	63	2400	50	500		88.9	500	200			
Fluorene	21.2	19	64	59	50	540		144	540	360		101	
Dibenzothiophene													
Anthracene	46.9	85.3	130	190	10	960		245	1100	1300		163	
Phenanthrene	86.7	240	320	2400	15	1500		544	1500	690	14000	368	
HAP-Low PM	312	552	610			5200		1442	3160	2950			
Fluoranthene	21.2	19	64	59	50	540		144	540	360		101	
Pyrene	153	665	430	850	260	2600		1398	2600	1600	49500	665	
Chrysene	108	384	670	1200	140	1400		846	2800	920	115000	384	
Benzo(a)pyrene	88.8	430	680	18000	160	1600		763	1600	360	450000	397	
Perylene							74						453
Indene(1,2,3-cd)pyrene							68						488
Benzo(g,h,i)perylene							67						497
PAH-High PM	655	1700	1800			12000		6676	9600	7280			
TOTAL PAH	1684	4022						16770	44792	10230			

Source: MacDonald, et al., (1996)
TEL-Level Effect Threshold
ERL-lowest range of effects
PSDDA-SL, Exploratory level
SQC-Chronic, Chronic Sediment Quality Criterion
SQO-Sediment Quality Target
PEL-probable effect level
ERM-mid-range effects
LAET-Lowest apparent effects threshold
HAET-high apparent effects threshold
SQC-acute, sediment quality acute criterion
SLC, Exploratory concentration level in the USA

Table IV.33 presents the quantified concentrations of each of the compounds per lagoon system. Observing total PAH concentrations, the greatest impact observed by the presence of these compounds was in Laguna Mecoacan > Tupilco > el Zorro > Machona > el Carmen.

Table IV. 33 Individual PAH concentration by assessed coastal lagoon.

Sistema	ng/g	Benzo(b)thiophene	Naphthalene	C1-Naphthalenes	C2-Naphthalenes	C3-Naphthalenes	Biphenyl	Acenaphthylene	Acenaphthene	Dibenzofuran	Fluorene	Dibenzothiophene	C1-Dibenzothiophenes	C2-Dibenzothiophenes	C3-Dibenzothiophenes	Anthracene	Phenanthrene	C1-Phenanthrenes/Anthracenes	C2-Phenanthrenes/Anthracenes	C3-Phenanthrenes/Anthracenes	HAP-BPM
	No anillos		2				2	3	3		3	3	3	3	3	3	3				
	C1		0.5	0.39			0.2										0.12				1.21
	C2		1.63	1.1			0.51			0.42		0.32	0.55			0.3	0.67	1.07			6.57
	C3		0.53	0.53			0.22					0.12	0.41				0.25	1.28	1.57	1.05	5.96
Carmen	C4		0.63	0.62			0.31	0.11	0.1	0.18	0.12	0.13	0.25				0.28	0.39			3.12
	M5	1.37	2.44	2.09			1.5	0.76	0.77	1.17	0.78	0.94	0.76	1.32		0.77	1.34	1.5			16.14
	M6		1.59	0.82			0.42			0.31	0.29	0.26	0.76			0.28	0.76	1			6.49
	M7		0.54	0.44			0.19					0.12	0.45				0.24				1.98
	M8		1.15	0.85			0.39	0.15		0.33	0.3	0.29	0.54			0.23	0.68	1.3			6.21
Machona	M9		1.63	1.23			0.6	0.25	0.23	0.46	0.28	0.29	0.54			0.28	0.62	0.99			7.4
	T10		0.64	0.61			0.26									0.12	0.37	0.62			2.62
Tupilco	T11		1.37	1.17	1.57		0.51				0.31	0.41				0.35	0.83	3.07			9.59
	Z12		0.81	0.94	1.5	1.09	0.26			0.22	0.12	0.21	0.65				0.8	1.51			8.11
Zorro	Z13		0.74	0.87	1.19		0.34			0.22		0.17	0.44				0.63	1.06	0.92		6.58
	ME14		0.54	0.55			0.22			0.14		0.14	0.42				0.36	0.67			3.04
	ME15		1.1	1.46	2.77		0.46			0.35	0.23		0.88			0.24	1.05	1.86			10.4
	ME16		1.51	1.58	1.84		0.62	0.26		0.53	0.37	0.39	1.07			0.29	1.14	1.74	2.35		13.69
	ME17		1.48	1.83	3		0.7			0.46	0.29	0.29	0.93	1.83	3.06	0.26	1.07	1.92			17.12
Mecoacán	ME18		2.07	2.24	5.61		1.07			0.69	0.51	0.76	2.71	8.42	16.09	0.67	2.59	3.86	6.8	8.09	62.18

Sistema	ng/g	Fluoranthene	Pyrene	C1-Fluoranthenes/Pyrenes	C2-Fluoranthenes/Pyrenes	Chrysene	C1-Chrysenes	C2-Chrysenes	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(e)pyrene	Benzo(a)pyrene	Perylene	Indeno(1,2,3-cd)pyrene	Benzo(g,h,i)perylene	2-Methylnaphthalene	1-Methylnaphthalene	2,6-dimethylnaphthalene	1-Methylphenanthrene	HAP APM
	No anillos	4	4			4			5	5	5	5		6	6					
	C1														0.37	0.32				0.69
	C2	0.67	0.72			1.02					0.47		1.73	0.52	0.61	0.9	0.49			7.13
	C3	0.17	0.23	0.71							0.24				0.23	0.5	0.23			2.31
Carmen	C4	0.17	0.23										0.66	0.15	0.17	0.45	0.29			2.12
	M5	1.66	1.61	1.19					1.28	0.68	0.98	0.73	4.36	0.82	0.94	1.63	1.18			17.06
	M6	0.8	0.89										1.03	0.29	0.47	0.68	0.34			4.5
	M7	0.22	0.25										0.62	0.26	0.37	0.4	0.19			2.31
	M8	0.96	0.83										3.62	0.46	0.72	0.64	0.28			7.51
Machona	M9	0.8	0.71										1.48	0.43	0.5	0.85	0.64			5.41
	T10	0.36	0.41										1.82	0.28	0.37	0.49	0.25			3.98
Tupilco	T11	1.32	1.39						1.36		0.88	0.5	9.98	0.65	1.13	0.79	0.65			18.65
	Z12	0.58	0.55								0.24		1.43	0.26	0.34	0.69	0.54			4.63
Zorro	Z13	0.43	0.39	0.42									1.6	0.15	0.24	0.6	0.44			4.27
	ME14	0.21	0.27										2.33		0.19	0.41	0.28			3.69
	ME15	0.83	0.92	1.04									3.04	0.34	0.44	0.98	0.87			8.46
	ME16	0.87	0.79	1.13							0.36		3.06	0.36	0.47	1.09	1.03	0.55		9.71
	ME17	0.96	0.98	1.57					0.8		0.51		6.03	0.59	0.63	1.25	1.16	0.42	0.48	15.38
Mecoacán	ME18	4.37	4.41	5.83	10.2	4.08	4.19	6.9	3.89		3.29	3.11	45.24	3.03	3.27	1.93	1.17			104.91

Despite having quantified different PAH species, levels for this season were considerably lower than sediment quality criteria for acute or chronic exposure, so it could be indicated pollution levels do not represent a significant impact, however, there are studies carried out with a sampling scheme with greater spatial and temporal coverage highlighting the Machona lagoon as an important contamination site.

Mendoza (2006) found total PAH concentration in the dry season of up to 359.3 µg/g with an average of 15.62 µg/g, in rainfall maximum of 29.93 µg/g and average of 1.3 µg/g and in northerlies maximum of 17.83 and average of 0.78 µg/g.

Contamination distribution in systems can be determined by sedimentary bed fines materials content and lagoon systems morphology which, due to their hydrodynamics, can favor areas of greater contaminant deposit and siltation.

Like in the present sampling, concentrations between high molecular weight and low molecular weight PAHs were relatively proportional suggesting continuous and recent contributions to the lagoon system.

Thus, lagoon system represents an important impact area due to the presence of polyaromatic hydrocarbons whose important sources can be inland water inputs of the Cuxcuchapa channel, the presence of the Dos Bocas Maritime Terminal, the intake of pyrolytic materials due to burning fields and to a lesser degree through organic matter diagenesis. Therefore, it is advisable to carry out continuous monitoring of the sediment of the lagoon system including contaminants bioavailability measurements for determining ecological and health risk.

Oil biomarkers

No oil biomarker compounds were identified in general in the Lagunas sediment, except in the Mecoacan lagoon, at site ME18 located in the mouth area of the Mecoacan system, at the sea-to-lagoon contact point to the right of Andrés Island. There, terpanes biomarkers were detected at concentrations of 0.63 to 3.25 ng/g (Table IV.34).

Table IV. 34 Biomarkers identified in the Mecoacan lagoon (ME18)

BIO MARKER	ng/g
C26, C27-TAS	3.25
C28-TAS (20S)	2.53
C27-TAS (20R)	2.69
C28-TAS (20R)	2.63
C21-MAS	0.63
C22-MAS	0.43
C28-20S-MAS	2.46
C27-C2920S/R-MAS	2.48

This compound type has not been identified in previous studies and in literature there are no reports of BMK levels in lagoons of the Gulf of Mexico. Biomarkers can provide information about: sedimentary organic matter biological sources, depositional media, organic matter maturity and geological age. These compounds are trace constituents and used as traces in oil characterization since they maintain their original carbon structure from the natural product and testify to oil generation conditions, support the relationship between oils, identify precursor organic matter type, product maturity, degradation and identification degree in the environmental case of the specific source product (Wang et al., 2007).

The presence of these compounds in the sediment of this point suggests influence of historical contributions from the facilities of the Dos Bocas Maritime Terminal receiving for treatment products and collateral wastes from exploration, production, transport and oil processing activities such as operations congenital waters on offshore platforms of the Sonda de Campeche.

Metals

Concentrations found in lagoons sediment are presented in Table IV.72 for the 9 metals reaching concentrations above MDL, while Table IV.73 presents metals descriptive statistics in each lagoon and in all the lagoons analyzed. Mercury and selenium are not presented in Tables as they were not recorded in any sample; while tin was measured in a single site in the Mecoacan lagoon; cadmium was found in two sites in el Carmen lagoon (averaging 1.358 mg/kg). Regarding cadmium levels, Caso et al (2004) presents concentrations in lagoons in the state of Tabasco from 1.3 mg/kg to 5.18 mg/kg, mentioning that all of them are above concentration to produce adverse biological effects to aquatic organisms (Effects Range Low value, ERL). Under this criterion, values found in this study also exceed ERL (1.2 mg/kg). However, information is limited to establish with certainty the risk posed by cadmium concentrations in el Carmen lagoon.

Aluminum was presented with a minimum concentration of 2318 mg/kg, an average of 5063 mg/kg and a maximum of 8124 mg/kg, which corresponded to a site in the Mecoacan lagoon. A similar behavior was observed for iron; both metals presented the maximum at ME18 site and the minimum at ME14 site. As is known, iron and aluminum are sediment constituent and abundant metals, so this is an expected result.

Arsenic concentrations were low, detectable only at 4 sites, two in el Carmen lagoon (averaging 5.279 mg/kg), one in Machona (4.228 mg/kg) and the highest in Mecoacan (5.934 mg/kg). The ERL value for this metal is 8.2 mg/kg, indicating arsenic does not pose a risk to life, under current conditions.

Barium was measured in all lagoons samples, fluctuating from 4.22 mg/kg to 33.14 mg/kg. Maximum concentrations were found in two sites of el Zorro lagoon, averaging 32.13 mg/kg. The second highest average was observed in la Machona lagoon with 13.74 mg/kg.

Cobalt showed concentrations with less variation compared to other metals, since the averages for the 5 lagoons ranged from 4.58 mg/kg (Machona) to 6.06 mg/kg (el Zorro). CV value (25) was the lowest of all metals.

Copper concentrations showed a minimum of 2.06, average of 4.78 and maximum of 7.38 mg/kg. On average, the highest concentrations corresponded to the Mecoacan lagoon (5.43 mg/kg). In literature, scarce, for copper concentrations in Tabasco’s lagoons, a higher level

(15,697 mg/kg) is reported for Machona. Referring to ERL for copper (34.0 mg/kg), there is no environmental risk under conditions determined in this study.

Chromium level found in lagoons ranged from 7.7mg/kg (site ME14) to 30.7 mg/kg (site ME16), with an overall average of 19.7 mg/kg. Concentrations were variable, however, in el Zorro and Tupilco they remained above 21.6 mg/kg. Results found in this study are lower than those reported in literature (Caso et al., 2004) where it is indicated chromium exceeds ERL value (81 mg/kg) in the states of Veracruz and Tabasco.

El Zorro lagoon presented the highest concentrations of manganese, averaging 1019.65 mg/kg. In the remaining lagoons el Carmen, Machona, Tupilco, and Mecoacan, much lower manganese levels were found (238.28, 279.86, 215.72 and 107.42 mg/kg, respectively). This metal does not have an ERL value, so it is not possible to establish whether the concentrations represent any level of environmental risk.

Nickel reached the highest concentrations (average 28.81 mg/kg) in el Zorro lagoon, followed by Mecoacan lagoon (21.43 mg/kg). This metal’s presence is associated, like vanadium, to crude oil, additionally, nickel is used as a catalyst in oil refining. It is for this reason sediments of the Gulf of Mexico have been identified as rich in this metal. Previous studies (Caso et al., 2004) reported nickel concentrations in Mecoacan of 42 mg/kg, i.e., higher than those found in this research. ERL value for nickel is 20.9 mg/kg, suggesting environmental risk exists in la Machona, el Zorro and Mecoacan lagoons (Figure IV.72).

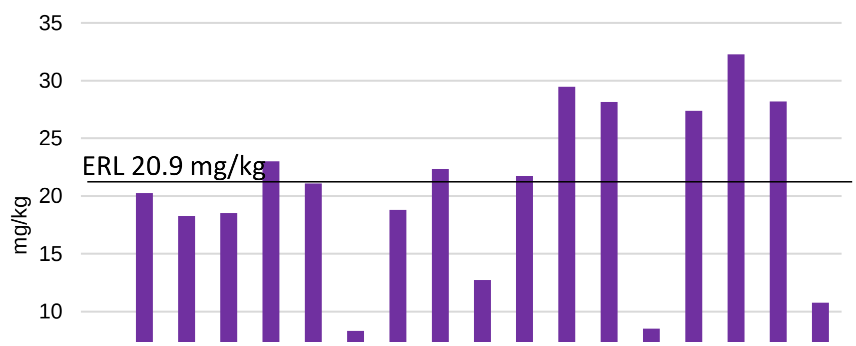


Figure IV. 72 Nickel concentration in lagoons sediments: el Carmen (C1-C4), Machona (MA5-MA9), Tupilco (T10-T11), el Zorro (Z12-Z13) and Mecoacan (ME14-ME18). ERL value indicates sites representing an environmental risk.

Lead had concentrations ranging from 2.1 to 5.96 mg/kg. Again, el Zorro lagoon showed the highest average, followed by la Machona. However, levels found in this study were lower than those reported in literature for the Mecoacan lagoon (56 mg/kg) and the Machona lagoon system (47.9 mg/kg) in 2004 by Caso et al., which concluded lead level exceeds ERL value (46.7 mg/kg) up to 150%. This suggests a decrease in this contaminant levels, the main source of which is attributed to anti-detonator manufacture, and current levels no longer represent environmental risk.

Relatively stable vanadium levels (CV of 24) with maximums in Tupilco and el Zorro lagoons (average of 12.38 and 9.95 mg/kg, respectively). There is no information on this metal concentrations in the lagoons comprising this study, so this information provides vanadium concentration general idea in lagoon systems. Vanadium does not have an ERL value indicating environmental risk.

El Zorro and Machona lagoons presented zinc highest concentrations, with an average of 24.37 and 21.97 mg/kg respectively. Some reports on this metal concentrations in sediment of the Machona lagoon system have a concentration of 137 mg/kg, i.e., higher than observed in this study. In none of the sites ERL value of 150 mg/kg was exceeded, so it is inferred there is no risk to aquatic life due to zinc levels.

Table IV. 35 Metals concentration in surface sediment of el Carmen, Machona, Tupilco, Zorro and Mecoacan lagoons.

		Al	As	Ba	Co.	Cu	Cr	Fe	Mn	Ni	Pb	V	Zn
Laguna el Carmen	C1	2814	5.027	13.91	3.849		8.144	7559	137.9	7.11	2.884	7.457	14.01
	C2	6124	5.532	9.047	4.932	5.052	20.62	12330	271.1	20.26	5.276	10.95	28.52
	C3	3508		10.27	8.391		14.64	8616	317.9	18.29	2.096	4.195	22.02
	C4	3128		9.389	4.715		15.96	8382	226.2	18.55		10.54	19.01
Machona lagoon	MA5	7170		13.41	5.216	5.365	23.65	14900	400.5	23.01	5.956	10.63	28.3
	MA6	7349		15.44	4.818	4.264	21.85	12840	406.4	21.08	4.011	9.929	23.72
	MA7	2879	4.288	5.119	3.997		8.841	8203	126.9	8.333	2.16	8.462	14.32
	MA8	5427		22.18	4.19	4.791	19.59	10150	154.7	18.83	3.519	8.478	19.58
	MA9	5991		12.54	4.655	4.641	22.73	12030	310.8	22.34	4.334	9.377	23.94
Tupilco lagoon	T10	3247		8.487	4.608	2.353	23.56	10200	124.4	12.73	2.389	13.51	16.59
	T11	5523		10.99	5.054	6.527	21.59	11730	90.43	21.76	4.695	11.24	23.28
el Zorro lagoon	Z12	6024		33.14	6.052	3.644	25.54	13570	1150	29.49	5.078	10.24	24.8
	Z13	5784		31.12	6.076	3.808	23.41	13020	889.3	28.13	4.099	9.668	23.93
Mecoacan lagoon	ME14	2318		6.886	2.832	2.06	7.698	5519	242	8.523		5.803	8.819
	ME15	7398		10.77	6.225	5.753	25.5	14790	262.7	27.4	4.271	11.44	26.07
	ME16	8124		10.46	6.294	6.512	30.17	14930	281.5	32.29	4.819	12.46	28.87
	ME17	5937	5.934	10.73	5.121	7.383	25.98	11800	221.8	28.19	4.2	10.44	21.05
	ME18	2393		4.218	3.403		9.66	6304	70.59	10.76	2.585	7.113	11.77
ERL value (mg/kg)			8.2				81		20.9		46.7		150

Table IV. 36 Metals concentrations descriptive statistics in surface sediment in complete lagoons system and per lagoon.

		Al	As	Ba	Co.	Cu	Cr	Fe	Mn	Ni	Pb	V	Zn
Full data	min	2318	4.29	4.22	2.83	2.06	7.70	5519	70.59	7.11	2.10	4.20	8.82
	p25	3158	4.84	9.13	4.29	3.81	14.97	8441	142	14.12	2.81	8.47	17.20
	average	5063	5.20	13.23	5.02	4.78	19.40	10937	316	19.84	3.90	9.55	21.03
	p75	6099	5.63	13.79	5.84	5.75	23.63	12975	316	26.30	4.73	10.87	24.59
	max	8124	5.93	33.14	8.39	7.38	30.17	14930	1150	32.29	5.96	13.51	28.87
	CV	38	14	60	25	33	36	27	88	39	30	24	28
Laguna el Carmen	min	2814	5.03	9.05	3.85	5.05	8.14	7559	138	7.11	2.10	4.20	14.01
	average	3894	5.28	10.65	5.47	5.05	14.84	9222	238	16.05	3.42	8.29	20.89
	max	6124	5.53	13.91	8.39	5.05	20.62	12330	318	20.26	5.28	10.95	28.52
Machona lagoon	min	2879	4.29	5.12	4.00	4.26	8.84	8203	127	8.33	2.16	8.46	14.32
	average	5763	4.29	13.74	4.58	4.77	19.33	11625	280	18.72	4.00	9.38	21.97
	max	7349	4.29	22.18	5.22	5.37	23.65	14900	406	23.01	5.96	10.63	28.30
Tupilco	average	4385		9.74	4.83	4.44	22.58	10965	107	17.25	3.54	12.38	19.94
Flores	average	5904		32.13	6.06	3.73	24.48	13295	1020	28.81	4.59	9.95	24.37
Mecoacan	min	2318	5.93	4.22	2.83	2.06	7.70	5519	71	8.52	2.59	5.80	8.82
	average	5234	5.93	8.61	4.78	5.43	19.80	10669	216	21.43	3.97	9.45	19.32
	max	8124	5.93	10.77	6.29	7.38	30.17	14930	282	32.29	4.82	12.46	28.87

As is known, metals enter aquatic ecosystems through natural and anthropic sources, being earth's crust weathering, urban and industrial residual discharges and fossil fuels combustion the most important sources. The association between metals and their potential sources identification was examined through factor analysis. The complete data were taken to have a database large enough for analysis. The results indicated 3 factors, the first with aluminum, iron, lead, zinc. This suggests a natural source, earth's crust weathering, and an industrial source that is frequently associated with mining (Blouni et al., 2009), although they can also be originated by minerals weathering such as galena (Chen et al., 2010). In order to identify sources with certainty, more detailed information is needed. The second Factor contains barium, suggesting an oil source, and manganese, which is widely used in the fertilizer industry (Botello et al., 1996). The third Factor presented chromium, vanadium and cobalt with the highest values; chromium is used in numerous industrial processes in petrochemistry and steel, while vanadium is also associated with oil and cement industry activities; partially treated urban discharges are usually rich in cobalt (Figure IV.73).

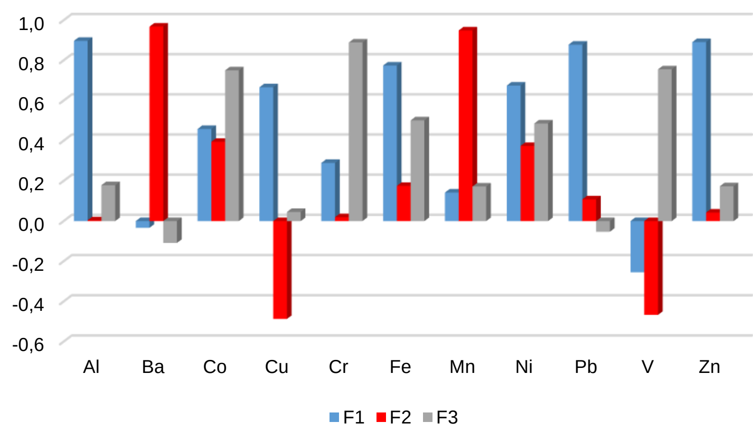


Figure IV. 73 Metals concentrations in lagoons sediments

Enrichment Factors (EF) and Geo accumulation Index (Igeo)

Enrichment Factors (EF) allow us to infer whether there is an anthropic contribution or, on the contrary, are levels that can be considered natural for the study area, since the calculation includes metal concentration normalization taking as reference sediment local characteristics. Generally iron concentration is used to perform standardization, as it is an abundant element in the earth's crust and its levels are significantly higher than other metals. The formula for calculating EF is:

$$FE = {\left({X_{sed}}/{Fe_{sed}}\right)} \Big/ {\left({X_{cor}}/{Fe_{cor}}\right)}$$

where X_{sed} and Fe_{sed} are the observed concentrations, and X_{cor} and Fe_{cor} are the reference concentrations.

There is a classification according to the value obtained from EF, which indicates that if the EF of a metal is less than 1, it is considered there is no enrichment, i.e., the presence of the metal in the study area is mainly due to natural processes. However, when EF value is greater than 1 and as it increases, it means metal concentration has an anthropogenic contribution. Thus, the categories are (Dong et al., 2012): 1) natural origin for EF values < 1; 2) minimum enrichment for cases where 1 < EF < 3; 3) moderate enrichment for EF values between 3-5; 4) severe moderate for 5 ≤ EF < 10; 5) severe for 10 ≤ EF < 25; 6) very severe for 25 ≤ EF < 50 and 7) extremely severe for EF ≥ 50.

EF results for each lagoons site indicated aluminum, vanadium, chromium, copper, barium and cobalt concentrations do not present significant influence on human activities. EF values for nickel showed correspondence with metal highest concentrations, suggesting human activities have a definite contribution to nickel levels in the studied lagoons. Manganese in el Zorro lagoon reached the highest EF values, indicating the contribution of anthropic sources is important in contamination level. Arsenic was detected only in 4 sites, however, in all of them a severe enrichment due to human activities is calculated. Cadmium and tin presented the highest EF indicating a very severe enrichment in both metals concentrations (Table IV.37). On the other hand, it is observed the four sites of el Carmen lagoon presented enrichment for some metal (in this case arsenic and cadmium); in la Machona arsenic at site MA7, although also in this lagoon the only site (MA8) was observed with EF values less than 1 for all metals (indicating a considerable dynamic in the lagoon). In el Zorro lagoon the highest EF for manganese were found, while in Mecoacan they stood out in arsenic and tin.

Table IV. 37 Metals Enrichment Factors (EF) in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons.

		Al	V	Cr	Mn	Co.	Ni	Cu	Zn	As	Sn	Ba	Pb	Cd
Laguna el Carmen	C1	0.16	0.26	0.39	0.69	0.73	0.45		0.95	13.30		0.16	1.10	
	C2	0.22	0.24	0.60	0.83	0.58	0.79	0.27	1.19	8.97		0.06	1.23	
	C3	0.18	0.13	0.61	1.40	1.40	1.02		1.31			0.10	0.70	29.31
	C4	0.16	0.34	0.69	1.02	0.81	1.06		1.17			0.09		28.20
Machona lagoon	MA5	0.21	0.19	0.57	1.02	0.50	0.74	0.24	0.98			0.08	1.15	
	MA6	0.25	0.21	0.61	1.20	0.54	0.79	0.22	0.95			0.10	0.90	
	MA7	0.15	0.28	0.39	0.59	0.70	0.49		0.90	10.45		0.05	0.76	
	MA8	0.23	0.22	0.69	0.58	0.59	0.89	0.31	0.99			0.19	1.00	
	MA9	0.22	0.21	0.68	0.98	0.56	0.89	0.25	1.02			0.09	1.04	
L. Tupilco	T10	0.14	0.35	0.83	0.46	0.65	0.60	0.15	0.84			0.07	0.67	
	T11	0.21	0.26	0.66	0.29	0.62	0.89	0.36	1.02			0.08	1.15	
L. Flores	Z12	0.19	0.20	0.68	3.21	0.64	1.04	0.18	0.94			0.21	1.08	
	Z13	0.19	0.20	0.65	2.59	0.67	1.04	0.19	0.95			0.20	0.91	
Mecoacan lagoon	ME14	0.18	0.28	0.50	1.66	0.74	0.74	0.24	0.82			0.11		
	ME15	0.22	0.21	0.62	0.67	0.61	0.99	0.25	0.91			0.06	0.83	
	ME16	0.24	0.22	0.73	0.71	0.61	1.04	0.29	0.99		35.39	0.06	0.93	
	ME17	0.22	0.24	0.79	0.71	0.62	1.15	0.41	0.92	10.06		0.08	1.03	
	ME18	0.17	0.30	0.55	0.42	0.78	0.82		0.96			0.06	1.18	

From the previous table, metals Enrichment Factors (EF) in el Carmen, Machona, Tupilco, el Zorro and Mecoacan lagoons. Natural origin (EF < 1) green; minimum enrichment (1 < EF < 3) yellow; moderate enrichment (EF between 3-5) orange; severe moderate enrichment (5 ≤ EF < 10) pink; severe enrichment (10 ≤ EF < 25) red; very severe enrichment (25 ≤ EF < 50) blue and enrichment extremely severe for EF ≥ 50, in purple.

To complement EF results, geo accumulation indices (Igeo) were also calculated, which are based on each metal reference concentrations. The formula is the following:

$$I_{geo} = log_2 \left({}^{X}/_{1.5Bn} \right)$$

where *X* is metal concentration, Bn is metal reference concentration and factor 1.5 is applied to correct lithogenic effects. Like EF, I_{geo} has 7 classes: if I_{geo} is less than 0, it is said there is no contamination; if $I_{geo} < 1$ is considered as uncontaminated or moderately contaminated;if I_{geo} has a value between 1-2, contamination by that metal is moderate; if I_{geo} is 2-3, it indicates moderate contamination; if I_{geo} reaches values between 3-4 it is strongly contaminated; for I_{geo} values between 4-5 is strong contamination; 5-6 indicates strong to very strong contamination; and if it is greater than 6 it is considered highly contaminated.

Igeo results found for metals showed a correspondence with EF, i.e., both indices highest values were obtained for the same sites. Igeo values confirm moderate contamination for cadmium and tin, being less than 1 for the remaining sites and metals. Arsenic presented values close to 1, so it is recommended to monitor these metals concentrations. Igeo values are shown in Table IV.38.

Table IV. 38 Geo accumulation indices (Igeo) for metals in Machona, Tupilco,el Zorro and Mecoacan lagoons. I_{geo} < 1 uncontaminated or moderately contaminated (green); I_{geo} between 1-2 moderate contamination (yellow).

		Al	As	Ba	Cd	Co.	Cu	Cr	Sn	Fe	Mn	Ni	Pb	V	Zn
el Carmen lagoon	C1	0.000	0.863	0.006		0.052		0.020		0.000	0.005	0.025	0.081	0.014	0.036
	C2	0.000	0.914	0.005		0.061	0.028	0.029		0.000	0.006	0.039	0.128	0.017	0.046
	C3	0.000		0.005	1.628	0.082		0.026		0.000	0.006	0.037	0.057	0.010	0.042
	C4	0.000		0.005	1.310	0.060		0.027		0.000	0.005	0.037		0.017	0.040
Machona lagoon	MA5	0.000		0.006		0.064	0.029	0.030		0.000	0.006	0.040	0.137	0.017	0.046
	MA6	0.000		0.006		0.060	0.025	0.030		0.000	0.006	0.039	0.107	0.016	0.044
	MA7	0.000	0.778	0.004		0.053		0.021		0.000	0.005	0.027	0.059	0.015	0.037
	MA8	0.000		0.007		0.055	0.027	0.029		0.000	0.005	0.038	0.097	0.015	0.041
	MA9	0.000		0.006		0.059	0.027	0.030		0.000	0.006	0.040	0.113	0.016	0.044
L. Tupilco	T10	0.000		0.005		0.059	0.015	0.030		0.000	0.005	0.033	0.067	0.019	0.039
	T11	0.000		0.005		0.062	0.033	0.030		0.000	0.005	0.039	0.119	0.017	0.043
L. Flores	Z12	0.000		0.008		0.069	0.023	0.031		0.000	0.007	0.043	0.125	0.017	0.044
	Z13	0.000		0.008		0.069	0.023	0.030		0.000	0.007	0.043	0.109	0.016	0.044
Mecoacan lagoon	ME14	0.000		0.004		0.040	0.013	0.020		0.000	0.006	0.027		0.013	0.030
	ME15	0.000		0.005		0.070	0.031	0.031		0.000	0.006	0.042	0.112	0.017	0.045
	ME16	0.000		0.005		0.071	0.033	0.033	1.625	0.000	0.006	0.045	0.121	0.018	0.046
	ME17	0.000	0.951	0.005		0.063	0.035	0.031		0.000	0.005	0.043	0.110	0.017	0.042
	ME18	0.000		0.003		0.047		0.022		0.000	0.004	0.030	0.073	0.014	0.034

Conclusions (metals, HC)

Aluminum, cobalt, copper, chromium, tin, iron, mercury, nickel and lead concentrations were higher in the Machona lagoon, while vanadium and zinc also had the highest values in the Tupilco lagoon. Arsenic and barium showed a different behavior, with high values in the Tupilco and Mecoacan lagoons. This suggests different contamination sources and physical and chemical factors governing As and Ba concentrations are different from the remaining metals. However, more information is needed to reach solid conclusions.

In sediments, metals highest concentrations (Al, Ba, Co, Cr, Fe, Mn, Ni, Pb, V and Zn) were observed in el Zorro lagoon, while in Mecoacan lagoon copper maximums were observed. With reference to ERL value, in order to avoid harmful effects on aquatic life, it was observed nickel exceeded this criterion in some sites of the Machona, Zorro and Mecoacan lagoons.

Factors analysis for metal concentrations in sediment indicated the presence of both natural and industrial sources, highlighting petrochemical, metallurgical, fertilizer production and urban discharges.

Calculated geo accumulation indices and Enrichment Factor for metals showed arsenic, tin and cadmium have an important contribution from anthropic sources raising their concentrations. Nickel, lead and zinc presented moderate enrichment in several sites in the lagoons, particularly in el Carmen lagoon.

IV.2.2 Biotic aspects

a) Land vegetation

To verify vegetation conservation status in the delimited SAR along the coastal strip, a vegetation sampling was carried out at defined points along the coastal area. This was aimed at current characterization, as well as verifying current problems to which coastal ecosystems are subjected by anthropogenic activities such as agriculture, livestock and industrial use areas, mainly by oil exploitation along the coast.

From field work, it is observed there has been a huge vegetation transformation of the coastal dunes. There are only relicts of herbaceous vegetation and shrubland in some dunes systems, but forest vegetation has largely disappeared from the SAR analyzed. In 1969, West et al still recorded forest remnants in the lowlands of the state (Patricia Moreno-Casasola et al, Inecol-SEMARNAT-CONAFOR).

Coconut trees planting, whose economic boom occurred since the last century due to the production of copra, still occupies large areas. Many of these coconuts are being destroyed by the lethal yellowing disease. However, despite this problem spreading along the Gulf of Mexico coast, current land use in the delimited SAR, continues to predominate agriculture with coconuts cultivation throughout the coastal strip.

Within these anthropic activities, livestock farming along the coastal zone, including on dunes near the coastline, occupy large expanses; as well as inter dunes lagoons are used as watering holes for cattle. To the west of the coast, jagüeyes can also be found in areas with less flooding, where water outcrops from the water table and form small artificial inter dunes lagoons.

To describe land and aquatic vegetation, as well as the diversity of species present in the Regional Environmental System (SAR), Area of Direct Influence (AID) and Project Area (PA), it was necessary to use methods such as:

Methods of sampling land vegetation

Variable Transects

Quantitative study of tree vegetation was carried out using the method by variable transects according to Foster et al (1995). Performing a total of four transects with coverage area of 0.2 hectares (20x100 m) at a distance between each of 20 m, outlined linearly and alternately within each polygon. Only tree species with the root system positioned within the boundaries of each transect were considered, otherwise they were discarded. The taxonomic identity of each specimen was recorded, as well as the total height and diameter at chest height (DAP1, 30 cm).

For shrub and herbaceous life forms (underbrush), transects of varying sizes were used for each case. Transects of an area of 16.0 sq. meters (4x4 m) for shrub and herbaceous species the established area was 1.0 sq. meters (1x1m) taking the measurements total height and diameter of the tree top. For each vegetation type, density, frequency and abundance were calculated per species within each polygon.

Species richness and abundance

Specified richness (S) is defined as the simplest way to measure biodiversity, since it is based only on the number of species present, without considering their importance value (Moreno, 2001). While abundance (number of individuals), is a variable population attribute in time and space expressed in absolute terms of population size (N = number of individuals in population).

Diversity

The diversity of each polygon was estimated by the Shannon-Wiener index (Moreno et al. 2001; Alvares et al. 2004), it combines information on species richness and equity, expresses the uniformity of importance values across all species in the sample, also measures the average degree of uncertainty, i.e., represents the probability two randomly selected individuals may belong to the same species within a delimited environmental system.

Similarity

It expresses the degree to which two samples are similar by the species present in them. There are many similarity indices, but the most used is Jaccard and Sorensen's. These indices are ideal for incomplete samples from communities with high richness, since they give equal weight to all species regardless of their abundance and therefore give importance to even the rarest species.

$$CCj = \frac{C}{S_1 + S_2 - C} = indice\ de\ Jaccard$$

$$CCj = \frac{C}{S_1 + S_2 - C} = indice\ de\ Sorensen$$

Where:

C=Number of species in common.

S=number of species in the sample.

The range of values for this index ranges from 0 (when there are no species shared between both sites) to 1 (when the two sites have the same species composition). To determine the estimates, specific software was used to handle this type of information, both for Windows.

Vegetation information analysis

According to INEGI's-2016 land use and vegetation Chart series VI, the project environmental system (SAR) in the land part is occupied by four main types of vegetation and/or land use: mangrove, tular, agriculture and cultivated pasture; as well as small areas without vegetation. In the following figure is shown the SAR, where the marine and land project location is indicated.

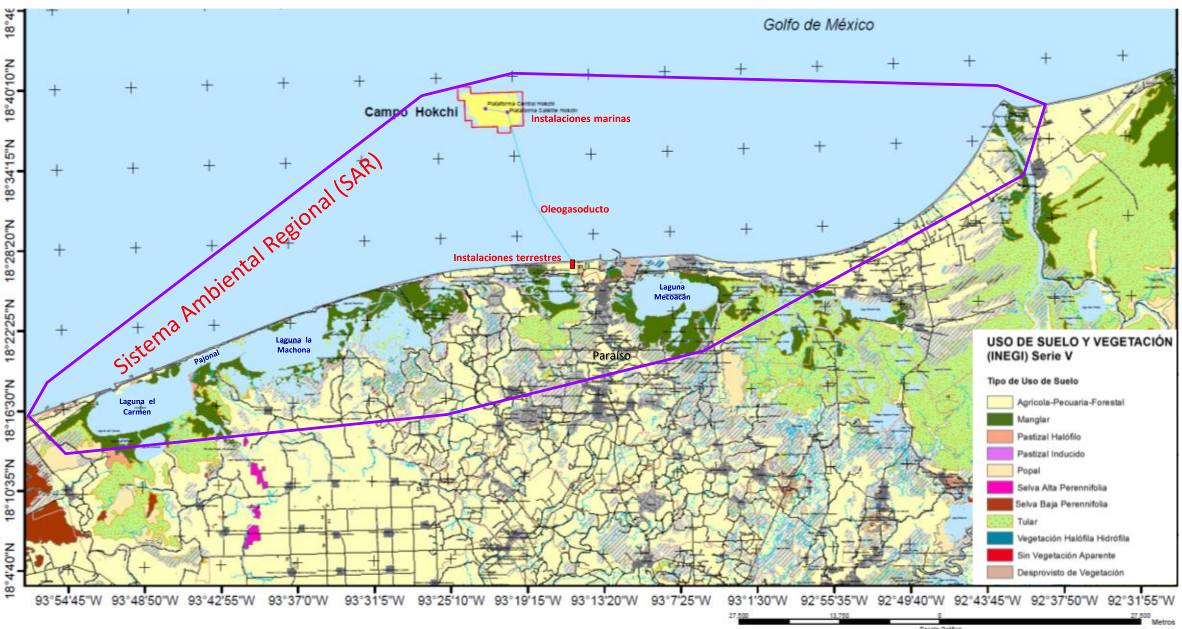


Figure IV. 74 INEGI's-2016 land use series VI and Marine-Land Project location.

In order to know vegetation structure and composition, as well as its organizational levels within the Environmental System for each polygon, it was necessary to evaluate its intrinsic attributes characterizing it, such as taxonomic composition, species richness and distribution, which together allow to obtain a more general ecosystem behavior and status.

To corroborate this information, field work was carried out, both for the **Property areas** where land facilities will be located and in the **SAR** , which are described below.

Vegetation characterization in "Land facilities areas"

Cultured palm grove

This type of vegetation was among the most representative in the areas where the land facilities (Hokchi Plant and Metering Station mainly) environmental system will be located, and according to INEGI's-2016 land use and vegetation Chart series VI, is considered as a growing area mainly for coconut trees (*Coco Nusifera*). The cultivation of coconut palms is an important source of income for the inhabitants of the area and is an activity that continues to date.

During field tours, this vegetation is found to be associated with characteristic fast-growing species, tall grass type and fruit trees species such as pepper (dioecious pepper) that is equally exploited by the inhabitants of the area.

Within the area where the Hokchi Plant will be located, the most representative species were coconut (*Cocos nucifera*) and few shrub species such as icaco (*Chrysobalanus icaco*) and crucietilla (*Randia aculeata*). Coconut palms mostly cover the mentioned area, which are a source of income for residents of the place and also function as a physical barrier to climatic phenomena.

Figure IV. 75 Cultivated palm grove associated with tall grass type tree species in the project area.

Cultivated and induced grassland:

Also within the area where the Hokchi Plant will be located mainly on the West side of the property and in the area where the Metering Station will be located with the highest coverage, gramines were identified with lower predominance, more predominant and widely distributed. This type of vegetation is mainly used for livestock purposes, therefore its importance and growing expansion. During field activities, two main grasslands subtypes were identified: cultivated and induced.

Figure IV. 76 .- Grassland with tree species vegetation present within the polygon

This type of vegetation is mainly characterized because the species developed there are low in size and of rapid growth, mainly used for livestock activities. The most common species used are: water grass (*Panicum purpurascens*), bermuda grass (*Cynodon dactylon*), star grass (*Cynodon plectostachyus*) and rice grass (*Echinochloa polystachya*).

Figure IV. 77 Bermuda grass (Cynodon dactylon) cultivated grassland and star grass (Cynodon plectostachyus) in the area where the metering station will be located.

Coastal dunes

This type vegetation was observed only in the Northern boundaries where the Hokchi Plant will be located next to the coastline. The species identified were: goats foot (*Ipomoea pes-caprae*), white dish breaker (*Ipomoea stolonifera*) and ash (*Croton punctatus*), which mostly present crawling life forms and are of the succulent type. These plants play an important role in this type of environment, as they adhere to the sand avoiding soil erosion due to weathering caused by wind and waves.

Figure IV. 78 Panoramic view in the northern part where the Hokchi Plant will be located, on the coast, we can see succulent species such as: goats foot (Ipomoea pes-caprae) and break white dish (Ipomoea stolonifera).

Aquatic vegetation

Some species characterizing low areas temporarily flooded (hydrophilic) were identified. Among the most common species of this ecosystem are: popal (*Thalia geniculata*), bulrush (*Typha latifolia*), hyacinth (*Eichhornia crassipes*), duckweed (*Lemna minor*), water lettuce (*Pistia stratiotes*) among others. This type of ecosystem is very changing depending on flood levels the diversity of species varies in the same way; being so, in dry season it is more common to find species such as: duck tail (*Sagittaria latifolia*), straw (*Pontederia lanceolata*), root hair (*Leersia hexandra*) and rush (*Cyperus ferax*).

During field activities, very little vegetation of this type was found, mainly in the Northern part of where the Metering Station is intended to be located, due to its environmental temporality and that during the dry season they disappear in their entirety, giving way to the growth of grasses used for livestock purposes.

Secondary vegetation or tall grass

Some of these species were identified in the area where the Hokchi Plant will be located, this type of vegetation is characterized by a very heterogeneous and fast-growing floristic composition such as: West Indian elm (*Guazuma ulmifolia*), trumpet tree (*Cecropia obtusifolia*), mallow (*Hampea macrocarpa*), jonote (*Heliocarpus donell-smithii*); as well as species of vines; bitter melon (*Momordica charantia*), Cardinal climber (*Quamoclit pinnata*) to mention just a few. The rapid development of these species also increases the competition for space with the site original vegetation as shown in the following Figure.

Figure IV. 79 Secondary vegetation view of the tall grass type

The photographic report for the area where land facilities will be located is found in Annex No. 5, as well as the location sketch of the images taken.

Vegetation in the Regional Environmental System (SAR).

Within the project delimited SAR, six different vegetation types and/or land use were identified based on their structural characteristics and floristic composition of both field tours of published information from sources such as INEGI, CONABIO, among others.

Aquatic vegetation

This is characterized by species inhabiting areas remaining flooded (hydrophilic) in a semi-permanent manner. Among the most common species of this ecosystem are: popal (*Thalia geniculata*), bulrush (*Typha latifolia*), hyacinth (*Eichhornia crassipes*), duckweed (*Lemna minor*), water lettuce (*Pistia stratiotes*) among others. This type of ecosystem is very changing depending on flood levels the diversity of species varies in the same way; being so, in dry season it is more common to find species such as: duck tail (*Sagittaria latifolia*), straw (*Pontederia lanceolata*), root hair (*Leersia hexandra*) and rush (*Cyperus ferax*).

During field activities, this type of vegetation was located on the West side outside future land facilities at about a kilometer, where there are areas of greatest flooding much of the year. Low-lying areas were also identified in a smaller proportion in the project area that eventually disappear in their entirety during the dry season, giving way to the growth of grasses that are used for livestock purposes by the inhabitants of the surrounding communities.

Figure IV. 80 Hydrophilic vegetation within the flooding areas polygon in the SAR

Figure IV. 81 Aquatic vegetation in SAR outside the property on the West side with hydrophilic species such as: bulrush (Typha latifolia) and root hair (Leersia hexandra).

Cultivated and induced grassland

Within the environmental system, grasses were the most predominant and widely distributed species. This type of vegetation is mainly used for livestock purposes, therefore its importance and growing expansion. During field activities, two main grasslands subtypes could be identified: those induced and wooded grassland.

This type of vegetation is mainly characterized because the species developed there are low in size and of rapid growth, mainly used for livestock activities. The most common species used are: water grass (*Panicum purpurascens*), bermuda grass (*Cynodon dactylon*), star grass (*Cynodon plectostachyus*) and rice grass (*Echinochloa polystachya*).

Within these plant communities, some tree species could be identified such as gumbo-limbo (*Bursera simaruba*), quick stick (*Gliricidia sepium*), amate (*Ficus padifolia*), rosy trumpet (*Tabebuia rosea*); in addition to some shrubs such as trumpet tree (*Cecropia obtusifolia*) and coco plum (*Chrysobalanus icaco*), used as living fences to delimit properties.

Figure IV. 82 Induced grassland associated with coconut palms and shrub vegetation

Mangrove

This type of vegetation is characterized by presenting only halophilic life forms, whose species have a special root system designed to be fastened to the substrate; in addition to empowering it to resist salt ions high concentrations. This system consists of a more homogeneous environment, where only one species is the dominant one.

During field work and information on INEGI's thematic maps, these plant communities (North side of Laguna Grande de Las Flores) were identified and observed on more than 100 meters from the in between street on the South side, outside the property boundaries and at more than 600 meters from where the facilities will be located to manage hydrocarbons.

As part of the regional characterization, this type of plant communities were also sampled on more than 1.5 kilometers outside the Southwest boundary of the property on the side of the Laguna Grande de las Flores. As well as near the Barra de Tupilco more than 20 kilometers to the East of future land facilities approximately, which according to INEGI's-2016 land use and vegetation chart VI, and subsequent field verification, are characterized by only mangrove vegetation with red mangrove (*Rhizophora mangle*) dominance.

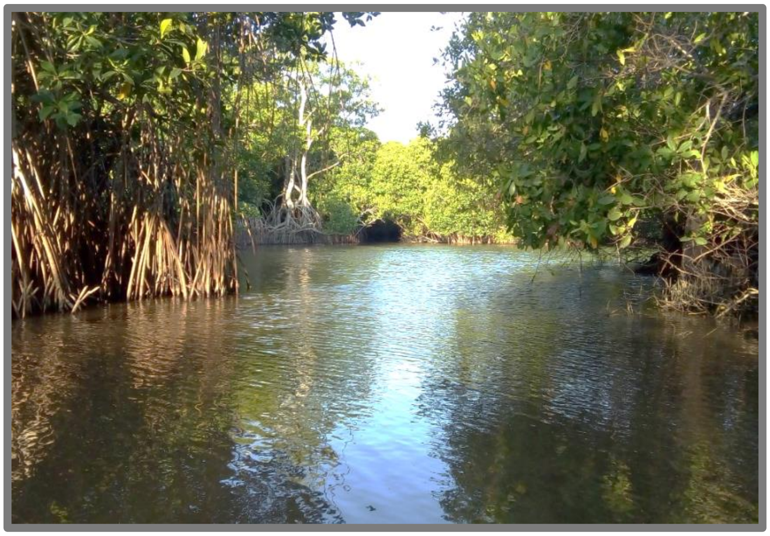


Figure IV. 83 Panoramic view of the mangrove present with red mangrove (Rhizophora mangle) near the Tupilco Bar

On the other hand, *Laguncularia racemosa* (white mangrove) and *Avicennia germinans* (black mangrove) mangroves, presented in a smaller proportion and size further away from the flooded areas where salt concentrations are lower. It was also possible to observe some specimens of the *Mexican Sabal* species, which can tolerate short flooding seasons and low salinity levels.

Despite the importance of this ecosystem type conservation, immoderate logging for coal manufacturing has led to a decrease in species populations such as black and white mangroves, which grow further away from flooding areas allowing easy extraction.

However, mangrove population high regenerative capacity allowed to identify sites with high conservation levels and in recovery process. See figure below.

Figure IV. 84 Red mangrove species (Rhizophora mangrove) in adult state and growing seedlings, observed at the sampling point more than 1 km to the South outside where the Plant will be installed (East side of the Laguna Grande de las Flores)

In Annex No. 2 is included the map of Land Vegetation Sampling Points.

Another of the mangrove areas included in the study is the Mecoacan lagoon system and according to information from INEGI and CONABIO, there are currently mangrove vegetation communities from the South of the Dos Bocas Maritime Terminal, the surroundings of the Mecoacan lagoon, Lake Juliva, Santa Anita, among others, of this lagoon system. The remaining mangrove species (Technical data sheet: Mecoacan—Juliva—Santa Anita lagoons, CONABIO) in the area are: Rhizophora mangle (red mangrove), Avicennia germinans (black mangrove) and Laguncularia racemosa (white mangrove).

Figure IV. 85 Mangrove on the North side of the Mecoacan lagoon more than 10 km East of the project

According to CONABIO reports, mangrove wood is still used today for building houses in rural areas, beach shades in restaurants and spas, poles for delimiting plots and falsework in construction, as well as fuel (coal and firewood) and sometimes as ornamental.

Cultured palm grove

This vegetation type was among the most representative within the environmental system, and according to INEGI's-2016 land use and vegetation Chart series VI, is considered as a cultivation area in the entire coastal strip from the mouth of the Grijalva river, passing through the area where will be located Project's land facilities up to the mouth of the Tonala river. Coconut palms cultivation is an important source of income for the inhabitants of the mentioned entire coastal strip along the coastline, an activity continuing to date.

During the field tour, this vegetation type was associated with some fruit trees species such as pepper (*Pimienta dioica*), cocoa (*Theobroma cacao*) and avocado (*Persea americana*) species used likewise by the area inhabitants.

Palm tree associated with tree vegetation also represents a source of shelter and food for some fauna species, such as the Grey Squirrel (*Sciurus aureogaster*) and the common Mexican mouse opossum (*Didelphis marsupialis*), which are among the most common species to find within this environment type.

Figure IV. 86 Coconut palm (Cocos nucifera) cultivation predominant within the coastal area anthropic activities.

Figure IV.86. Coconut palm (Cocos nucifera) cultivation predominant within the coastal area anthropic activities.

Secondary vegetation or tall grass

It is also common to find this type of vegetation throughout the coastal strip which is associated with the agricultural and livestock use of the entire delimited SAR for this Project. This system is characterized for presenting a very heterogeneous and fast-growing floristic composition, among the most abundant species are the following: West Indian elm (*Guazuma ulmifolia*), trumpet tree (*Cecropia obtusifolia*), mallow (*Hampea macrocarpa*), jonote (*Heliocarpus donell-smithii*); as well as species of vines; bitter melon (*Momordica charantia*), Cardinal climber (*Quamoclit pinnata*) to mention just a few.

The rapid development of these species also increases competition for space, which leads to original vegetation species displacement in the area. This vegetation was most often found in cultivated areas throughout the coastal strip to the limits with the coastline on the North side. They were characterized by presenting this vegetation type with dense spots isolated from urban areas occupying abandoned cultivation sites. Likewise, high heterogeneity makes these environments ideal spaces for some species of fauna, mainly for birds, which use them as refuge and feeding areas.

Figure IV. 87 Secondary vegetation of tall grass.

Floristic composition.

Studied areas and sampling points floristic composition are indicated in the vegetation and fauna sampling points location map included in Annex 2. Together, these sampling points form the environmental system representation in the land part considered for the present project study. In general, taxonomically represented by 54 families, 96 genera and 108 species were identified. The most representative families were: the Fabaceae family with a total of 15 species, followed by the Poaceae family with 13 and the Araceae family with 4 species.

On the other hand, it was found the type of vegetation and/or land use in the area where the property will be located (Hokchi Plant) is represented by secondary vegetation, grassland and palmar (coconut cultivation of the nucifera species); as well as the area where the metering shed will be installed where the cultivated pasture predominates followed by coconut nucifera as can be seen in the figures in the previous sections.

The mangrove vegetation as a dominant species was only recorded and observed in the vicinity of Laguna Grande de Las Flores and the area closest to these plant communities, is located on the south side, outside the boundaries of the land more than 100 meters, with road in between and more than 600 meters from where facilities handling hydrocarbons will be located.

Vegetation distribution

Vegetation distribution within the environmental system was characteristic within each polygon and sampling points, finding that grassland and wooded grassland vegetation, as well as coconut cultivation, were the most widely distributed along the entire coastal strip included in SAR. The mangrove vegetation was representative only in lagoon systems and close to them such as Laguna el Carmen, el Pajonal, La Machona, Barra de Tupilco, Laguna Grande de las Flores, around the lagoon system of Mecoacan, Barra de Chiltepec and mangrove relicts at the mouth of the Grijalva river and Tonala river, East and West sides of the SAR respectively (INEGI, CONABIO).

Density

Density (*D*) is defined as the number of individuals (*N*) existing in a given area (*A*), which is estimated by counting the number of individuals in each sample unit.

Details of this sampling can be found in Annex No. 4 of the present study.

The density analysis carried out in the sampling zones only for those species with a $DAP_{1,3\ m}$*,* height and it was found the species *Cocos nucifera* was the most representative for: the area where the Hokchi Plant will be located and where the metering, also towards the East and West side of the coastal strip.

Of the sampling points performed in the environmental system characterization defined for this Project in the coastal area, the species *Rhizophora mangle* presented the highest density in the characterization areas located to the South, near Laguna Grande de las Flores, and to the West, near Barra de Tupilco and Laguna la Redonda. The following Table presents the relative density estimated for the representative species in the study area.

Table IV. 39Sampling areas most representative species relative density (%).

Species	Flora-Fauna A	Flora-Fauna B	Flora-Fauna 1	Flora-Fauna 2	Flora-Fauna 3
Avicennia germinans	0.00	0.00	0.98	0.00	2.51
Bursera simaruba	9.32	1.03	0.00	3.05	0.00
Bursera graveolens	9.32	0.00	0.00	0.00	0.00
Cocos nucifera	**25.42**	**23.71**	0.00	**38.17**	0.25
Glyricidia sepium	8.47	20.62	0.00	0.00	0.00
Laguncularia racemosa	0.00	0.00	2.94	0.00	7.52
Pachira aquatica	0.00	13.40	0.00	0.54	0.00
Pimenta dioica	7.63	0.00	0.00	3.41	0.00
Rhizophora mangle	0.00	0.00	**96.08**	0.00	**87.72**
Tabebuia rosea	5.93	9.28	0.00	25.27	0.00
37 remaining species	33.91	31.96	0.00	29.56	2.00
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Flora-Fauna A = Hokchi Plant Area

Flora-Fauna B = Metering Station Area

Flora-Fauna 1 = West Area outside Hokchi Plant between Barra de Tupilco and Laguna la Redonda

Flora-Fauna 2 = Area 1 km West of Hokchi Plant

Flora-Fauna 3 = Area East of Laguna Grande de las Flores

Diversity and Dominance Indexes

The results of **Shannon-Wiener's** species diversity analysis in each of the studied areas are as follows:

With regard to vegetation species diversity, as well as its dominance, it was found in the area where the Hokchi Plant will be located values were lower and is mainly due to the fact dominant species was the coconut palm (coco nusífera) with interspersed vegetation tall grass type, followed by the cultivated grassland, this type of vegetation was also recorded in the vicinity of the property. The area where the Metering Station will be located, the dominant species was the cultivated grassland, followed by the coconut palm (coco nusífera).

With regard to the sampling points towards Laguna Grande de las Flores and the areas between Barra de Tupilco and Laguna la Redonda characterized as mangrove areas, presented the highest dominance values by mangrove species, where the dominant species was the red mangrove (*Rhizophora mangle*) which is characteristic of these areas.

Species in the Project Area (Hokchi Plant and Metering Station)

Below are listed the vegetation species recorded during the field work in the area where land facilities will be located (Hokchi Plant and Metering Station). It also indicates its protection status under NOM-059-SEMARNAT-2010 and CITES.

Table IV. 40 Vegetation in the Project Area (Hokchi Plant) Part "A" and "B"

Species (scientific name)	**Common name**	**Usage**	**Category NOM-059 and CITES**
Cocos nucifera	*Coconut*	Food and commercial, among others	No
Bursera simaruba	*Palo mulatto, Chaka*	Delimitation of properties	No
Ceiba pentandra	*Ceiba*	Household utensils, handicrafts, charcoal, medicinal, etc. It had totemic significance in Mayan families	No
Guazuma ulmifolia	Guacimo	Delimitation of properties	No
Cecropia obtusifolia	Guarumo	Occasional medicinal	No
Pimenta dioica	Pepper	Culinary use	No
Chrysobalanus icaco	Icaco	Edible fruit	No
Hampea macrocarpa	Majagua	Occasional medicinal	No
Heliocarpus donell-smithii	Jolotzin	Occasional medicinal	No
Randia aculeata	Crucetilla	No use, grows on disturbed sites	No
Roystonea regia	Royal Palm (9 adult specimens)	The trunk for local houses, roofing houses, use in gardening or ornament, etc.	**Pr**
Momordica charantia	Cundeamor (vine)	No local use	No
Quamoclit pinnata	Campanita	No local use	No
Lantana camara	Cinco negritos	Ornamental	No
Panicum purpurascens	Water grass (vine)	Forage, grazing	No
Cynodon dactylon	Bermuda grass	Forage, grazing	No
Cynodon plectostachyus	Star grass	Forage, grazing	No
Echinochloa polystachya	Rice grass	Forage, grazing	No

Ipomoea pes-caprae	Riñonina	Occasional ornamental, coastal stabilizer, medicinal, etc.	No
Ipomoea stolonifera	Break white dish	Possible dune stabilizer	No
Ipomoea purpurea	Break purple dish	Possible dune stabilizer	No
Croton punctatus	Cenizo	No use	No
Thalia geniculata	Popal	Occasionally ornamental	No
Typha latifolia	Espadaño	Occasional gardening, roofs, chairs, hats, etc.	No
Eichhornia crassipes	Hyacinth	Forage, ornamental, among others.	No
Lemna minor	Duckweed	Food for some animals	No
Pistia stratiotes	Water lettuce	Occasional gardening, decorative	No
Sagittaria latifolia	Duck tail	Occasional gardening, decorative	No
Pontederia lanceolata	Popote	Occasional gardening, decorative	No
Leersia hexandra	Pelillo	Occasional forage (secondary vegetation	No
Cyperus ferax	Navajuela	Occasional Gardening	No

Category NOM-059-SEMARNAT-2010: Endangered (P), Threatened (A) and **Subject to Special Protection (Pr)**

Table IV. 41 Vegetation in the Project Area (Metering Station)

Species (scientific name)	**Common name**	**Usage**	**Category NOM-059 and CITES**
Cocos nucifera	*Coconut*	Food and commercial, among others	No
Bursera simaruba	*Palo mulatto, Chaka*	Delimitation of properties	No
Crataeba tapia	*Coscorron*	Delimitation of properties	No
Cynodon dactylon	bermuda grass	Forage, grazing	No
Cynodon plectostachyus	star grass	Forage, grazing	No
Typha latifolia	Espadaño	Occasional gardening, roofs, chairs, hats, etc.	No
Eichhornia crassipes	Hyacinth	Forage, ornamental, among others.	No
Lemna minor	duckweed	Food for some animals	No
Pistia stratiotes	water lettuce	Occasional gardening, decorative	No

Category NOM-059-SEMARNAT-2010: Endangered (P), Threatened (A) and **Subject to Special Protection (Pr)**

The areas are currently classified by INEGI as agricultural areas, which was corroborated during field work. It was also observed there are currently areas for livestock use in the areas where land facilities are intended to be built.

It should be noted that mangrove species with protection status in NOM-059-SEMARNAT-2010 mentioned below were not found in the project areas, only in the SAR outside the project area.

Table IV. 42 Mangle registered outside the Project area and its status in NOM-059-SEMARNAT-2010

Family	Species	Common name	Category
Avicenniaceae	*Avicennia germinans*	Black mangrove	To
Combretaceae	*Laguncularia racemosa*	White mangrove	A
Meliaceae	*Cedrela odorata*	Cedar	Pr
Rhizophoraceae	*Rhizophora mangle*	Red mangrove	A

Category NOM-059-SEMARNAT-2010: Endangered (P), Threatened (A) and **Subject to Special Protection (Pr)**

The Vegetation List in the SAR can be found in Annex No. 4 of the present study.

Endemic species

Of the total species number reported and included in lists in Annex No. 4 for the present project SAR, none are considered endemic, since they have a wide distribution beyond the study area limits.

b) Fauna

Land fauna sampling methods

In order to know fauna species diversity present in the Regional Environmental System (SAR), Area of Direct Influence (AID) and Project Area (PA) included for the project in the land part, it was necessary to use direct and indirect field sampling methods specific to each taxonomic group. These methodologies consist mainly in establishing transects and monitoring stations, allowing to make a more precise estimate of the species held in the area under study. It is important to mention species records were made according to direct and indirect methods, noting those present, possible and those probable (bibliographic record). Each methodology used by taxonomic group is briefly described below:

Birds monitoring stations

This method consisted in following a transect along the property with points delimited at a distance of 100.0 m approximately between each point, to ensure independence, at each point the observation time and radius was 10 min and 50 m respectively. Surveys were carried out in two schedules, one during daytime (06:00 to 10:00am) and another in the afternoon (16:00 to 18:00pm) shifts where bird species have their greatest activity. For organisms identification, it was done directly through the use of binoculars and photographs, as well as the use of specialized guides to confirm each species spotted. In addition to direct spotting, identification method through singing or vocalization allowed to increase the record and therefore species diversity and abundance within each polygon. During field bird watching, notes were also taken on other behavior parameters such as perching, flying, singing, walking, nesting or feeding, among others, and were recorded in the same way for each species spotted within the different polygons.

Mammals direct search

To estimate mammals presence within the environmental system, the *direct search* method proposed by Wallace (1999) was used. Therefore, linear transects were used, which were randomly plotted and distributed within each polygon with a length of 0.5 km. Transects survey was carried out at a slow pace (approximately 0.5 km/h) with observation range as far as the vegetation allowed, survey schedules were: daytime (06:00 to 10:00am) and in the afternoons (14:00 to 18:00pm) placing momentary observation points every 100 m for 10 min in each transect, making the lowest possible noise and at night with the lights off. During the survey, each observed species was recorded, as well as the approximate distance to the central line of the transect. In addition to direct observation, records were performed by indirect methods, such as identification by footprints, excreta, bone remains, fur and so-called guttural. Specialized guides for Aranda's taxon (2000) and Ceballos & Oliva (2005) were used to identify species.

Amphibians and reptiles transects

Herpetofaunistic diversity was estimated by using the transects method according to Barragan-Vazquez (2007). These had a length of 0.5 km and variable width depending on vegetation type. Surveys were carried out slowly (1.0 km/h approximately) in two schedules: daytime (09:00 to 10:00am) and nighttime (16:00 to 22:00pm). For specimens identification and registration, it was through direct capture or singing. Data on specimens, sex, place and time of capture were taken for the captured specimens. Captured specimens were released at the same site, always considering doing the least damage and stress possible. Field guides used for the group were those of Calderón-Mandujano *et al. (*2005) y Cedeño-Vázquez *et al.* (2006).

Fauna present composition and structure in the Project SAR

Fauna composition within the Regional Environmental Systems was represented by 26 orders, 56 families, 86 genera and 97 species, of which birds were the most representative constituting 60.48% of the total, followed by reptiles with 14.4%, mammals 9.6% and finally amphibians with 7.68% (Table IV.43).

Table IV. 43 Faunistic composition present in Project SAR

Class	**Order**	**Family**	**Gender**	**Species**
Amphibians	1	5	9	9

Birds	18	34	56	63
Reptiles	3	11	13	15
Mammals	4	7	8	10
Total	26	57	86	97

Wealth

The group of birds was made up of 18 orders, 34 families, 56 genera and 63 species, in terms of species richness, the passeriformes order was the one with most richness, with eight families and 15 species, followed by the order falconiformes and Ciconiiformes with eight and seven species, respectively; later the Charadriiformes with four families and five species and the Columbiformes with one genus and four species. The orders with the lowest richness were Apodiformes, Coraciformes, Pelecaniformes and Psittaciformes with three species each, followed by Anseriformes, Caprimulgiformes, Cuculiformes, Gruiformes and Podicediformes with only one genus and one species.

The second group was represented by reptiles, with three orders, 10 families and 14 species. The Squamata order was the richest with a total of 9 families and 13 species, followed by the orders Crocodrilia and Testudines with one family and one species each.

For mammals, four orders were recorded, seven families and 10 species, with the Carnivorous order being the one with most richness, with three families and four species, followed by the orders Chiroptera, Didelphimorphia and Rodentia with two species each.

As for amphibians, they were represented by only one order with six families and nine species, thus being the ones with less richness. Hylidae family was the best represented with a total of four species, followed by Bufonidae family with two and finally Leptodactylidae, Microhylidae and Ranidae families with only one species.

Abundance

As with specific richness, birds were the ones showing the highest values of abundance compared to other taxons (see figure below). These results were directly related to the types of environments present within the study area, which mostly present characteristics suitable for the reproduction of this group of organisms, as well as presenting water bodies that serve to obtain food for many bird species.

For the amphibian group a different situation was observed, although they presented low richness; they formed the second group with greater abundance (see figure below). This high frequency is given by two species *Leptodactylus melanonotus* and *Dendropsophus microcephalus*, which are common to be found in environments with little vegetation and with permanent to semi-permanent flooding zones, such as those located within the assessed environmental system.

Mammals represented the third group with the highest abundance, most of which were nocturnal habits such as bats and raccoons.

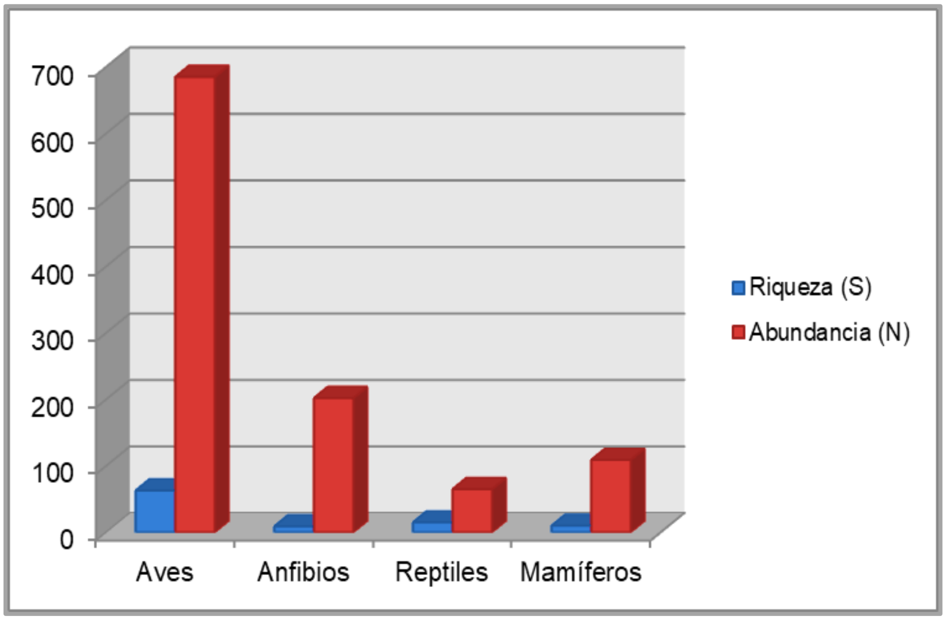


Figure IV. 88 Richness and abundance comparison by taxonomic group

Wealth and abundance comparative analysis per polygon is shown in Table IV.44. The sampling area in the Western part outside the site where the Hokchi Plant will be located was the one presenting the greatest species richness and abundance; the first was associated with the different types of environments characterizing the polygon; while the second was due to high frequency indices mainly of amphibians and birds.

The sampling areas to the East of Laguna Grande de las Flores showed the lowest abundance index where only mangrove was observed (see next Table).

Table IV. 44 Richness and abundance per taxonomic group at sampling points

Polygons	Wealth (S)	Abundance (N)				
		Amphibians	Reptiles	Birds	Mammals	Total
Flora-fauna A	41	40	10	94	19	163
Flora-fauna B	32	60	6	84	13	189
Flora-fauna 1	37	4	12	167	17	200
Flora-fauna 2	65	91	26	209	49	368
Flora-fauna 3	35	7	11	131	11	160
Total	**96**	**195**	**65**	**685**	**109**	**1061**

Flora-Fauna A = Hokchi Plant Area

Flora-Fauna B = Metering Station Area

Flora-Fauna 1 = West Area outside Hokchi Plant between Barra de Tupilco and Laguna la Redonda

Flora-Fauna 2 = Area 1 km West of Hokchi Plant

Flora-Fauna 3 = Area East of Laguna Grande de las Flores

Diversity and similarity

The values obtained by the Shannon-Wiener diversity index were considered high for each evaluated polygons. These results were associated with the heterogeneity of ecosystems characterizing the environmental system. Although the mangrove environment showed the lowest richness levels for the amphibian and reptile group, it was compensated by a greater number of bird species, which balances diversity indices with the other polygons (see Table below).

On the other part, Chao's 1 similarity index showed high homogeneity for each of the sampled polygons. This stability was given by the species shared with greater or lesser numbers within each polygon as shown below.

Table IV. 45 Shannon-Wiener (H') diversity indices and similarity per polygon.

Polygon	**(H´)**	**Similarity**
Flora-Fauna A	3.55	0.96
Flora-Fauna B	3.08	0.93
Flora-Fauna 1	3.36	0.95
Flora-Fauna 2	3.74	0.96
Flora-Fauna 3	3.17	0.93

Flora-Fauna A = Hokchi Plant Area

Flora-Fauna B = Metering Station Area

Flora-Fauna 1 = West Area outside Hokchi Plant between Barra de Tupilco and Laguna la Redonda

Flora-Fauna 2 = Area 1 km West of Hokchi Plant

Flora-Fauna 3 = Area East of Laguna Grande de las Flores

Distribution

Fauna distribution is characterized by following certain patterns, where species highest concentration is located near the most equatorial latitudes (Ceballos and Oliva, 2005). Tropical systems located in the Neartic-Tropical transition are the systems presenting the greatest species richness and diversity, such as the one characterizing the studied environmental system.

The species present within the project environmental system are species of wide distribution, ranging from the Neotropical region to the sub region in Mesoamerica, which together make up the Mesoamerican Biological Corridor (Icaza, 2003). In Mexico, these biological corridors allow species mainly (non-flying) mammals to move without any hindrance, from the center of the country to the South on the Yucatan peninsula; extending even further to the Northeast near the Equator, which also allows genetic flow between species as shown in next figure.

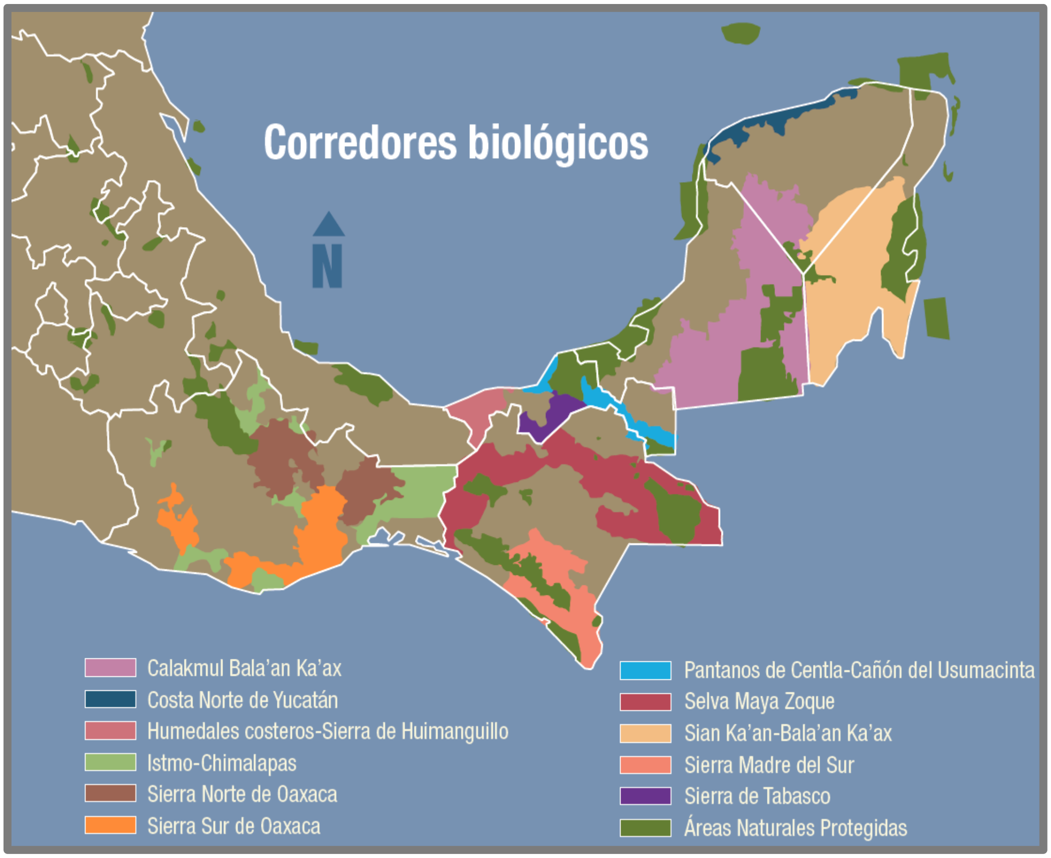


Figure IV. 89 Mexican biological corridors close to the project area, CONABIO, 2013.

Birds Reproduction

Reproduction in birds is a phenomenon is characterized for resulting only at specific times of the year, and in some cases involves migration to specific nesting sites. In most bird species, reproduction begins in early spring. However, in Neotropical species there may be two to three reproductive seasons throughout the year, depending on climatic conditions, altitudinal gradient and photoperiod (Berlanga & Rodríguez, 2010).

As shown in the following Table:

Table IV. 46 Some birds present in the SAR reproductive seasons

Scientific name	Common name	Reproductive period	Habitat
Amazona albifrons	White fronted parrot	January to May	Hollow tree tops
Ardea alba	Great egret	March to June	Top of trees and shrubs
Egretta caerulea	Great blue heron	May to June	Top of trees and shrubs
Bubulcus ibis	Cattle egret	May	Top of trees and shrubs
Eudocimus albus	American white ibis	March to June	Dense vegetation area
Caracara cheriway	Northern crested caracara	January to March	--
Coragyps atratus	Black vulture	May	Dense vegetation area
Icterus auratus	Orange oriole	April to August	Top of trees and shrubs

Source: Alvarez-Romero *et al*. 2008; Piña-Ortiz *et al*. 2017

The disturbance of nesting and breeding sites (mainly of migratory birds), can lead organisms to leave the nest and end the reproductive cycle, resulting in the failure of this generation and therefore the decrease of the annual population (González-Valdivia *et al*. 2012). During field trips, it was possible to spot some bird species in reproductive state, which were characterized by the change of color in their plumage, courtship through singing, nesting construction or as in some cases in nesting. However, no specific nesting sites were observed, as species spotted in reproduction because they are resident, implying that their nesting is not specific to a particular nesting place, implying that their reproduction is almost throughout the study area.

Figure IV. 90 Chick of buff-bellied hummingbird (Amazilia yucatananensis) species observed (outside the project area) at the sampling point East of Laguna Grande de las Flores.

Mammals

The reproductive season in the mammals group is associated with environmental factors and the availability of food, in some species reproductive season begins during the first months of the year, with variable gestation stages, where the birth of the brood can even occur at the end of the year. During field activities on the different polygons, no organisms of this group were observed in courtship or mating state, as well neither specific breeding sites. However, the possibility that there were species in reproductive state according to the literature is not ruled out. As shown in the following table:

Table IV. 47 Reproductive seasons of some mammals recorded in the SAR

Scientific name	**Common name**	**Reproductive period**	**Habitat**
Didelphis marsupialis	Opossum	January-October	BTH
Didelphis virginiana	Peeled tail Mexican opossum	January to February/June to July	BTH
H. yagouaroundi	Jaguarundi	January to March	BT, MG
Leopardus wiedii	Margay	----	BT, MG
Canis latrans	Coyote	January-April	TV
Procyon lotor	Racoon	December to March	BT, MG
Artibeus jamaicensis	Fruit bat	July-April	BT, MG
Artibeus lituratus	Great fruit-eating bat	July-April	BT, MG
Peromyscus mexicanus	Deer mouse	May-April	BTH
Sciurus aureogaster	Grey squirrel	March to April	AP

Source: Ceballos and Oliva, 2005.

BTH= Humid Tropical Forests, BT= Tropical Forests, Mg=Mangrove, TV= All Vegetation Types, AP= Disturbed Areas

Amphibians

Reproduction in amphibians is mainly marked by rains and due to their nocturnal mating habits (amplexus-embrace), which occurs only during these hours. Most species are oviparous and lay their eggs in water or in humid environments; from birth and until reaching the adult state, they undergo a series of morphological changes (metamorphosis) enabling them to move from aquatic to land medium, although not in all species (Cedeño-Vasquez *et al*. 2006). During the mating season, males are the only ones that emit singing (typical of each species) to attract females. However, the change in the environment due to natural or anthropogenic conditions, can reduce males success in finding a couple and consequently lose the reproductive season, even disappearing from the area.

The environmental system evaluated is characterized by having warm humid environmental conditions with abundant summer rains, in addition to having permanent or semi-permanent close water bodies that promote reproduction more than once a year as in the common toad (*Rhinella marina*). During field activities it was possible to spot and hear some species of amphibians in reproduction, and in some cases in the final process of their metamorphosis

(Figure IV.91). Among the species that could be identified are the dark loin frog (*Leptodactylus melanonotus*) and *cricket frog (Dendropsophus microcephalus*), which were also the most abundant in the environmental system.

Figure IV. 91 Specimen of the species Leptodactylus melanonotus in the terminal phase of its metamorphosis.

Reptiles

Reproduction in reptiles is synchronized in each species to gain maximum benefit from favorable weather in environmental conditions and food resources. Within this diverse group, strategies and reproduction forms are less variable than in amphibians (Chávez-Ávila *et al*. 2006). In most cases, reproductive activity occurs in early spring and it is characteristic to observe common ethological behaviors within each species such as; persecution of females, aggressive behavior (territory defense), color changes, among others. Reproductive sighting of any recorded species was not possible in the field. However, some species in juvenile status could be identified, indicating the reproductive season had already ended.

Threatened and endangered species in the defined SAR (Outside the property area)

Of the 97 species of fauna identified within the Hokchi-Land environmental system, 15 fall within one of the categories of NOM 059-SEMARNAT-2010 (Table IV.48). The group of birds presented the highest number, with seven species, followed by reptiles with four and finally mammals and amphibians with two species each.

Table IV. 48 Species in the SAR (NOM-059-SEMARNAT-2010)

Species				
Family	**Gender**	**Species**	**Common name**	**Category**
Amphibians				
Ranidae	*Lithobates*	*berlandieri*	Leopard frog	Pr
Microhylidae	*Gastrophryne*	*elegans*	Narrow-mouth toad	Pr
Reptiles				
Crocodylidae	*Crocodylus*	*moreletii*	Swamp crocodile	Pr
Colubridae	*Thamnophis*	*proximus*	Western ribbon snake	A
Iguanidae	*Ctenosaura*	*similis*	Black spiny-tailed iguana	A
Iguanidae	*Iguana*	*iguana*	Green iguana	Pr
Birds				
Ardeidae	*Botaurus*	*pinnatus*	Pinnated bittern	A
Accipitridae	*Buteogallus*	*anthracinus*	Common black hawk	Pr
Accipitridae	*Rostrhamus*	*sociabilis*	Snail kite	Pr
Aramidae	*Aramus*	*guarauna*	Carrao	A
Podicipedidae	*Tachybaptus*	*dominicus*	Least grebe	Pr
Psittacidae	*Amazona*	*albifrons*	White fronted parrot	Pr
Psittacidae	*Aratinga*	*nana*	Olive throated parakeet	Pr
Mammals				
Felidae	*Herpailurus*	*yagouaroundi*	Jaguarundi	A
Felidae	*Leopardus*	*wiedii*	Margay	P
Category NOM-059-SEMARNAT-2010: Endangered (P), Threatened (A) and Subject to Special Protection (Pr)				

Endemic species

Of the total number of fauna species identified within the environmental system, none are considered endemic, since they are widely distributed, from Northern Mexico to Central America.

Migratory species

A total of seven species mainly of birds, are migratory within the Hokchi-Land environmental system, which represents only 4.4% of the total number of species reported within the environmental system. See Table below.

Table IV. 49 Migratory species present in the SAR

Species	
Scientific name	**Common name**
Anas discors	Blue winged teal
Archilochus colubris	Ruby-throated hummingbird
Actitis macularius	Spotted sandpiper
Megaceryle alcyon	Belted kingfisher
Tringa melanoleuca	Greater yellow leg
Stelgidopteryx serripennis	Northern rough-winged swallow
Sturnella neglecta	Western meadowlark
Mniotilta varia	Black-and-white warbler

For mammals, amphibians and reptiles, no species is considered to be migratory and, if applicable, all are considered as residents for the study site.

Closed season species

According to the hunting calendar published by SEMARNAT for the 2017-2018 hunting season, Tabasco is not considered a hunting site for these seasons. However, until 2016, a total of 13 species of fauna (6 birds, 7 mammals) were included in this list of species (Table IV.50.).

Table IV. 50 Species of hunting interest for the state of Tabasco, 2015-2016

Species			
Scientific name	**Common name**	**Catching dates**	
		Start	**End**
Birds			
Gallinago gallinago	Common snipe	10/15	02/16
Ortalis vetula	Plain Chachalaca	11/15	02/16
Colinus virginianus	Bobwhite Quail	11/15	02/16
Bartramia longicauda	Upland sandpiper	08/15	11/15
Zenaida asiatica	White winged dove	09/15	02/16
Columba flavirostris	Red billed pigeon	11/15	20/16
Mammals			
Dasypus novemcinctus	Nine banded armadillo	09/15	02/16
Sylvilagus floridanus	Eastern cottontail	10/15	02/16
Canis latrans	Coyote	09/15	02/16
Procyon lotor	Racoon	09/15	02/16
Nasua narica	White nosed coati	09/15	02/16
Didephis marsupialis	Opossum	09/15	02/16
Odocoileus virginianus	White tailed deer	11/15	02/16
SEMARNAT, 2016.			

Fauna of scientific or commercial value

According to the Wildlife Protection Act **Chapter 1**, **Articles 14** and **16** states that the State has the obligation to conduct and promote scientific research leading to the rational use of wildlife and establish research centers that would be necessary. Also, will encourage and support, with the conducive measures, the study or research carried out by individuals or private institutions for the conservation, protection, promotion and rational use of wildlife.

On the other hand, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) aims to ensure international trade in wild animals and plants specimens does not pose a threat to their survival. Species are grouped in Appendices according to the degree of threat due to international trade.

Appendix I: endangered species and CITES prohibits international trade in organisms of these species, except when import is done for non-commercial purposes, such as scientific research.

Appendix II: species not necessarily threatened with extinction but may become so unless their trade is strictly controlled. This Appendix also contains so-called “similar species”, i.e. species whose specimens object of trade are similar to those of the species included for conservation purposes.

Appendix III: species included at the request of a Party (country) which already regulates trade in that species and needs cooperation from other countries to prevent unsustainable or illegal exploitation thereof.

According to CITES-2018, of the total number of species recorded in the SAR, 19 species fall within one of the above mentioned categories as shown below:

Table IV. 51 Species of commercial value according to CITES-2018

Species		
Scientific name	**Common name**	**CITES Appendix**
Amphibians		
Agalychnis callidryas	Red-eyed tree frog	II
Reptiles		
Crocodylus moreletii	Swamp crocodile	I/II
Iguana iguana	Green iguana	II
Birds		
Amazilia yucatanensis	Buff-bellied hummingbird	II
Amazilia candida	Ruby-throated hummingbird	II
Archilochus colubris	Ruby-throated hummingbird	II
Buteo magnirostris	Roadside hawk	II
Buteogallus anthracinus	Common black hawk	II

Species		
Scientific name	**Common name**	**CITES Appendix**
Elanus caeruleus	Black-winged kite	II
Pandion haliaetus	Osprey	II
Rostrhamus sociabilis	Snail kite	II
Caracara cheriway	Northern crested caracara	II
Herpetotheres cachinnans	Laughing falcon	II
Ortalis vetula	Plain Chachalaca	III
Amazona autumnalis	Red-lored parrot	II
Amazona albifrons	White fronted parrot	II
Aratinga nana	Olive-throated parakeet	II
Glaucidium brasilianum	Ferruginous pygmy owl	II
Mammals		
Leopardus wiedii	Margay	I

Of the 19 species recorded in the study area and are included by CITES, birds were the most representative with 15 species, followed by reptiles with two species and finally amphibians and mammals with one species as shown below:

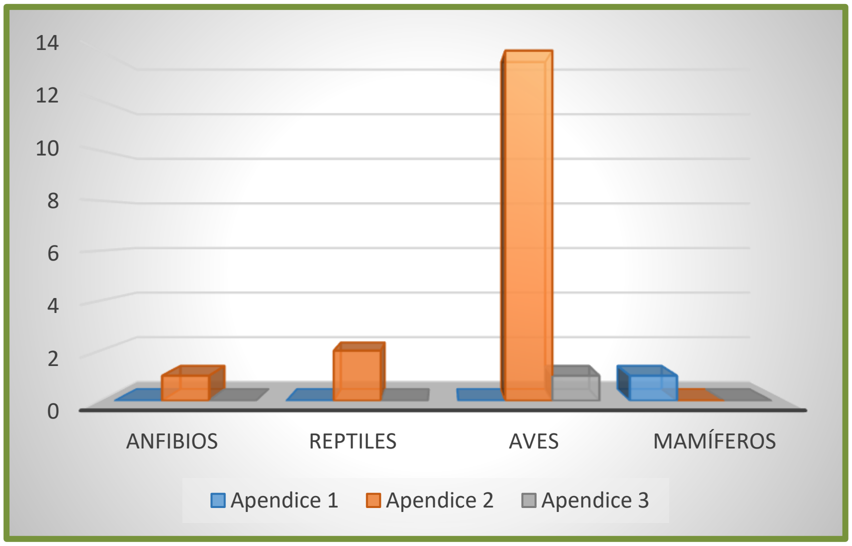


Figure IV. 92 Graphic representation of species number within a CITES category per taxonomic group.

Local consumption fauna

Among the different types of uses given to wildlife identified in the regional environmental system of the project, food, ornamental, fur and medicinal can be mentioned. The following table shows the species and uses given to fauna by the inhabitants of the municipality of Paraíso, Tabasco.

Table IV. 52 Wildlife species with local use in the SAR

Wildlife		
Scientific name	**Common name**	**Usage**
Amphibians		
Rhinella marina	Cane toad	M/P
Lithobates berlandieri	Leopard frog	A
Reptiles		
Crocodylus moreletii	Swamp crocodile	A/P
Ctenosaura similis	Black spiny-tailed iguana	A
Iguana iguana	Green iguana	A
Kinosternon leucostomun	White-lipped mud turtle	A

Birds		
Anas discors	Blue winged teal	A
Columbina inca	Inca dove	O
Columbina talpacoti	Ruddy ground dove	O
Patagioenas flavirostris	Red billed pigeon	A
Zenaida asiatica	White winged dove	A
Ortalis vetula	Plain Chachalaca	A
Icterus auratus	Orange oriole	O
Icterus cuculatus	Hooded oriole	O
Sturnella neglecta	Western meadowlark	O
Dendroica petechia	Yellow warbler	O
Dendroica petechia	Mangrove warbler	O
Mniotilta varia	Black-and-white warbler	O
Turdus grayi	Clay-colored thrush	O
Amazona autumnalis	Red lored parrot	O
Amazona albifrons	White fronted parrot	O
Aratinga nana	Olive-throated parakeet	O
Mammals		
Herpailurus yagouaroundi	Jaguarundi	A/P
Leopardus wiedii	Margay	A/P
Canis latrans	Coyote	P
Procyon lotor	Racoon	A
Didelphis marsupialis	Common opossum	A
Didelphis virginiana	Virginia opossum	A
A= food, O= ornamental, M= medicinal, P= fur.		

Harmful fauna

From the ecological point of view, the term harmful fauna is non-existent, since it is assumed that each species present in an ecosystem has a specific function. However, from an anthropocentric point of view, are named "pest species" or "noxious" to any individual or population, native or introduced, wild or domestic, conflicting with human interests as a health hazard, food or desirable natural resources destroyer (Elias and Valencia, 1984; Howard, 1983).

Among the group of vertebrates that can be considered as "pest species" are, among others, mice, squirrels, bats, hares, rabbits and some birds, which mostly attack cultivation areas (cited in Ojasti, 2000).

During field trips, no fauna with high population densities were observed, to be considered as a "pest". However, according to area inhabitants, the gray squirrel (*Sciurus aureogaster*) has caused significant losses in coconut cultivation and low copra production. Despite this, in the field it was possible to spot fauna such as coyotes, owls, prey eagles, natural predators of squirrels, which suggests that in the environmental system a stable fluctuation of their species is maintained as shown in the following figure.

Figure IV. 93 Bird of prey devouring a small opossum observed inside the Flora-Fauna A polygon.

On the other hand, and with regard to noxious fauna, generally represented by snakes, these were scarcely recorded and in some cases the identification of species was possible only by indirect methods, i.e. by bone and moult remains. However, for the study site there are reports of species such as lancehead (*Bothrops asper*) and milk snake (*Lampropeltis triangulum*), considered to be the most poisonous for the municipality and the state in general (Barragan-Vazquez, 2007).

The fauna constituted by invertebrates such as mosquitoes, spiders, scorpions, crickets, etc., was low, possibly due to the great diversity of birds, bats and amphibians predominant in the area and which are mostly predators of this type of organism (Table IV.53).

Table IV. 53 Fauna identified as noxious within the SAR

Noxious Fauna		
Species	**Common name**	**Disease (transmitter) and/or damage**
Vertebrate		
Crotalus sp	Rattlesnake	Venom poisoning
Bothrops asper	Lancehead	Venom poisoning
Lampropeltis triangulum	Milk snake	Venom poisoning
Crocodylus moreletii	Crocodile	Bite
Peromyscus mexicanus	Mouse	Leptospirosis, crop damage
Sciurus aureogaster	Squirrel	Crop damage
Invertebrates		
Aedes aegypti	Mosquito	Dengue, Chikungunya
Latrodectus sp	Black widow	Venom poisoning
Centruroides limpidus	Scorpio	Venom poisoning
Rickettsia sp	Tick	Rickettsiosis
Triatoma sp	Kissing bug	Chagas disease
Apis mellifera	Western honey bee	Apitoxin poisoning

Ecosystem dynamics

An ecosystem is a set of interdependent parts functioning as a unit, where fundamental parts are producers, consumers, organisms responsible for decomposition, and abiotic component. The biological cycles predominating within each ecosystem allow natural ecological processes experimentation in their biotic and abiotic components over time (Villareal *et al*. 2004).

Changes in land use for livestock and agricultural purposes involve the almost total removal of the original vegetation; to introduce one or two commercial interest species, which also facilitates resident fauna displacement of that place to sites with less favorable conditions for feeding and reproduction.

This type of modification to the environment was observed within the sampling zones where the Hokchi Plant and the Metering Station will be installed; as well as its surroundings, where land use change for livestock and agricultural activities are predominant.

The anthropogenic pressure exerted on ecosystems and resources unsustainable use leads to the rapid deterioration of vital sites such as mangroves outside the Project area, which are directly impacted by man for coal production and as poles (fences) in livestock activities (**Image 20**). However, during the tours it was possible to spot sites in good conservation state and areas in recovery process.

Figure IV. 94 Anthropogenic pressure on mangrove populations.

On the other hand, in relation to ecosystem dynamics with the climatic conditions prevailing within the environmental system, these maintain a strong relationship with species diversity and abundance both of flora and fauna, since during rainy seasons aquatic vegetation presents a greater abundance and variety, which is taken advantage by many fauna species for reproduction.

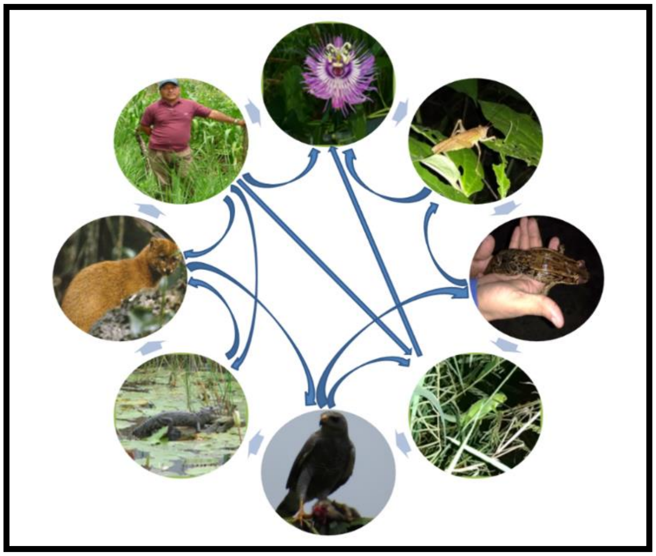


Figure IV. 95 Trophic network identified within the project area.

Another dynamic and one of the most important within an ecosystem, is the relationship of each species as part of trophic chains and networks. Within the Hokchi environmental system in the coastal strip, it was possible to identify different types of trophic relations between species, which extend throughout the SAR defined for the present study.

As part of food chain base, several plants species were observed, presenting fruits or flowering, used by primary consumers such as iguanas, squirrels and some birds. Among secondary consumers some birds of prey and carnivorous mammals such as raccoons and coyotes can be mentioned, while among tertiary consumers there are larger species such as crocodiles and larger felines. It is substantial to include man as an important part of the trophic network identified within the environmental system, as it maintains direct contact and makes use of all resources to meet various favorable needs and commercial purposes.

Marine biota

Fossil hydrocarbons exploration and extraction operations in the Marine System cause two levels of ecological effects. The first level is of greater severity in the coastal ecosystem due to the reduction or permanent removal of some of its basic components, such as aquatic vascular plant communities. Substrate alterations caused by dredging operations, opening channels, pipelines and platforms installations in the coastal and marine environment, generate alterations in flora and fauna of different complexity. In contrast, in the marine environment, potential alterations resulting from the oil industry are attenuated by the buffer capacity of the system itself.

Natural fluctuations in each of its ecological components are recognized in the marine environment; such fluctuations are compensated by internal homeostatic mechanisms which contribute to maintaining a balance in the matter and energy cycle. The preliminary study of organic carbon flow in shallow water area of the southern Gulf of Mexico shows a system highly subsidized by origin organic materials of continental origin contributions, whose final destination is the sedimentary component of the continental shelf and adjacent deep sea.

Phytoplankton

Knowledge about the specific richness structure and patterns of phytoplankton spatial-temporal variability is limited in the study area. The areas with the best information are the Laguna de Terminos and the adjacent coastal zone.

There is general knowledge about the structure and rhythms and fluctuations of primary producers community in the marine area. The spatial-temporal variability of this component is high and correlated with riparian discharge pulses in the Southeastern Gulf of Mexico sector. Changes recorded in its structure are attributable to successive rhythms typical of the community, which occur in the short term. Under disturbance conditions caused by accidental fossil hydrocarbons spills, marine phytoplankton shows effects on species composition and biomass. However, its balance is restored in the short term (about 40 days). Phytoplankton community structure reestablishment in the Sonda de Campeche, once the deleterious effects caused by the presence of fossil hydrocarbons in the water column are attenuated by dilution, dispersion or weathering effects. (Licea et al, 1982).

According to background studies, the highest phytoplankton diversity in the Sonda de Campeche, is recorded during the summer months (June-July) and decreases significantly during the season of greatest climatic disturbance (winter storms). Hydrodynamics of the Sonda in the neritic environment changes from a stratified system to a homogeneous condition, also reducing the euphotic layer thickness between 12 and 15 m deep. During the summer season the system tends to stability, and the phytoplankton community presents pulses of abundance and diversity associated mainly with coastal processes.

The primary productivity values recorded in the Sonda de Campeche (0.04-1.3 mg C/cubic meters/hr) correspond to an oligotrophic system supported essentially by Bacillariophyta and Dinophyceae algae growth. However, under disturbance circumstances by fossil hydrocarbons in the medium, the specific dominance is reversed; i.e., phytoflagellate algae predominate followed by diatoms.

The Sonda de Campeche systemic study (IMP, 2002) revealed that phytoplankton component is the main organic elements contributor to debris reservoir, followed by infauna and zooplankton. This means phytoplankton from the Sonda de Campeche maintains a low ecotrophic efficiency hindering herbivory by zooplankton and filter feeders. It can therefore be inferred successive cycles of primary producers must be short and spatially random; these two properties can contribute to restoring community stability level when environmental disturbances (natural or anthropogenic) are attenuated.

Zooplankton

Quantitative data from this community are restricted to predominant groups such as copepod and fish larvae, Chaetognata and appendicularies, recognized for their association with certain bodies of ocean waters. In the Sonda de Campeche zooplankton specific composition, its biomass, diversity, and its spatial-temporal distribution patterns are known. Zooplankton production maximum values are concentrated in the area opposite the Laguna de Terminos and the Delta of the Grijalva-Usumacinta rivers. In severe disturbance conditions caused by fossil hydrocarbon spills, zooplankton biomass can be reduced to an order of magnitude 4. The complexity of this component is reset once the deleterious effect ceases.

Marine ichthyoplankton has been the subject of recent research. Their patterns of spatial-temporal variability are known. Its community structure is influenced by the hydrodynamics prevailing in the carbonated and terrigenous areas, and the intrusion of ocean waters over the continental shelf.

Benthos

This component is well documented in terms of its specific composition and biomass, density and diversity values. The data compiled are, however, heterogeneous in quality and continuity in time and space. Inter annual variation patterns are predictable and spatial patterns respond to seabed complexity and continental shelf topography (extension area and shelf break). The diversity values indicate a relatively stable community, with a trophic chain of a detritivore nature composed of 5 levels. The benthos is included in level II, within which the infauna, epifauna and penaeid shrimp are included.

The study of benthos in the Hokchi Field area and its influence area up to the coastline, based on the main attributes of the community analysis (Abundance, Species Richness and Biomass) together with the granulometric characteristics evidenced the following observations:

- A total of 20,910 organisms classified in 8 Phylum, 13 Classes, 38 Orders, 122 Families, 121 Genera, 56 Species and 167 taxa were identified.
- Of the 20,910 registered organisms, were classified as follows: Abundant (65.6% of total abundance); Common (33.18%) and Rare (1.11%), this in order to determine fauna proportionality and establish the most frequent and dominant species in the area. It was decided to use the common species group to relate the community structure to environmental factors previously defined.
- The diversity varied generally between values of 2.8 to 3.8 sprouts/ind.
- Abundant species were 11, which dominate throughout the area, among them 4 species were the most important Quinqueloculina, Cupuladria, Polynices and Triloculina who accounted for 46.41% of the total fauna recorded. The common were represented by 95 taxa that together account for 33.18% of the total abundance, finally the rare species group with 61 taxa, which represent only 1.11% of the total abundance.

- The most coastal area presented biomass values, abundance, species richness and lesser diversity in relation to the most distant stations from the coast.
- In the studied area it presents high structural complexity of the marine benthonic invertebrates community, the general trend between stations varied little except for some stations and that the general pattern of diversity decreases towards the more coastal stations.
- The most frequent food strategies were omnivores with 68 species, 44 detritivores, 43 carnivores, 7 herbivores and 5 parasites. This structure indicates it is a highly competitive environment where food resources of each species determine population size. A system depending on coastal and ocean environments contribution; increasing its dynamism and in itself, fragility. The direct effect on one or more populations would have an impact on the entire community structure, amplifying the effect of any kind of impact.
- It was confirmed sediment type, temperature and depth greatly influence the processes determining fauna structure. In other words, it was identified fauna spatial distribution is defined, not only by biotic and abiotic factors, but by organisms biology itself (dynamics).
- The best analysis strategy was to use the common species group to better represent community structure. It represents 94.8% of the fauna that could potentially be observed in the study habitat.
- Because it is a spot sample, it was not possible to test the correlation level these biotic and abiotic factors have in the community-environment interaction, so in the future, more precise work should be done in this context, if one wants to know system functioning and how it can be susceptible to anthropic alteration.

The following figure summarizes in a spatial way the behavior of benthos in the study area.

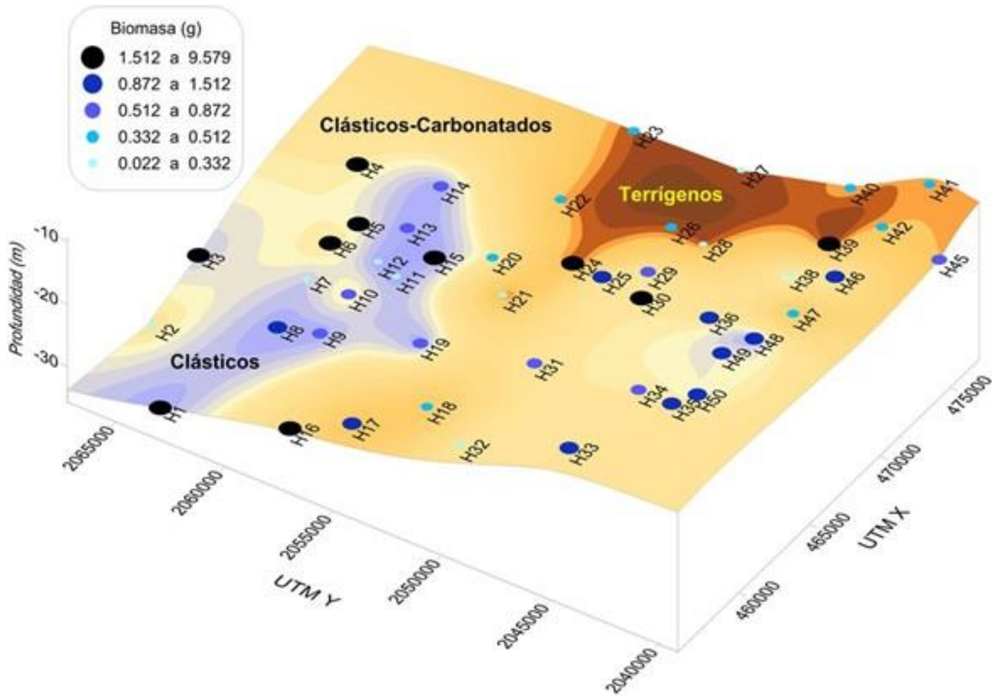


Figure IV. 96 Biomass distribution in relation to sediment type

Macrobenthos

Based on the information available from the study area covering the project area and its area of influence resulting from sediment samples analysis collected on the oceanographic cruise in February 2016 in the Hokchi area and the area of influence, area faunistic composition comprises seven rows of macrobenthic invertebrates: annelids, crustaceans (Arthropoda), echinoderms, mollusks, nematodes, sipunculids and amphioxus (Cephalochordata).

In total, annelids represented 63.7% of the macrofauna (478 organisms), nematodes 28.2% (212 organisms), amphioxus 3.2% (24 organisms) and crustaceans and sipunculids 2.2 (17 organisms in each phylum), the other groups were scarce. In general, polychaete annelids predominance was reflected in all stations, followed by nematodes, while the presence of the other groups was sporadic. Only two stations presented an equal proportion between these two taxonomic groups (C3 and S2), and only in two stations found more nematodes than polychaete found (C2 and O2).

In relation to polychaete, 22 families were collected, the best represented in terms of abundance and incidence in stations were, in decreasing order, Cirratulidae (99 individuals in 12 stations), Spionidae (87 individuals in 14 stations), Paraonidae (45 individuals in 12 stations), Glyceridae (41 individuals in 13 stations), Syllidae (36 individuals in 12 stations), Dorvilleidae (30 individuals in 13 stations) and Pisionidae (30 individuals in 9 stations)

The particular distribution and abundance of polychaete in each station was variable, which can be observed. Annelids were the dominant component of the benthic macrofauna, which coincides with the records of Salazar-Vallejo and Londoño Mesa (2004) for different parts of the world. However, this study highlights the abundance of nematodes and the low abundance of crustaceans, echinoderms and mollusks. Nematodes are important as components of the meiofauna; however, eventually its size may exceed the limit between macro and meiofauna (0.5 mm).

In general terms, the three dominant families of annelids were Cirratulidae, Spionidae and Paraonidae. These organisms are inhabitants of areas impacted by excess organic matter in the sediment (Mendez 2002; Ferrando and Mendez 2011).

Apparently, due to Macrobenthos faunistic composition, the study area is subject to different organic enrichment conditions: the central area slightly contaminated, the surrounding areas uncontaminated and the transition zone between them. See list of Macrobenthos included in Annex No. 4.

Nekton

The spatial-temporal patterns of this component are significantly correlated with the three recognized climate periods in the Gulf of Mexico; that is, they are highly predictable. The carbonated province concentrates biomass highest values and diversity and an increase tendency in abundance is recognized in the area near the area of oil platforms in the Sonda de Campeche. This can be interpreted by the sanctuary effect representing the physical structures of such facilities, and the organic materials transfer through the trophic chain.

This ichthyofaunal component study in the Hokchi project area and its area of influence up to the coastal area within maximum depth of 130 m recorded a total of 102 are bony fish and 6 elasmobranchii belonging to 1 Phylum, 2 Classes, 21 Orders, 47 families, 82 genera and 108 taxons.

- All captured species were classified into trophic guilds, the result identified only two food strategies, the first being the vast majority were carnivorous (96) and only 12 omnivorous.
- The biological conditions observed in the present work and compared to works in the region, allow us to establish that the area, despite being a coastal sediment environment, is very complex due to all the variety of factors that ecologically allow to consider it as a very dynamic and highly diverse environment.
- The study area, being dominated by carnivorous species, is supported by the high abundance of groups such as crustaceans, micro-crustaceans, polychaete and small fish. This means as food is abundant, it has not received external pressures that have allowed the proliferation of species feeding the fish.

However, other studies (oceanographic cruise in February 2016 in the Hokchi area and influence area) indicate in other seasons of the year the total number of species has been low, indicating the area has been strongly impacted by anthropogenic activities carried out in that region of the country. On the other hand, several of the species caught are of some commercial importance in the region, especially for artisanal fishing, in so-called "scale" fishing, which mainly catches demersal fish. From the above it can be deduced that it is an area with a dominance of demersal species, a low diversity and richness in general, and that the ichthyofauna throughout the studied area is the same. See the list of ichthyofauna included in Annex No. 4.

Marine system endangered species (NOM-059-SEMARNAT-2010)

As for the community formed by organisms inhabiting the bottom of aquatic ecosystems (benthic),none of these species of invertebrates identified nor fauna (nektonic) represented by fish species in the area and project area of influence are quoted in NOM-059-SEMARNAT-2010.

Table IV. 54 Marine fauna under protection status of NOM-059-SEMARNAT

Marine Fauna			
Species (scientific name)	**Common name**	**Endemic**	**Category NOM-059 and CITES**
Lepidochelys kempii	Atlantic ridley sea turtle	No	P
Chelonia mydas	Green sea turtle	No	P
Eretmochelys imbricata	Hawksbill sea turtle	No	P
Caretta caretta	Loggerhead sea turtle	No	P
Dermochelys coriacea	Leatherback sea turtle	No	P

Category NOM-059-SEMARNAT-2010: **Endangered (P)**, Threatened (A) and Subject to Special Protection (Pr) and CITES Appendix I

Within marine species per their location in the entire coastal strip covered by the SAR delimited for the Project, are the most sensitive species because due to their behavior for both feeding and reproduction they tend to arrive or enter the sand and even some of these species tread into the lagoon system included in the SAR under study. However, although it is a species that does not present endemism due to its wide distribution in the Atlantic, it is classified as endangered.

Sea turtles

The lack of monitoring and conservation programs for sea turtles in the Hokchi area of environmental influence was evidenced by the scant information published. However, the presence in said area of the five sea turtles species reported for the Gulf of Mexico and Atlantic region was documented. The species *Lepidochelys kempii* (ridley sea turtle), *Chelonia mydas* (green sea turtle), *Eretmochelys imbricata* (hawksbill sea turtle), *Caretta caretta* (loggerhead sea turtle) and *Dermochelys coriacea* (leatherback sea turtle) are referenced for this area.

Figure IV. 97 Sea turtle species distribution in the SAR of the Project Source: Hokchi Field Environmental Impact Statement

In the same Hokchi Field MIA study indicates historically recorded turtles distribution were located according to beach zoning carried out during field survey carried out in February 2016. Records at sea, related to migratory routes and feeding and development habitats are shown in the following figure.

Figure IV. 98 Sea turtle distribution pattern in the Project SAR Source: Hokchi Field Environmental Impact Statement

On the map, the marine-coastal area highlights el Carmen-La Machona and Mecoacan lagoons front can be considered as feeding and development areas for sea turtles. According to information available in Hokchi Field Environmental Impact Statement and its area of influence; as well as complement to the present study, the marine area located in front of the mouth of el Carmen lagoon mouth was identified as feeding zone for the five species found in the Gulf of Mexico; presence of sea turtles within the lagoon and in the surrounding marine area is indicated.

As for the fauna of rivers and in the lagoon system, otter, manatee, iguana, turtle, and fish such as spotted gar, catfish, sea bass and mojarra have been reported; towards the sea it is common to find several species of shrimp, red snapper and sea bream (CONABIO, 1998).

IV.2.3 Landscape

To carry out the landscape assessment, an approach to the agglutinating effect will be given considering as the joint result of environmental factors such as relief, slopes, land and vegetation uses, hydrology, etc., without forgetting intrinsic factors that are the observer subject and the project area, emphasizing mainly their visual and spatial qualities.

The landscapes to be evaluated can be both natural and anthropic, paying special attention to human groups as transformers of physical-ecological dynamics; i.e., the evaluation of a natural landscape that could provide ecosystems conservation status, vegetation health, integration of animal communities, land use and exploitation, and therefore society's care for its environment by providing environmental services without causing ecological imbalances.

It should be noted that the evaluation of this element becomes more relevant when projects pretend to be installed in areas declared under some protection status, where impacts caused by the project could result very significant.

It is important to note that although land use according to information from INEGI’s thematic maps and the municipality, has been classified as agriculture, in fieldwork it was confirmed there are also areas such as livestock use with cultivated pasture.

The present project has not taken advantage of this classification, since within its design it includes green areas conservation as a scenic view and areas that can function as mitigators to avoid diminishing landscape quality and also considers constructions characteristics include buffer strips with local vegetation according to those surrounding land uses, so that in the sight of own and strangers this project does not present a significant contrast to the factors considered for this element analysis binding the physical environment different characteristics, as well as its ability to assimilate new facilities.

Evaluation Methodology

The methodology considered is that of “Landscape Assessment” by Andrés Muñoz-Pedreros (2004), considering the three most important aspects: **visibility**, **landscape quality (Visual) and visual fragility**, which consists in landscape components classification and through preset tables are considered values for environmental components ranging from 3 when it is high, 2 when value is medium and 1 when it is a low value.

For landscape assessment using this methodology, three landscape units were determined, which were established based on visual aspects from strategic points where there is accessibility to potential observers (See Figure IV.99). In the current state, these landscape units were established taking into account as a central component the relief with almost flat topoforms with slopes less than 5%, vegetation on the observable sides where coconut crops (Coco nusífera) predominates, cultivated and induced grassland and tall grass type (herbaceous-shrub) vegetation. The contrasts that may exist with background landscape components as a whole were also considered.

Figure IV. 99 Area where the Hokchi Plant will be located (Part "A and B"), where observation points of the 3 landscape units to be evaluated are indicated.

Landscape 1.- Topoforms landscape unit with slopes less than 5%, for which the predominant vegetation of cultivated grassland and coconut crops (*Coco nusífera*) were taken into account. The observable boundaries to the left with houses of the Ranchería Las Flores 2a Seccion. Current land use is agricultural with cultivated grassland (See Figure IV.100) mainly.

Figure IV. 100 View to the Southwest of the property where the Project will be located, where the predominant vegetation of grassland and coconut crops is observed.

Landscape 2.- Landscape unit on the South side of the property is topoforms with slopes less than 5% as can be seen in the image, in the background predominant coconut crops and as secondary vegetation of tall grass type with herbaceous shrub stratum (See Figure IV.101 a and b).

(a)

(b)

Figure IV. 101(a and b) Project Southeast Side taken from the Barra de Tupilco-Paraíso highway, where you can see the South-Southeast side of the Property with coconut crops and secondary herbaceous shrub vegetation.

Landscape 3.- Another of the landscape units that could be seen from the beach on the North side of the property, which adjoins the Gulf of Mexico, where species of coastal vegetation stand out. Another image of the property seen from the Northeast part is also presented, where the landscape with predominant grassland vegetation and coconut crops stand out (See Figure IV.102 a and b).

(a)

(b)

Figure IV. 102 Image (a) View from the beach on the North side of the property where the surrounding coastal vegetation is observed, (b) Northwest part with grassland vegetation and coconut crop

Visibility, fragility and quality assessment of the three landscape units is described below:

Visibility

From the Southwest side of the project, Landscape 1 visibility is partial, however, due to potential observers proximity, they could currently perceive some topography details of the almost flat property without elevations; as well as details of the predominant vegetation of cultivated grassland and coconut crops, which provides an indication of deforestation effects for mainly agricultural and sometimes livestock use, where agricultural land presents tall grass vegetation with herbaceous shrub stratum. Another indication this landscape provides us is it presents agricultural and livestock physiognomic features with rural type landscape that in the future will be transformed into industrial landscape units (see Figure IV.100).

Landscape 2 visibility from another angle of the possible observers (Southeast side), topography details of the almost flat property are perceived in the foreground, as well as the herbaceous and shrub vegetation resulting from land use transformation to which landscape has been subjected (see 102 a and b).

Another observation point in Landscape 3, is by the Beach located in the Northern part of the Property, from where it can be seen a landscape typical of the coastal areas where coconuts plantations and adjacent coastal vegetation are common. In the property background with coconut crops and secondary vegetation induced grassland and with herbaceous and shrubby stratum (See Figure IV.103 a and b).

Landscape quality (Visual)

For landscape visual quality analysis, the images presented above and supported by the field tours made by the current accesses on the outskirts near the Project were used. Images presented show direct relationship and representativeness of the different angles, as well as the possible distances of appreciation in order to have a greater support to topography, vegetation and fauna analysis inclusive of the area and its surroundings. To obtain a nominal assessment by this indirect method, a list of adjectives based on the *"Scale of Universal Purposes"* established in the same methodology of landscape assessment (Table IV.55.) was used, which gives us a landscape rating in the project area.

Landscape 1, in Muñoz-Pedreros' scale qualifiers for this Landscape Unit was assigned a qualifier of without interest, which coincides with the Scale of Universal Purposes, mainly due to its geomorphological features not presenting contours with attractive views due to primary vegetation fragmentation, giving rise to grassland and secondary species in herbaceous-shrub stratum; as well as scarce fauna own of these ecosystems, altered by anthropogenic activities, these areas and their surroundings are not of historical interest to observers.

Landscape 2, Similarly, this Landscape Unit presents similar characteristics to Landscape Unit 1, with the difference that in it could become monotonous for observers who inhabit and adjoin the South-Southeast part of the Project.

Landscape 3, alluding to this Landscape Unit, for most observers it could be denoted according to the scale of qualifiers and scale of universal values as acceptable and pleasant view, due to its almost natural features for observers to find coastal landscapes with coconut crops mainly.

Following is a list of hierarchized adjectives (in the sense of Muñoz-Pedreros et al 1993) and their correlation with the universal scale of values (in the sense of Purposes 1968), VP= Landscape value; as well as Project Landscape Units valuation.

Table IV. 55 Landscape Assessment with the Muñoz-Pedreros Qualifying Scale and the Scale of Universal Purpose Values

Qualifying scale (Muñoz-Pedreros et al. 1993)		Scale of Universal Values (Purposes 1968)		Landscape Assessment 1, 2 and 3		
VP	**Adjectives**	**VP**	**Category**	**1**	**2**	**3**
1	Insufferable	0	Ugly			
2	Horrible	0.25				
3	Unpleasant	0.5				
4	Dreadful	0.75				
5	Ugly	1.0				
6	Dismal	1.10	**Without interest**			
7	Wretched	1.25				
8	Cold	1.50				
9	**Monotonous**	**1.75**			**1.75**	
10	**Without interest**	**2.0**		**2**		
11	Common	2.10	**Pleasant**			
12	Unpretentious	2.50				
13	Tolerable	3.0				
14	Ordinary	3.50				
15	**Acceptable**	**4.0**				**4**
16	Interesting	4.1	Distinguished			
17	Pleasurable	5				
18	Agreeable	6				
19	Preserved	7				
20	Remarkable	8				
21	Multifarious	8.1	Fantastic			
22	Provocative	10				
23	Fetching	12				
24	Lovely	14				
25	Precious	16				
26	Wonderful	16.1	Stunning			
27	Superb	20				
28	Magnificent	24				
29	Fantastical	28				

Qualifying scale (Muñoz-Pedreros et al. 1993)		Scale of Universal Values (Purposes 1968)		Landscape Assessment 1, 2 and 3		
VP	Adjectives	VP	Category	1	2	3
30	Grandiose	30				

Based on visual quality values of the above list we can assume that:

- Landscape 1 and 2 could be qualified with the adjectives of: **Without interest**, and **Monotonous**, corresponding to a landscape value (**VP**) of **2.0** and **1.75** respectively.

These values reflect the altered ecological character of the study area due to the various activities to which the property has been dedicated over time (agricultural) and some areas to livestock activities, which is mainly due to the undue disturbance to which the ejidos were subjected without taking care of the sustainability of said activities thus diminishing over the years primary vegetation and wildlife until they become very scarce in the Project area and its surroundings.

- Landscape 3, with respect to the scale of values of visual quality could reach a category of **Acceptable and agreeable** with a value of **VP = 4** , mainly due to the perception that observers might have about this type of coastal landscapes where there is cultivated or natural vegetation with palm trees or coconuts; as well as vegetation near the beach.

By associating these obtained values with the nominal values or numerical values given in Table IV.56:

Table IV. 56 Landscape rated value and numerical value

(in the sense of Muñoz-Pedreros et al 1993)			Visual Quality 1, 2 and 3		
VP Range	Rated value	Numeric value	1	2	3
0 – 2	Low	1	2	1	
2.1 - 8	Mean	2			2
8.1 - 32	High	3			

Evaluation

- For Landscape Units 1 and 2, the **visual quality** is **Low** with a **rated value of 1**. This indirect analysis was based mainly on the existence of agricultural and grassland vegetation with secondary vegetation of tall grass type within the project area, highlighting its attributes of the almost flat relief and the apparent details that could be appreciated by observers at distances less than 100 meters. Finally, another important aspect for landscape quality assessment was taking into account the current agricultural land use classification according to INEGI's thematic map.
- Similarly, for **Landscape 3** it turns out that **visual quality** is **Medium** corresponding to a **numerical value of 2** , which is mainly due to its apparent attributes that could be observed from the beach as coastal vegetation regardless of whether it is cultivated, induced or natural.

Landscape fragility

In order to define the capacity of how landscape absorbs project's new facilities or changes caused by it, it is considered that all environmental elements with which the project interacts should be analyzed (soil, structure and vegetation diversity, chromatic contrast, morphological features, etc.), without forgetting the most important variable to consider that is the frequency of human presence passing on the South-Southwest side and on the beach on the North side. For Landscape Units 1 and 2 where traffic frequency is higher; as well as for Landscape 3 with temporary visits in holiday season.

Landscape fragility was estimated using Muñoz-Pedreros 2004 methodology, based on Escribano et al (1991), a methodology resulting in visual fragility depending on biophysical factors weighing visual fragility of the study area and the historical cultural character that weighs landscape singular values according to scarcity, its traditional value or historical interest. Methodology application allows to give fragility values (VF) to each landscape unit (VP) according to the following equation:

$$VFVP = \sum f / nf$$

Where:

VFVP is the Point Visual Frailty Value, is equal to the sum of biophysical factors ***f*** evaluated and ***n*** the number of factors considered. Each factor values fluctuate between 1 and 3, **C** is a code assigned to each factor defined by Muñoz-Pedreros 2004.

Considerations for Landscape Fragility:

Based on the visual frailty factors and biophysical factors considered described below, the **Visual Frailty Value** of Landscape Units 1, 2 and 3 is calculated.

Landscape 1.- With the image presented support for this case and the field travel through the Project area, it is observed vegetation density covered with woody species is very low and according to methodology, it corresponds to an entire value 0-34%, vegetation strata less than 3, average vegetation height lower at 1 m, the dominant vegetation is evergreen, monochrome contrast of vegetation where green color prevails, the visual contrast vegetation-soil is low, the gentle slopes in the project area are in the range of 0-5%, with landscape orientation to the Northeast, finally considering the historical cultural value in the study area is low.

Landscape 2.- From the image presented for this Landscape Unit and with the routes during the field work, it is also observed that vegetation density covered with woody species fall in the range greater than 34%, vegetation strata less than 3, average vegetation height up to 3 meters, dominant vegetation vegetation vegetation is deciduous, monochrome contrast of vegetation where green color prevails, visual vegetation-soil contrast is low, gentle slopes in the project area are in the range of 0 -25%, with landscape orientation to the Northwest, finally considering the historical cultural value in the study area is low.

Landscape 3.- Finally from the image it is observed vegetation density covered with woody species is higher than previous cases, reaching a range of 67 to 100%, an arboreal stratum (bordering the Jamapa river) with vegetation height greater than 3 meters, vegetation seasonality is mixed due to its closeness to the Jamapa river where there are perennial species, prevailing green color giving a monochrome contrast of vegetation, the visual contrast vegetation-soil medium, gentle slopes in the project area are in the range of 0-25%, with landscape orientation to the East and finally considering that cultural history on the riverbank could be classified as high, due to conservation importance for all three government levels.

Table IV.57. presents the Visual Frailty Factors of Muñoz-Pedreros to evaluate the Landscape Visual Frailty of the area where land facilities will be located:

Table IV. 57 Muñoz-Pedreros' (2004) Visual Frailty Factors and Project Area Landscape Frailty Values

Muñoz-Pedreros (2004)						Landscape 1, 2 and 3 Frailty Value		
Factor	C	Features		Frailty Value				
				Rated	Numerical	1	2	3
Vegetation density	D	Soil covered with woody species	67-100%	Low	1			
			34-67%	Medium	2		2	2
			0-34%	High	3	3		
Vegetation strata diversity	E	Vegetation strata	more than 3	Low	1			
			less than 3	Medium	2		2	2
			Only 1	High	3	3		
Vegetation Height	A	Average height	more than 3 m	Low	1		1	1
			>1 m and < 3 m	Medium	2			
			less than 1 m	High	3	3		
Vegetation seasonality	ES	Dominant vegetation	Evergreen	Low	1	1	1	1
			Mixed	Medium	2			
			Deciduous	High	3			
Chromatic contrast vegetation/ vegetation	CV	Stains	Polychromatic, no clear pattern	Low	1			
			Polychromatic, with clear pattern	Medium	2	2		
			Monochromatic	High	3		3	3
Chromatic contrast vegetation/ soil	CS	Visual Contrast	Low	Low	1			
			Moderate	Medium	2			
			High	High	3	3	3	3
Pending	P	Percentage	0 - 25%	Low	1	1	1	1
			25 - 55%	Medium	2			
			More than 55%	High	3			
Landscape orientation	O	Exposure	North/East	Low	1			1
			Southwest/Northwest	Medium	2	2	2	
			Southwest	High	3			
Historical cultural value	H	Uniqueness, Singularity and/or value	Low	Low	1			
			Mean	Medium	2	2	2	2
			High	High	3			
				$VFVP = \sum f / nf$		2.2	1.9	1.8

From the table and according to the equation, landscape units Visual Frailty Value are: Landscape 1 ≈ **2.2**, Landscape 2 ≈ **1.9** and Landscape 3 ≈ **1.8**, which corresponds to an **average** rated VP.

Criteria for final classification were determined in accordance with Table IV.58.

Table IV. 58 Recommended uses according to quality and visual frailty (Muñoz-Pedreros 2004)

Class	Features		Recommended Uses
	Visual Quality	Visual Frailty	
1	High	High	Conservation
2	High	Medium	Low-impact tourism/recreation
3	High/Medium	Low	Tourism-Recreation
4	Medium	High/Medium	According to more in-depth studies it can be incorporated into class 2 or 1
5	Low	High/Medium	According to more in-depth studies it can incorporate to class 6
6	Low	Low	Locating activities with high visual impact

With **visual quality** combination resulting for each landscape unit and **visual frailty** rated values, they give as final result:

Landscape 1 and **2** Low Visual Quality and Medium Visual Frailty, according to the previous table the recommended use is according to more in-depth studies can be incorporated into class 6; i.e., activities with high visual impact can be carried out.

Landscape 3 Medium Visual Quality and Medium Visual Frailty, according to the previous table the recommended use is that activities with low visual impact (recreation) could be carried out on the site.

Conclusion

From the above, we can conclude that in the Northern part of the property near the beach, the project will have to include mitigation measures for observers visual impact, a strip could be conserved with existing vegetation or cultivated coastal vegetation that would also function as a measure to prevent wind erosion.

IV.2.4 SAR Socioeconomic Factors (Cardenas, Comalcalco, Paraiso and Centla)

The Regional Environmental System (SAR) delimited for this project, includes four municipalities (Cardenas, Comalcalco, Paraiso and Centla). However, the municipality of Paraíso is described below in first instance because part of the Project (land facilities) will be located in the coastal area of Paraiso.

Another consideration is due to the fact that direct impacts the project could have due to its infrastructure activities, the need for services, etc., possible impacts on its environment, will be directly on the surrounding communities and on the municipal head of the same municipality that is the city of Paraiso.

Municipality of Paraíso

The municipality of Paraiso has an area of 406.85 sq.km, area percentage it represents with respect to the state is 1.65%, has 40 localities, total population in 2010 is 86,620 inhabitants (42,887 men and 43,733 women). The municipal seat is the city of Paraiso, which has a population of 25,186 inhabitants, information based on SEMARNAT, CONABIO and INEGI report.

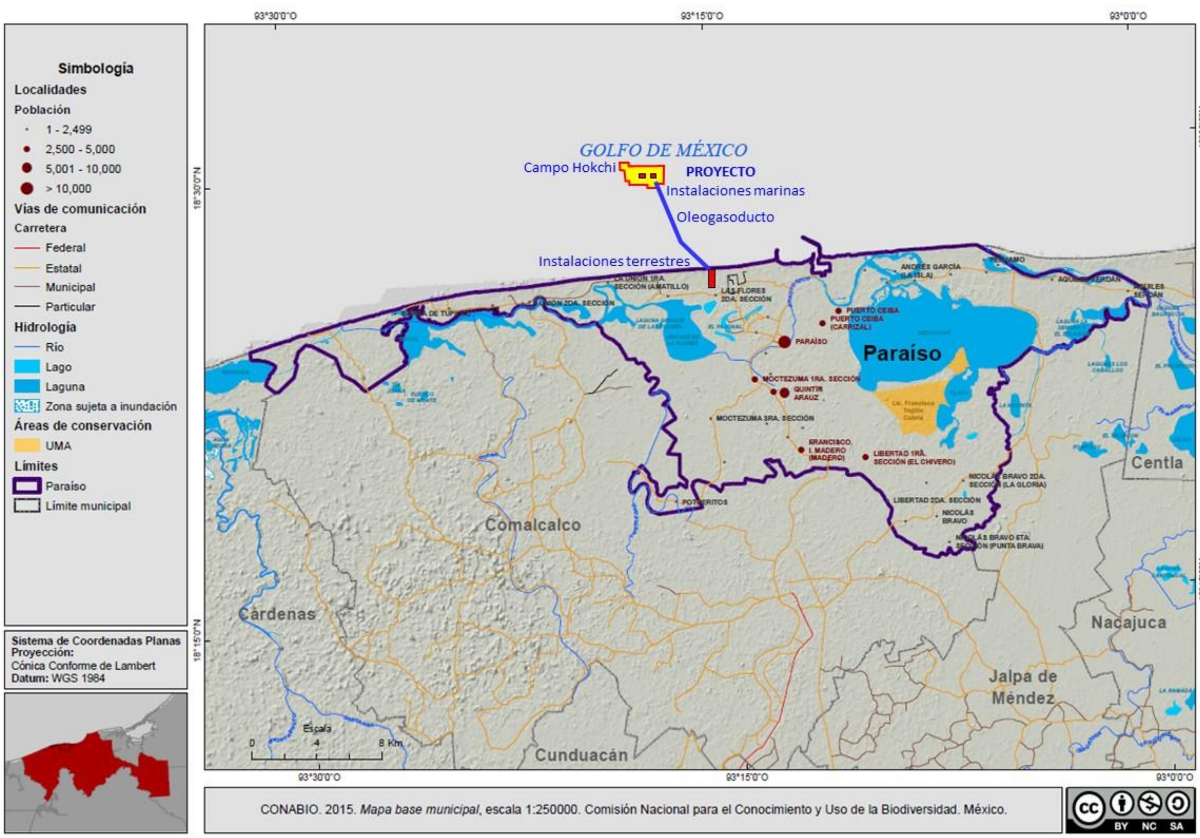


Figure IV. 103 Paraiso municipality, Tabasco, location map

Population and municipal demographics

From the same source, total population and by sex is as follows:

Table IV. 59 Municipality total population and by sex

Sex/Year	1990	1995	2000	2005	2010
Men	29,234	32,642	34,906	38,900	42,887
Women	29,169	32,624	35,858	39,619	43,733
Total	58,403	65,266	70,764	78,519	86,620

Population growth trend

Population growth trend is shown in the following figure:

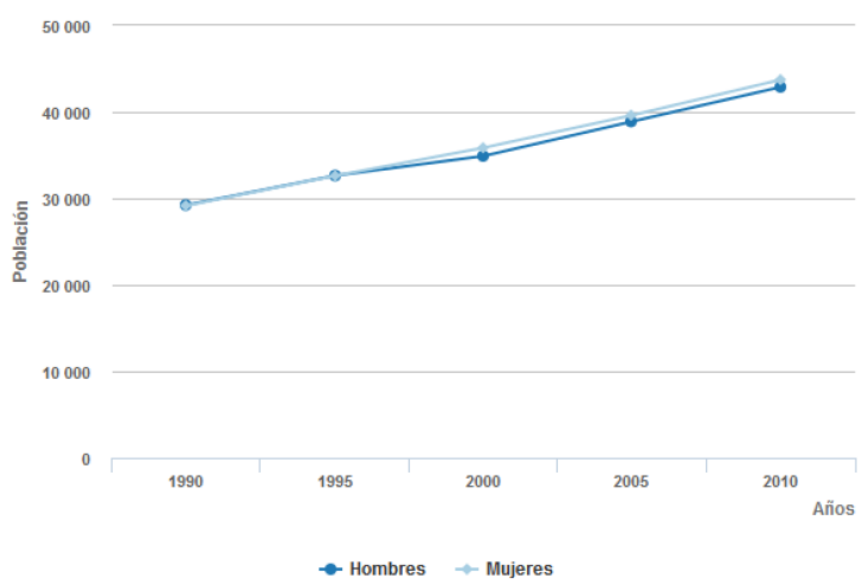


Figure IV. 104 Population growth trend

It indicates that in population censuses of recent decades it has been of slow growth. Population indicators are as follows:

Table IV. 60 Population indicators of the municipality

Sex/Year	1995	2000	2005	2010
Population density of the municipality (Inhabitants/sq.km)	161	176	193	213
Population percentage in relation to state	3.73	3.74	3.95	3.87
Male/female ratio	100	97	98	98

Population density indicator trend is as follows:

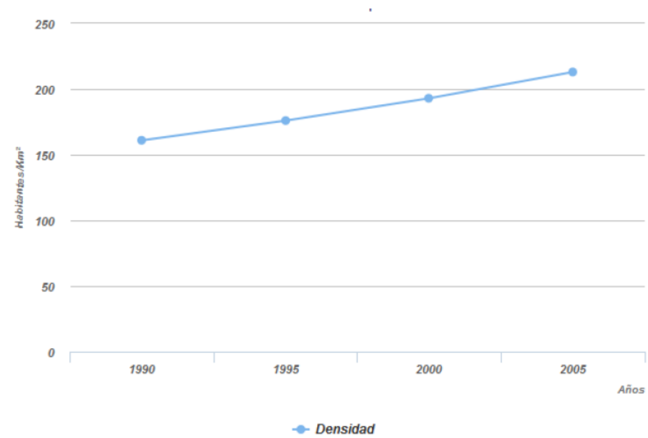


Figure IV. 105 Population density growth trend

Population distribution and structure by sex and age, including the economically active population, is as shown in the following figure:

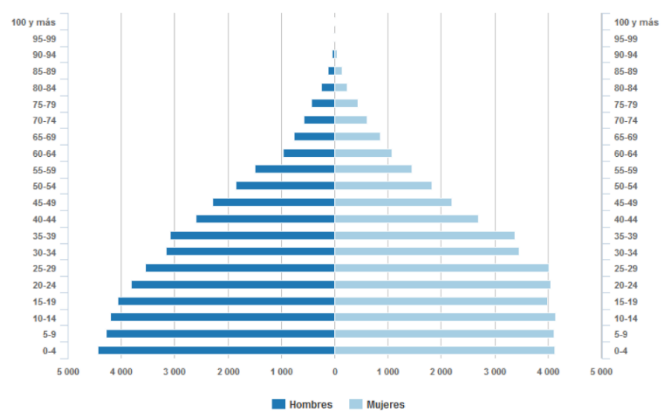


Figure IV. 106 Population distribution

Indigenous population

Population distribution aged 3 and over, according to indigenous and Spanish speaking status, in the last 2010 census, the total indicator of men and women was as follows:

Table IV. 61 Population distribution aged 3 and over in the municipality

Indicator	Total	Men	Women
Population aged 3 and over	79,912	39,433	40,479
Indigenous language speaking population	186	104	82
Spanish speaking	103	58	45
Not Spanish speaking	0	0	0
Not specified	83	46	37
Population not speaking an indigenous language	79,424	39,175	40,249
Not specified	302	154	148

Reported indigenous population and indigenous languages speaking indicators:

Table IV. 62 Indigenous population indicators

Indigenous typology	Indigenous population
Marginalization degree	Low
Total population	86,620
Indigenous population	521
Difference	86,099
Percentage	1

Table IV. 63 Indigenous languages spoken in the municipality

Language	Total	Men	Women
Speaks indigenous language	186	104	82
Chol (Ch'ol)	5	0	2
Tabasco's Chontal	4	2	2
Not specified indigenous language	77	43	34
Maya	11	8	3
Mazateco	3	3	0
Mixteco	3	0	3
Nahuatl	9	5	4
Totonaca (Totonaco)	4	2	2
Tzotzil (Tsotsil)	7	5	2
Zapoteco	60	34	26
Zoque	3	2	1

Migration rate

Migration intensity at municipal level to the United States is "very low", in the state context it ranks in ninth place and in the national context, 2220.

Economically active population

Municipality population distribution by economic activity condition and sex is given below.

Table IV. 64 Municipality economically active population, 2010

Indicadores de participación económica	Total	Hombres	Mujeres
Población de 12 años y más	64,459	31,548	32,911
Población Económicamente Activa (PEA)	29,816	22,645	7,171
Ocupada	27,970	21,065	6,905
Desocupada	1,846	1,580	266
Población no económicamente activa (PEI)	34,207	8,601	25,606
No especificado	436	302	134

Note: Economically active population is people aged 12 and over who worked, had work but did not work or sought work in the reference week.

Economically non-active population is people aged 12, plus pensioners or retired individuals, students, people engaged in household chores, those who had some permanent physical or mental limitation preventing them from working.

Occupancy according to economic activity sector:

Table IV. 65 Occupancy and distribution according to sector

Employed population	Economic activity sector				
	Primary	Secondary	Commerce	Services	Not specified
26,275	6,640	6,081	2,511	10,286	757
Percentage	25.27	23.14	9.56	39.15	2.88

Working population and its percentage distribution according to occupational division.

Table IV. 66 Working population and its percentage distribution by occupational division

Working population	Economic activity sector				
	Professionals, technical and administrative	Agricultural workers	Industry workers	Traders and workers in miscellaneous services	Not specified
26,275	5,524	6,401	5,058	8,370	922
Percentage	21.02	24.36	19.25	31.86	3.51

Productive sector

Below are some data on what the productive sector represents at municipal level, among which stand out:

Agricultural sector Autumn-Winter season

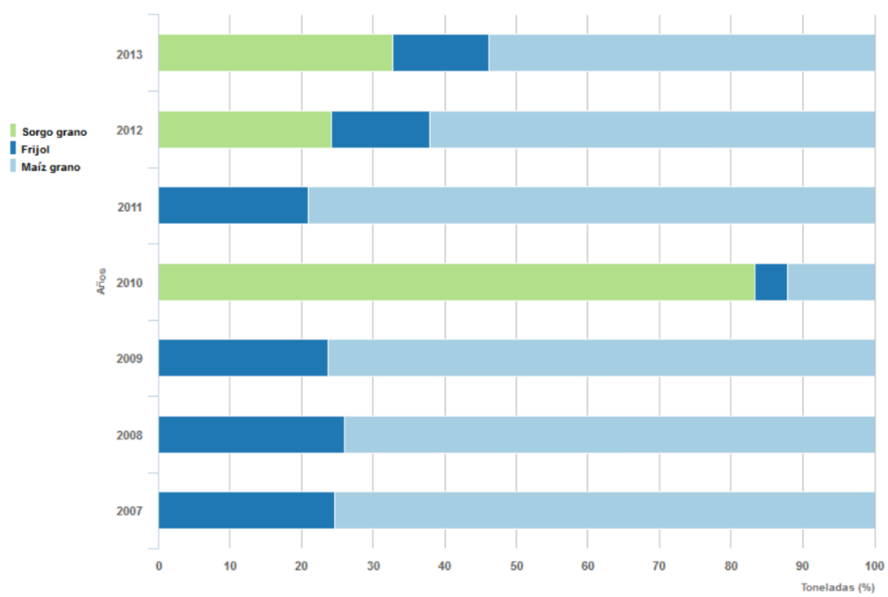


Figure IV. 107 Fall-Winter rainfed agricultural production

Agricultural sector Spring-Summer season

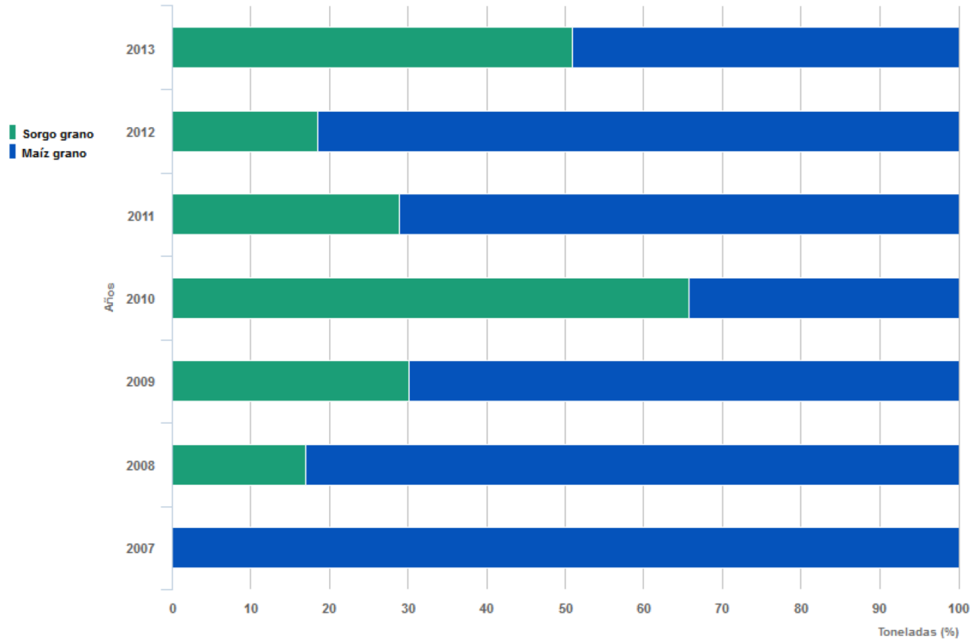


Figure IV. 108 Spring-Summer rainfed agricultural production

Agriculture sector evergreen crops

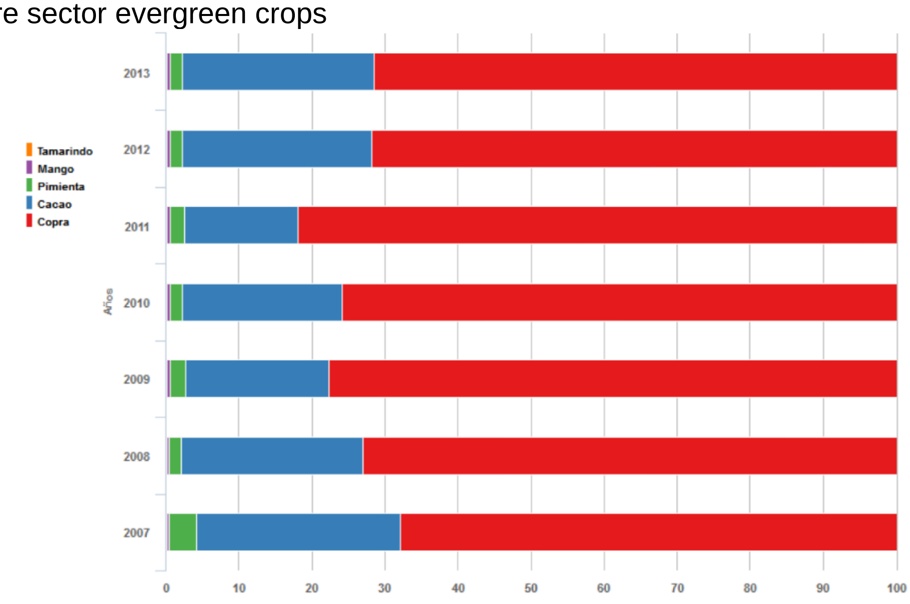


Figure IV. 109 Evergreen agricultural production

Livestock Sector

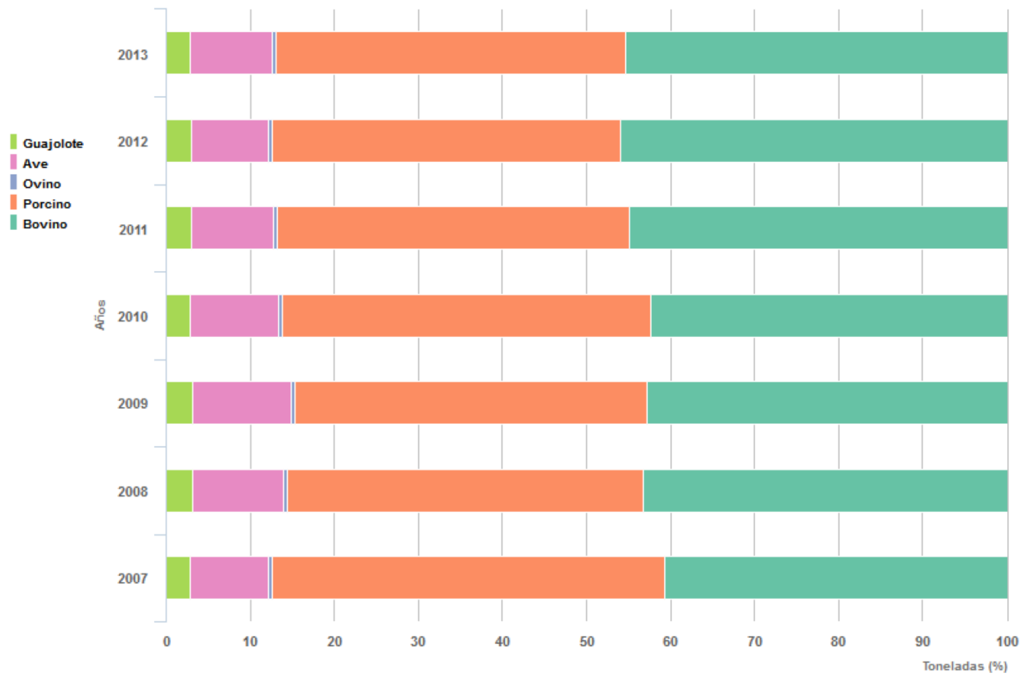


Figure IV. 110 Livestock production

Housing and poverty at municipal level

Below are some data on housing and poverty indicators reported in the afore mentioned INEGI, SEMARNAT and CONABIO document.

Table IV. 67 Housing and poverty indicators

Indicador de pobreza	Personas	Porcentaje	Carencias	Intensidad
Población total	85,321	100	0.0	0.0
Pobreza	53,987.00	63.30	2.50	0.27
Pobreza extrema	11,882.00	13.90	3.60	0.08
Pobreza moderada	42,105.00	49.30	2.20	0.18
Vulnerables por carencia social	21,787.00	25.50	2.20	0.00
Vulnerables por ingreso	3,576.00	4.20	0.00	0.00
No pobres y no vulnerables	5,971.00	6.10	0.00	0.00
Rezago educativo	17,238.00	20.20	0.00	0.00
Carencia por acceso a los servicios de salud	16,312.00	19.10	0.00	0.00
Carencia por acceso a la seguridad social	70,130.00	82.20	0.00	0.00
Carencia por calidad y espacios de la vivienda	15,183.00	17.80	0.00	0.00
Carencia por acceso a los servicios básicos en la vivienda	37,015.00	43.40	0.00	0.00
Carencia por acceso a la alimentación	29,991.00	35.20	0.00	0.00
Población con al menos una carencia social	75,774.00	88.80	0.00	0.00
Población con tres o más carencias sociales	34,779.00	40.80	0.00	0.00
Población con ingreso inferior a la línea de bienestar	57,563.00	67.50	0.00	0.00
Población con ingreso inferior a la línea de bienestar mínimo	20,352.00	23.90	0.00	0.00

From the above table, 49.3% of the population lives in moderate poverty, indicating that much of the population may require better wages or employment sources at municipal level.

Illiteracy

Finally, another of the main topics addressed is the number of people who cannot read or write in the population over 15 years of age. Of a total population of 59,583 persons, 2,767 cannot read or write, representing 4.64% of the total population. Distributed in 1,030 men and 1,737 women who do not know how to read or write.

Marginalization and social backwardness

Marginalization and social backwardness indices reported up to the last INEGI census in 2010, the marginalization index was -1.03, which represented a Low marginalization degree with a social backwardness index of -1.18 and Very low social backwardness degree.

Cultural

Religious groups

In the region, the main religion professed is Catholic, although there are various religious groups, both Protestant and Evangelical, as well as non-evangelical biblical religions.

Types of predominant social organizations

In the municipality of Paraiso, Tabasco, various associations, organizations and chambers of producers, traders and service providers are legally integrated, among which are the following: Mexican Republic Oil Workers Union (STPRM) Section 50; National Peasant Confederation (CNC); Construction, Drilling, Mechanical Work and Personnel Transport of the Industry and Related Trade Workers Union; Maritime Workers Union; Section 47 Oil Workers Union, Civil and Mechanical Work, Drilling, Rig Operator and Similar; Livestock Associations, among others.

Municipality of Cardenas

The municipality of Cardenas is located to the West of Paraiso municipality where ground facilities intend to be located. This municipality was selected as part of the SAR for its common boundary westward of future land facilities on the coastal strip from the Tonala river mouth, passing through the complex lagoon system el Carmen, Pajonal, La Machona, La Redonda; as well as the Tupilco bar already within the municipality of Paraiso.

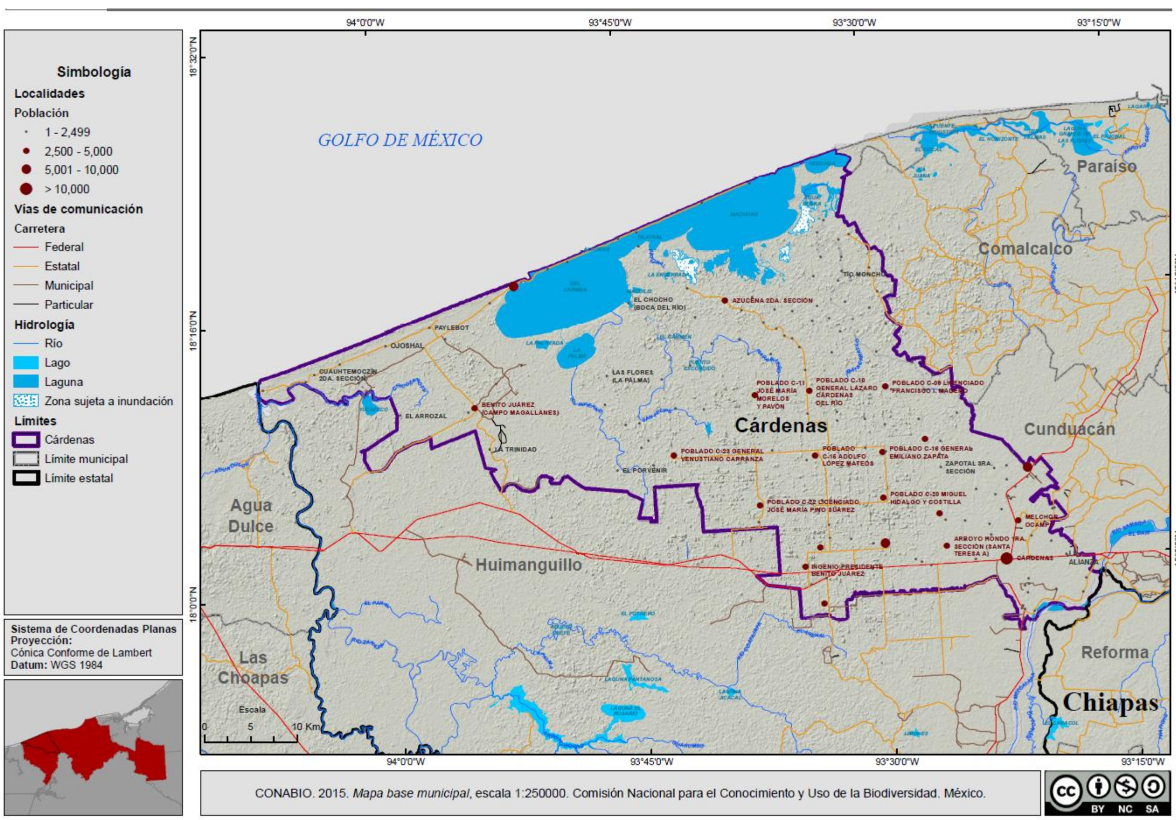


Figure IV. 111 Municipality of Cardenas, Tabasco location map

It is important to mention these environmentally sensitive areas, due to various activities carried out in the coastal area and lagoon system, both fishery and oyster crops among others, as well as the great biodiversity still existing and there may be interactions between the project and these environmental elements, mainly if there were any significant spills in marine installations included in the project during drilling or crude production activities, which would be influenced by prevailing sea currents and wind direction and which would be transported until possible arrival at coastal areas if preventive measures or emergency response are not taken immediately.

Cardenas municipality has an area of 2,044.44 sq.km, area percentage it represents with respect to the state is 8.28%, has 172 localities, total population in 2010 is 248,481 inhabitants (95,084 men and 97,718 women); the municipal seat is the city of Cardenas, which has a population of 91,558 inhabitants, based on SEMARNAT, CONABIO and INEGI report.

Population and municipal demographics

From the same source, total population and by sex is as follows:

Table IV. 68 Municipality total population and by sex

Sex/Year	1990	1995	2000	2005	2010
Men	86,470	102,350	107,305	107,557	122,234
Women	86,165	102,460	109,956	112,006	126,247
Total	172,635	204,810	217,261	219,563	248,481

Population growth trend

Population growth trend is shown in the following figure:

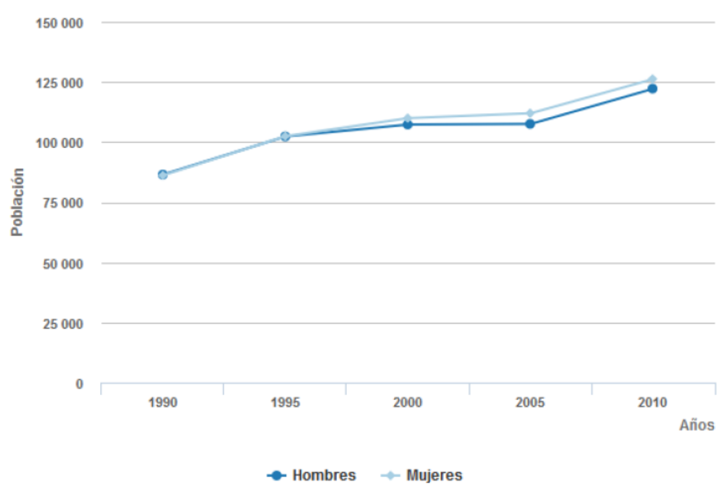


Figure IV. 112 Population growth trend

It indicates that in population censuses of recent decades it has been of slow growth. Population indicators are as follows:

Table IV. 69 Population indicators of the municipality

Sex/Year	1995	2000	2005	2010
Population density of the municipality (Inhabitants/sq.km)	102	107	107	122
Population percentage in relation to state	11.71	11.48	11.03	11.10
Male/female ratio	100	98	96	97

Population density indicator trend is as follows:

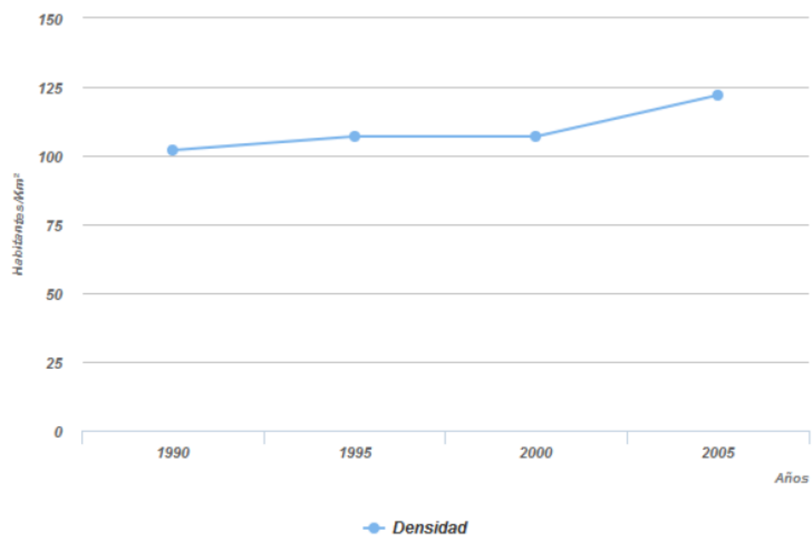


Figure IV. 113 Population density growth trend

Population distribution and structure by sex and age, including the economically active population, is as shown in the following figure:

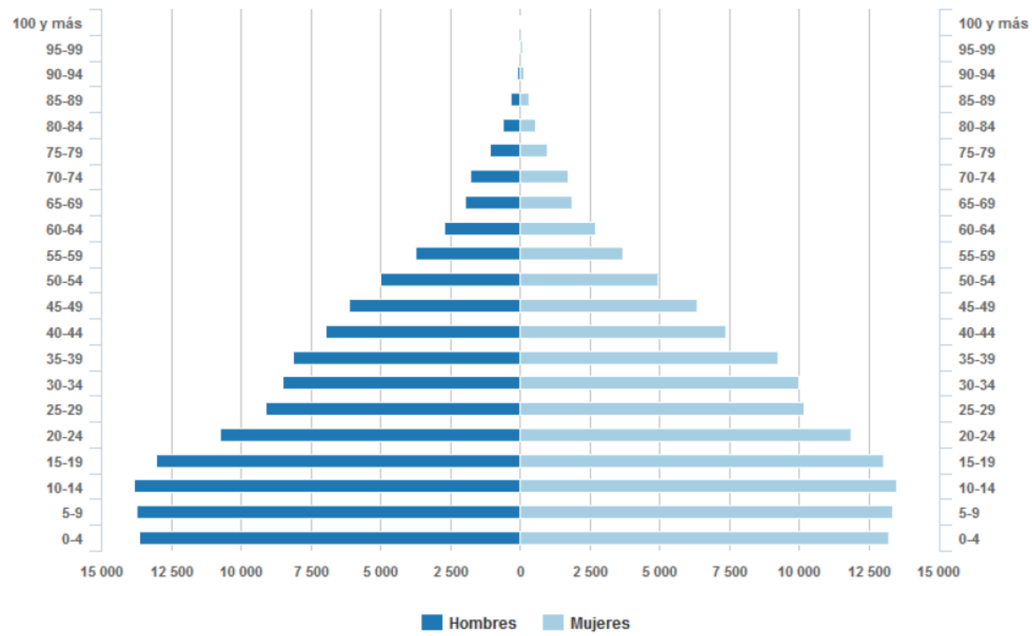


Figure IV. 114 Population distribution

Indigenous population

Population distribution aged 3 and over, according to indigenous and Spanish speaking status, in the last 2010 census, the total indicator of men and women was as follows:

Table IV. 70 Population distribution aged 3 and over in the municipality

Indicator	Total	Men	Women
Population aged 3 and over	230,525	113,115	117,410
Indigenous language speaking population	1,021	576	445
Spanish speaking	729	407	322
Not Spanish speaking	6	2	4
Not specified	286	167	119
Population not speaking an indigenous language	227,808	111,656	116,152
Not specified	1,696	883	813

Reported indigenous population and indigenous languages speaking indicators:

Table IV. 71 Indigenous population indicators

Indigenous typology	Indigenous population
Marginalization degree	Medium
Total population	248,481
Indigenous population	2,995
Difference	245,486
Percentage	1

Table IV. 72 Indigenous languages spoken in the municipality

Language	Total	Men	Women
Speaks indigenous language	1,021	576	445
Chinanteco	1	0	1
Chol (Ch'ol)	37	18	19
Chontal	1	1	0
Tabasco's Chontal	65	49	16
Huave	1	1	0
Huichol	2	0	2
Kanjobal (Q'anjob'al)	1	0	1
Not specified indigenous language	236	136	100
Maya	117	75	42
Mazahua	5	4	1
Mazateco	2	0	2
Mixe	18	12	6
Mixteco	42	22	20
Mixteco from the low Mixteca	1	0	1
Nahuatl	205	101	104
Popoloca	1	0	1
Popoluca	1	0	1
Tojolabal	2	1	1
Totonaca (Totonaco)	6	6	0
Triqui	1	1	0
Tzeltal (Tseltal)	41	20	21
Tzotzil (Tsotsil)	28	17	11
Zapoteco	143	82	61
Zoque 65	30	35	

Migration rate

Migration intensity at municipal level to the United States is "very low", in the state context it ranks fourth and in the national context 2,017.

Economically active population

Municipality population distribution by economic activity condition and sex is given below.

Table IV. 73 Municipality economically active population, 2010

Indicadores de participación económica	Total	Hombres	Mujeres
Población de 12 años y más	181,473	88,234	93,239
Población Económicamente Activa (PEA)	84,545	65,267	19,278
Ocupada	80,575	61,878	18,697
Desocupada	3,970	3,389	581
Población no económicamente activa (PEI)	95,793	22,302	73,491
No especificado	1,135	665	470

Note: Economically active population is people aged 12 and over who worked, had work but did not work or sought work in the reference week.

Economically non-active population is people aged 12, plus pensioners or retired individuals, students, people engaged in household chores, those who had some permanent physical or mental limitation preventing them from working.

Occupancy according to economic activity sector:

Table IV. 74 Occupancy and distribution according to sector

Working population	Economic activity sector				
	Primary	Secondary	Commerce	Services	Not specified
72,246	18,367	14,653	13,241	24,754	1,231
Percentage	25.42	20.28	18.33	34.26	1.70

Working population and its percentage distribution according to occupational division.

Table IV. 75 Working population and its percentage distribution by occupational division

Working population	Economic activity sector				
	Professionals, technical and administrative	Agricultural workers	Industry workers	Traders and workers in miscellaneous services	Not specified
72,246	16,424	17,255	11,997	25,202	1,368
Percentage	22.73	23.88	16.61	34.88	1.89

Productive sector

Below are some data on what the productive sector represents at municipal level, among which stand out:

Agricultural sector Autumn-Winter season

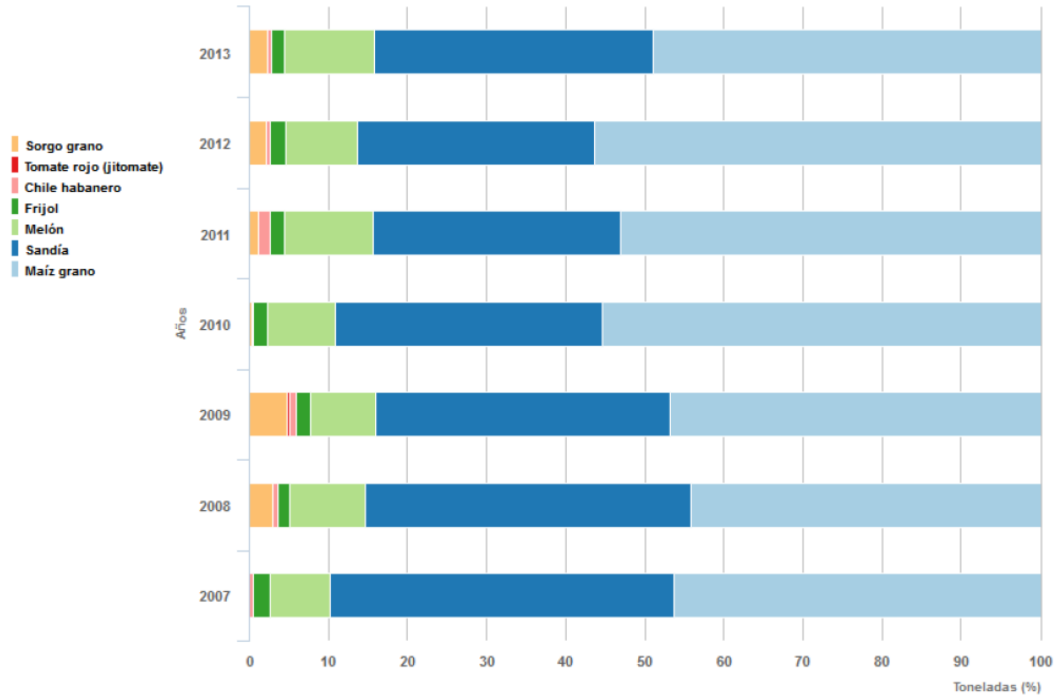


Figure IV. 115 Fall-Winter rainfed agricultural production

Agricultural sector Spring-Summer season

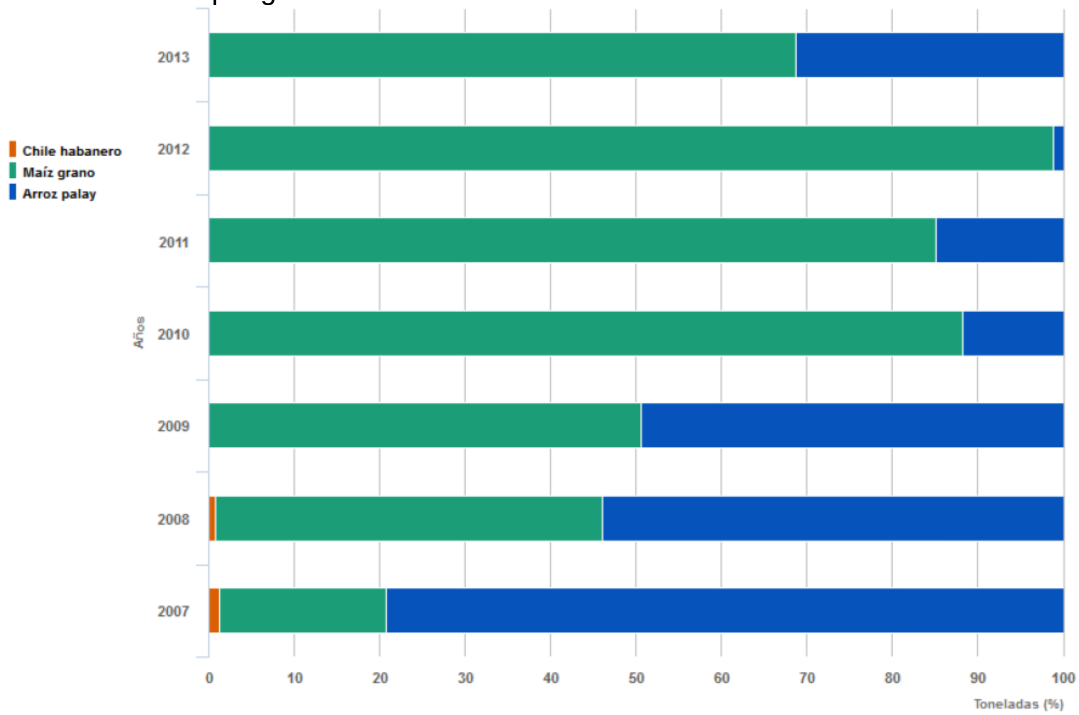


Figure IV. 116 Spring-Summer rainfed agricultural production

Agriculture sector evergreen crops

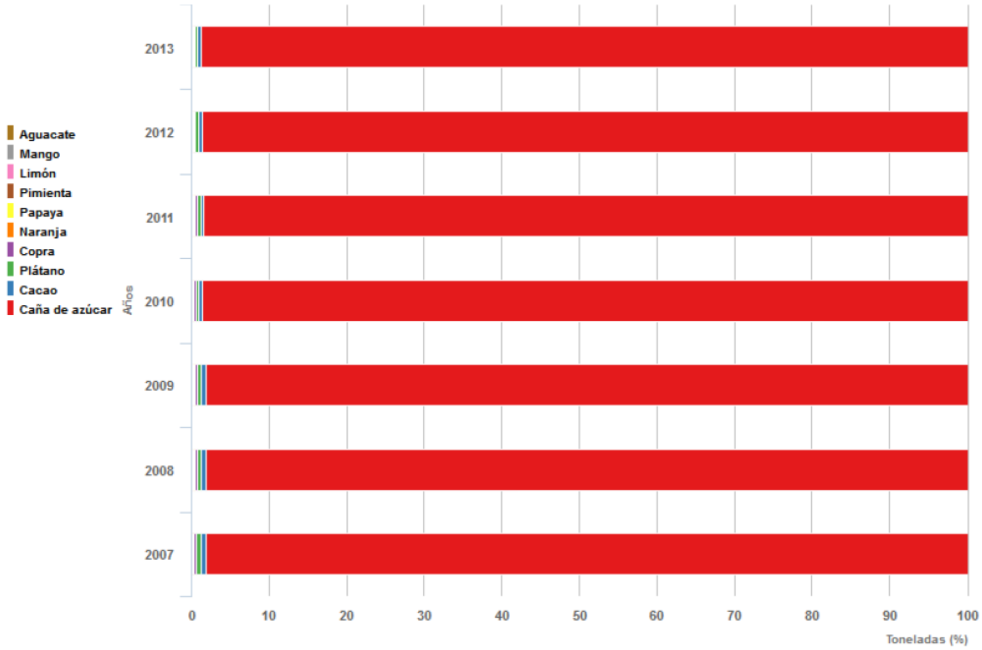


Figure IV. 117 Evergreen agricultural production

Livestock Sector

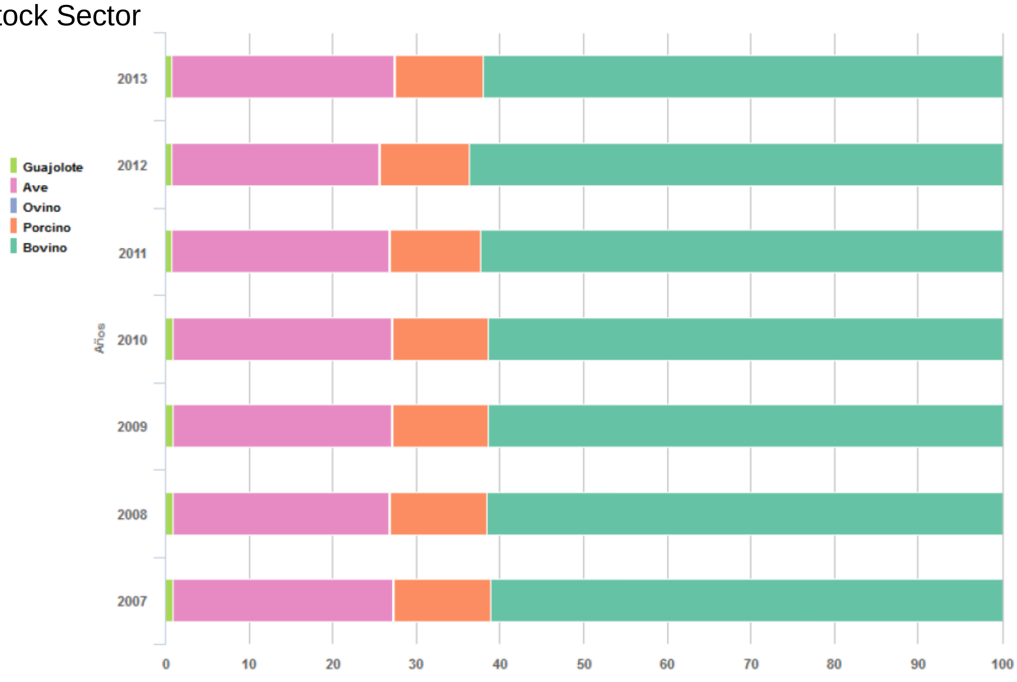


Figure IV. 118 Livestock production

Housing and poverty at municipal level

Below are some data on housing and poverty indicators reported in the afore mentioned INEGI, SEMARNAT and CONABIO document.

Table IV. 76 Housing and poverty indicators

Indicador de pobreza	Personas	Porcentaje	Carencias	Intensidad
Población total	231,617	100	0.0	0.0
Pobreza	151,222.00	65.30	2.90	0.31
Pobreza extrema	47,207.00	20.40	3.80	0.13
Pobreza moderada	104,015.00	44.90	2.50	0.18
Vulnerables por carencia social	49,703.00	21.50	2.30	0.00
Vulnerables por ingreso	12,182.00	5.30	0.00	0.00
No pobres y no vulnerables	18,510.00	7.10	0.00	0.00
Rezago educativo	50,758.00	21.90	0.00	0.00
Carencia por acceso a los servicios de salud	53,495.00	23.10	0.00	0.00
Carencia por acceso a la seguridad social	167,398.00	72.30	0.00	0.00
Carencia por calidad y espacios de la vivienda	48,521.00	20.90	0.00	0.00
Carencia por acceso a los servicios básicos en la vivienda	132,312.00	57.10	0.00	0.00
Carencia por acceso a la alimentación	95,612.00	41.30	0.00	0.00
Población con al menos una carencia social	200,925.00	86.70	0.00	0.00
Población con tres o más carencias sociales	110,839.00	47.90	0.00	0.00
Población con ingreso inferior a la línea de bienestar	163,404.00	70.50	0.00	0.00
Población con ingreso inferior a la línea de bienestar mínimo	67,795.00	29.30	0.00	0.00

From the above table, 44.9% of the population lives in moderate poverty, indicating that much of the population may require better wages or employment sources at municipal level.

Illiteracy

Finally, another of the main topics addressed is the number of people who cannot read or write in the population over 15 years of age. Out of a total population of 165,094 individuals, 12,142 are unable to read or write, which represents 7.35% of the total population. Distributed in 4,819 men and 7,323 women who do not know how to read or write.

Marginalization and social backwardness

Marginalization and social backwardness indices reported up to the last INEGI census in 2010, marginalization index was -0.57, representing a Medium degree of marginalization with a social lag index of -0.68 and a Very low degree of lag.

Cultural

It has a Carlos Pellicer Museum located in the city of Heroica Cardenas, where works of the poet, photographs and archaeological pieces of the Olmec culture are exhibited. It also has a mural: “The Evolution of Man”, by Ponce Montuy, at the Carlos Pellicer Museum; as well as with a Cardenas Cultural Center

The archaeological area has a site museum where pieces and mascarones found in the archaeological area are exhibited.

As well as numerous tourist sites located in the coastal area of Laguna el Carmen, Pajonal and Machona.

Religious groups

In the region, the main religion professed is Catholic, although there are various religious groups, both Protestant and Evangelical, as well as non-evangelical biblical religions.

Types of predominant social organizations, such as: Union of Rig Operators and Loading and Unloading Operations; Union of Telephone Operators; Union of Agricultural Production Ejidos of Plan Chontalpa Cardenas d Huimanguillo; Rice Producers Local Agricultural Association; National Union of Workers of La Sagarpa; Oil Workers Union of the Mexican Republic, H Section 26; Union of Farmers and Agricultural Group, A.C., Single Union of Workers in the Service of the State; Union of Workers of the Sugar Industry of the Republic, among others.

Municipality of Comalcalco

The municipality of Comalcalco is located to the South of the municipality where land facilities are intended to be located in the coastal strip of Paraíso. This municipality was selected for its South common boundary and a portion on the West side of the nearby coastal strip, where there could be interactions of the project with some of its environmental elements, mainly in water, land vegetation and fauna present in the coastal strip of said municipality.

The municipality of Comalcalco has an area of 76616 sq.km, the area percentage it represents with respect to the state is 3.10%, has 118 localities, the total population in 2010 is 192,802 inhabitants (95,084 men and 97,718 women). The municipal seat is the city of Comalcalco, which has a population of 41,468 inhabitants, information based on the SEMARNAT, CONABIO and INEGI report.

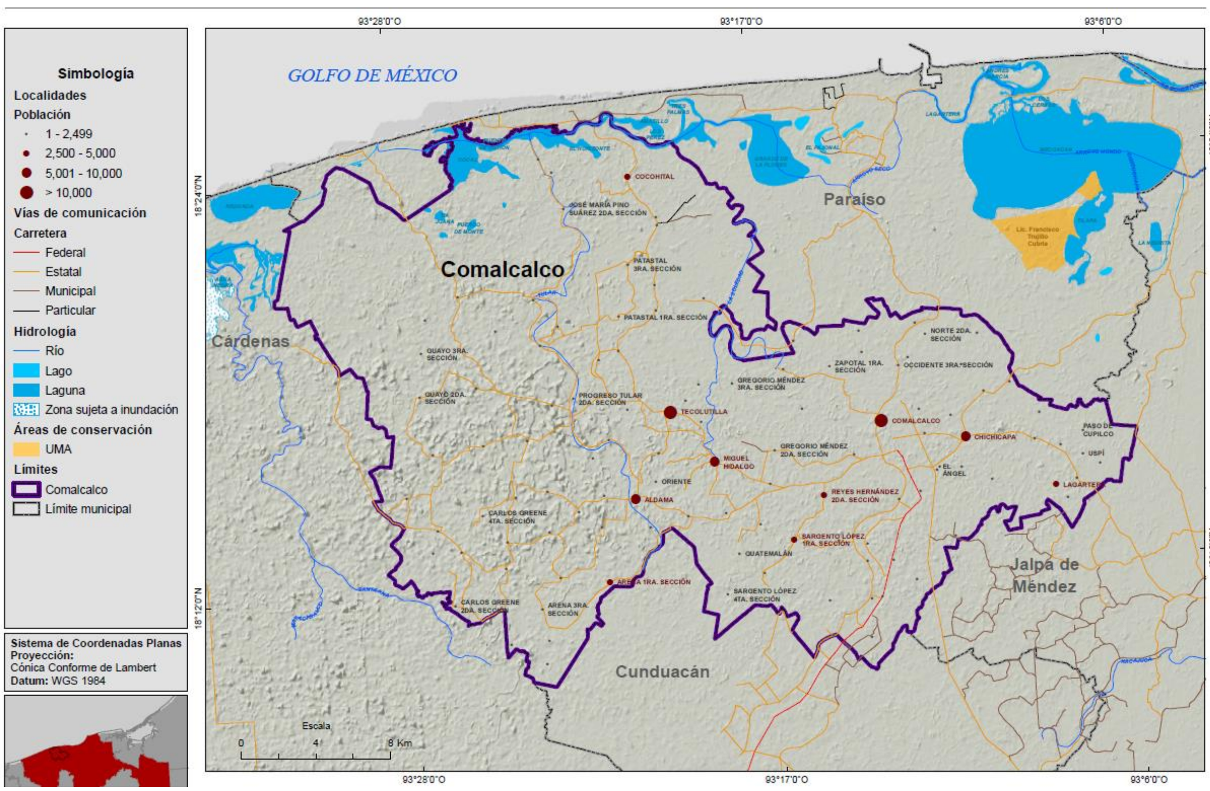


Figure IV. 119 Municipality of Comalcalco, Tabasco location map

Population and municipal demographics

From the same source there is the total population and by sex is as follows

Table IV. 77 Total population and by sex municipality

Sex/Year	1990	1995	2000	2005	2010
Men	70,609	78,164	81,299	85,645	95,084
Women	70,676	78,170	83,338	88,128	97,718
Total	141,285	156,334	164,637	173,773	192,802

Population growth trend

Population growth trend is shown in the following figure:

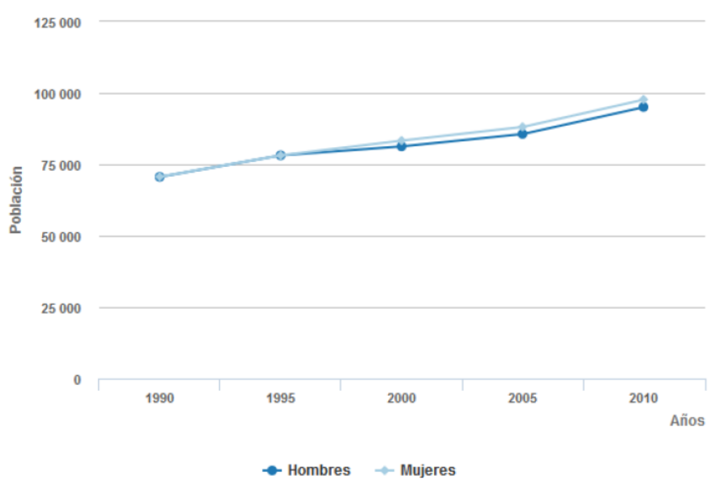


Figure IV. 120 Population growth trend

It indicates that in population censuses of recent decades it has been of slow growth. Population indicators are as follows:

Table IV. 78 . Population indicators of the municipality

Sex/Year	1995	2000	2005	2010
Population density of the municipality (Inhabitants/sq.km)	204	212	227	252
Population percentage in relation to state	8.94	8.70	8.73	8.61
Male/female ratio	100	98	97	97

Population density indicator trend is as follows:

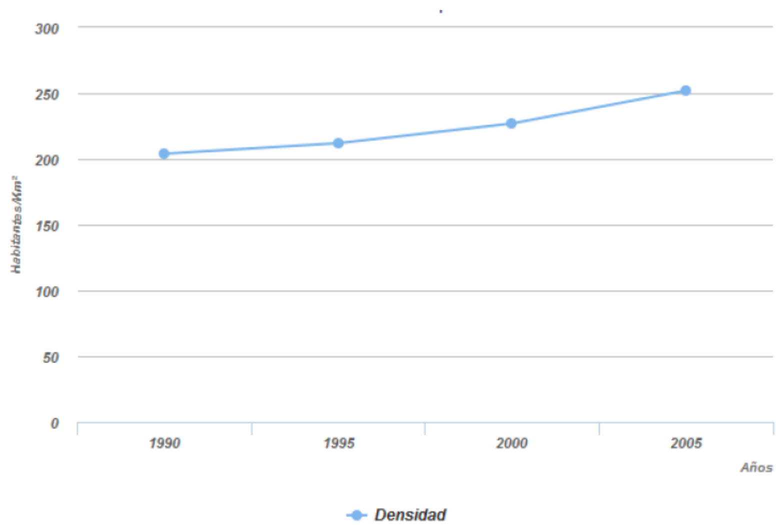


Figure IV. 121 Population density growth trend

Population distribution and structure by sex and age, including the economically active population, is as shown in the following figure:

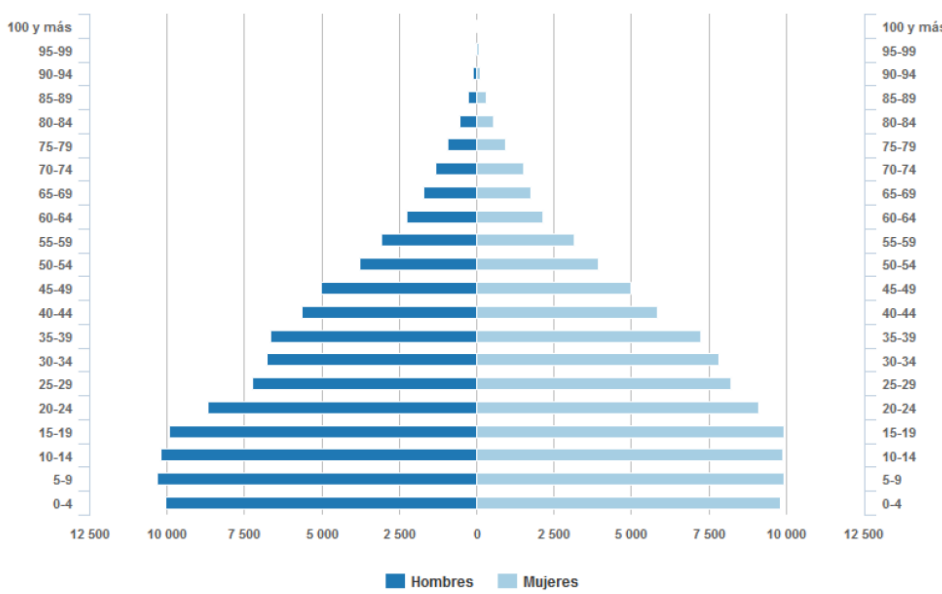


Figure IV. 122 Population distribution

Indigenous population

Population distribution aged 3 and over, according to indigenous and Spanish speaking status, in the last 2010 census, the total indicator of men and women was as follows:

Table IV. 79 Population distribution aged 3 and over in the municipality

Indicator	Total	Men	Women
Population aged 3 and over	180,391	88,750	91,641
Indigenous language speaking population	565	320	245
Spanish speaking	355	203	152
Not Spanish speaking	1	0	1
Not specified	209	117	92
Population not speaking an indigenous language	178,933	87,987	90,946
Not specified	893	443	450

Reported indigenous population and indigenous languages speaking indicators:

Table IV. 80 Indigenous population indicators

Indigenous typology	Indigenous population
Marginalization degree	Medium
Total population	192,802
Indigenous population	1,472
Difference	191,330
Percentage	1

Table IV. 81 Indigenous languages spoken in the municipality

Language	Total	Men	Women
Speaks indigenous language	565	320	245
Chinanteco	1	0	1
Chol (Ch'ol)	29	16	13
Tabasco's Chontal	50	32	18
Huave	1	0	1
Kekchi (Q'eqchi')	1	0	1
Not specified indigenous language	195	116	79
Mame (Mam)	1	0	1
Maya	52	29	23
May	1	1	0
Mazateco	4	3	1
Mixe	4	2	2
Mixteco	25	12	13
Nahuatl	105	56	49
Otomi	2	2	0
Popoluca	1	1	0
Tojolabal	1	0	1
Totonaca (Totonaco)	10	4	6
Tzeltal (Tseltal)	11	2	9
Tzotzil (Tsotsil)	34	23	11
Zapoteco	33	18	15
Zoque	4	3	1

Migration rate

The intensity of migration at the municipal level to the United States is "very low", in the state context it ranks fourth and in the national context 1936.

Economically active population

Municipality population distribution by economic activity condition and sex is given below.

Table IV. 82 Municipality economically active population, 2010

Indicadores de participación económica	Total	Hombres	Mujeres
Población de 12 años y más	143,754	70,207	73,547
Población Económicamente Activa (PEA)	65,015	51,454	13,561
Ocupada	60,325	47,309	13,016
Desocupada	4,690	4,145	545
Población no económicamente activa (PEI)	77,827	18,185	59,642
No especificado	912	568	344

Note: Economically active population is people aged 12 and over who worked, had work but did not work or sought work in the reference week.

Economically non-active population is people aged 12, plus pensioners or retired individuals, students, people engaged in household chores, those who had some permanent physical or mental limitation preventing them from working.

Occupancy according to economic activity sector:

Table IV. 83 Occupancy and distribution according to sector

Working population	Economic activity sector				
	Primary	Secondary	Commerce	Services	Not specified
61,683	12,740	14,624	10,305	19,942	4,072
Percentage	20.65	23.71	16.71	32.33	6.60

Working population and its percentage distribution according to occupational division.

Table IV. 84 Working population and its percentage distribution by occupational division

Working population	Economic activity sector				
	Professionals, technical and administrative	Agricultural workers	Industry workers	Traders and workers in miscellaneous services	Not specified
61,683	10,436	10,962	11,891	24,790	3,604
Percentage	16.92	17.77	19.28	40.19	5.84

Productive sector

Below are some data on what the productive sector represents at municipal level, among which stand out:

Agricultural sector Autumn-Winter season

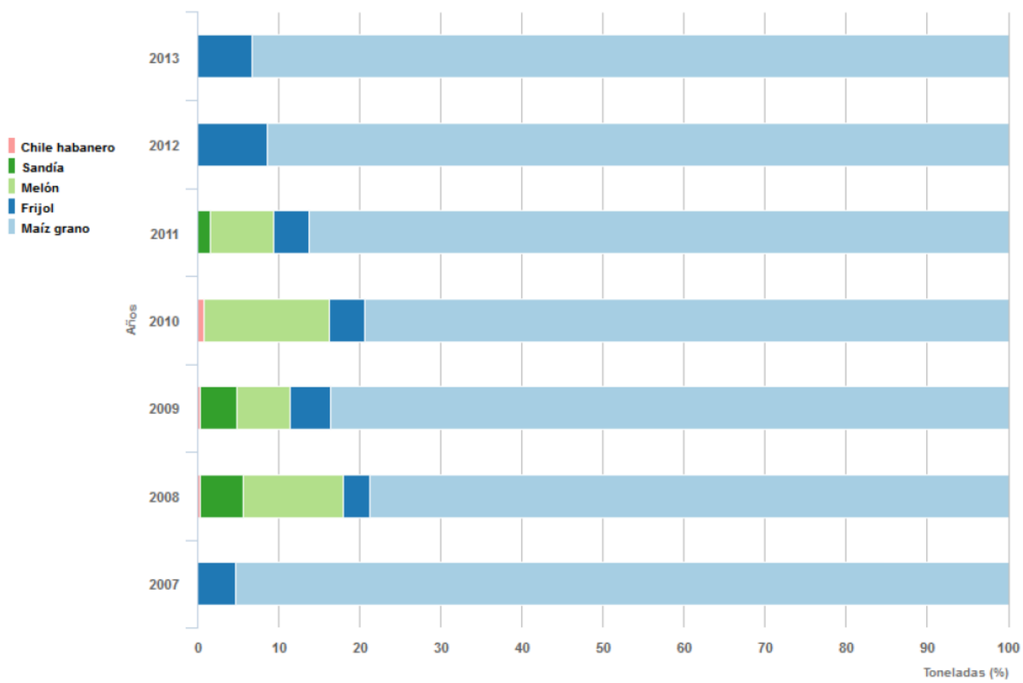


Figure IV. 123 Fall-Winter rainfed agricultural production

Agricultural sector Spring-Summer season

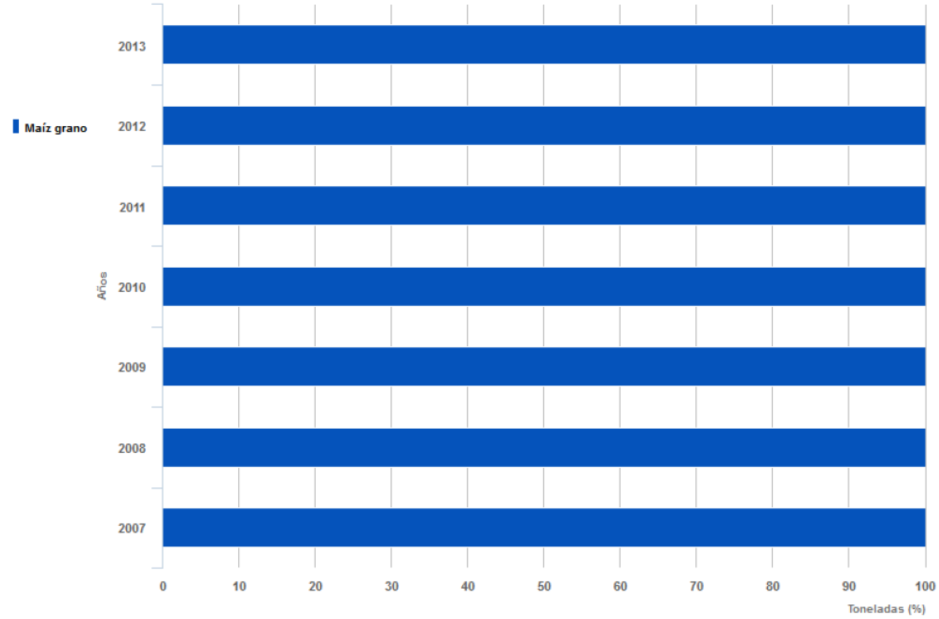


Figure IV. 124 Spring-Summer rainfed agricultural production

Agriculture sector evergreen crops

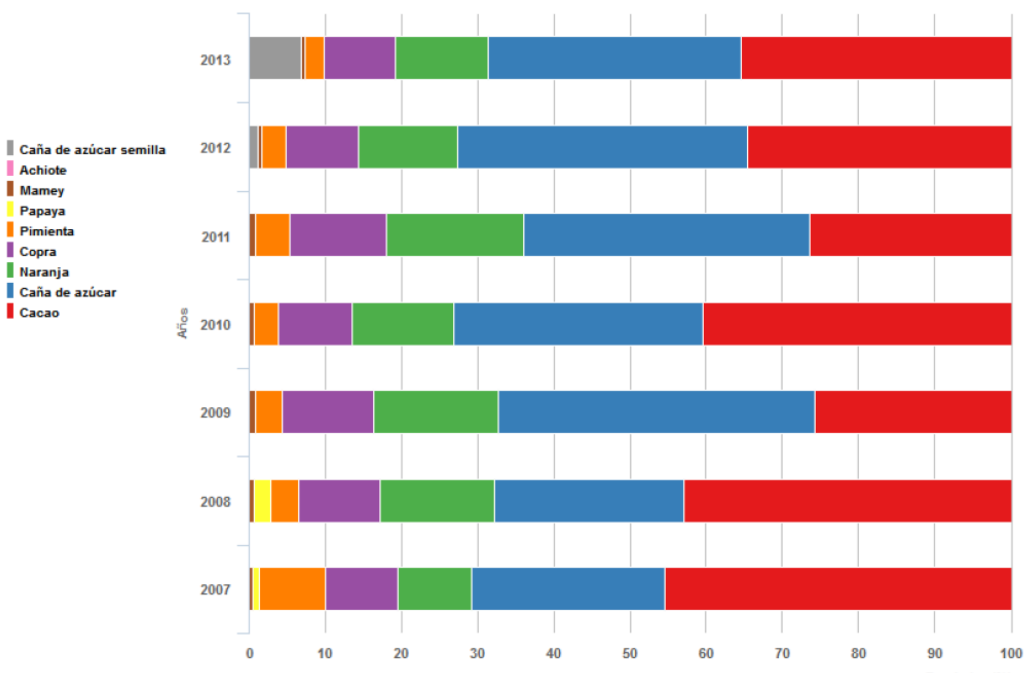


Figure IV. 125 Evergreen agricultural production

Livestock Sector

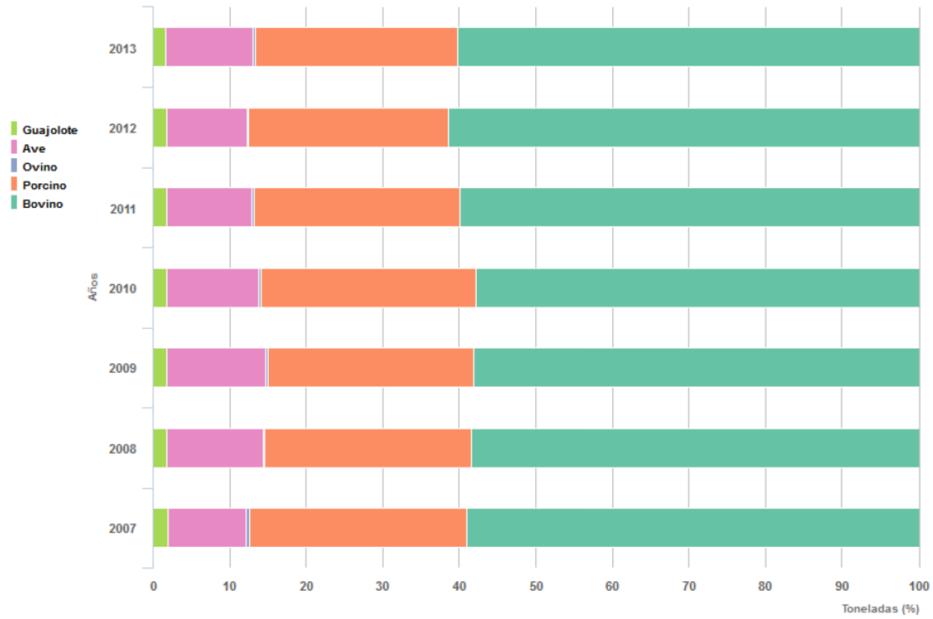


Figure IV. 126 Livestock Production

Housing and poverty at municipal level

Below are some data on housing and poverty indicators reported in the afore mentioned INEGI, SEMARNAT and CONABIO document.

Table IV. 85 Housing and poverty indicators

Indicador de pobreza	Personas	Porcentaje	Carencias	Intensidad
Población total	196,245	100	0.0	0.0
Pobreza	129,742.00	66.10	3.10	0.34
Pobreza extrema	37,072.00	18.90	3.90	0.12
Pobreza moderada	92,671.00	47.20	2.80	0.22
Vulnerables por carencia social	52,225.00	26.60	2.60	0.00
Vulnerables por ingreso	5,514.00	2.80	0.00	0.00
No pobres y no vulnerables	8,764.00	4.50	0.00	0.00
Rezago educativo	52,907.00	27.00	0.00	0.00
Carencia por acceso a los servicios de salud	82,300.00	41.90	0.00	0.00
Carencia por acceso a la seguridad social	163,705.00	83.40	0.00	0.00
Carencia por calidad y espacios de la vivienda	52,629.00	26.80	0.00	0.00
Carencia por acceso a los servicios básicos en la vivienda	109,348.00	55.70	0.00	0.00
Carencia por acceso a la alimentación	79,578.00	40.60	0.00	0.00
Población con al menos una carencia social	181,967.00	92.70	0.00	0.00
Población con tres o más carencias sociales	113,676.00	57.90	0.00	0.00
Población con ingreso inferior a la línea de bienestar	135,257.00	68.90	0.00	0.00
Población con ingreso inferior a la línea de bienestar mínimo	50,978.00	25.10	0.00	0.00

From the above table, 47.20% of the population lives in moderate poverty, indicating that much of the population may require better wages or employment sources at municipal level.

Illiteracy

Finally, another of the main topics addressed is the number of people who cannot read or write in the population over 15 years of age. Out of a total population of 131,671 individuals, 9,997 do not know how to read or write, representing 7.59 % of the total population. Distributed in 3,675 men and 6,322 women who do not know how to read or write.

Marginalization and social backwardness

Marginalization and social backwardness indices reported up to the last INEGI census in 2010, the marginalization index was -0.59, which represented a Medium degree of marginalization with a social lag index of -0.76 and a Very low degree of lag.

Cultural

It has an archaeological area that is the main Mayan vestige of the state of Tabasco, it is located just 2 km from the city of Comalcalco. This is the only Mayan city built with baked brick, and fixed with a mixture based on ground oyster shells.

The archaeological area has a site museum where pieces and mascarones found in the archaeological area are exhibited.

Religious groups

In the region, the main religion professed is Catholic, although there are various religious groups, both Protestant and Evangelical, as well as non-evangelical biblical religions.

Types of predominant social organizations

In the municipality of Comalcalco, Tabasco, several fishing cooperatives are mainly legally integrated.

Municipality of Centla

The municipality of Centla is located to the East of the municipality where land facilities are intended to be located in the coastal strip of Paraiso. Said municipality was selected for being part of the SAR on the Eastern side from where the land facilities will be located, considering the coastal strip where the project could interact with some of its environmental elements, mainly in water, land vegetation and fauna present in the coastal strip of said municipality.

The municipality of Comalcalco has an area of 2,685,62 sq.km, area percentage it represents with respect to the state is 10.8%, it has 204 localities, the total population in 2010 is 102,110 inhabitants (50,925 men and 51,185 women). The municipal seat is the city of Frontera, which has a population of 22,795 inhabitants, information based on SEMARNAT, CONABIO and INEGI report.

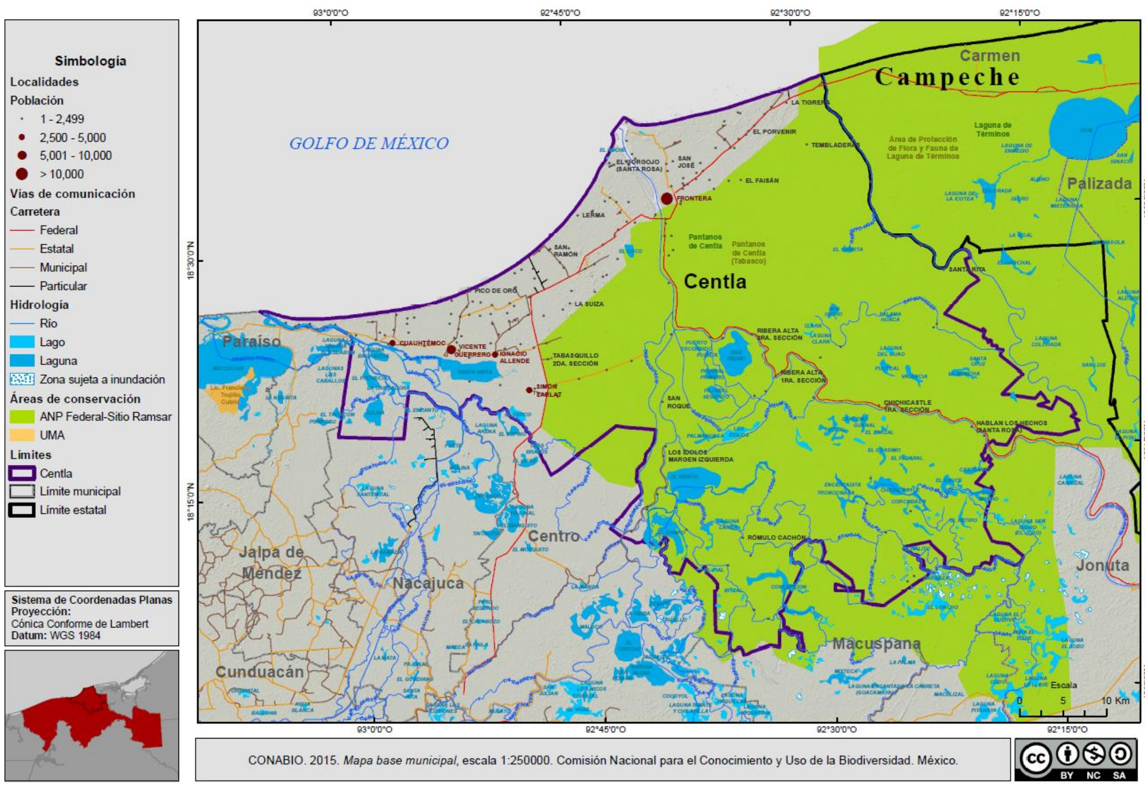


Figure IV. 127 Municipality of Centla, Tabasco location map

Population and municipal demographics

From the same source, total population and by sex is as follows:

Table IV. 86 Total population and by sex municipality

Sex/Year	1990	1995	2000	2005	2010
Men	35,498	39,034	44,350	46,411	50,925
Women	34,555	38,509	43,868	46,344	51,185
Total	70,053	77,543	88,218	92,755	102,110

Population growth trend

Population growth trend is shown in the following figure:

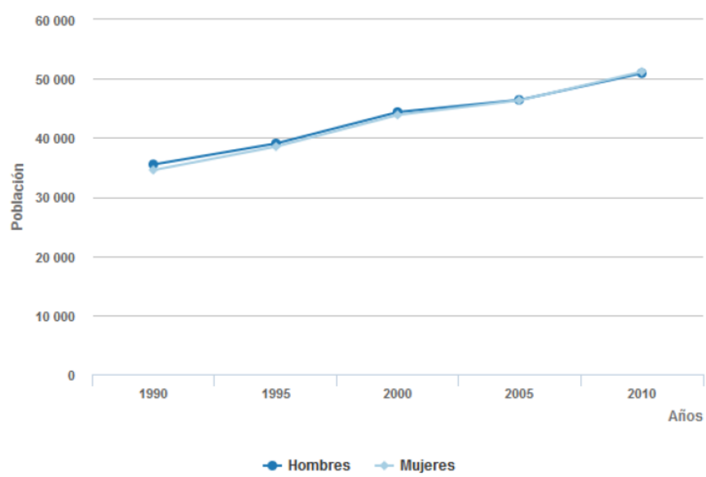


Figure IV. 128 Population growth trend

It indicates that in population censuses of recent decades it has been of slow growth. Population indicators are as follows:

Table IV. 87 Population indicators of the municipality

Sex/Year	1995	2000	2005	2010
Population density of the municipality (Inhabitants/sq.km)	29	33	35	38
Population percentage in relation to state	4.43	4.66	4.66	4.56
Male/female ratio	101	101	100	99

Population density indicator trend is as follows:

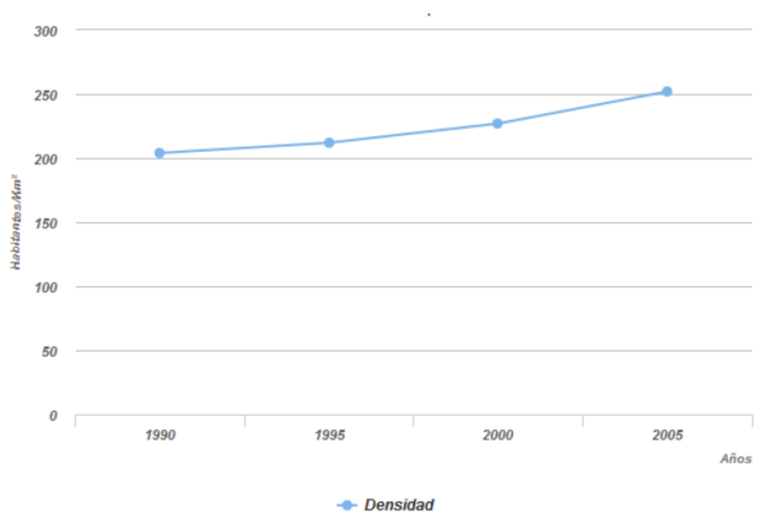


Figure IV. 129 Population density growth trend

Population distribution and structure by sex and age, including the economically active population, is as shown in the following figure:

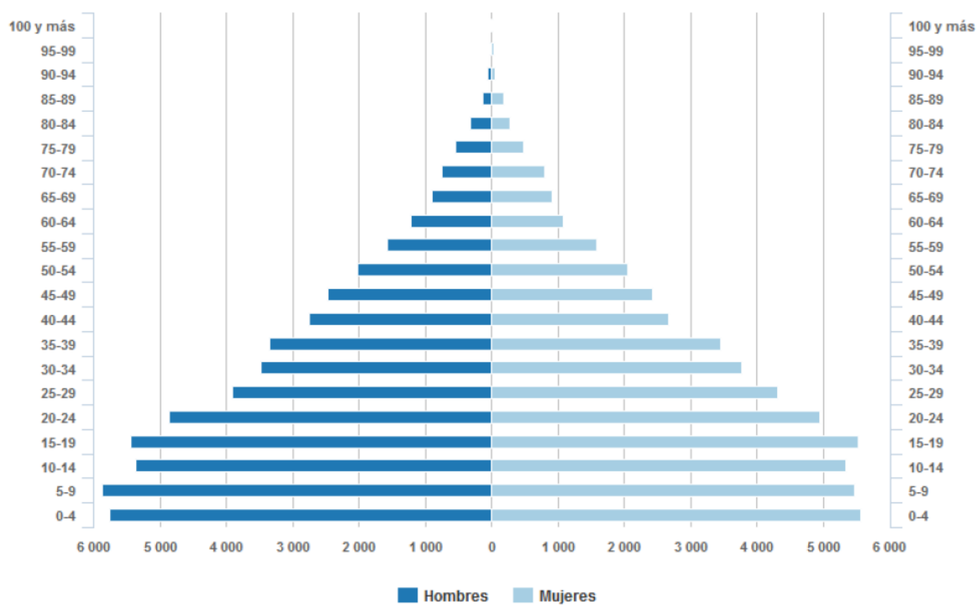


Figure IV. 130 Population distribution

Indigenous population

Population distribution aged 3 and over, according to indigenous and Spanish speaking status, in the last 2010 census, the total indicator of men and women was as follows:

Table IV. 88 Population distribution aged 3 and over in the municipality

Indicator	Total	Men	Women
Population aged 3 and over	95,148	47,455	47,693
Indigenous language speaking population	3,486	2,050	1,436
Spanish speaking	3,269	1,938	1,331
Not Spanish speaking	6	1	5
Not specified	211	111	100
Population not speaking an indigenous language	91,343	45,244	46,099
Not specified	319	161	158

Reported indigenous population and indigenous languages speaking indicators:

Table IV. 89 Indigenous population indicators

Indigenous typology	Indigenous population
Marginalization degree	Medium
Total population	102,110
Indigenous population	11,042
Difference	91,068
Percentage	11

Table IV. 90 Indigenous languages spoken in the municipality

Language	Total	Men	Women
Speaks indigenous language	3,486	2,050	1,436
Chinanteco	1	0	1
Chol (Ch'ol)	29	14	15
Chontal	3	3	0
Tabasco's Chontal	3,237	1,913	1,324
Huasteco	1	1	0
Huave	1	0	1
Not specified indigenous language	107	62	45
Maya	36	20	16
Mixe	4	2	2
Mixteco	5	3	2
Nahuatl	17	11	6
Tzeltal (Tseltal)	15	2	13
Tzotzil (Tsotsil)	7	4	3
Yaqui	1	1	0
Zapoteco	21	14	7
Zoque	1	0	1

Migration rate

The intensity of migration at the municipal level to the United States is “very low”, in the state context it ranks fourth and in the national context 1936.

Economically active population

Municipality population distribution by economic activity condition and sex is given below.

Table IV. 91 Municipality economically active population, 2010

Indicadores de participación económica	Total	Hombres	Mujeres
Población de 12 años y más	74,891	37,017	37,874
Población Económicamente Activa (PEA)	32,567	26,916	5,651
Ocupada	30,603	25,238	5,365
Desocupada	1,964	1,678	286
Población no económicamente activa (PEI)	41,912	9,834	32,078
No especificado	412	267	145

Note: Economically active population is people aged 12 and over who worked, had work but did not work or sought work in the reference week.

Economically non-active population is people aged 12, plus pensioners or retired individuals, students, people engaged in household chores, those who had some permanent physical or mental limitation preventing them from working.

Occupancy according to economic activity sector:

Table IV. 92 Occupancy and distribution according to sector

Working population	Economic activity sector				
	Primary	Secondary	Commerce	Services	Not specified
27,275	8,481	4,045	3,793	10,872	84
Percentage	31.09	14.83	13.91	39.86	0.31

Working population and its percentage distribution according to occupational division.

Table IV. 93 Working population and its percentage distribution by occupational division

Working population		Economic activity sector				
		Professionals, technical and administrative	Agricultural workers	Industry workers	Traders and workers in miscellaneous services	Not specified
27,275		4,625	7,604	5,263	9,699	84
Percentage		16.96	27.88	19.30	35.56	0.31

Productive sector

Below are some data on what the productive sector represents at municipal level, among which stand out:

Agricultural sector Autumn-Winter season

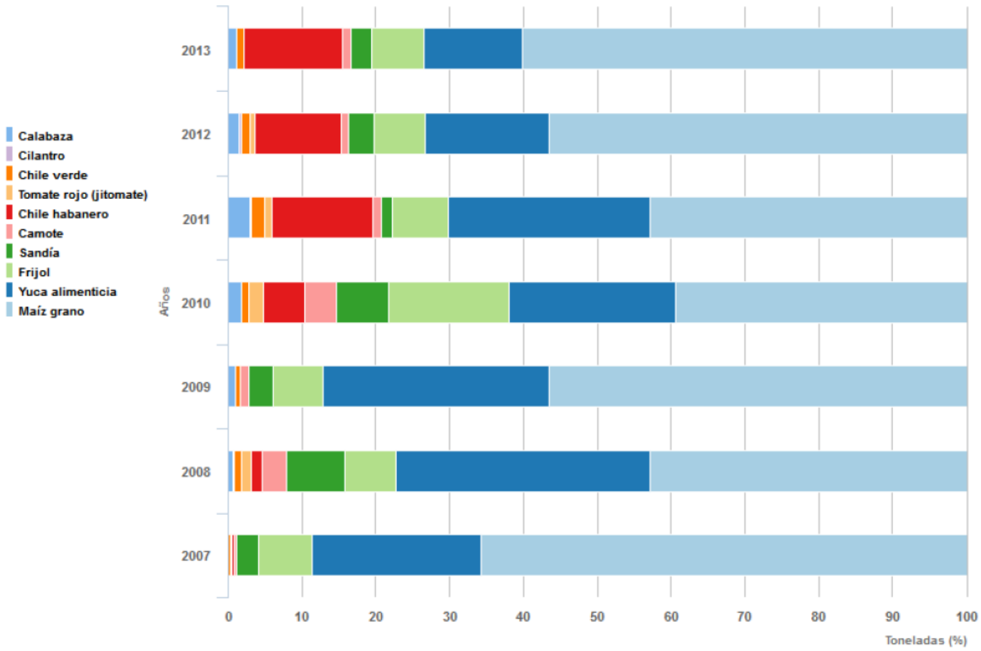


Figure IV. 131 Fall-Winter rainfed agricultural production

Agricultural sector Spring-Summer season

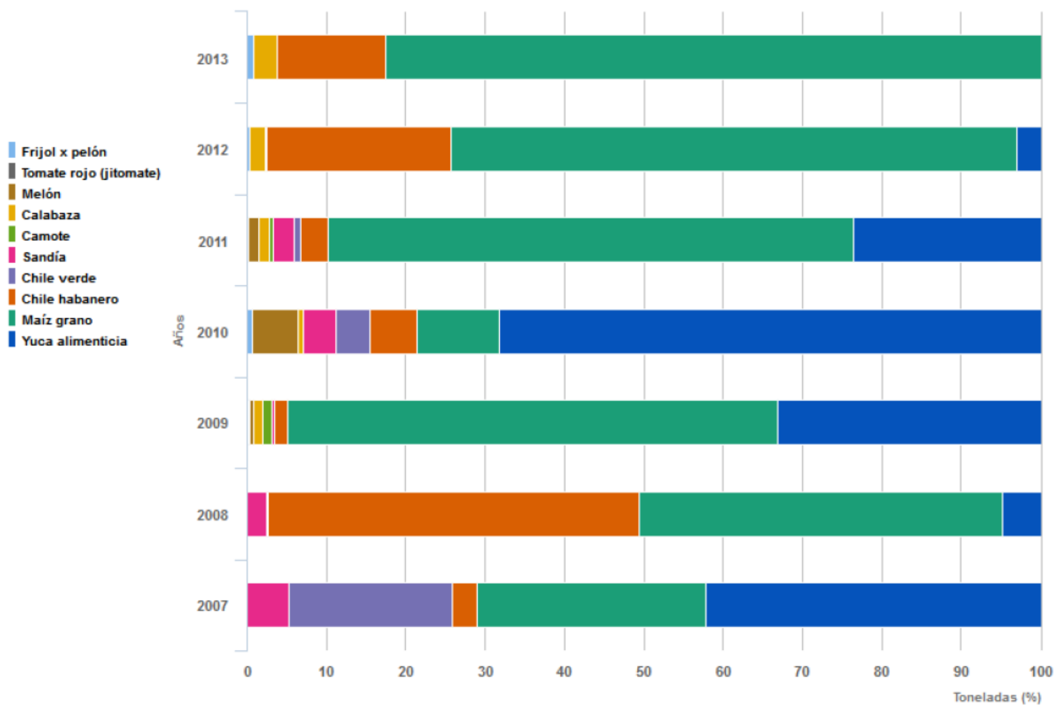


Figure IV. 132 Spring-Summer rainfed agricultural production

Agriculture sector evergreen crops

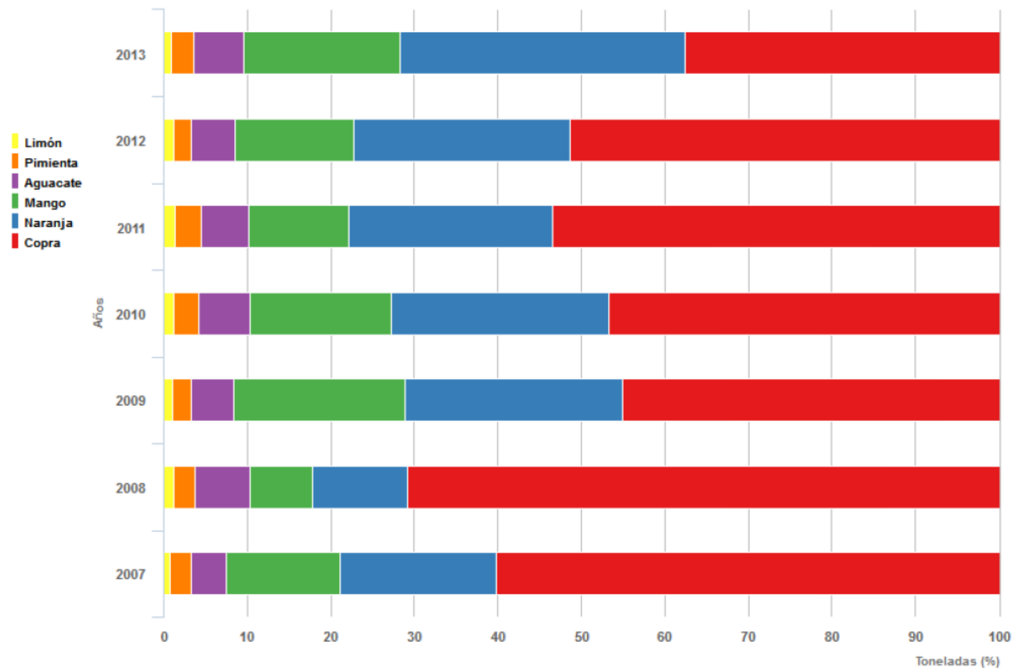


Figure IV. 133 Evergreen agricultural production

Livestock Sector

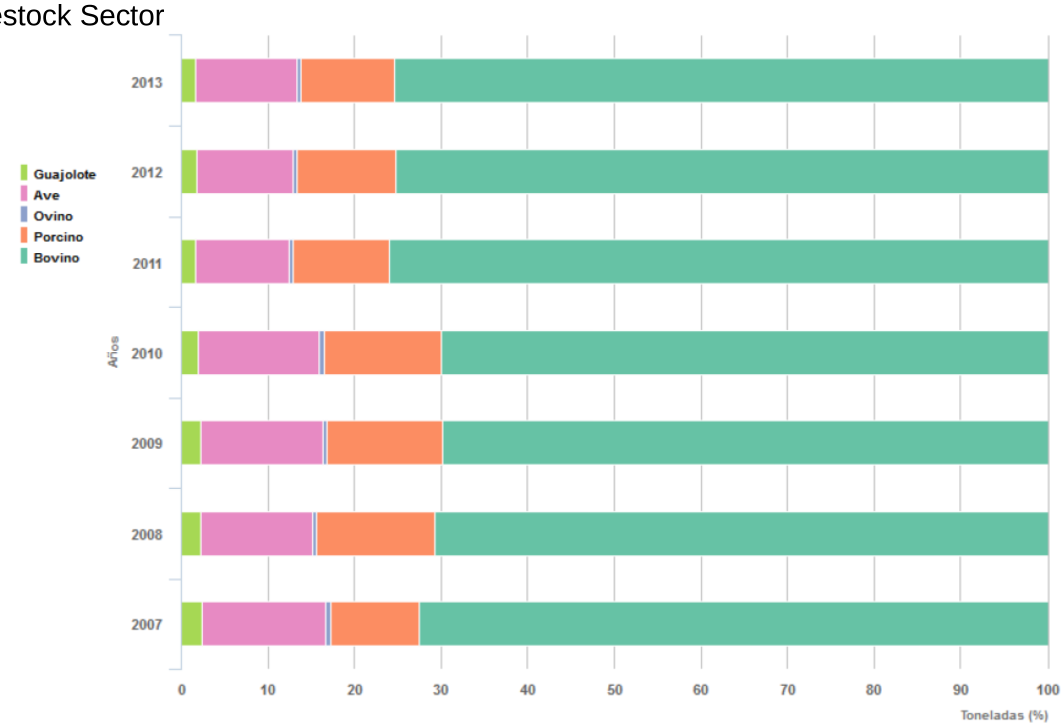


Figure IV. 134 Livestock Production

Housing and poverty at municipal level

Below are some data on housing and poverty indicators reported in the afore mentioned INEGI, SEMARNAT and CONABIO document.

Table IV. 94 Housing and poverty indicators

Indicador de pobreza	Personas	Porcentaje	Carencias	Intensidad
Población total	101,417	100	0.0	0.0
Pobreza	70,317.00	69.30	2.10	0.35
Pobreza extrema	25,722.00	25.40	3.80	0.16
Pobreza moderada	44,595.00	43.10	2.50	0.19
Vulnerables por carencia social	20,634.00	20.30	2.50	0.00
Vulnerables por ingreso	3,732.00	3.70	0.00	0.00
No pobres y no vulnerables	6,735.00	6.60	0.00	0.00
Rezago educativo	18,327.00	18.10	0.00	0.00
Carencia por acceso a los servicios de salud	28,486.00	28.10	0.00	0.00
Carencia por acceso a la seguridad social	79,627.00	78.50	0.00	0.00
Carencia por calidad y espacios de la vivienda	30,768.00	30.30	0.00	0.00
Carencia por acceso a los servicios básicos en la vivienda	69,858.00	68.90	0.00	0.00
Carencia por acceso a la alimentación	36,625.00	36.10	0.00	0.00
Población con al menos una carencia social	90,951.00	89.70	0.00	0.00
Población con tres o más carencias sociales	56,665.00	55.90	0.00	0.00
Población con ingreso inferior a la línea de bienestar	74,049.00	73.00	0.00	0.00
Población con ingreso inferior a la línea de bienestar mínimo	36,603.00	36.10	0.00	0.00

From the above table, 43.10 % of the population lives in moderate poverty, indicating that much of the population may require better wages or employment sources at municipal level.

Illiteracy

Finally, another of the main topics addressed is the number of people who cannot read or write in the population over 15 years of age. Out of a total population of 68,411 individuals, 5,551 cannot read or write, representing 8.11% of the total population. Distributed in 2,174 men and 3,377 women who do not know how to read or write.

Marginalization and social backwardness

Marginalization and social backwardness indices reported up to the last INEGI census in 2010, the marginalization index was -0.05, representing a Medium degree of marginalization with a social lag index of -0.42 and a low degree of lag.

Cultural

Due to its natural conditions, the city near the coast has the beach el Bosque, Miramar, Playa Bruja, La Estrella, Pico de Oro, Boquerón and La Victoria.

Even outside the delimited SAR, with regard to ecotourism, 30 km South of the port of Frontera, is located the station “Tres Brazos”, within the Pantanos de Centla Biosphere Reserve where there is thematic-museum “La casa del agua”, cabins, restaurants, tower-viewpoint and motorboats and tourist catamarans services to tour the reserve.

Religious groups

In the region, the main religion professed is Catholic, although there are various religious groups, both Protestant and Evangelical, as well as non-evangelical biblical religions.

Predominant social organizations

In the municipality of Centla, Tabasco, various fishing cooperatives are legally integrated, such as: Union of Offshore Fishermen del Puerto de Frontera, Tabasco A. C., Cooperative Society for Aquaculture Production Maranatha de Centla S. C. of R. L. de C.V., Pesquera d Acuícola del Municipio de Centla, Tabasco, S.C. de R.L., Cooperativa de Pesca d Acuacultura Simón Sarcay Nova R. L. C.V., Federation of Cooperative Societies and Fisheries Organizations, Federation of Cooperative Fisheries Production and Aquaculture Societies of the Municipality of Centla, Cooperatives Fishers del Grijalva, among other organizations such as San José and Unidad y Fortaleza S. C. de R. L. de C. V., Women in Action, etc.

Conclusion

Municipalities included in the SAR: Cárdenas, Comalcalco, Paraiso and Centla; according to available information, its population growth has been very low in the last 20 years, with trends of slow population growth and have a population density of 200 inhabitants per square kilometer. Until now, population distribution in the four municipalities included in the SAR, its behavior is similar; i.e., both in number of men and women is similar including age.

As for indigenous languages spoken in the study area, 10 languages were recorded in the municipality of Paraíso, Cárdenas 23, Comalcalco 20 and Centla 15. This indicates that although in recent years there has been pressure for the development of oil activities, there has not been much influence on these population sectors. It is worth mentioning that this continues, due to the low or almost zero migration of the population, with a “very low” migration rate.

Employment of the economically active population is almost homogeneous in the municipalities included in the SAR; 21 to 30% carry out activities in the primary sector, 30 to 40 % in service activities and 15 to 20 % in the secondary sector. This indicates that there is still a high percentage of the population engaged in agriculture and livestock activities, as well as population migrating within the same municipality to cities in search of better opportunities resulting in services demand (housing, health, safety, etc.).

Agricultural and livestock sector production is still reflected in population occupational percentage and at SAR level in the coastal zone of the four municipalities, with a large percentage of coconut production and livestock production predominant, which is reflected in the land use map annexed to the study.

IV.2.5 Environmental Diagnosis

Information and integration analysis

This environmental diagnosis is circumscribed and integrates environmental information in an area including project dimensions, provisional and definitive works and activities, meteorological, geo-morpho-edaphological, hydrographic, vegetation and fauna; as well as socio-cultural factors, both of the Project Area (AP) including marine and land facilities,and city of Paraíso as Direct Influence Area (AID).

It also includes the delimited Regional Environmental System (SAR) where the Project could interact with some environmental elements, covering the latter from the contractual area of the Hokchi Field where the marine installations will be located until the coastal area at the mouth of the Tonala River on the Southwest side in the coastal zone of municipalities of Cardenas, Comalcalco, Paraiso and Frontera Eastward of future land facilities (see figure IV. 135).

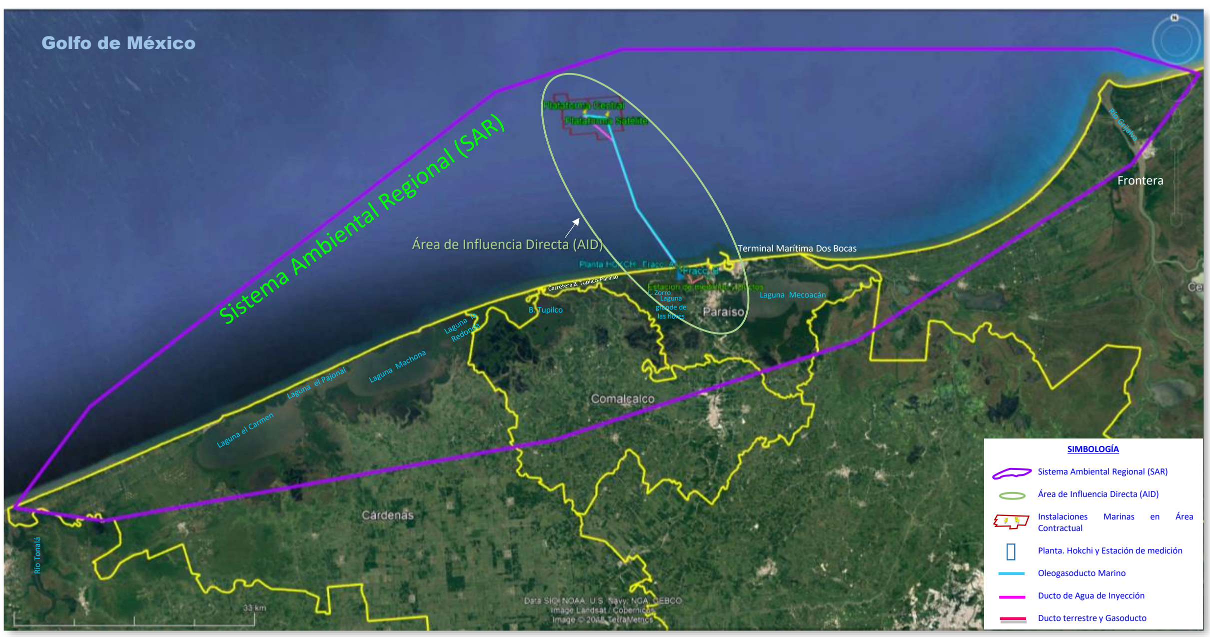


Figure IV. 135 Marine and land facilities (Project Area "AP"), Direct Influence Area (AID) and Regional Environmental System (SAR)

Environmental diagnosis includes environmental information integration in the coastal area from the Tonala River, El Carmen Lagoon System, El Pajonal, La Machona, La Redonda lagoon, Barra de Tupilco, Mecoacan lagoon system to the mouth of the Grijalva River in the municipality of Frontera. This environmental information will allow present diagnosis determination which aims to indicate the conditions existing at a pre-operational stage of the project; i.e., the **"zero status or base scenario"**.

The diagnosis presented here corresponds to the environmental, economic and social situation prevailing in the geographical space where the project prior to site preparation, construction, operation/maintenance and abandonment is intended to be carried out.

Specifically for the Regional Environmental Impact Statement for the Project called **"Hokchi Area Development Plan Execution"**, which includes marine installations to be located in the Southern part of the Gulf of Mexico in front of the coastal area of the municipality of Paraíso and land facilities in the municipality of the same name in the state of Tabasco. As for:

Ecological Regulations and UGAs included in the SAR

That ecological criteria and environmental strategies at the three levels of government (General Territorial Ecological Regulations, DOF 11-24-2012; Marine and Regional Ecological Regulatory Program of the Gulf of Mexico and the Caribbean Sea, DOF 11-24-2012; and Ecological Regulatory Program of the State of Tabasco, DOF 12-20-2006 modified on 12-22-2012):

→ They **do not prohibit** productive activities development in the oil sector and infrastructure, they only guide and promote species of flora and fauna protection throughout the **SAR** and in the area where the project will be located.

→ The purpose of these legal provisions is to reduce such activities impacts; reduce forest cover loss, promote resources rational use; waste proper management in accordance with current regulations that lead to the avoidance of soil, surface and groundwater contamination, etc.

→ As well as the use of technologies promoting productive activities development and good performance using best practices and preventive measures, both restoration and compensation to maintain ecosystems health, runoffs, and biological connectivity.

Hydrocarbon spill trajectory models at sea (GENOME) results

That in the event of an accidental spill or leak to the operating conditions of the facilities, weather conditions (prevailing winds), direction and sea currents established for the simulation of a catastrophic scenario established in the risk study (See Risk Study) for the dispersion of the oil spot at sea, and mentioned at the beginning of this Chapter.

→ There is a 90% probability that oil spots will reach 30 km along the coast, from la Redonda lagoon to el Pajonal lagoon (see yellow spots in figure IV.136).

→ There is also a 10% chance that oil spots will reach 40 km along the coast, from el Carmen lagoon to the mouth of the Tonala River (see red spots in figure IV.136).

The following figure shows the possible effects due to oil leakage in any of the 25.58 km of the 14" Oil gas pipeline, from the Satellite Platform to coastal arrival at the Hokchi Plant.

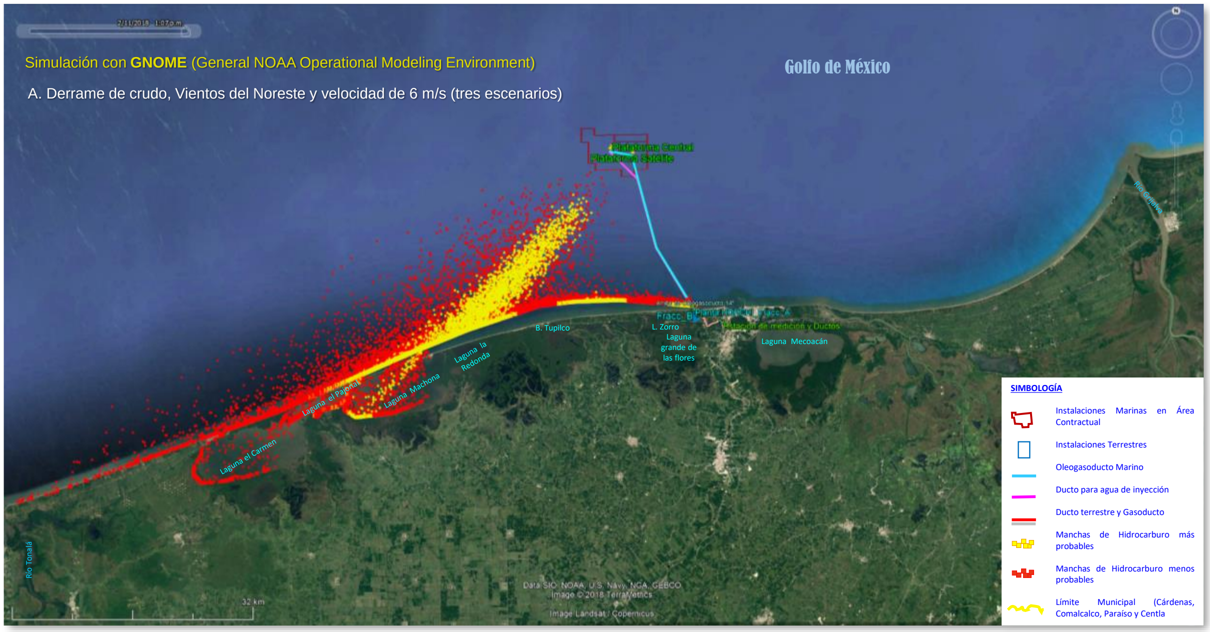


Figure IV. 136 Possible affectations due to hydrocarbons spill from the Satellite Platform, Midpoint and Before Coastal Arrival of the Pipeline (Prevailing Winds)

In this same sense, if rapid and effective emergency response actions are not taken during a significant spill from the Satellite Platform, sensitive areas that could be affected are:

→ To recreational and economic activities taking place in the coastal area of the municipalities of Cardenas, Comalcalco and Paraiso, including those carried out in la Machona, el Pajonal and el Carmen lagoon system;

→ As well as possible affectations on the marine and land flora and fauna of the coastal area included mainly in the SAR.

When a possible leakage occurs at some point in the middle part of said oil gas pipeline and near the coastal arrival, possible environmental damage would reach:

→ When a potential leakage occurs at the midpoint of the oil gas pipeline the potential damage would be to recreational and economic activities taking place in the coastal area from 8 km West of the coastal area of the Hokchi Plant to the coastal zone and la Machona lagoon.

→ When potential leakage occurs near the coastal arrival off Hokchi Plant, potential environmental damage would occur from the coast off Hokchi Plant up to 20 km west of the coastal strip heading towards barra Tupilco.

→ As well as possible affectations on the marine and land flora and fauna of the coastal area included in the SAR.

In order to cover other possible effects during critical weather seasons, the northerlies season (dominant winds) was also considered, where possible affectations would be the coasts of Paraíso (see figure IV.137).

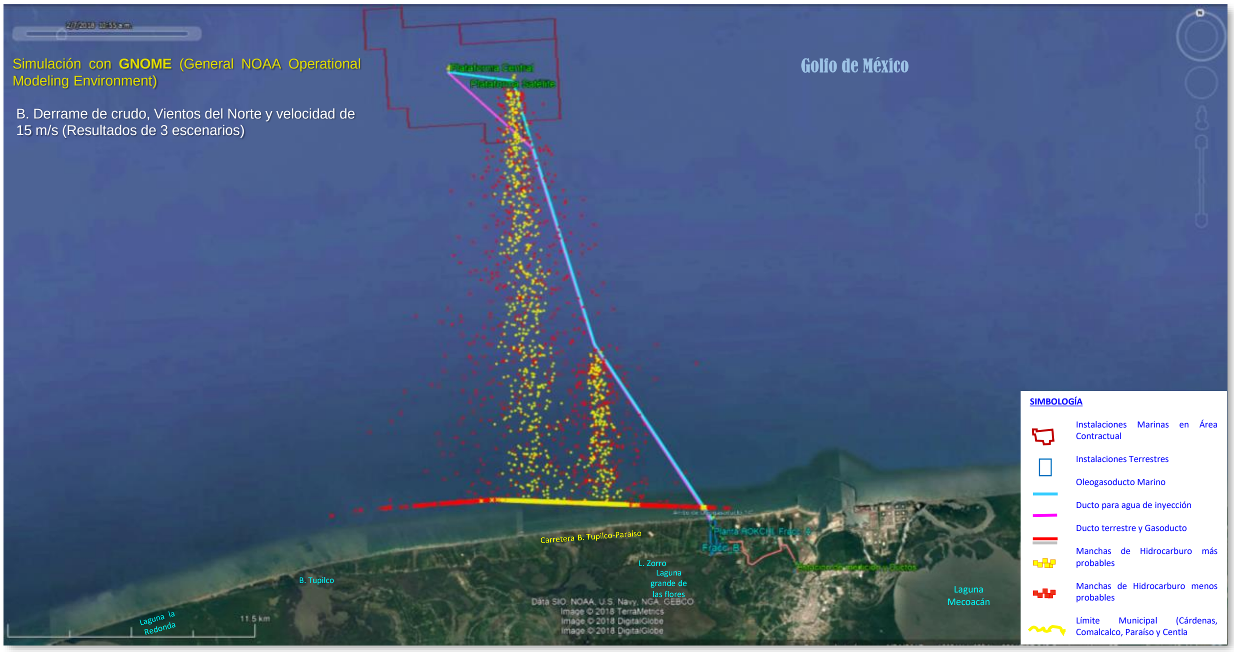


Figure IV. 137 Possible affectations due to hydrocarbons spill from the Satellite Platform, Midpoint and Before Coastal Arrival of the Pipeline (Prevailing Winds)

From the above figure it is observed results obtained to winds critical conditions, sea currents direction and velocity, possible affectations could reach 3 km East of the Plant before the Dos Bocas Maritime Terminal and 17 km West to Barra de Tupilco on the coast line (see figure IV.137).

Within the SAR, it was also considered the coastal area East of the Plant towards the municipality of Centla until the mouth of the Grijalva River, which considering that the directions of the prevailing sea currents and their velocities are from Northeast to Southwest, ensures information analysis is more complete.

Abiotic aspects

Climate

The SAR shows an *Am(f)* climate type according to Köppen classification, modified by Enriqueta Garcia (1981), corresponding to a warm humid climate with year-round rainfall where precipitation for the driest month is less than 60 mm. It is characterized by mean annual temperatures above 18°C and mean annual temperatures between 24 and 28°C.

From information provided by the National Meteorological Service of CONAGUA, the average annual temperature range (maximum, medium and minimum) in the SAR is between 30°C-34°C, 26°C-28°C and 20°C-25°C respectively. The average rainfall from 1490 mm to 1850 mm per year over fifty years with relative humidity in SAR fluctuate between 80% and 86%.

Recorded wind speeds range from 2 to 4 m/s with gusts of up to 10 m/s and dominant winds ranging from 9 to 12 m/s.

Air Quality

Results obtained from monitoring air quality in the Project area of influence, in general, for Ozone, Carbon Monoxide, Nitric Oxide (NO), Nitrogen Dioxide (NO_2) and Nitrogen Oxides (NOx) values found are below air quality standard. This indicates there is a good contaminants dispersion currently, including those from hydrocarbons exploitation in the Sonda de Campeche and the Litoral de Tabasco, the good dispersion is also influenced by wind velocities, temperature and relative humidity in the SAR.

Geology and Geomorphology

In general, marine and land facilities will be located within the Petroleum Province called **"Southeast Basin"**, which is located in the Coastal Plain of the Gulf of Mexico and the Continental Shelf of Southeastern Mexico, including a land and marine portion of shallow water; this province in its part land covers the South of the State of Veracruz, the North of the State of Chiapas, almost the entire State of Tabasco and the far Southwest of the State of Campeche. In this "Southeast Basin" you will find:

- Isthmus Saline Basin.
- Comalcalco basin.
- Macuspana Basin.
- Pilar Reforma-Akal Basin.

The Southeastern Basins is the most prolific oil producer in the whole country.

In this North-Northwest coastal portion of the state of Tabasco including the municipalities of Cardenas, Comalcalco, Paraiso and Centla, as well as the marine area adjacent to these municipalities, the structural geology consists mainly of sedimentary rocks (limestones, sandstones and evaporite deposits), which were subjected to severe compression efforts, which caused the most plastic rocks to fold and the most tenacious ones to fracture, generating structures bounded by two normal faults leading to traps formation where hydrocarbons and natural gas were accumulated.

Hydrocarbons generating rocks are considered of Tithonian, Middle Jurassic and Superior Jurassic age, which are rich in organic matter, mainly of algae that gave rise to these hydrocarbons.

Stratigraphically this physiographic province “Coastal Plain of the South Gulf” and the Sub province “Tabasco’s Plains and Swamps” bordering the Southern portion of the Gulf of Mexico, is a plain of sedimentary composition whose origin is related to the Atlantic Ocean regression initiated from the Lower Tertiary; as well as the gradual filling development of the ocean basin in the marine part of this Environmental System where until today large volumes of detrital material are accumulated dragged by the epicontinental water bodies unto their mouth.

Coastal platform continuous rejuvenation has allowed subsequent erosion of tertiary age marine and continental deposits, manifesting with few low-rise slopes made of limestones and sandstones, representing an almost flat relief as it approaches the Gulf of Mexico. In the “Tabasco’s Plains and Swamps” sub province, rivers have had unstable courses, which is due to the accumulation of recent alluvial material covering much of the plain mainly on the Eastern side of the municipality of Paraíso towards Centla and in a lesser proportion to the West thereof towards the municipalities of Comalcalco and Cardenas.

Beach areas and coastal bars of the Southern Gulf Coast Plain, the soils are of the Litoral type along the coastline from the Tonala River, Laguna el Carmen, El Pajonal, La Machona, La Redonda, Barra de Tupilco, Playa El Limon, Laguna Barra Chiltepec, Playa Azul, Playa Pico de Oro, Playa Miramar, among others, to the mouth of the Grijalva river in the municipality of Centla. The soils in these areas are formed by sand accumulation reworked by the waves and distributed along the coastline. Adjacent to the Southern part to these soils Litoral type are Lacustrine and Palustre types composed by silty, clayey sediments and lenticular bodies characteristic of these floodplains.

As for tectonism, according to geophysical seismology studies (Fugro McClelland, 1996) suggest that the area of marine influence constitutes a tectonically stable area. At regional level, in the marine area where the facilities will be located, they are immersed in the Southeast Basins, where tectonic activity over millions of years has led to the formation of the Saline Isthmus Basin and the Macuspana Basin. In its marine portion, in this basin different oil prospects are recorded, as a continuation of the producer alignment of the land area.

Seismicity

The area where land facilities of the Project and its surroundings will be located is classified according to the Federal Electricity Commission's Manual on Civil Works Seism Design as a **seismic area B**, which is an intermediate zone where earthquakes are not so frequently recorded.

In the area of interest, the telluric movements that have been felt so far have their epicenter in the states of Chiapas and Oaxaca.

Floods and Vulnerability before Climate Change

The coastal area of the municipalities included in the SAR (Cardenas Comalcalco, Paraiso and Centla) present a vulnerability of “medium”, “high” and “very high” due to flooding (National Disaster Prevention Center, ENAPRED), the most sensitive areas are the areas close to the lagoon system from el Carmen lagoon to Mecoacan lagoon.

However, the Eastern part of the SAR towards the coastal area of the municipality of Centla vulnerability is “medium” and “low” to the West of Laguna el Carmen towards the mouth of the river Tonala.

The Tabasco Coastal Vulnerability Index, according to studies by the UNAM Geographical Research Institute for the coastal area in question, also considers sea level rise is an extreme event that will impact the low-lying coastal areas of Tabasco. From this same study, it is agreed that sectors with the greatest vulnerability are found precisely in front of the Carmen-Pajonal Machona and Mecoacan lagoon system, the latter with a higher degree of vulnerability.

Specifically the area where land facilities will be located, the coastal vulnerability index **is medium**. Considering both results of these studies, land facilities will have to make the necessary arrangements before an index going from a medium to high according to information obtained.

Finally, it is worth mentioning that currently there is still a beach width of approximately 35 m and a width with coastal vegetation of approximately 60 m functioning as an erosion mitigator caused by waves and coastal wind on the North side of the property, vegetation that could be conserved to continue its natural function.

Soils

Soils in the SAR according to the FAO-UNESCO and INEGI classification, from the Tonala River, along the coastal area along the coast line to the mouth of the Grijalva River, predominate Regosols; their fertility is variable and their productivity is conditioned on depth. These Regosols, have calkaric type subunits rich in lime and nutrients for plants, may even have acidic characteristics, rich in nitrogen, but poor in other important nutrients for plants such as calcium, magnesium and potassium or slightly acidic to alkaline. Usually these soils have a slightly alkaline (6.5) to neutral pH.

It could also be confirmed that Regosol of beaches and dunes, is very low in fertility and very high susceptibility to erosion due to sea waves movement and winds prevailing over the littoral. Just as, also in some areas of the coastal floodplain (lower parts), from the mouth of the Tonala River to the mouth of the Grijalva River, soil types are associated with molic Glaysol, glyic Solonchak, and glyic Fluvisol, these soils are originated by marsh and clay materials with high content of decomposing organic matter, which sometimes presents fetid odor.

The almost permanent flooding condition allows the growth of aquatic vegetation as popal-tular in the lower parts of the relief, also allows the growth of cultivated and induced grasslands.

In the Regosol type soils, predominantly presents rainfed agriculture with permanent crops of coconut trees, cultivated grassland and in a smaller extent rainfed agriculture with annual crops and its fertility ranges from moderate to high and has a susceptibility of moderate to high erosion.

During field work, it was confirmed that in the area where land facilities will be located the predominant land use is agriculture with the presence of *coco nusifera* and cultivated grassland vegetation where the Hokchi plant and the Metering Station will be installed, with predominance of cultivated grassland.

Finally, as part of soils characterization in the Project area and the area of influence and in order to verify the current soil status, the results obtained are:

→ There is high soil deterioration due to anthropic activities (agriculture and livestock) necessary as a means of livelihood for the inhabitants of the entity throughout the coastal strip.

→ In the nearby area where the metering station will be located, because it is close to the population of Paraíso, there is disorderly population growth.

→ In general, beach soils are composed of fine light gray sand without odor and light to dark brown in the slightly low parts with the presence of odorless clay.

→ The soil where the Hokchi Plant and the Metering Station will be located, presented brown clay sand without smell characteristics. In general, soils near the coastline presented characteristics in cation exchange of Middle Class for Calcium and Magnesium, and Low Class for Potassium with low organic matter content, indicating they are poor soils in organic matter. This capacity is increased with soils with less marine influence.

→ Hydrocarbons presence in the area of influence and project area, with respect to the Official Mexican Standard NOM-138-SEMARNAT/SSA1-2012, it was found that only on the coastline on the North side of the property where the Hokchi Plant will be located exits presence of medium fraction hydrocarbons (30.09 mg/kg b.s.) although well below limits of maximum allowable hydrocarbons (1200 mg/kg b.s.) of the Standard for Agricultural, Forestry, Livestock and Conservation Land Use.

→ Polycyclic aromatic hydrocarbons in HAP soils. Low concentrations found in these soils indicate an association with soil organic matter with coconut trees vegetation and wetland vegetation in the lower parts (range from 0.01 to 0.07 mg/kg) as those that have changed to agricultural use, the increase of HAPs in soils for agricultural use may also be due to depositation due to organic material burning for agricultural purposes, as well as to oil installations in the coastal strip.

→ Polychlorinated biphenyls (BPCs), Arsenic, Beryllium, Mercury, Silver, Selenium and Thallium, these contaminants were not found in the sampled points.

→ As for cadmium, although well below the maximum allowable for agricultural/residential/commercial soils use established in the standard, there is a presence 100 m outside the Southwest limit of the property where the plant will be located and 350 m approximately from the Barra de Tupilco-Paraiso highway.

→ Another of the pollutants found was Vanadium, with presence in the sample taken approximately 800 m on the West side of the property on the coastline. This exceeds the maximum allowable limit for agricultural, residential/commercial soils use.

→ It should be noted that during the field work, a “Pear” or “Location” was also identified with their respective dams outside but very close to the boundaries of the property in the Northeast part, where it was determined there is hydrocarbons presence for heavy fraction hydrocarbons and mean fraction of the sample from the main dam, resulting in 24,399.49 and 53,543.60 ppm respectively, values exceeding the maximum allowable limit for agricultural and industrial land use.

Approximate distances with respect of the property limit are: 50 m from the main dam and 30 m from the pear or location on the Northeast side of the property. The importance is due to the fact there could be contamination of the shallow water table at the property limits where the Hokchi Plant will be located.

In general, the presence of some hydrocarbons traces found at specific points glued to the coastline may be indicative of contamination by natural emanations deposits or possible hydrocarbons spills in offshore installations.

Physical and chemical changes experienced by oil spots in the sea are known as “natural degradation processes”, mainly sedimentation process of oil spilled into the sea, which is due to adhesion of organic matter to oil particles until they exceed water density to precipitate and with the passage of time and marine dynamics of both waves, winds and sea currents have influenced their arrival in the coastal area.

Although they do not exceed the maximum allowed values so far, they are indicative of potential cumulative effects if there would be incidents mainly at marine facilities.

Surface Hydrology

Regional Environmental System (SAR), Direct Influence Area (AID) and Project Area (PA), specifically marine facilities will be located in the southern portion of the Gulf of Mexico off the municipality of Paraíso Tabasco coast and land facilities will be immersed in hydrological region RH29 called “Coatzacoalcos”.

Project land facilities will be located within the “Tonala River and Coatzacoalcos Lagoons” Basin **A,** as well as within the “Lagunas el Carmen and Machona” sub-basin **a**, belonging to Hydrological Region RH29.

The basin, sub-basin and lagoon system to the West of the facilities towards the mouth of the Tonala river are el Carmen and La Machona lagoons linked by el Pajonal (see Figure IV.135 of the SAR) and as part of that complex lagoon system also includes La Redonda and La Palma lagoons; which belong to RH29.

On the East side, at approximately 4 kilometers from the property where the Hokchi Plant will be located, begins Hydrological Region RH30 known as “Grijalva-Usumacinta” to which belongs the Mecoacan lagoon system, where are included the lagoons Juliva, La Tinaja, El Eslabon, Pomposu, Pucte, Troncon, El Provecho, El Desague, El Espino, El Cerco and Laguna Santa Anita, to its mouth in Barra de Chiltepec, which are located within the municipalities of Paraiso and Centla towards the eastern coastal area of the SAR to the Grijalva River Delta.

These lagoon systems are due to marine regression phenomena and dynamic fluvio-terrestrial sedimentation processes due to tidal effects, sea currents and swell. In this same context, due to water bodies uses since their origin in the states of Chiapas and the entire route through the state of Tabasco; as well as the land uses throughout the SAR coastal plain, there are possible anthropogenic type threats, which are mainly due to:

→ Hydrocarbons contamination due to activities, both exploration and hydrocarbons production throughout the region defined as SAR for this project, as well as storage and transport thereof at the length and width of the coastal region.

→ Pollution by fecal coliforms due to municipal wastewater discharged by localities to water bodies flowing into these lagoon systems.

→ Alteration of physicochemical characteristics (salinity) of lagoon bodies and their flooding zones by the opening of the mouth of Panteones.

→ Contamination through nutrients carried by agricultural runoffs

→ Pressure on some species of fishing importance, such as oyster in El Carmen, Pajonal and La Machona lagoons.

→ On the West side of the project where the Mecoacan lagoon system is located up to the mouth of the Grijalva River, surface water main uses are for communication routes, supply to populations and smaller scale for industrial use.

From data on surface water quality in these lagoon systems, the Energy, Natural Resources and Environmental Protection Secretariat of the state of Tabasco 2016 reports, indicates that:

→ At the mouth of Laguna el Carmen, at the height of La Villa de Sanchez Magallanes, Total Suspended Solids (116 mg/L) indicate that water is in an acceptable range; Biochemical Oxygen Demand (BOD_5 3 mg/L) indicates that it is in excellent quality conditions; and as for Coliforms (240,000 NMP/100 mL), indicates it is strongly contaminated.

→ The Machona at the height of the Puente Boca de Panteones, at the height of the Ejido “el Alacran”, Total Suspended Solids (SST 80 mg/L) indicate it is in an acceptable range; Biochemical Oxygen Demand (BOD_5 5 mg/L) indicates it is of good quality; and as for Coliforms (240,000 NMP/100 mL), indicates it is heavily contaminated.

→ Water quality of the Mecoacan lagoon, at the height of puente de el “Bellote”, Total Suspended Solids SST (88 mg/L) indicate it is in an acceptable range; Biochemical Oxygen Demand (BOD_5 2 mg/L) indicates it is of good quality; and as for Coliforms (24,000 NMP/100 mL) indicates it is heavily contaminated.

→ Water quality for the Grijalva river for Total Suspended Solids (SST 28 mg/L) indicating it is in a good quality range; Biochemical Oxygen Demand (BOD_5 6 mg/L) indicates it is acceptable; and Coliforms 54,000 NMP/100 mL, indicating it is strongly contaminated.

Water quality results (Lagoon System)

From water quality analysis results for different points of the SAR, we have:

Salinity El Carmen lagoon has an average of 24.89 ppmil in surface and 25.78 ppmil in bottom; Machona lagoon average surface values were 3.30 ppmil and 3.48 ppmil in bottom; in both Tupilco and Zorro lagoon (Laguna Grande de las Flores) values found in all stations were values < 2 ppmil.

The saline behavior of el Carmen lagoon indicates it is strongly influenced by sea dynamics through the mouth (Boca Santa Ana) connecting the lagoon system with the sea, the opposite case for the lagoons in Tupilco and Laguna Grande de las Flores (El Zorro) for not having contact with sea salinity has very low salinity values. Regarding the Mecoacan lagoon the average surface values were 21.31 ppmil, it should be noted that for this lagoon system variation is seasonal, indicating they are clearly influenced by tide ebb and rivers in other seasons contributions.

Hydrogen potential (pH). All the highest average reported values were presented at the level of bottoms in all systems, however, these values are within the allowed range in NOM-001-ECOL-1996 for wastewater discharges into water and national assets, which is from 5 to 10.

Dissolved oxygen. In general throughout the lagoon system, a relatively homogeneous behavior is observed, however, only in Laguna el Carmen at bottom level was a value of 4.51 mg/L that does not meet the minimum allowable limit established in the Ecological Criteria of 1989 which is 5 mg/L for the protection of aquatic life in fresh and marine water.

Total Suspended Solids (SST) For this parameter, it is concluded values detected in the lagoon systems evaluated do not represent a pollution problem in the water column for the development of aquatic life.

Nutrients Nutrient values, for ammoniacal nitrogen, the lowest values were presented in Laguna el Carmen and Mecoacan stations and the highest concentrations in Machona, Tupilco and Zorro stations, however, in the five lagoons the values exceeded the maximum value of the interval reported in the criteria of water quality and of literature.

Ammonium Ammonium is a very common form in these ecosystems and its permanence is constant throughout the annual cycle, sometimes its decrease is related to greater photosynthetic activity or higher water oxygenation. In general, the amount of ammonium present in lagoon waters is closely related to biological processes with heterotrophic characteristics, both in the water column and in sediments (Contreras et al. 1996).

Nitrites In the case of nitrites, a similar behavior was obtained with the lowest values in the stations of Laguna el Carmen and Mecoacan, and the highest in Machona, Tupilco and Zorro. In the entire study area values were below 0.024 mg/L, lower or equal to those reported in water quality ecological criteria and those in literature of 0 .02 and 0.07 mg/L respectively.

Nitrates With regard to nitrates, lowest concentrations of this nutrient were found in el Carmen, Machona and Mecoacan lagoons. Tupilco and Zorro obtained values above 0.05 mg/L. The lagoons of Carmen, Machona and Mecoacan did not exceed water quality concentrations ecological criteria.

Nitrates and nitrites average values tend to be lower compared to those of ammonium, often maximum are reached during the rainy season. Nitrogenated forms, the dominant is ammonium and whose relation to total inorganic nitrogen ranges from 60 to 98%, the aforementioned has a strong relationship with the presence and dominance with nanophythoplanktonic forms which manifest a considerable contribution to total biomass of phytoplankton, since as has been proven nanophythoplankton captures preferably regenerated nitrogen (ammonium), while microphytoplankton does it with new nitrogenated forms (nitrates), (Contreras et al., 1996).

Phosphates The results in total phosphorus and total phosphates in lagoons were to obtain a behavior similar to that of ammoniacal nitrogen and nitrites with the lowest values in Laguna el Carmen and Mecoacan stations, and the highest in Machona, Tupilco and Zorro. Mecoacan lagoon stations, as well as two stations of Laguna el Carmen in surface and bottom showed total phosphorus values below the maximum value reported in literature of 0.14 mg/L. With respect to total phosphates, all sampling points in the five lagoons were above concentrations reported in the criteria and literature of 0.002 and 0.034 mg/L respectively. Nutrients seasonal variations are wide. The highest concentrations are located after the rainy season, when in addition to the autochthonous elements, those coming from terrigenous dragging originated by rivers are added.

Minimal concentrations are detected after spring phytoplankton flowering but even in these months nutrients are detected in higher amounts than those available in the nearby marine area.

Silica. Silicon dissolved in water Si(OH4) has a variable concentration (higher in inland waters) and is normally in excess of nitrogen and phosphorus, except in domestic discharges areas and large diatom blooms. Dissolved silica is called reactive because it responds to the colorimetric test with molybdate, acquiring a typical blue color. In this way, reactive silica values in the five lagoons obtained values in an interval of 0.91 and 15.32 mg/L. The lowest concentrations were present in el Carmen and Mecoacan lagoon with a minimum value of 0.91 mg/L in surface water in el Carmen and a maximum of 10.2 mg/L in Mecoacan in surface water. On the other hand, the highest concentrations were in Machona, Tupilco and Zorro with a minimum value of 9.92 mg/L in bottom water in Machona lagoon and the maximum in el Zorro surface water with 15.32 mg/L. All obtained values are above the range of 0.65-3.32 mg/L of silicates reported in literature.

Total Organic Carbon In the case of Total Organic Carbon (TOC), the lowest concentrations of this parameter were found in el Carmen and Mecoacan lagoons and the highest were for Machona, Tupilco and el Zorro. Concentrations obtained in the five lagoons are generally higher than those obtained in the Gulf of Mexico shallow area.

Photosynthetic pigments: Chlorophylls a, b, c and pheophytins Regarding chlorophyll a in surface water, the highest values were presented in la Machona lagoon and in bottom water with values reaching a median of 26.487 mg/cubic meters and a maximum value of 54.535 mg/cubic meters, for surface water, median value was 17.511 mg/cubic meters and an extreme value of 49.456 mg/cubic meters.

The other lagoons obtained values less than 10 mg/cubic meters, of the five lagoons sampled, el Carmen, Tupilco and el Zorro, chlorophyll “a” values were found within these intervals.

In general, relation between the amount of chlorophyll “a” and pheophytins is indicative of the physiological status of phytoplankton populations, a relative abundance of pheophytins indicates the presence of a population in decline, which was only shown in four seasons of the five sampled in la Machona lagoon. Intervals reported in literature in coastal lagoons go from 0.0 to 11.0 mg/cubic meters. Pheophytins presence is sometimes explained in terms of phytoplankton populations decay and degradation because they are in an advanced stage of succession, or in terms of grazing by zooplankton.

Polynuclear polycyclic aromatic hydrocarbons (HAP). Polycyclic aromatic hydrocarbons did not reach the minimum detectable concentration according to the methods used in any of the water samples in the lagoons. Some HAPs (acenaphthylene, anthracene, Benzo(a) anthracene, Benzo(a) anthracene, Benzo(a) pyrene, Benzo(g, h, i) perylene, phenanthrene, fluoranthene, naphthalene and Pyrene) are reported in concentrations below 0.15 µg/L, which are lower than the established ecological criteria for the protection of marine aquatic life.

Metals The general behavior of metals in water for aluminum, cobalt, copper, chromium, tin, iron, mercury, nickel and lead presented the highest concentrations in the Machona lagoon, while vanadium and zinc also presented the highest values in the Tupilco lagoon. Arsenic and barium presented high values in the Tupilco and Mecoacan lagoons.

Petroleum Total Hydrocarbons (HTP), Oil Biomarkers or BTEX monoaromatic Hydrocarbons were not detected in water samples collected in el Carmen, Machona, Coral, Zorro and Mecoacan lagoons.

Water quality results (marine system)

For Oil Biomarkers (BMK), no petroleum biomarker compounds or monoaromatic hydrocarbons (BTEX) were identified in water samples in this marine area project.

Metals Metals concentrations in water were low, in all cases lower than detection limit of the analytical method (LDM) for arsenic, barium, cadmium, cobalt, copper, lead and vanadium. For chromium, nickel, tin and zinc, only two samples were found with detectable concentrations at sites other than the Hokchi Field. Aluminum had lower concentrations than those representing chronic or acute environmental effects, while iron had some concentrations (8 in total) higher than chronic effect (0.05 mg/L) and one higher than acute effect (0.30 mg/L). It is suggested to monitor iron variation to verify if the observed peak concentration is an isolated event or represents a trend in concentrations.

RedOx Potential Rust reduction potential (RedOx) of marine sediment is a characteristic related to various sediment conditions, highlighting material depositation degree, organic matter flow, benthic fauna activity and oxygen concentration at the water column bottom. Oxid-reduction potential values in Hokchi Field showed an interval of -58.2 to 242.6 mV, with negative values in 42 of 48 samples. The sites with positive potential were located in the North of the study polygon. The result indicates during the study reducing conditions prevailed and theoretically an increase in organic matter occurs due to a low decomposition rate.

Total Petroleum Hydrocarbons (HTP). No detectable amounts of HTP were found in surface sediments of Hokchi Field. HTPs were also not found in the Round 1 Regional Environmental Baseline Studies of Shallow Water Fields, nor in the Gulf of Mexico Environmental Monitoring, Ueyatl 1 Oceanographic Campaign, recently conducted by the Mexican Petroleum Institute in 2014.

Polynuclear polycyclic aromatic hydrocarbons (HAP) in surface sediment of Hokchi Field did not reach the minimum detectable concentration in any of the samples taken during the cruise.

Oil biomarkers (BMK), Oil biomarker compounds were not identified in sediment samples in Hokchi Field.

Metals Metals general distribution showed the highest concentrations occurred in the sites located along the oil gas pipeline, followed by the grid area, particularly copper, cobalt, iron, nickel, lead, vanadium, zinc and chromium showed this behavior. Minimum concentrations of vanadium, chromium, manganese, cobalt, nickel, aluminum and zinc were most frequently observed in the Southern area of the Grid (sites 46 and 47). It is also observed metals concentrations in the 2016/2017 Replica Field area generally showed the most stable concentrations (lower CV) compared to the other areas of the Hokchi Field. In the Grid area variability in the concentration increases, reaching TEL criterion at the pipeline sites the highest concentrations were presented more frequently, as well as in one of the coastal sites. This behavior was observed for copper, zinc, cobalt, chromium and aluminum.

The behavior of arsenic suggests it has a different source than the one related to wells.

In general for the marine area, organic compounds (total petroleum hydrocarbons, polycyclic aromatic and monoaromatic compounds, biomarkers) were not detected in water or sediment in the Project area in the marine area. These results are consistent with studies conducted in the Southern Gulf of Mexico, in which few compounds have been identified and in low concentrations.

Of the 16 metals analyzed in sediment, cadmium was not detected anywhere, while mercury, selenium and tin were identified in few sites. In general, remaining metals concentration in decreasing order was: Mn > Ba > Zn > V > Cr > As > Ni > Sn > Cu > Co > Pb. The result is similar to what was observed in other studies in the Southern Gulf region, where manganese and barium were also the most abundant metals in sediment.

With regard to the possible environmental effect, arsenic was the only metal exceeding TEL criterion in 80% of sites within Hokchi Field, so it is recommended to monitor its concentrations evolutions. Analysis of enrichment factors and geo-accumulation indices for arsenic indicated their concentrations are highly influenced by human activities, showing in most cases severe and very severe enrichment.

Underground Hydrology

As for underground hydrology, the SAR is located within two aquifers, on the Southwest side, from the mouth of the Tonala river to the Dos Bocas Maritime Terminal, including ground facilities of the Project will be located on the 2702 aquifer known as “La Chontalpa”. Towards the East of the future Maritime Terminal Dos Bocas, there is aquifer 2704 “Centla”.

→ Both aquifers have fairly shallow saturation levels reflected by the presence of lakes and lagoons that make up the surface even beyond the SAR.

→ The hydraulic behavior of this aquifer indicates static levels are at depths ranging from 5.0 to 1.0 m “La Chontalpa” and from 14 to 4 m for “Centla”, registering the deepest in the Southern part of the aquifer, gradually ascending towards the coastline.

→ The direction of the groundwater flow runs from South to North until reaching the Gulf of Mexico as final destination.

With regard to contamination, the National Water Commission (DOF: April 20, 2015), indicates the following human activities influence the pollution of these aquifers:

→ Oil industry installations (Petrochemical, batteries and compressors) along the length and width of these aquifers.

→ Discharges of domestic wastewater from populations.

→ Sugar Industries to the South of the SAR.

→ Agriculture with extensive agrochemicals application (cultivation of lemon, orange, pineapple, rice, sorghum, sugarcane, papaya, etc.).

The Annual Average Groundwater Availability according to the publication of groundwater availability of the 653 aquifers of the United Mexican States (DOF: Monday, April 20, 2015) for the hydrological and administrative regions of the Southern Border, states that:

→ “La Chontalpa (27-02)” aquifer, where the Project could be supplied from that resource, has an availability of 1580,863,690 million cubic meters per year to grant concessions or allocations to maintain it in sustainable conditions and there is no resource deficit.

→ For the “Centla (27-04)” aquifer that complements the SAR, it has an availability of 829,236,336 million cubic meters per year.

On the basis of these available data, it is considered the Federal Water Authority will have no objection to granting the concession to the Project for its exploitation, use and water development.

Biotic Aspects

Land vegetation and fauna

Vegetation sampling results at defined points along the coastal area were aimed at current characterization, as well as verifying current problems to which coastal ecosystems are subjected by anthropogenic activities such as agriculture, livestock and industrial use areas, mainly by the exploitation of oil along the coast.

From field work, it is observed there has been a huge transformation of the coastal dunes vegetation, in some cases there are only relicts of herbaceous vegetation and scrublands in the dunes systems, but forest vegetation has disappeared in much of the coastal strip of the SAR included for the present study.

Coconut trees planting, whose economic boom occurred since the last century due to the production of copra, still occupies large areas. Current land use in the delimited SAR continues to predominate agriculture with coconuts cultivation throughout the coastal strip.

Within these anthropic activities, livestock farming along the coastal zone, including on dunes near the coastline, occupy large expanses; as well as inter dunes lagoons are used as watering holes for cattle. To the west of the coast, jagüeyes can also be found in areas with less flooding, where water outcrops from the water table and form small artificial inter dunes lagoons.

Vegetation in the Project Area:

→ Specifically in the project area where the Hokchi Plant will be located, in the polygon called **Part "A"** and **Part "B"**, vegetation consists of plant communities of the agricultural type (*Coco nusífera*) and grassland cultivated and induced with species such as: water grass (*Panicum purpurascens*), bermuda grass (*Cynodon dactylon*), star grass (*Cynodon plectostachyus*) and rice grass (*Echinochloa polystachya*), as well as fast-growing tall grass vegetation represented by bay cedar (*Guazuma ulmifolia*), trumpet tree (*Cecropia obtusifolia*), majagua (*Hampea macrocarpa*), jolotzin (*Heliocarpus donell-smithii*); as well as species of vines; cundeamor (*Momordica charantia*), hummingbird vine (*Quamoclit pinnata*).

  Also identified were 7 specimens of Palma real (*Roystonea regia),* which is in status (Pr) Subject to Special Protection in NOM-059-SEMARNAT-2010; of which, 2 specimens are located in the polygon called **Part "A"** and 5 specimens in the polygon **Part "B"**.

→ The vegetation in the area where the Metering Station will be built was found to be constituted by predominant species of cultivated grassland and Coco nusífera mainly.

→ It was also observed that vegetation in the existing right of way, is constituted by scarce vegetation of induced grassland and some herbaceous species typical of the area.

→ Fauna species spotted and observed in the SAR and in the Project Area are listed in Annex No 4 and photographic evidence in Annex No 5 of the MIA.

It should also be mentioned within the most sensitive vegetation at regional level there are mangroves outside the Polygon where the land facilities will be located, mainly those species located in el Carmen-Pajonal and Machona lagoon System, which are those that could be affected in case of a spill or accidental leak from marine platforms and even fauna and economic activities of the site.

Biota

Phytoplankton, Zooplankton and Meroplankton

As for phytoplanktonic biota, it is observed in the seasons with greater phytoplanktonic richness they are located along the coast between the heights of 15 to 50 m deep. These are particularly observed in areas with strong influence of pluvial discharges. The stations with fewer taxa were the furthest from the coast. The Hokchi contract area and ground support facilities have been located in sites of medium wealth and abundance.

The stations with greater abundance are located off the coast of Campeche and Tabasco where the concentration of nutrients, particulate and dissolved organic matter is higher, which favors phytoplankton density.

90.6% of the richness is represented by only 21 taxa; Proboscia alata was the most abundant species with a contribution of 43.21%, followed by Hemiaulos hauckii with 9.35%, while the genus Chaetoceros was the most abundant represented with 10 taxa of the 21. The diversity was greater in those stations near the coast, which generally resulted in greater biological complexity.

Zooplankton and meroplankton. Off the coast of Tabasco, the highest zooplankton taxon values are presented, the high concentrations of suspended organic solids and phytoplankton compared to the discharges of the Grijalva-Usumacinta rivers, it is facilitated by the enrichment of the euphotic layer, resulting in water column fertilization by supply of epicinental nutrients, which is usually increased during rainy and stormy seasons (June - October) and due to coastal currents. Thus, this nutrient availability is exploited by phytoplankton through algal blooms and as a consequence an increase in zooplankton fauna.

Unlike phytoplankton spatial distribution, that of zooplankton was higher in the central area of the study polygon, the lowest values were observed towards the North and in more oceanic conditions, away from the influence of river and coastal lagoons discharges.

Benthos

Inter annual variation patterns are predictable and spatial patterns respond to seabed complexity and continental shelf topography (extension area and shelf break). The diversity values indicate a relatively stable community, with a trophic chain of a detritivore nature composed of 5 levels. The benthos is included in level II, within which the infauna, epifauna and penaeid shrimp are included.

The study of benthos in the Hokchi Field area and its area of influence up to the coastline, based on the analysis of the main attributes, it was confirmed that sediment type, temperature and depth greatly influence the processes determining fauna structure. In other words, it was identified fauna spatial distribution is defined, not only by biotic and abiotic factors, but by organisms biology itself (dynamics).

Macrobenthos

Based on information available from study area covering project area and its area of influence resulting from sediment samples analysis collected on the oceanographic cruise in February 2016 in the Hokchi area and the area of influence, the faunistic composition of the area comprises seven rows of invertebrates macrobenthic: annelids, crustaceans (Arthropoda), echinoderms, mollusks, nematodes, sipunccullides and amphioxos (Cephalochordata).

In relation to polychaete, 22 families were collected, the best represented in terms of abundance and incidence in stations were, in decreasing order, Cirratulidae (99 individuals in 12 stations), Spionidae (87 individuals in 14 stations), Paraonidae (45 individuals in 12 stations), Glyceridae (41 individuals in 13 stations), Syllidae (36 individuals in 12 stations), Dorvilleidae (30 individuals in 13 stations) and Pisionidae (30 individuals in 9 stations)

The particular distribution and abundance of polychaete in each station was variable, which can be observed. Annelids were the dominant component of the benthic macrofauna, which coincides with the records of Salazar-Vallejo and Londoño Mesa (2004) for different parts of the world.

In general terms, the three dominant families of annelids were Cirratulidae, Spionidae and Paraonidae. These organisms are inhabitants of areas impacted by excess organic matter in the sediment (Mendez 2002; Ferrando and Mendez 2011).

Nekton

The spatial-temporal patterns of this component are significantly correlated with the three recognized climate periods in the Gulf of Mexico; that is, they are highly predictable. The carbonated province concentrates biomass highest values and diversity and an increase tendency in abundance is recognized in the area near the area of oil platforms in the Sonda de Campeche.

This ichthyofaunal component study in the Hokchi project area and its area of influence up to the coastal area within maximum depth of 130 m recorded a total of 102 are bony fish and 6 elasmobranchii belonging to 1 Phylum, 2 Classes, 21 Orders, 47 families, 82 genera and 108 taxons.

However, other studies (oceanographic cruise in February 2016 in the Hokchi area and influence area) indicate in other seasons of the year the total number of species has been low, indicating the area has been strongly impacted by anthropogenic activities carried out in that region of the country. On the other hand, several of the species caught are of some commercial importance in the region, especially for artisanal fishing, in so-called "scale" fishing, which mainly catches demersal fish. From the above it can be deduced that it is an area with a dominance of demersal species, a low diversity and richness in general, and that the ichthyofauna throughout the studied area is the same.

As for the community formed by organisms inhabiting the bottom of aquatic ecosystems (benthic),none of these species of invertebrates identified nor fauna (nektonic) represented by fish species in the area and project area of influence are quoted in NOM-059-SEMARNAT-2010.

From documentary information from previous studies, it is known in the study area there are five species of sea turtles reported for the Gulf of Mexico and Atlantic region: The species are: *Lepidochelys kempii* (parrot turtle),*Chelonia mydas* (white or green turtle),*Eretmochelys* *imbricata* (hawksbill turtle),*Caretta caretta* (Loggerhead sea turtle) and *Dermochelys coriacea* (Leatherback sea turtle).

These marine species, due to their location in the entire coastal strip covered by the delimited SAR for the Project, are the most sensitive species because their behavior for both feeding and reproduction tend to arrive or enter the sand and even some of these species to enter the lagoon system that is included in the SAR under consideration.

However, although it is a species that does not have endemism due to its wide distribution in the Atlantic, it is listed in the NOM-059-SEMARNAT-2010 under the Hazard of Extinction Category (P).

Landscape

Once evaluated the **visual quality** and **visual fragility** of the landscape, it is concluded according to the evaluation method, the recommended use from the perspective of the South and Southeast view of Property Part “A” and Part “B” with deeper studies can be incorporated into high-impact visual activities such as is the Hokchi Plant. On the North side from the beach perspective, although being the recommendation for the use of low-visual impact activities (recreation), measures could be included to mitigate the visual impact of observers, which could be conserved a strip with existing vegetation or cultivating coastal vegetation that would also function as a measure to prevent wind and marine erosion in that coastal area.

Finally, on the socio-economic side, we have:

Socioeconomic factors

Municipalities included in the SAR: Cárdenas, Comalcalco, Paraíso and Centla; according to available information, there is:

Population growth has been very low in the last 20 years, with slow population growth trends and a population density of 200 inhabitants per square kilometer. Until now, population distribution in the four municipalities included in the SAR, its behavior is similar; i.e., both in number of men and women is similar including age.

As for indigenous languages spoken in the study area, 10 languages were recorded in the municipality of Paraíso, Cárdenas 23, Comalcalco 20 and Centla 15. This indicates that although in recent years there has been pressure for the development of oil activities, there has not been much influence on these population sectors. It is worth mentioning that this continues, due to the low or almost zero migration of the population, with a “very low” migration rate.

Employment of the economically active population is almost homogeneous in the municipalities included in the SAR; 21 to 30% carry out activities in the primary sector, 30 to 40 % in service activities and 15 to 20 % in the secondary sector. This indicates that there is still a high percentage of the population engaged in agriculture and livestock activities, as well as population migrating within the same municipality to cities in search of better opportunities resulting in services demand (housing, health, safety, etc.).

Agricultural and livestock sector production is still reflected in population occupational percentage and at SAR level in the coastal area of the four municipalities, predominant with a large percentage coconut production and livestock production, which is reflected in the land use map in Annex 2 of this study.

This indicates Project development could contribute or generate positive impacts in terms of jobs or labor required at any stage of its development and in turn increase the quality of life for some sectors of the population, influenced by direct and indirect jobs.