Volumen 3 de 3

Marina Puerto Real
Fajardo, Puerto Rico

Junta de Planificación
Consulta Número 2000-24-0437-JPU

Julio 2006

DECLARACIÓN DE IMPACTO AMBIENTAL FINAL
PROYECTO MARINA PUERTO REAL
BAHÍA DE FAJARDO, PUERTO RICO

PREÁMBULO

Identificación del Documento	:	Declaración de Impacto Ambiental Final
Agencia Proponente	:	Junta de Planificación de Puerto Rico
Funcionario Responsable	:	Junta de Planificación de Puerto Rico Box 4119 Minillas Station Santurce , Puerto Rico Tel. (787) 723-6200, Ext. 2481
Proponente	:	AVE, Inc. PO Box 474 Trujillo Alto, Puerto Rico 00974 Tel. (787) 764-5151 Fax (787) 764-4870
Acción Propuesta	:	Se propone la expansión de la Marina Puerto Real en Fajardo, Puerto Rico. El proyecto incluye obras de dragado, la construcción de un rompeolas, la ampliación de las facilidades de servicio para botes, la construcción de una estructura de acero de 76,9000 pies cuadrados para aproximadamente 500 botes de hasta 35 pies de largo, en un solar de 5.95 cuerdas de tierra firme que se usa actualmente para el almacenamiento de botes como "Dry Stack". También, se construirá una estructura de estacionamiento de dos niveles, alrededor del edificio para botes, con capacidad para 450 automóviles (45,000 pies cuadrados por nivel). A nivel del terreno, hacia la calle, en la estructura de estacionamiento se proveerá espacio de 13,00 pies cuadrados para alquiler comercial. El proyecto incluye además, un muelle en hormigón para la comunidad de pescadores en el perímetro de la Marina Puerto Real, con una rampa para echar botes al mar. Estas instalaciones tendrán acceso directo al espacio público de la calle. Todo lo anteriormente descrito estará en la bahía de Fajardo al este del muelle propiedad de Isleta Marina. Entre la calle municipal y el límite del agua se propone el desarrollo de un área pasiva, un restaurante contiguo al borde del agua y calle de acceso para dejar y recoger personas en las instalaciones de la Marina Puerto Real. Esta sección constituirá una continuación al paseo lineal planificado por el Municipio de Fajardo.
Consulta de Ubicación	:	2000-24-0437-JPU
Fecha de Circulación	:	

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WATER QUALITY AND SEDIMENT TRANSPORT

MARINA PUERTO REAL, FAJARDO, PUERTO RICO

DRAFT

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EXECUTIVE SUMMARY

This report presents the results of a numerical modeling study of the proposed Marina Puerto Real, Puerto Rico. The project site is located on the northeast coast of Puerto Rico at Fajardo. The site is in a semi-protected cove with a series of small offshore islands that dissipate the incident wave energy. The study addresses the potential impacts to water quality and nearshore sedimentation patterns resulting from the construction of perimeter breakwaters around the proposed marina. Water exchange and pollutant tracer concentration reduction times within the proposed marina were evaluated and compared to United States Environmental Protection Agency (USEPA) guidelines. Nearshore sedimentation patterns driven by tidal- and sediment laden riverine discharge from the Rio Fajardo were assessed to determine if the proposed perimeter breakwater would increase impacts to biological receptors of concern located just offshore of the proposed marina basin.

The proposed perimeter breakwaters caused no discernable redirection of nearshore sediment transport even with the introduction of mean or peak Rio Fajardo discharges. The overall sediment transport pathways were similar for the pre- and post-project model simulations. The tidal-induced currents that flow along the main north-south navigation channel capture and dispersed sediment from the Rio Fajardo before it reaches the four areas of concern (seagrass, coral, area north of marina, and Isleta Marina).

Water exchange times and residual pollutant concentration after 4 days did not meet USEPA recommended guidelines with the enclosed basin. Three openings in the breakwater were introduced, two in the northern end and one at the southern end. The insertion of openings or culverts in the marina breakwaters improved circulation and provided adequate flushing to maintain acceptable levels of water quality. The model simulation of the marina with three opening in the breakwaters resulted in a residence time of less than two days and the reduction of a conservative tracer contaminant to residual levels of 10% in four days.

Marina Puerto Real is a proposed marina situated north of the mouth of the Rio Fajardo in Fajardo, Puerto Rico. The marina will house approximately 165-boats ranging from 60 to 80-feet in length and provide ancillary facilities support for these boats. Two rubble-mound breakwaters extend from the shore to provide wave protection and to minimize sedimentation inside of the basin. A conceptual design layout of the breakwaters is shown in Figure 1.1.

Moffatt & Nichol Engineers (M&N) has been retained to perform a numerical modeling evaluation of the potential water quality and nearshore sediment transport changes resulting from the construction of the perimeter breakwaters. The results will be used to guide the design of the structures and marina basin as well as to support the permitting effort with the United States Army Corps of Engineers (USACE). This report supplements a report dated December 2001 that discussed the results of a wave refraction and tidal- and wave-induced nearshore sediment transport study at the proposed site.

1.1 Scope

This study was undertaken to evaluate if the introduction of the breakwaters as shown would potentially redirect sediment-enriched discharge from the Rio Fajardo into sensitive nearshore biological resources or degrade nearshore water quality within or adjacent to the proposed marina basin. Two numerical modeling investigations were undertaken; one examining the flushing characteristics of the marina basin, the other evaluating the dispersion and transport of sediment from the Rio Fajardo. The December 2001 numerical modeling effort was used as a foundation and supplemented with river flow data from the United States Geological Survey (USGS). The U.S. Army Corps of Engineers (USACE), Jacksonville District, has recently completed preliminary engineering studies for the construction of 2100 meters of levees, one low flow structure, and interior drainage facilities near the mouth of the river. This analysis does not incorporate these improvements.

Dispersion of the sediment plume by tidal-induced currents was qualitatively assessed by representing the suspended sediment as a unit constituent. The unit concentration was used to assess how the sediment plume disperses with tides and if it would reach the four areas of

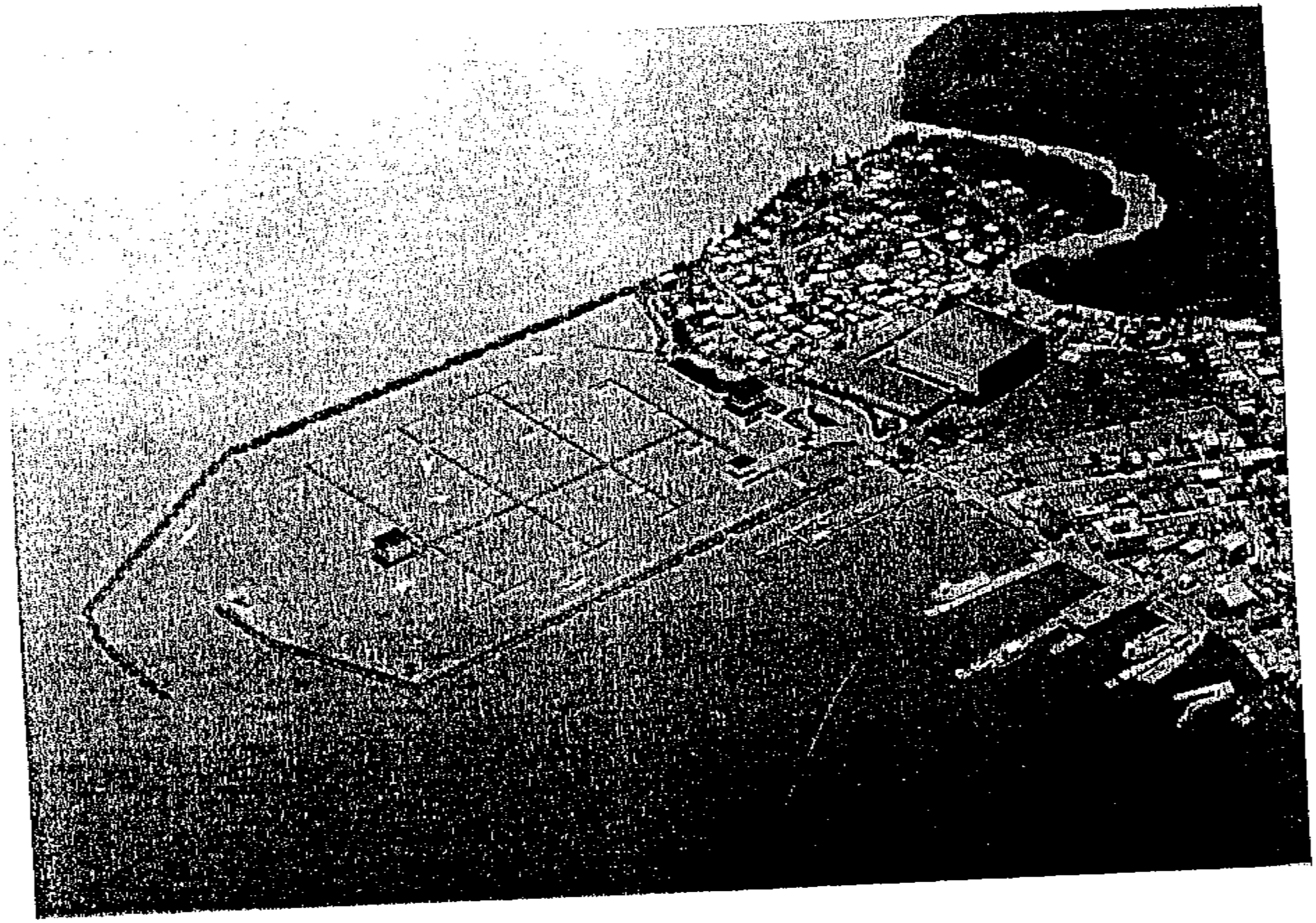

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Figure 1.1: Conceptual Design Layout

concern (seagrass, coral, area north of marina, and Isleta Marina). In addition, a qualitative evaluation of how prevailing wind conditions may influence the dispersion was also completed. Because sediment characteristics (size and settling rate) as well as quantity of the sediment load from the Rio Fajardo are not available, a quantification of deposition rates was not performed. Pre- and post-marina conditions were assessed to determine if the proposed marina alters the dispersion patterns or impacts the four areas of concerns.

The hydrodynamic model utilized in the sedimentation analysis was modified to assess circulation patterns, water exchange time, and pollutant dilution time (time required to reduce an initial concentration of a pollutant to 10% of its initial value) within the proposed marina. The pollutant dilution time was evaluated using an advection-dispersion model coupled with the hydrodynamic model. The advection-dispersion model tracked the distribution of the unit pollutant to determine the concentration at the end of the 96-hour period. The results were compared to the USEPA guidelines to determine if they met or exceeded the 96-hour threshold. If either exchange time did not meet this criterion, breaches in the marina breakwater were introduced to determine if they would enhance the circulation.

The following tasks were performed as part of this study:

- Data Collection and Review,
- Hydrodynamic Analysis,
- Water Quality Analysis,
- Sediment Transport Analysis, and
- Summary Report

1.2 Numerical Modeling Approach

The following points summarize the approach used for the numerical modeling:

- Modify nearshore bathymetry of existing hydrodynamic and wave models to incorporate river mouth and delta. Water depths in proposed marina basin were obtained from information shown on the plan sheet prepared by Alcaide, Inc. The inner two-thirds of the marina is a depth of 8 feet MLW; the outer third at a depth of 10 feet MLW.

- Modify finite difference modeling grid to increase resolution within the proposed marina basin and river delta,
- Perform numerical modeling to determine the residence time of the proposed marina basin,
- Introduce breaches into the perimeter breakwaters, if necessary, to reduce residence time, and perform numerical modeling to determine the residence time and flushing characteristics of the modified marina basin,
- Perform numerical modeling to determine the pathways for sediment emanating from Rio Fajardo for existing and proposed conditions.

Marina Puerto Real is located on Fajardo Bay in the City of Fajardo, Puerto Rico as shown in Figure 2.1. Fajardo is situated on the northeastern coast of Puerto Rico, approximately 35 miles east of San Juan and 5 miles north of Roosevelt Roads Naval Air Station. Fajardo Bay is separated from the Caribbean Sea by a series of islands that limits the wave exposure of the coastline to small windows to the northeast and east-southeast. The Isleta Marina is located northeast of the project site. Shoreline orientation is generally northwest to southeast.

2.1 Bathymetric Data

The nearshore bathymetry was digitized from the National Oceanic and Atmospheric Administration (NOAA) nautical chart 25663. The model domain is shown in Figure 2.2 and encompasses the northeast coast of Puerto Rico from the San Juan Passage to the Bahia Demajagua, encompassing Fajardo Bay and the offshore islands. A grid spacing of 10 meter in the X- direction and 40 meters in the Y-direction was used. A fine local model grid (4m × 4m) was used to model a 2 km by 2 km area within and around the proposed marina. The modeling region is also shown in Figure 2.2.

2.2 Tides and Water Levels

The Caribbean coast of Puerto Rico experiences tides classified as mixed diurnal with a small semi-diurnal component resulting in two high and two low tides per day of unequal heights. The tidal current moves south during the flood tide and north during the ebb tide. The maximum (spring) tide occurs during the new moon and summer solstice. The astronomical tidal range fluctuates between 1.6 foot (0.5 meters) Mean Higher High Water (MHHW) and 0.0 feet (0.0 meters) Mean Lower Low Water (MLLW).

2.3 Prevailing Winds

Ten years of the one-minute wind speed measured at Roosevelt Roads Naval Air Station was obtained from the National Climatic Data Center, a division of the National Oceanographic and Atmospheric Administration (NOAA). The wind rose shown in Figure 2.3 indicates that the prevailing winds are generally from the easterly quadrants, with a strong predominance of

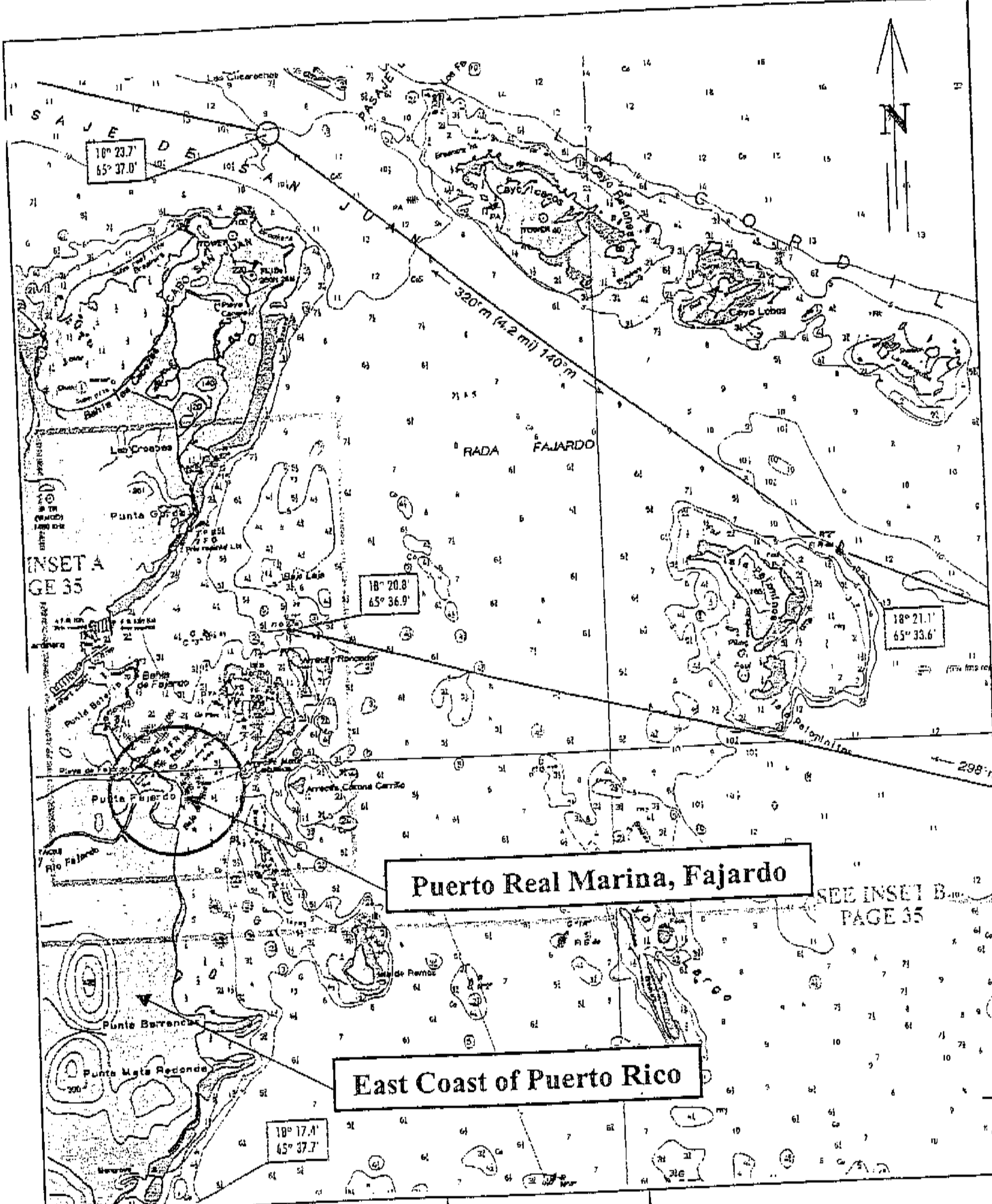

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Figure 2.1:Project Site

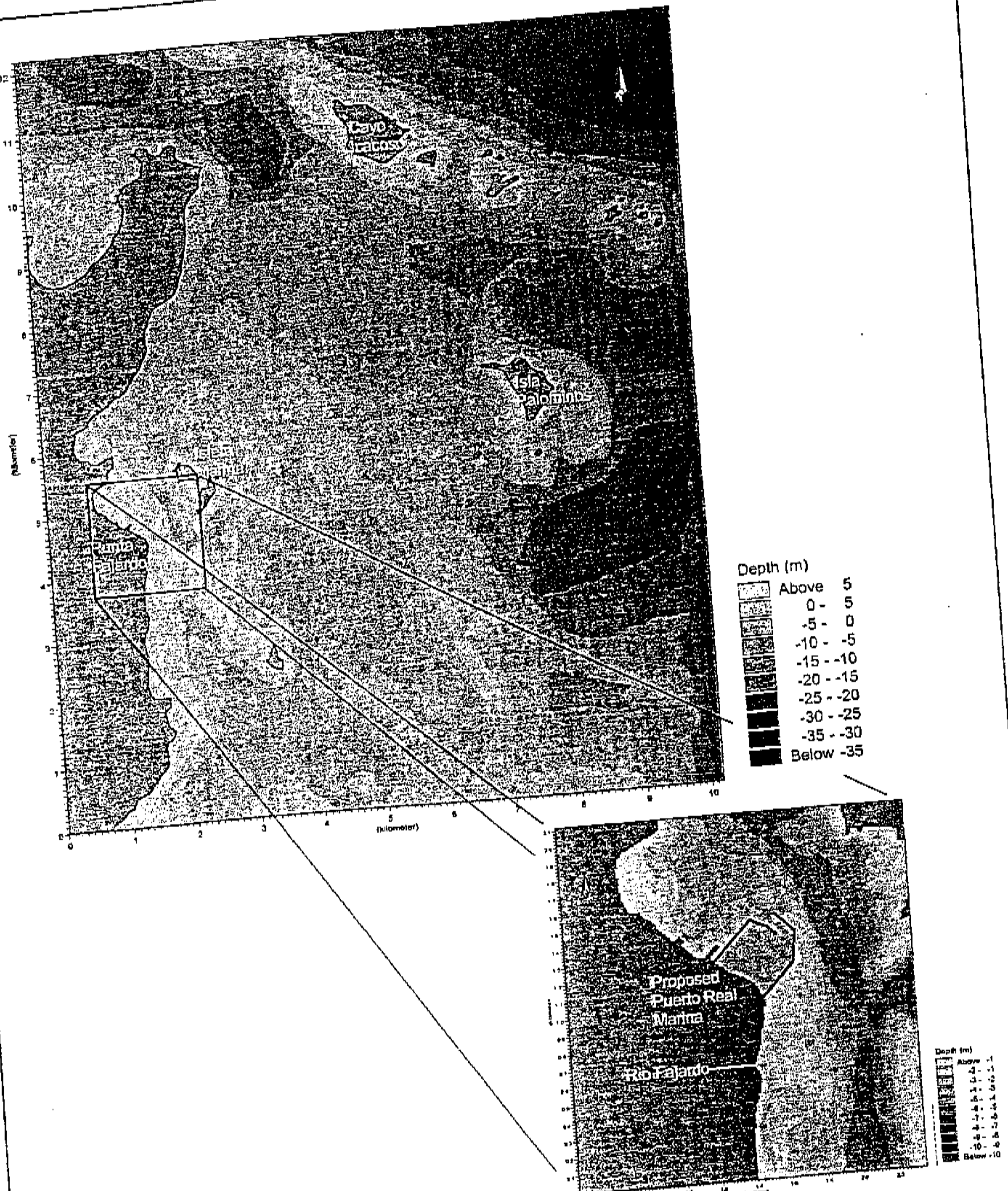

Figure 2.2:
Study Region Bathymetry

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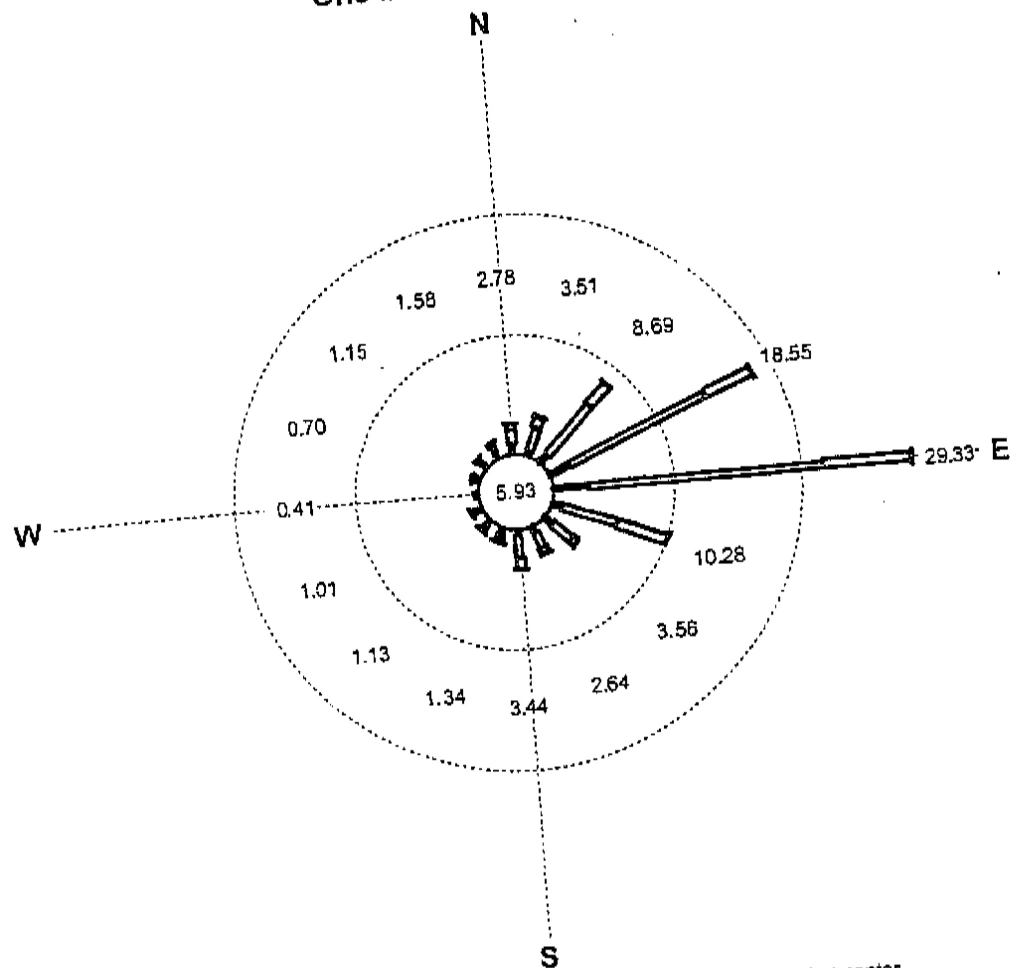
Roosevelt Roads Naval Air Station
Puerto Rico
One Minute Windspeed



Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
9.91% of observations were missing.

0.1 1.5 3.5 4.5 6.5 11

Wind Speed (m/s)

PERCENT OCCURRENCE: Wind Speed (m/s)
LOWER BOUND OF CATEGORY

DIR	0.1	1.5	3.5	4.5	6.5	11
N	0.33	0.66	1.22	0.47	0.07	0.03
NNE	0.12	0.37	2.04	0.93	0.04	0.01
NE	0.18	0.73	5.45	2.27	0.06	0.01
ENE	0.27	1.74	12.37	4.10	0.05	0.02
E	0.48	2.61	18.90	7.14	0.16	0.04
ESE	0.23	0.73	4.84	4.37	0.11	0.01
SE	0.23	0.81	1.96	0.54	0.02	0.01
SSE	0.16	0.55	1.37	0.53	0.03	0.01

TOTAL OBS = 82093 MISSING OBS = 8133

PERCENT OCCURRENCE: Wind Speed (m/s)
LOWER BOUND OF CATEGORY

DIR	0.1	1.5	3.5	4.5	6.5	11
S	0.20	0.38	1.79	1.02	0.05	0.01
SSW	0.19	0.33	0.55	0.24	0.03	0.01
SW	0.25	0.45	0.35	0.05	0.02	0.01
WSW	0.38	0.46	0.14	0.02	0.01	0.01
W	0.22	0.13	0.05	0.00	0.00	0.00
WNW	0.33	0.28	0.07	0.01	0.00	0.01
NW	0.39	0.56	0.15	0.04	0.00	0.00
NNW	0.34	0.78	0.41	0.05	0.00	0.00

CALM OBS = 4866 PERCENT CALM = 5.93

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Figure 2.3
Wind Rose
Roosevelt Roads Naval Air Station

due east winds during the summer months. Winds from the northeast and southeast are also fairly common, especially in the winter months.

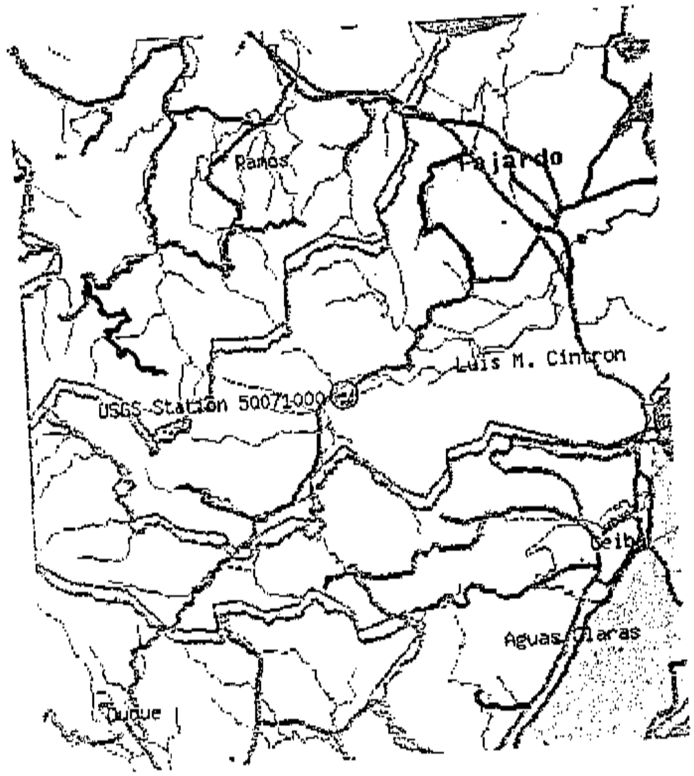

Figure 2.4 USGS Gage Location

2.4 Rio Fajardo

The Rio Fajardo drains approximately 22 square miles of watershed from its mouth near El Yunque National Park until it exits into Bahia de Fajardo. The flow rate of Rio Fajardo is variable and is influenced by seasonal rainfall trends, water supply diversions, and tropical storm events. The United States Geological Survey (USGS) maintains a streamflow gage on the river 3.5 km upstream of the mouth (Figure 2.4). Daily mean streamflow measurements were taken from April 1961 to September 2000. The USGS performed a statistical analysis of the data to determine the annual mean streamflow for each year. The average annual mean flow for the period of record is approximately 68 cfs. This value does not take into account watershed contributions downstream of the gage. Daily peak flows from the 39-year record were also analyzed to determine the average annual peak flow.

For this analysis, the flows were adjusted to account for this additional drainage area between the gage location and the river's mouth using linear interpolation. The average annual flow at the river's mouth for the period of record was 72 cfs and the peak was taken as 353 cfs, which was exceeded as a daily flow less than 3 % of the time over the entire 40 year period of record. The two flows (one mean and one peak) were applied to the model as a point source to represent annual and peak events. This point source acts as the forcing mechanism for the initial dispersion of the sediment plume from the river.

Detailed sediment characteristics of material transported by Rio Fajardo were not available. Therefore, sediment transport rates or volumes could not be assessed in this study. Instead, a qualitative analysis was performed to determine potential sediment transport pathways. Based on the direction and extent of the pathways, an evaluation of potential impacts to sensitive biological areas could be made.

2.5 Study Focus Areas

The federal resource agencies (U.S. Fish and Wildlife Service –USFWS and National Marine Fisheries Service – NMFS, a division of the NOAA, have identified four areas that the proposed project may potentially impact. The four areas of concern are the seagrass beds and mudflats at or in close proximity to the project site, the coral reefs situated southwest of Arrecife Mata Caballos, and the Isleta Marina site. The Nation Ocean Service, a division of NOAA, has created maps of the benthic habitats along the coast of Puerto Rico using aerial photographs taken in 1999. Figure 2.5 shows the biogeography map of the Fajardo Region.

The benthic map indicates that seagrass beds are evident from just north to approximately one mile south of the river's mouth. Seagrass is also evident on the leeward side of Arrecife Mata Caballos. The seagrass is very sparse at the river mouth but is dense south of the river and on the leeward side of Arrecife Mata Caballos. Coral is shown at the southeastern tip of Arrecife Mata Caballos. Benthic habitats have not been identified at the proposed marina site. In July

2002, a marine resources assessment conducted at the project site confirmed that benthic habitats were not present.

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Figure 2.5:
Biogeography Map

The numerical modeling package used for this analysis was the MIKE series developed and maintained by the Danish Hydraulic Institute (DHI). The two MIKE21 modules used in this study were the Hydrodynamics Module and the Advection / Dispersion Module.

3.1 MIKE21 HD Overview

MIKE21 HD is the basic model of the entire MIKE 21 system. It provides the hydrodynamic basis for the computations performed in the models for sediment processes and environmental hydraulics. The HD model simulates the water level variations and flows in response to a variety of forcing functions in lakes, estuaries, and coastal areas. The water levels and flows are resolved on a rectangular grid covering the area of interest when provided the bathymetry, bed resistance coefficients, wind field, hydrographic boundary conditions, etc.

The system solves the full-time dependent nonlinear equations of continuity and conservation of momentum. The solution is obtained using an implicit ADI finite difference scheme of second order accuracy. The following effects are included in the equations (as applicable):

- Convective and cross momentum
- Bottom shear stress
- Wind shear stress at the surface
- Barometric pressure gradients
- Coriolis forces
- Momentum dispersion
- Wave-induced currents
- Sources and sinks (e.g. outfalls, intakes)
- Evaporation
- Flooding and drying.

The outcome of a simulation is the water level and fluxes (velocities) in the computational domain. (Danish Hydraulic Institute, MIKE21 Hydrodynamic Module - User Guide and Reference Manual.)

3.2 Finite Difference Grids

The models within MIKE21 require that the system be represented by a grid of nodal points defined by coordinates in the horizontal plane and water depth. The two most important aspects in the definition of a finite difference grid are: (1) determining the level of detail (grid spacing in X and Y between adjacent nodes) necessary to adequately represent the region to be modeled and (2) determining the extent or coverage of the grid. The level of detail required for the grid can be forced by the complexity of the bathymetry or the spacing required for the solution stability of different models.

There are several factors that influence the spatial extent of the grid. First, it is desirable to extend the grid to areas which are sufficiently distant from the proposed areas of change so as to be unaffected by that change. Second, the outer regions of the grid must be located along boundaries where conditions can be reasonably described to a computer model.

A 4-meter by 4-meter grid spacing extending approximately 2,000 meters along shore and 1,750 meters offshore to the nearest island was used for analysis of the water quality and sediment transport as illustrated in Figure 2.2.

3.3 Modeling Approach

Tides were input as boundary conditions along the open boundaries of the hydrodynamic model grid. Tidal water levels for the predicted tides at Playa de Fajardo based on the NOAA station at San Juan, Puerto Rico were used (Tides & Currents, Nautical Software Inc.). The modeled water levels and approximate depth averaged current velocities were then calibrated based on available local tidal and current measurements by varying the time lag of tidal water surface elevations across the model gird. A typical daily tidal cycle from 9:20 a.m. on May 24, 2001 to May 25, 2001 at 9:20 a.m. was calibrated and the tides from May 22 to June 5, 2001 used for the model runs. The river flow was modeled over the 14-day tidal period as a constant point source input discharge for both the annual mean and peak discharge events.

3.4 Wave-induced Currents

As waves approach the shoreline at an oblique angle and begin to break, a small current is produced that transports nearshore sediments along shoreline. This alongshore current is one of the primary mechanisms that adjusts the shoreline position or configuration over time. Alongshore currents are strongest in the surf zone (area between the shoreline and the wave breaking line) and decay rapidly seaward of the breaker line. Since the focus of this study is to assess marina circulation and dispersion of the suspended sediments discharged by the Rio Fajardo, wave-induced currents have negligible effect on either assessment. Therefore, inclusion of wave-induced currents in the hydrodynamic modeling was not performed.

4.1 MIKE21 AD Overview

MIKE21 AD simulates the spreading of a dissolved or suspended substance subject to advection and dispersion processes. Using a method similar to the HD module, the concentration of a substance is calculated at each point of a rectangular grid covering the area of interest. Fluid transport information, such as currents and water levels, is provided by the HD module. The system solves the equation of conservation of mass for a dissolved or suspended substance using a two-dimensional form of the QUICKEST finite difference scheme. It has several advantages over other schemes, especially that it avoids the 'wiggle' instability problem associated with central differencing of the advection terms, and at the same time it greatly reduces the numerical damping, which is characteristic of first-order upwinding methods.

4.2 Dispersion Coefficient

The most important factor in this analysis is the tidal dispersion of a substance. This is the overall phenomenon of mixing due to the temporal variation of tidal velocity, lateral and vertical gradients in velocity, turbulence, and density differences. Physical processes involved in the mixing and spreading of substances occur simultaneously at different spatial and temporal scales. The mathematical representation of fluid motions over areas requires spatial scales larger than the microscopic spaces associated with molecular agitation of substances. Therefore, when producing mathematical models of larger scales, the dispersive processes that occur at smaller scales must be represented in the model in a bulk form using dispersion coefficients. There are large variations in reported dispersion coefficients. In numerical modeling the dispersion coefficients used are also dependent on the grid spacing and time step used. Estimation of the tidal dispersion coefficient generally requires field-testing since it depends on various site-specific factors. Since field measurements are not readily available, a dispersion coefficient of 0.15 m^2/s was used for Fajardo Bay and the proposed marina in the advection-dispersion modeling, which is similar to those used in past studies of similar scale.

4.3 Water Quality Modeling Approach

In conjunction with the hydrodynamic model, the advection-dispersion model was used to determine residence time (water exchange time) and pollutant dilution time (time required to reduce an initial concentration of a pollutant to 10% of its initial value) within the proposed marina.

Criteria for water quality in marina basins are often expressed in terms of residence time. Residence time is defined as the average time a particle spends in the basin. For small basins residence time, the average time for a particle to enter and leave a basin has been shown to equal the volume of the basin divided by the rate at which new water is added to the basin [1,2].

$$\tau_r = \frac{VT}{\varepsilon P}$$

where τ_r = residence time

V = average volume of the basin over a tide cycle

T = tidal period

ε = fraction of new water entering the basin for each tidal cycle

P = the tidal prism

The residence time can also be calculated as the time required to reduce the total mass of a substance's concentration by a factor 'e' [1,2]. The USEPA uses the residence time as a measure of water quality for marina facilities; recommending four days as the maximum time for complete exchange.

Pollutant dilution time, commonly referred to as the flushing time, is the time required to reduce the concentration of a conservative pollutant to ten percent of its original concentration. Generally, flushing times of four days or less are desirable for marina facilities as an indication that pollutants will not accumulate to the extent where water quality is a serious issue.

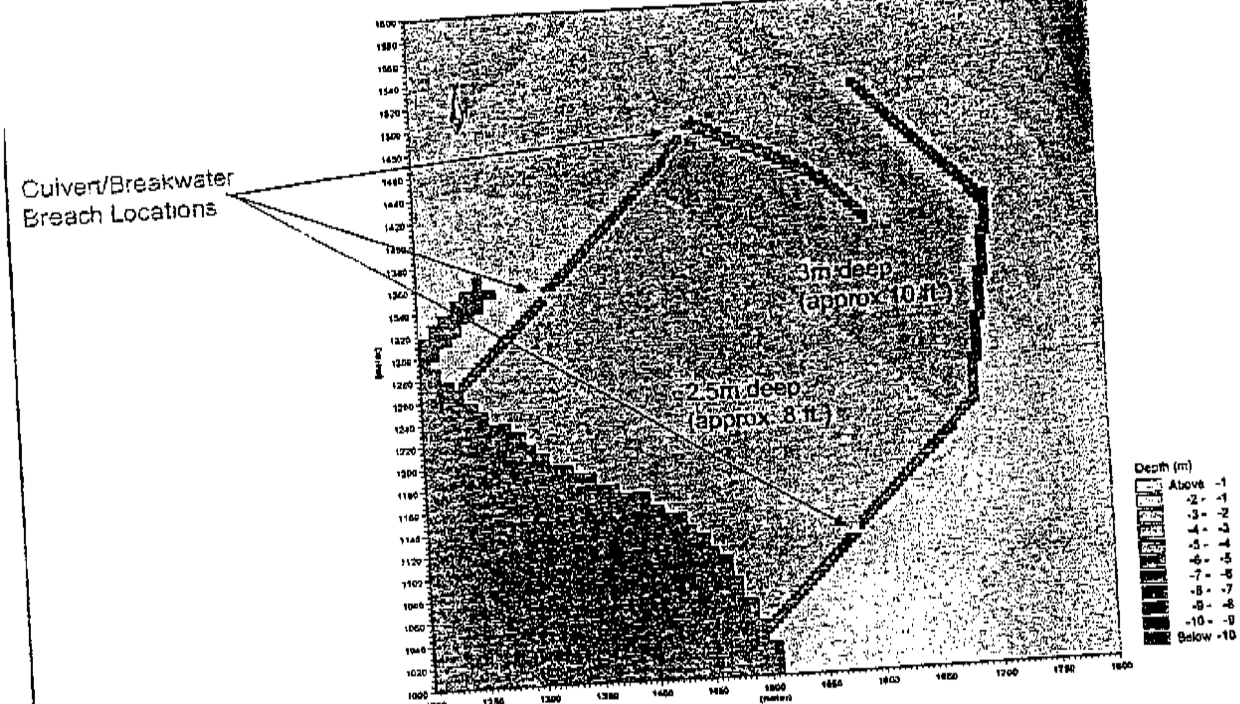
To assess the residence time and basin flushing for the proposed marina basin, a unit concentration of a conservative tracer substance was initially applied to the entire marina basin area. All areas outside the basin were set to "clean" water with a given a concentration of zero, including the open boundary conditions. The model was then run for a two-week period to determine the rate with which the concentration was diluted within the basin. Three cases were modeled for the marina breakwater. The first case was the marina breakwater as proposed. The second involved the introduction of braches or openings into the breakwater to improve circulation in the marina basin. The third option simply involved increasing the size of the breaches or openings modeled in the second case (see Figure 4.1).

4.4 Water Quality Results

Figure 4.2 shows the rate at which the concentration within the proposed marina basin dilutes over time. It indicates that proposed marina breakwaters with only the main entrance requires nearly 10 days to reduce the pollutant concentration to ten percent of its initial level. This long flushing time is a result of limited circulation in the marina basin, which is attributed to having one main entrance. Breaches or openings in the two perimeter breakwaters were introduced to improve circulation. Initially, only one breach on the north side was added but only minor improvements resulted. The addition of a second breach on the north side showed more improvement but limited circulation was still evident on the southwest corner of the marina basin. Three breaches or openings in the breakwater greatly enhanced the flushing characteristics of the marina basin. The locations of the openings are shown in Figure 4.1. With the addition of the three smaller openings (12 meters or one model grid cell in size), the residence time was significantly reduced to less than 4 days (87 hours) but the time for the tracer contaminant to dilute to 10% of its initial concentration in the marina was approximately 200 hours. Increasing the size of the openings in the breakwater to 24 meters (two grid cells) produces a residence time of 44 hours and 10% residual concentration in 96 hours.

Since the breach width is dependent on the grid spacing, the final width of the openings falls somewhere between 12 and 24 meters. A finer mesh grid of the marina basin will need to be

Option 2: Breakwater with 3 Openings
(One model grid cell wide – approximately 5.65 m diagonal)



Option 3: Breakwater with 3 Openings
(Two model grid cells wide – approximately 11.3 m diagonal)

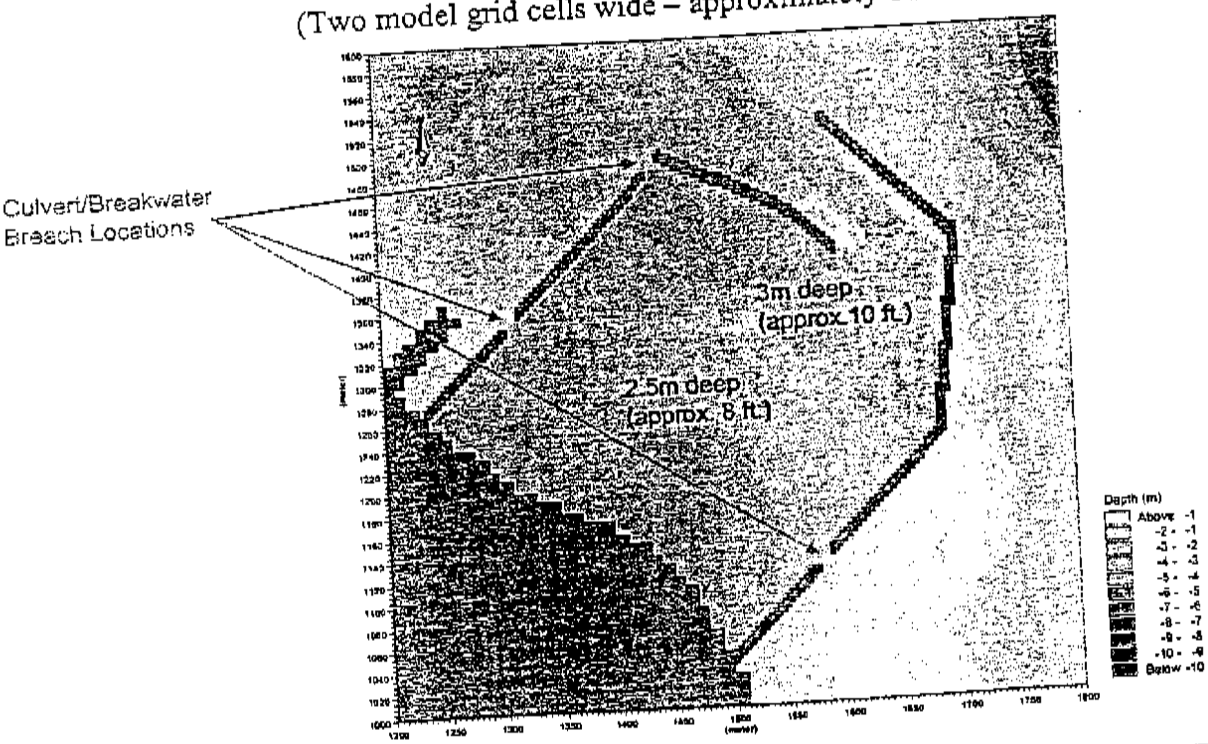


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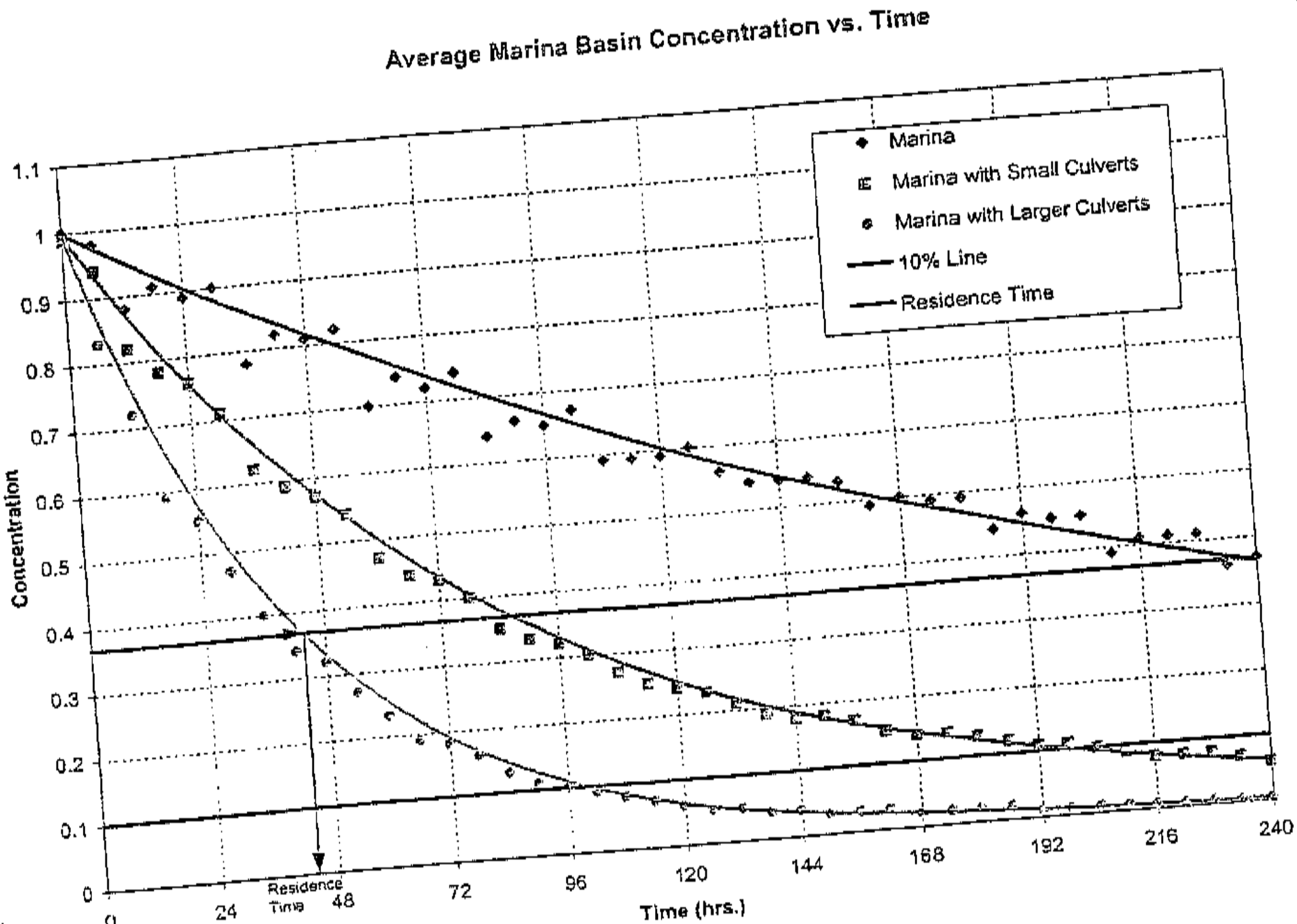
Figure 4.1:
Breakwater Openings
for Improved Circulation



Option	Residence Time (h)	Time to 10% (h)
Marina with proposed breakwaters	238	-
Breakwaters with 3 culverts or openings	87	200
Breakwaters with 3 larger culverts or openings	44	99 – from "best fit" curve 96 – from model calculations

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Figure 4.2:
Marina Water Quality and Basin Flushing

undertaken during the final design of the project to determine the exact dimensions of the breaches.

The locations of the breaches shown in Figure 4.1 were selected to improve circulation and water exchange within the proposed basin. The final location of the breaches may shift slightly to reduce potential maintenance dredging of the breaches that may occur. The breach on the southern side is most susceptible to infilling as suspended sediment from the river moves in a northerly direction (see subsequent discussions). There are several means to minimize sedimentation of the breaches including placement of an underwater sill seaward of the opening to capture suspended sediment while maintaining flow. Another solution consists of dredging a deep hole in front of the breach to act as a sump, capturing sediment before it reaches the marina basin. These potential or other alternative solutions will be addressed during final design.

5.1 Sediment Transport Modeling Approach

The MIKE21 AD model was also used to determine how material suspended in flows from the Rio Fajardo are dispersed once they encounter tidal currents. The potential sedimentation pathways and fate of sediment discharged by the river can be qualitatively assessed by modeling the spread of a conservative substance from the river mouth. Two conditions were modeled for both the existing bathymetry and with the proposed marina in place. These conditions were assessed for the average annual mean and peak river flow events.

5.2 Sedimentation Discussion

The sedimentation analysis indicates that the marina breakwaters have little impact on the overall sediment transport pathways and fate. Comparison of extended simulations (3 to 9 days) of the existing shoreline and post-project marina configurations in Figures 5.1 to 5.4 illustrate that the proposed marina has a minor effect on redirecting the sediment discharged from the Rio Fajardo during mean river flow conditions. A very low percentage, less than 15% of the unit concentration of sediment during low tide, is redirected further north. This slight redirection does not impact benthic resources as shown on the biogeography map or the Isleta Marina. During transition or high tide conditions, imperceptible changes in dispersion or direction of the sediments are evident.

The peak flow event comparisons for extended durations are shown in Figures 5.5 to 5.8. The sediment plume dispersion patterns are similar to the annual mean flow events except a slight extension of the plume on the northern end during low tide condition. Minor concentration (10%) of sediment do filter in the Bahia de Fajardo during transitional and high tides. The biogeography map indicates that a strand of mangroves in the Bahia may be impacted slightly but the impacts to the four areas of concern do not differ from the existing conditions.

For both the annual and peak flow cases, the suspended sediment plume characteristics are illustrated every four hours over a typical daily tide cycle in Figures 5.9 to 5.14. These figures demonstrate the extent of the sediment plume over a short duration. The dispersion patterns in the model results match closely with the visible sediment deposition area shown in aerial photographs (Figure 5.15). The sediment plume is contained near the river mouth and does not cross the deep channel between shoreline and the islands to the east.

Prevailing wind speeds and their affect on the outcome of the modeling were reviewed. Since the prevailing wind speeds are generally from the easterly quadrants, the winds would tend to "push" the sediment plume toward the shore, reducing seaward migration away from the coral and seagrass beds near the southwest corner of Arrecife Mata Caballos. In most instances, wind would tend to assist sediment transport towards the north or south, which is the general direction of sediment movement with just the tidal forcing.

For both short- and long-term simulation results, the sediment dispersion after the introduction of the proposed marina does not affect coral reefs or the Isleta Marina site. Except for the mudflats underneath the proposed marina footprint, impacts to seagrass or other mudflats has not changed between pre- and post-marina conditions. Figures 5.16 and 5.17 provide graphical representations of the model results (low tide conditions after 9 days for both annual mean and peak flows) transposed on the biogeography map. These figures show the relationship between the four areas and the benthic resources.

The only noticeable sedimentation issue related to the proposed marina is the potential accumulation of sediment along the south breakwater where it joins the shore. The introduction of a breach in the southern breakwater may result in higher than anticipated maintenance dredged of the marina basin. As previously discussed, the breach location and other solutions to minimize basin sedimentation will be addressed during the final design phase.

Overall, it is important to note that the model most likely overly represents the lateral or areal extents of sediment transport since the simulations do not include the effects of sediment settling. Therefore, the majority of the sediment from the river will most likely settle out prior to reaching the limits shown. The results of this study should be viewed as a conservative evaluation of sediment dispersion.

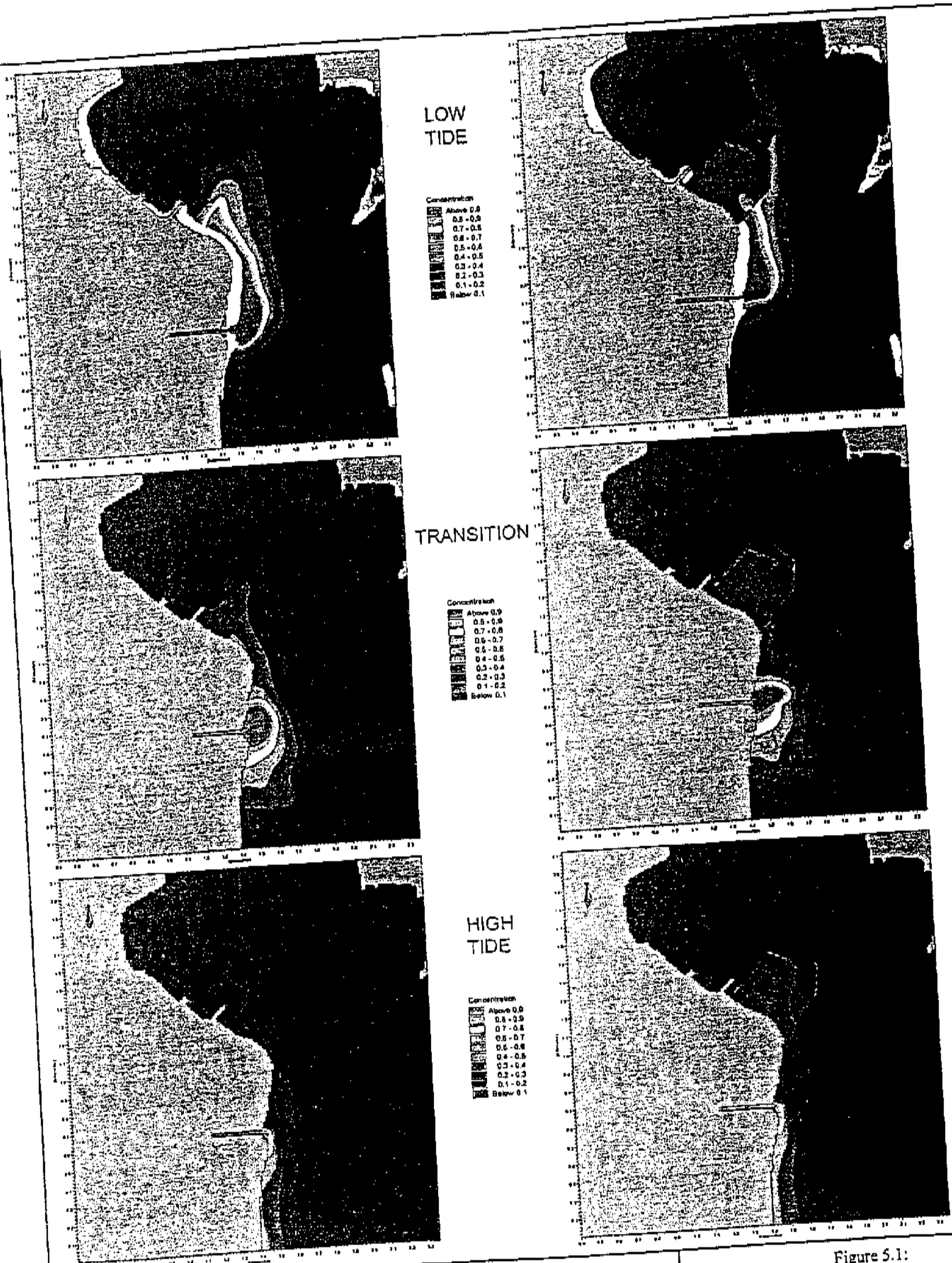

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Figure 5.1:
Comparison of Existing and Project Conditions
After 3 Days of Simulation
(Average River Flow)

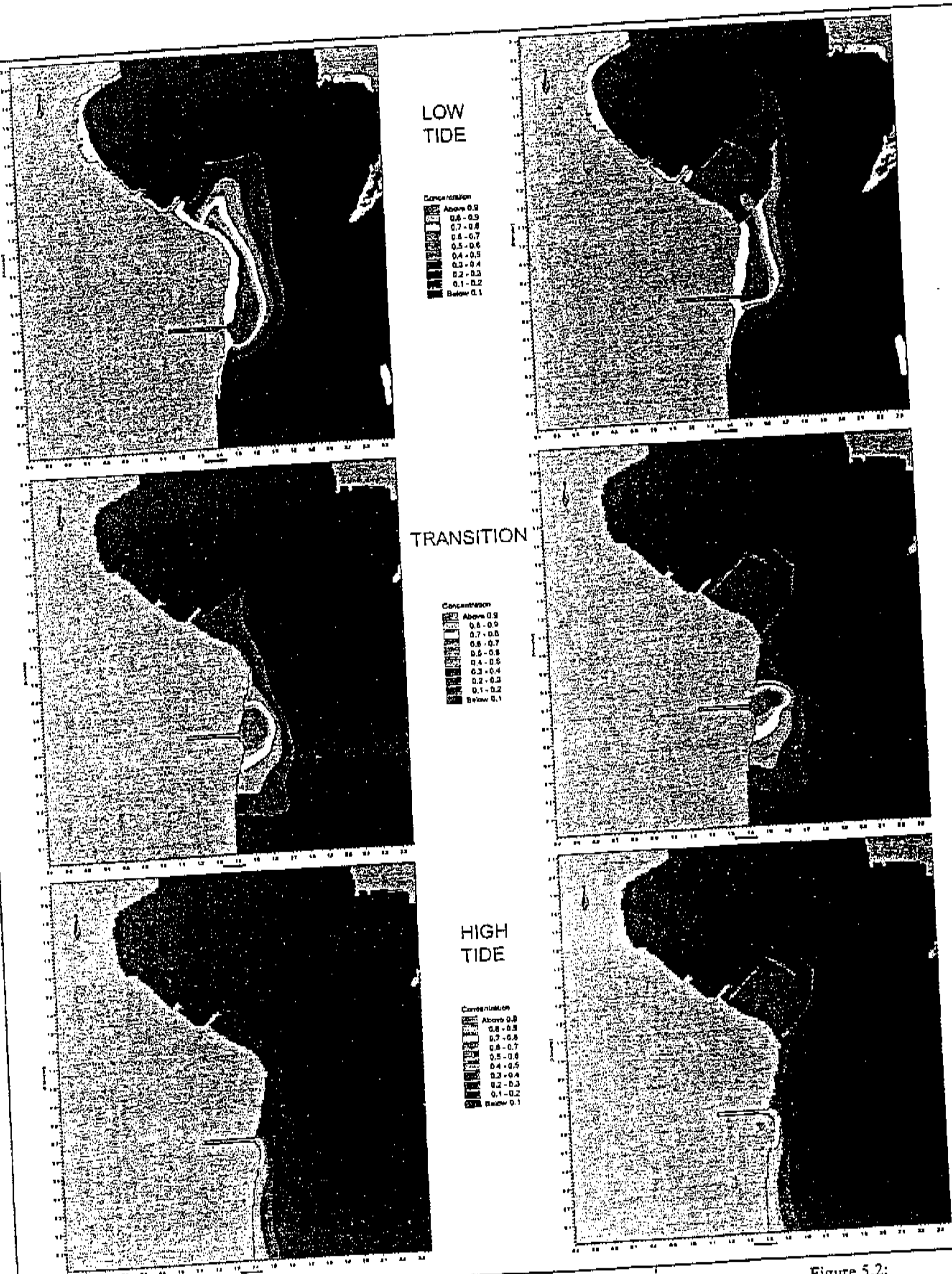

Figure 5.2:
Comparison of Existing and Project Conditions
After 5 Days of Simulation
(Average River Flow)

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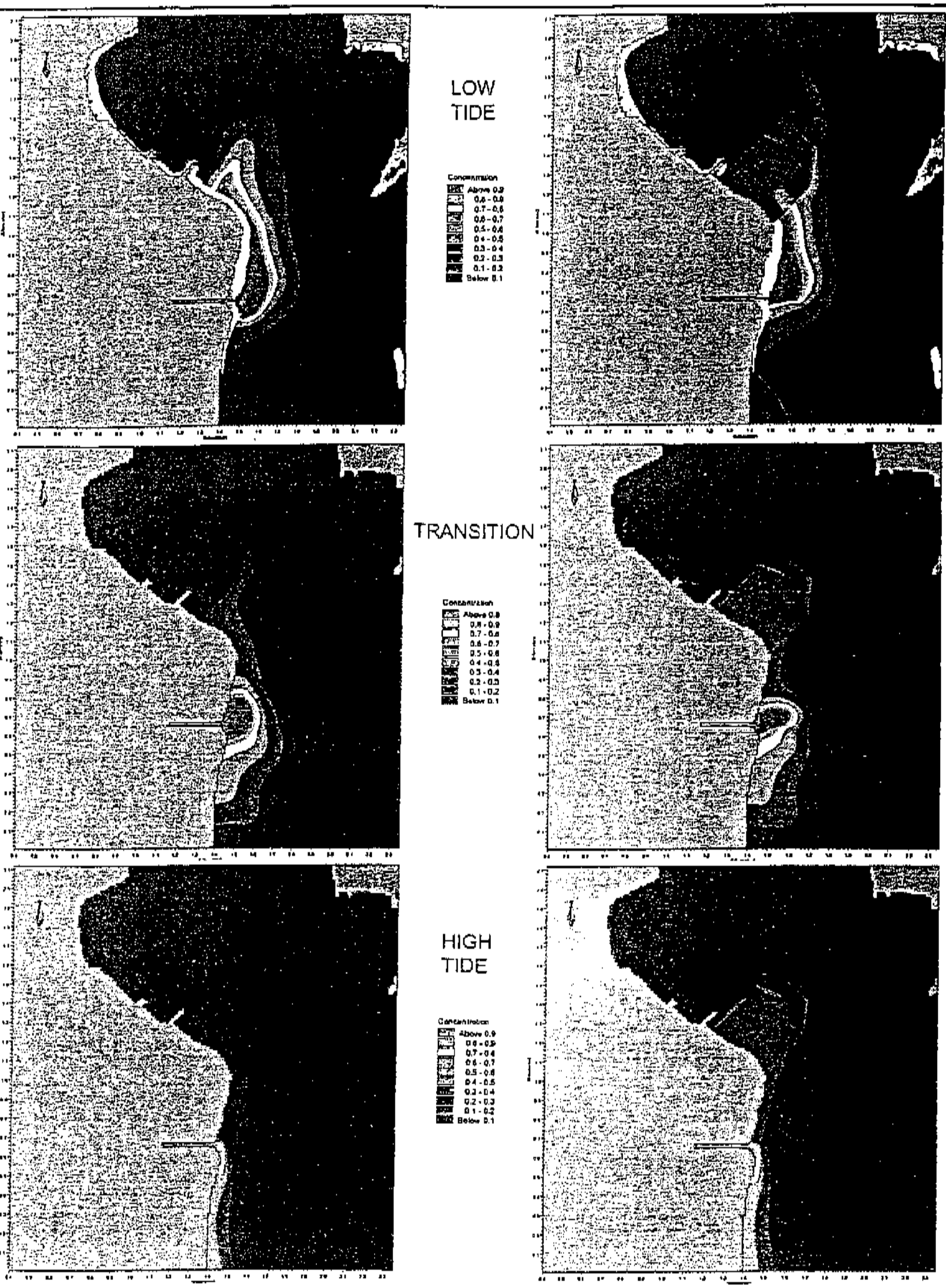

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Figure 5.3:
Comparison of Existing and Project Conditions
After 7 Days of Simulation
(Average River Flow)

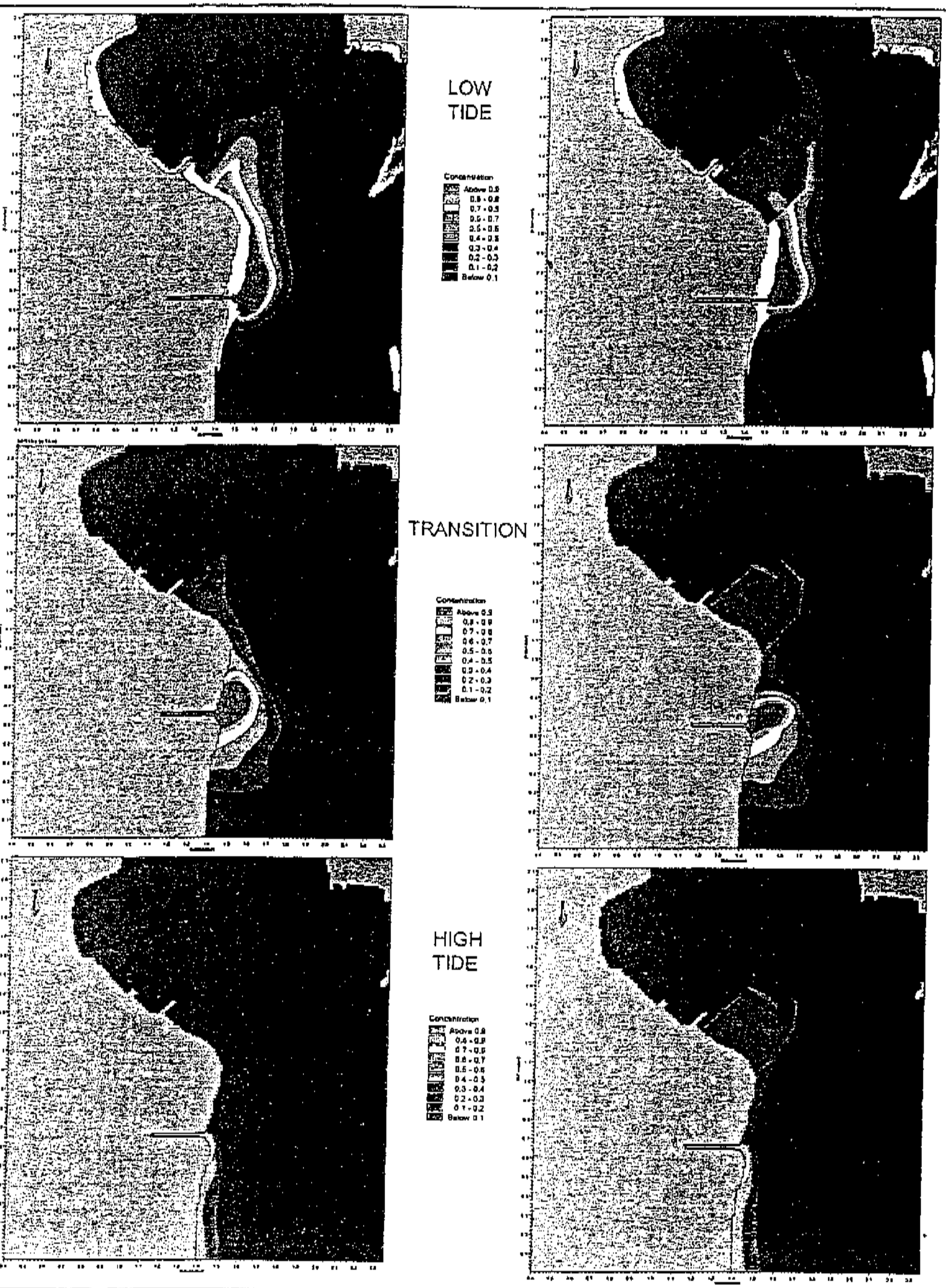

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Figure 5.4:
Comparison of Existing and Project Conditions
After 9 Days of Simulation
(Average River Flow)

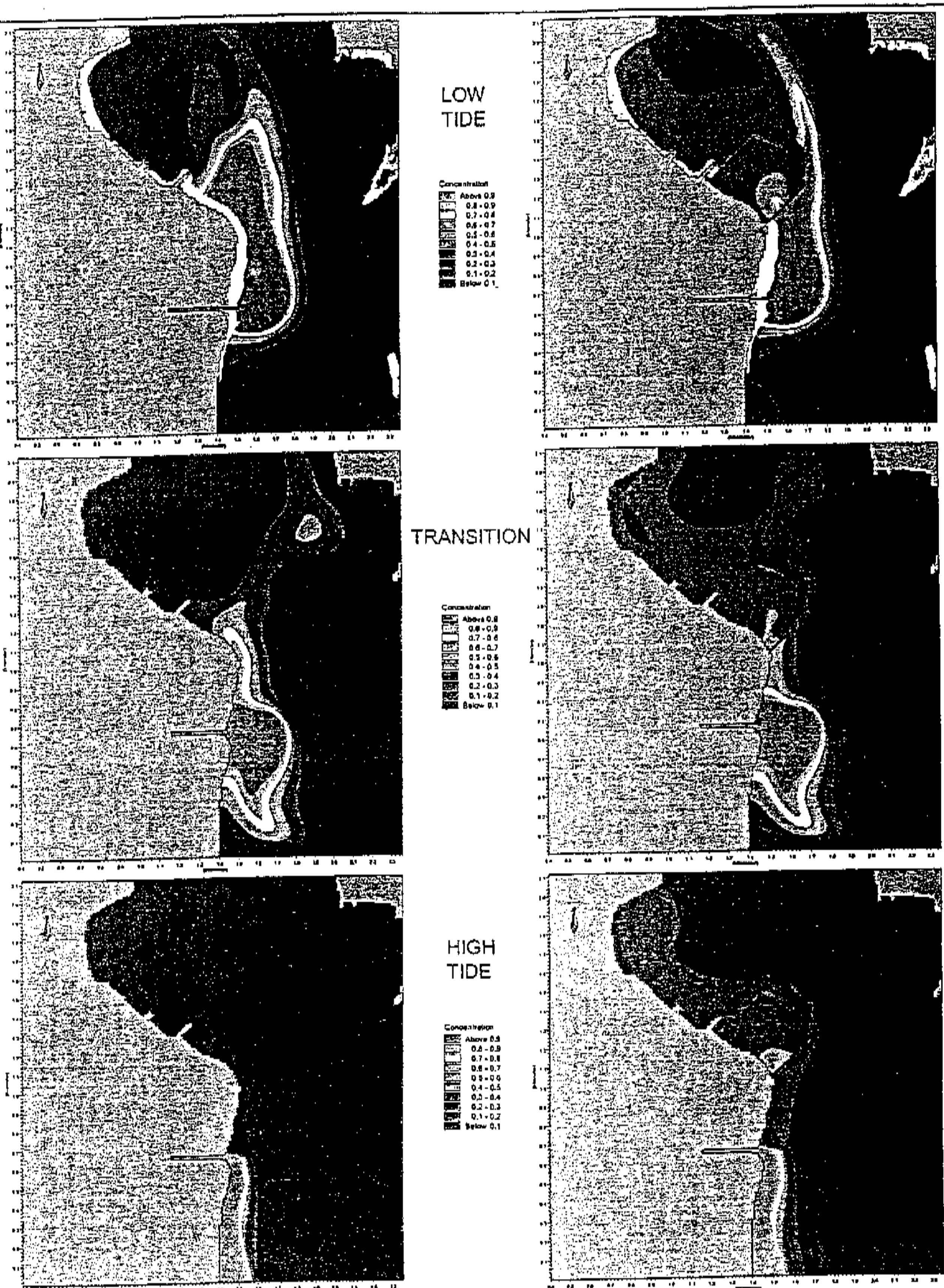

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Figure 5.5:
Comparison of Existing and Project Conditions
After 3 Days of Simulation
(Peak River Flow)

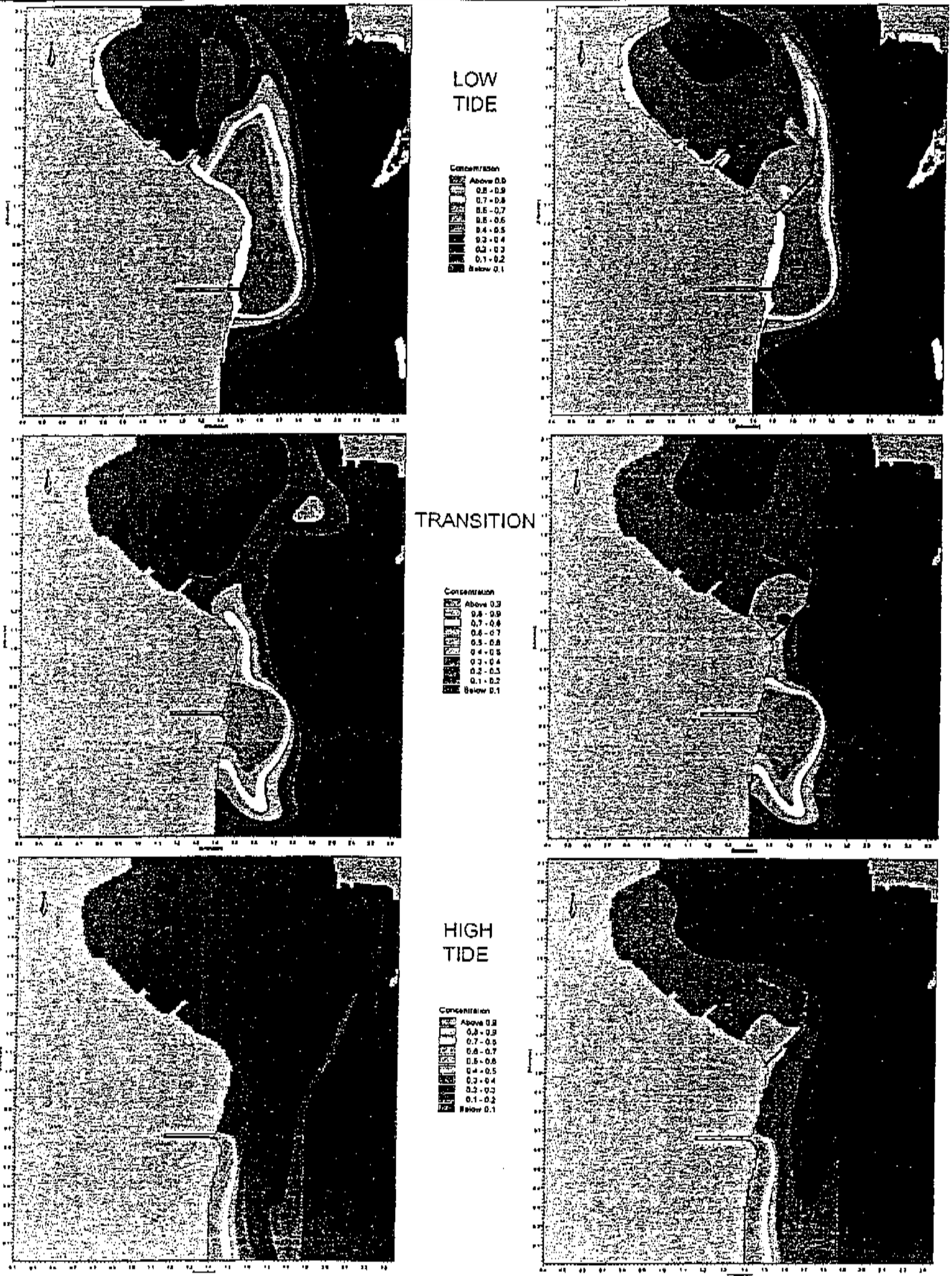

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Figure 5.6:
Comparison of Existing and Project Conditions
After 5 Days of Simulation
(Peak River Flow)

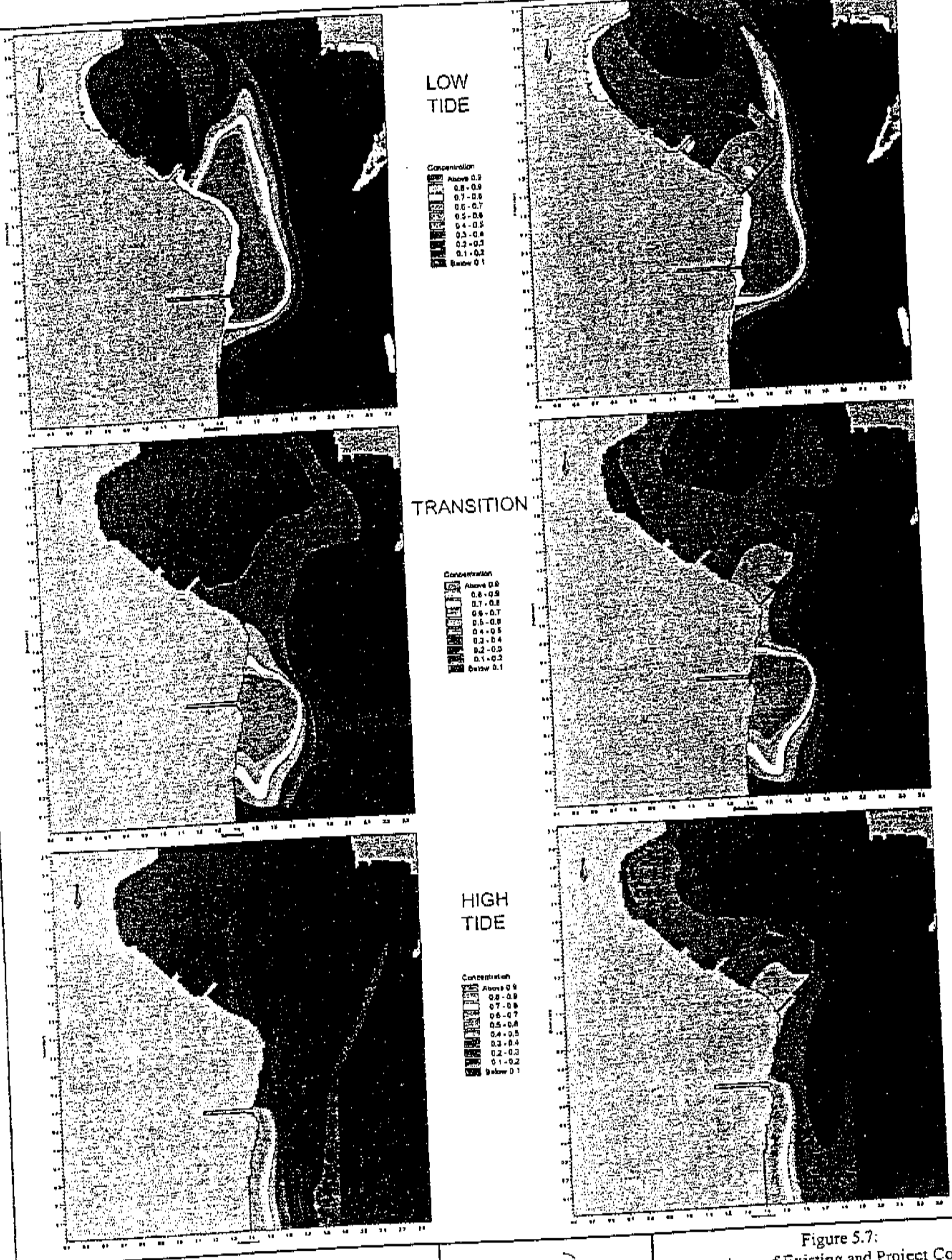

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Figure 5.7:
Comparison of Existing and Project Conditions
After 7 Days of Simulation
(Peak River Flow)

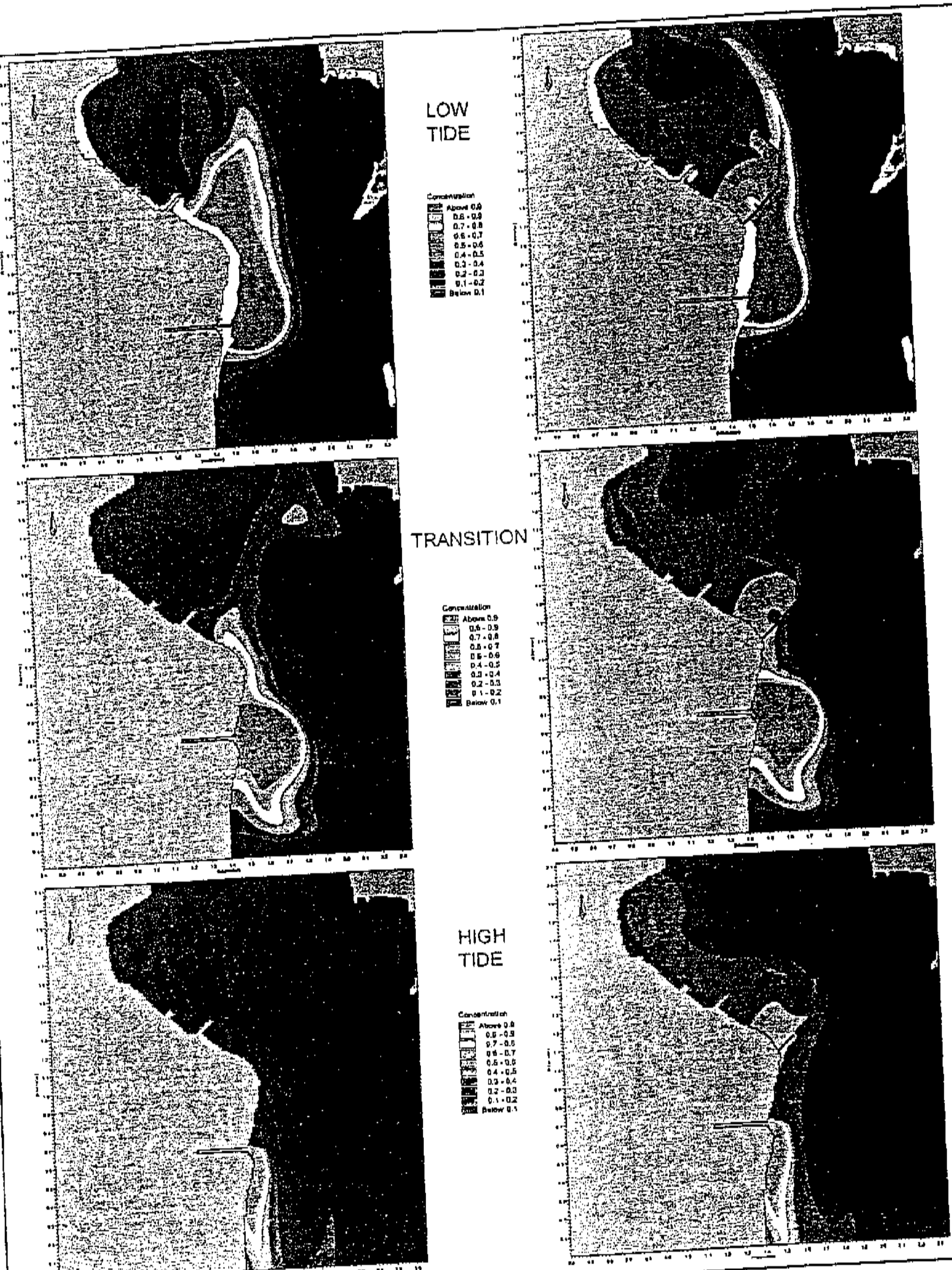

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Figure 5.8:
Comparison of Existing and Project Conditions
After 9 Days of Simulation
(Peak River Flow)

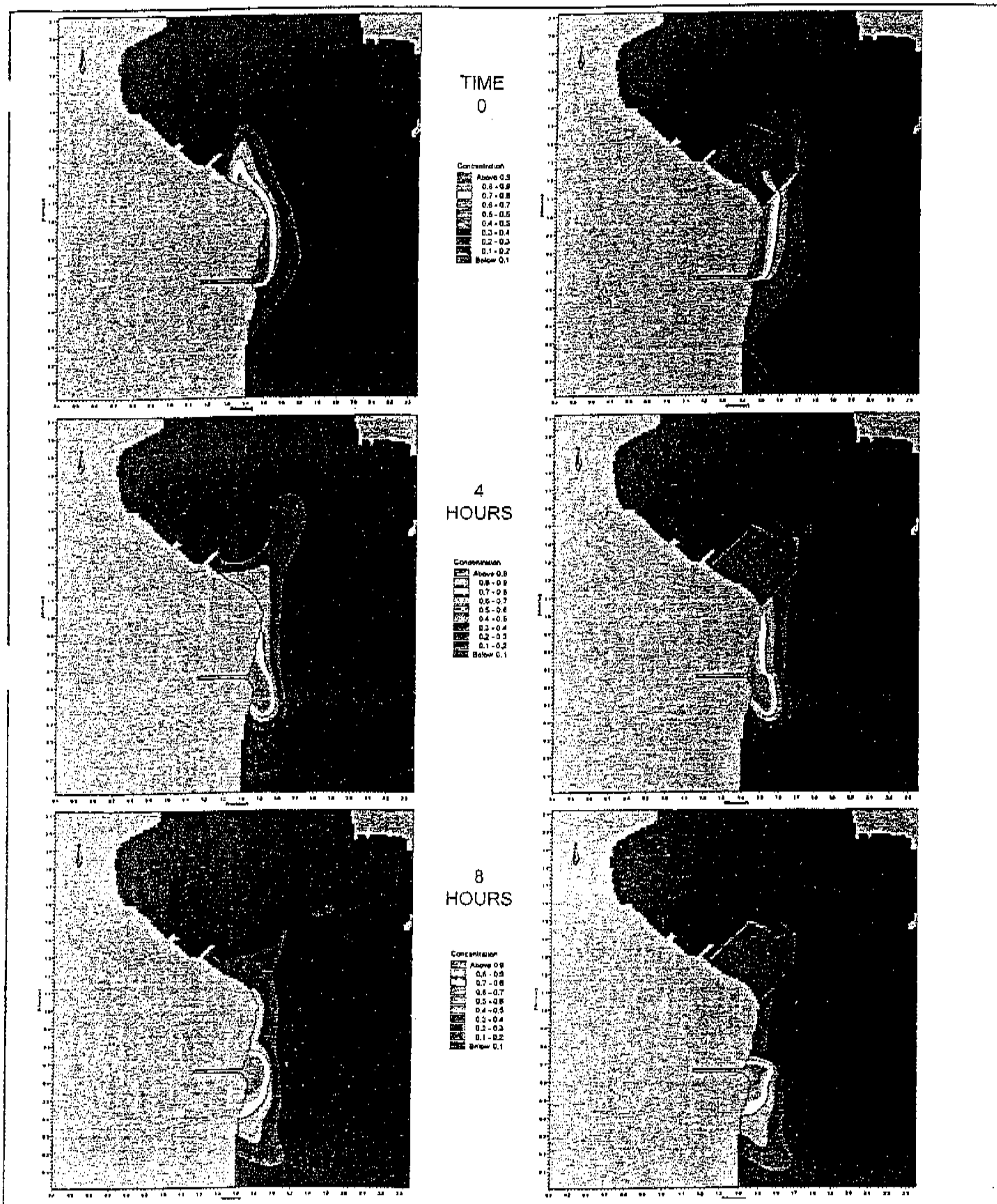

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Figure 5.9:
Comparison of Existing and Project Conditions
Over a Daily Tide Cycle
(Average River Flow)

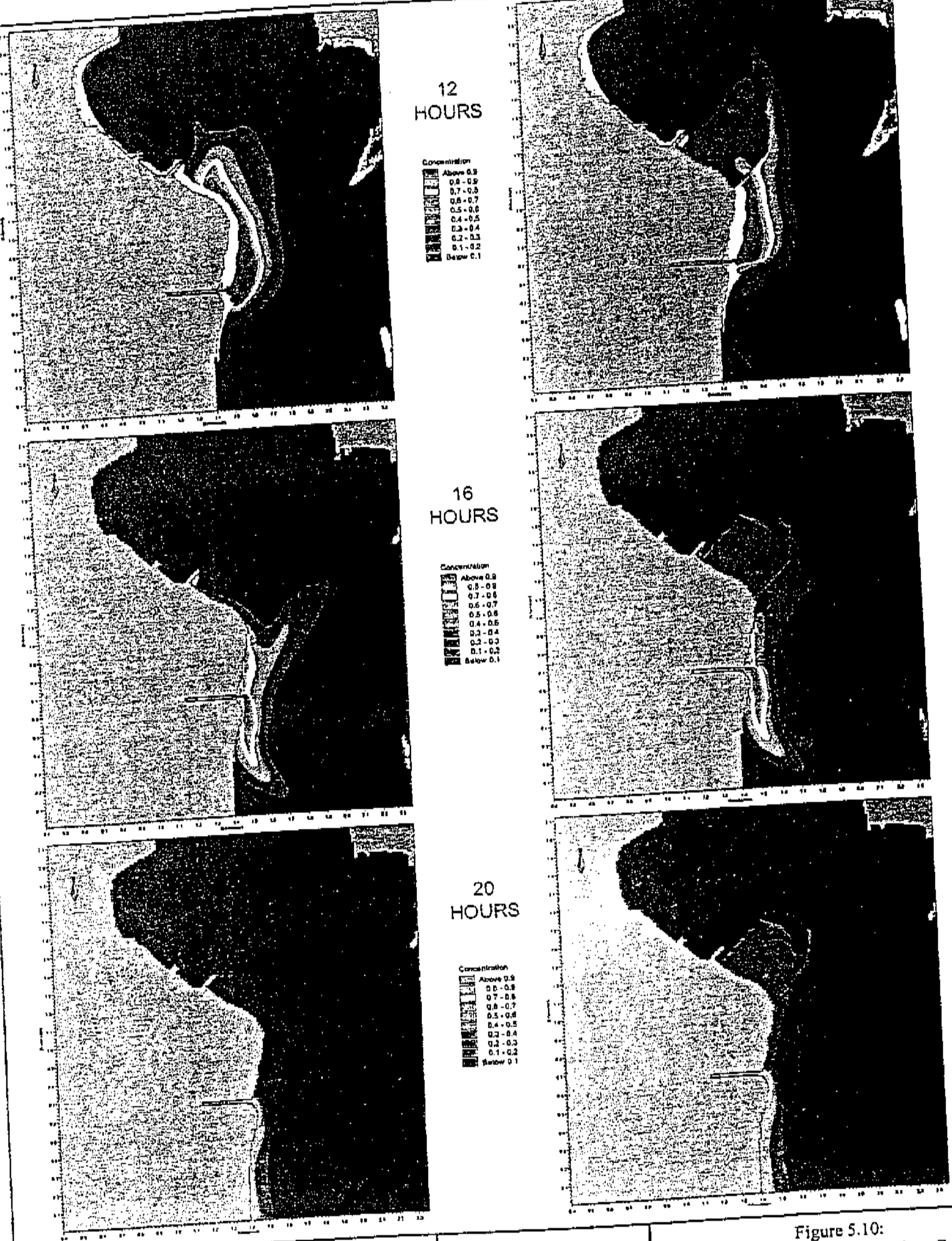

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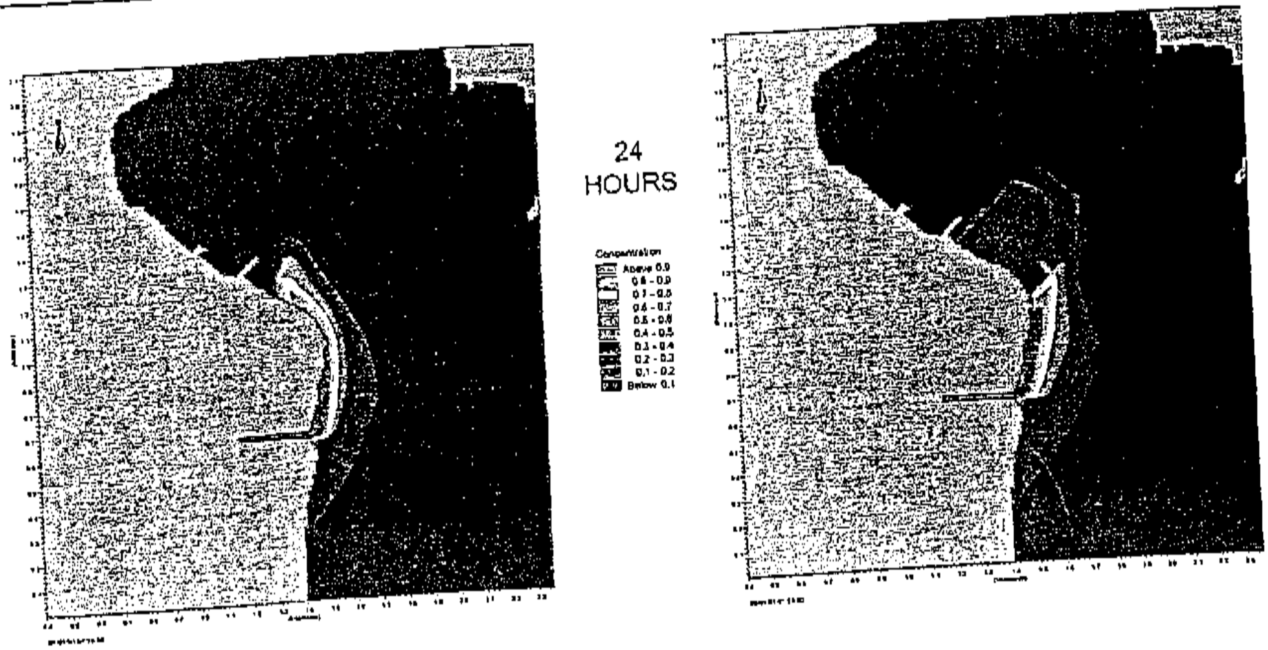
Figure 5.10:
Comparison of Existing and Project Conditions
Over a Daily Tide Cycle
(Average River Flow)



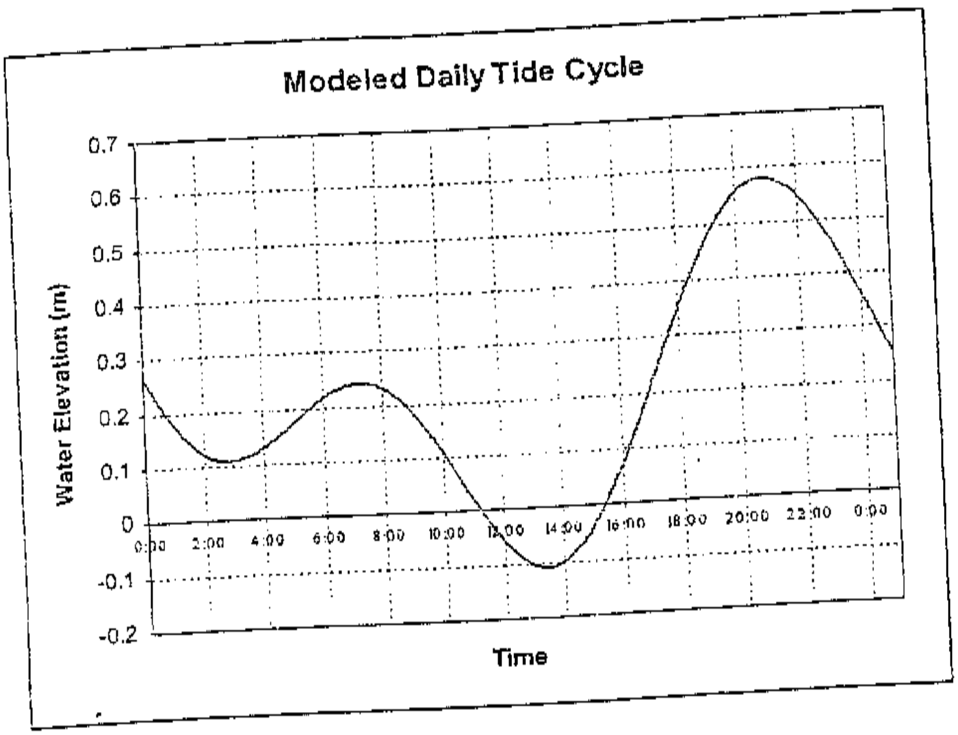


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Figure 5.11:
Comparison of Existing and Project Conditions
Over a Daily Tide Cycle
(Average River Flow)

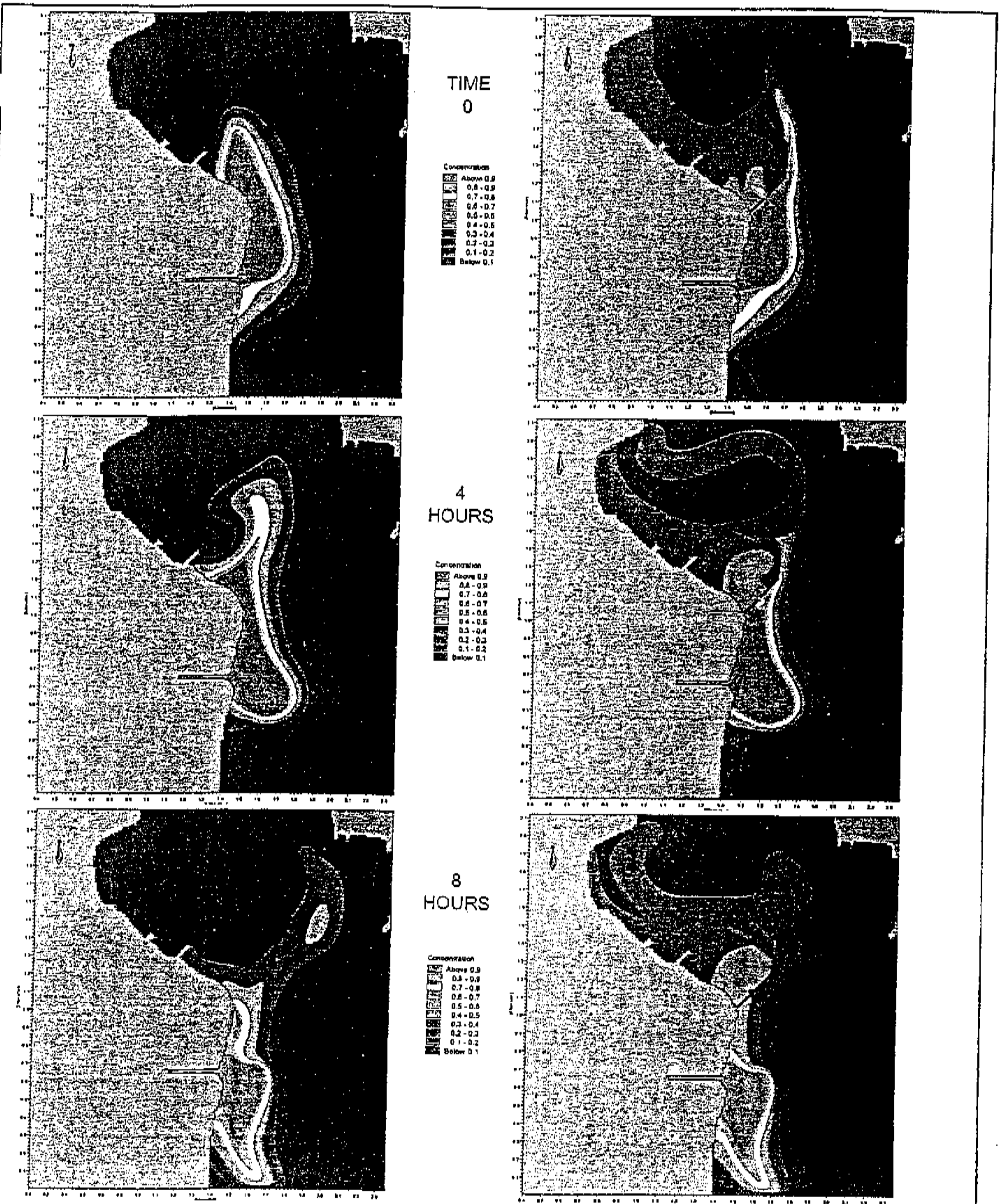

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Figure 5.12:
Comparison of Existing and Project Conditions
Over a Daily Tide Cycle
(Peak River Flow)

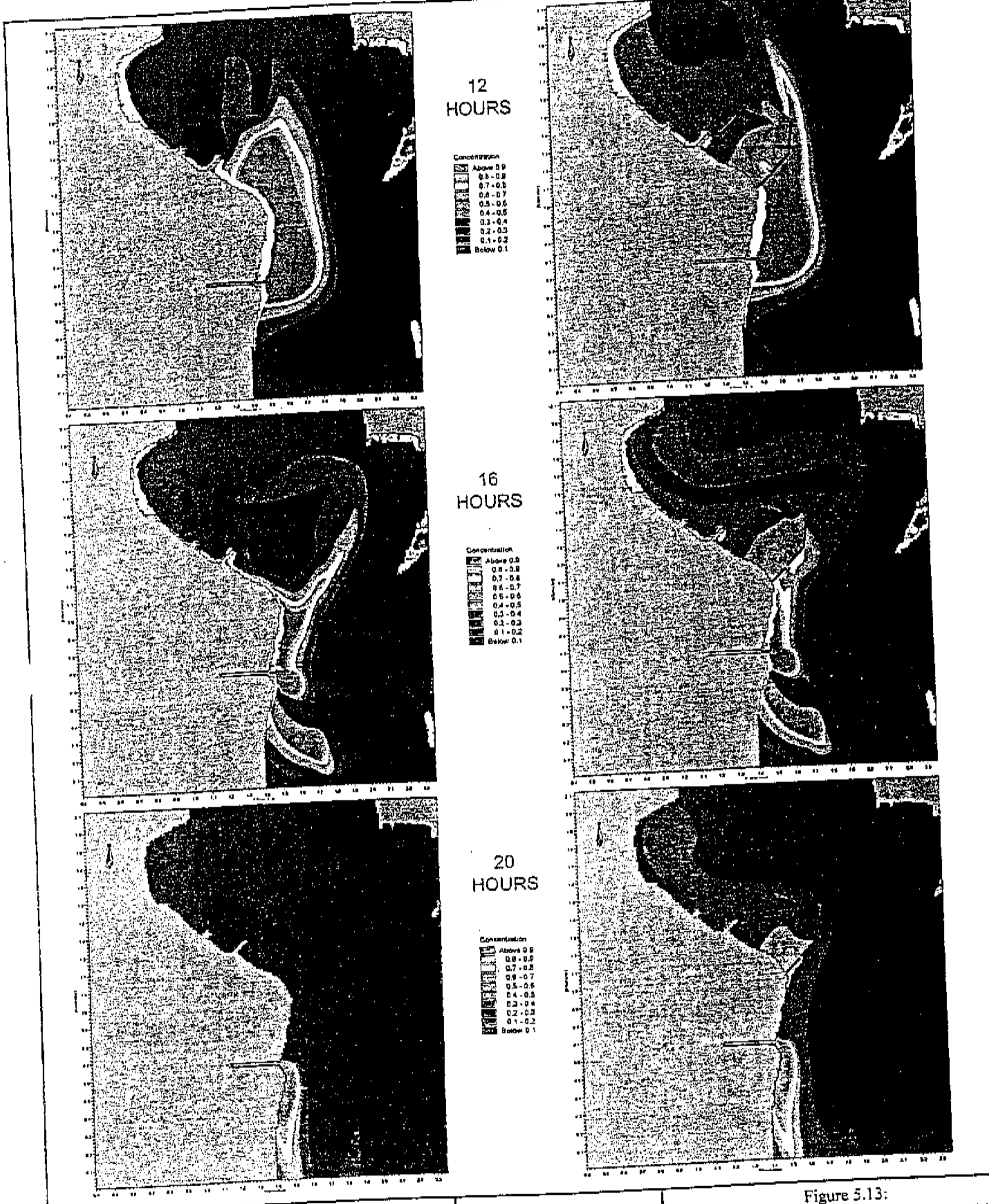

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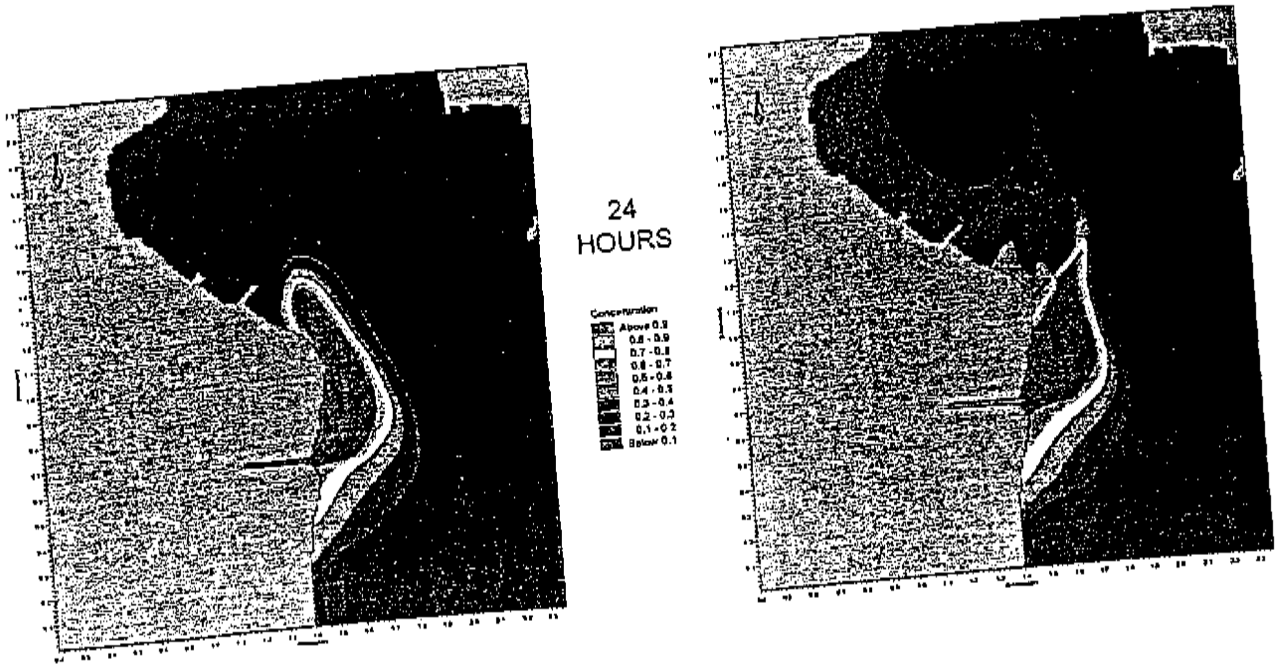
Figure 5.13:
Comparison of Existing and Project Conditions
Over a Daily Tide Cycle
(Peak River Flow)



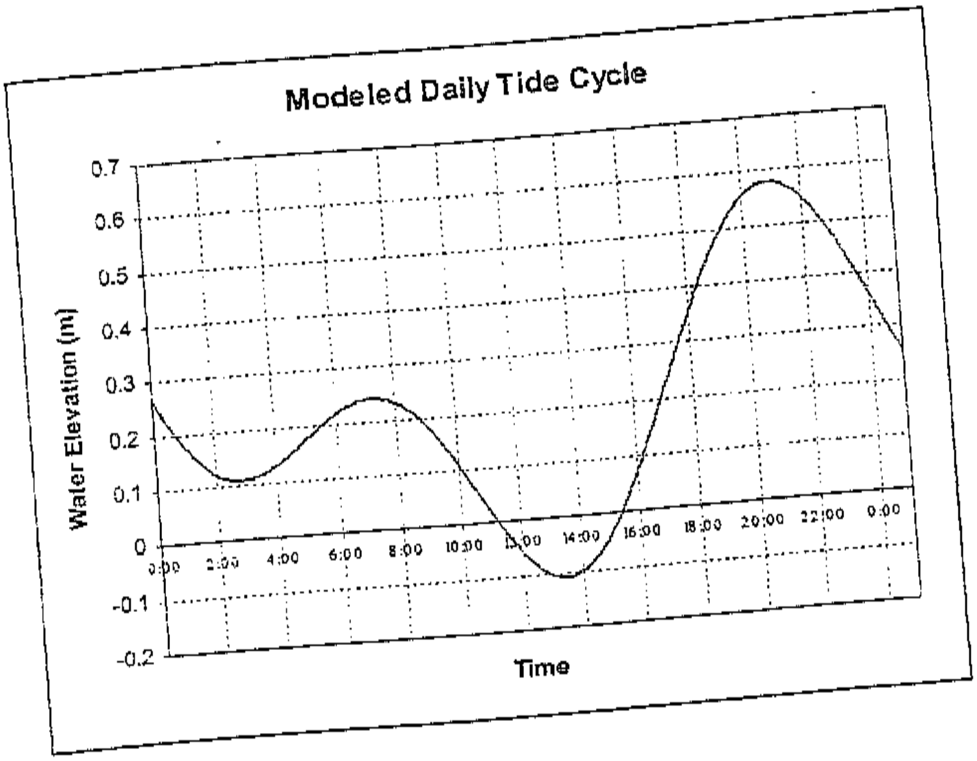


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Figure 5.14:
Comparison of Existing and Project Conditions
Over a Daily Tide Cycle
(Peak River Flow)

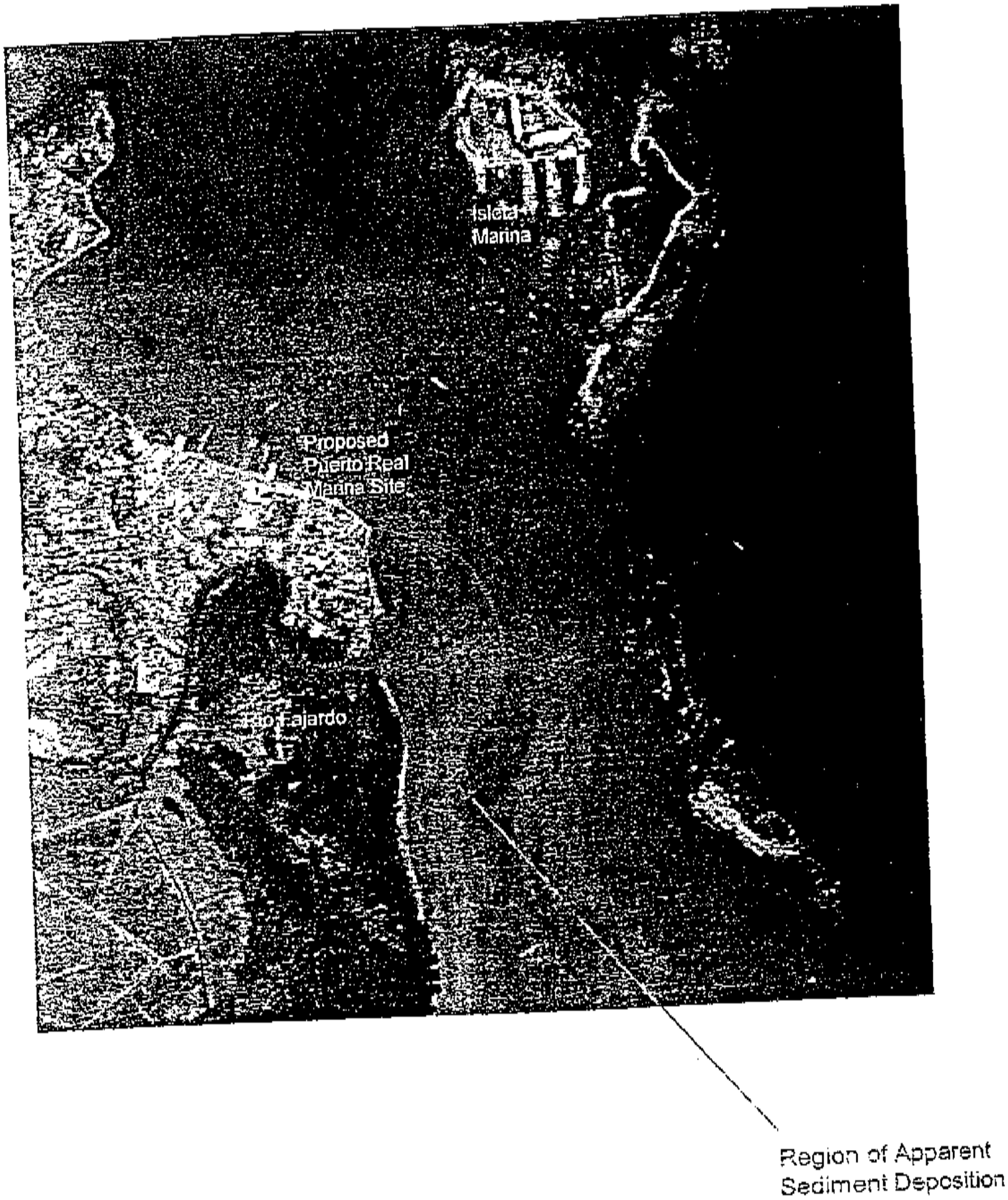

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Figure 5.15:
Aerial Photograph of Study Region

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Figure 5.16:
Transposition of Model Result
and Benthic Resources
(9 Day Simulation – Low Tide & Mean Flow)

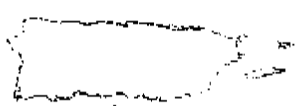

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Figure 5.17:
Transposition of Model Result
and Benthic Resources
(9 Day Simulation – Low Tide & Peak Flow)