CHAPTER C.11
WATER QUALITY MODULE

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11.1 Introduction

The description and results of the final approach used to estimate nitrogen (N) removal rates, chlorophyll a concentrations, and primary production rates as result of the different freshwater diversion alternatives proposed by the LCA program are presented in this document. The approach is based on statistical models that include a large variety of coastal ecosystems (*e.g.*, geomorphological settings) in the USA and other sites around the world. It is clear to us that the proposed rates estimated for the different processes considered in this water quality module are, at the most, preliminary first rate approximations to complex biogeochemical processes. It should be pointed out that results of the analyses do not reflect or are not aimed to establish actual "water quality" standards as could be perceived by the current name of the module.

The potential beneficial and deleterious effects of freshwater diversions on the productivity of wetlands and coastal waters in Louisiana have been widely discussed; therefore, these arguments and ideas will not be addressed in this document. For excellent reviews and descriptions of issues regarding freshwater diversions in the Missippi River, hypoxia, and eutrophication please refer to the documents by Boesch *et al.* 2001, Mitsch *et al.* 2001, Turner 2001, Rabalais *et al.* 1996, Rabalais *et al.* 2002, Goolsby 2001, and Dubravko *et al.* 2003. These documents are listed in the reference chapter.

11.2 Approach

The approach uses several published papers that discuss empirical relationships relating N-removal (Dettmann 2001, Seitzinger 2001), chlorophyll a concentrations (Boyton 996), and primary productivity versus N loading rate and water residence time (Nixon 1996). These models include N-removal/N-loading relationship for estuaries in general, and for wetland systems (Mitsch *et al* 2001). The objective was to use these relationships to generate estimates of N-removal, algal bloom potential (chlorophyll a), and aquatic primary productivity. This simplified approach was applied at the scale of entire estuarine systems. Single estimates for each estuarine system were developed (see below) and calculations for each variable were conducted. Each estimate integrates N-loading rates, freshwater water residence time, and wetland-water ratios for the entire estuarine system. As much hydrodynamic output as possible, such as salinity, water level, and water depth was incorporated. TN and NO3 loadings were estimated using mean concentrations (1983-200) in the lower Mississippi River (Dubravko 2003).

Estimates were generated for N-removal, primary productivity, and chlorophyll a for each alternative restoration scenario provided by the Corps of Engineers in each of the following regions:

1. Subprovince 1, Mississippi East (Breton/Pontchartrain)
2. Subprovince 2, Mississippi West (Barataria)
3. Subprovince 3, Terrabone, Atchafalaya and Teche/Vermillion

Subprovince 4 was not considered since no diversions are planned for this region.

11.3 Methods

Each province was subdivided into boxes based on the boundries of watersheds and other hydrological criteria (see habitat switching final report for box models distribution in each subprovince). Output from the Habitat Switch Module and the hydrodynamic models were used to compute sumaries of salinity, water level and temperature and to estimate surfaces areas and volumes for open water, marsh surface water, and marsh pond water within each box. Information from the Habitat switch module and the hydrodynamic models were merged using LCA identification per cells, which has been previously assigned (see report by John Barras. "Construction of the LCA cells database) (Figure C.11-1, 11-2). Other inputs used to estimate total nitrogen loading, N-removal, primary productivity, and chlorophyll a were diversion flow, streamflow, rainfall generated surplus, endmember salinity (see below), and nitrogen concentrations (Figure C.11-3).

Once water quality variables were estimated, suitability indexes (Figure C.11-4) were assigned to establish values from 0-1 to be used by the Benefits Group to establish ecosystem benefits measures for restoration planning and assessment. Suitability index curves for primary productivity and chlorophyll *a* were determined based on average published values measured in coastal systems throughout Louisiana (*e.g.* Madden *et al.* 1988). The suitability index curve for N-removal was represented by a linear curve since a direct relationship between the maximum suitability value (1.0) and the maximum percentage of removal (100%) was assumed (Figure C.11-4).

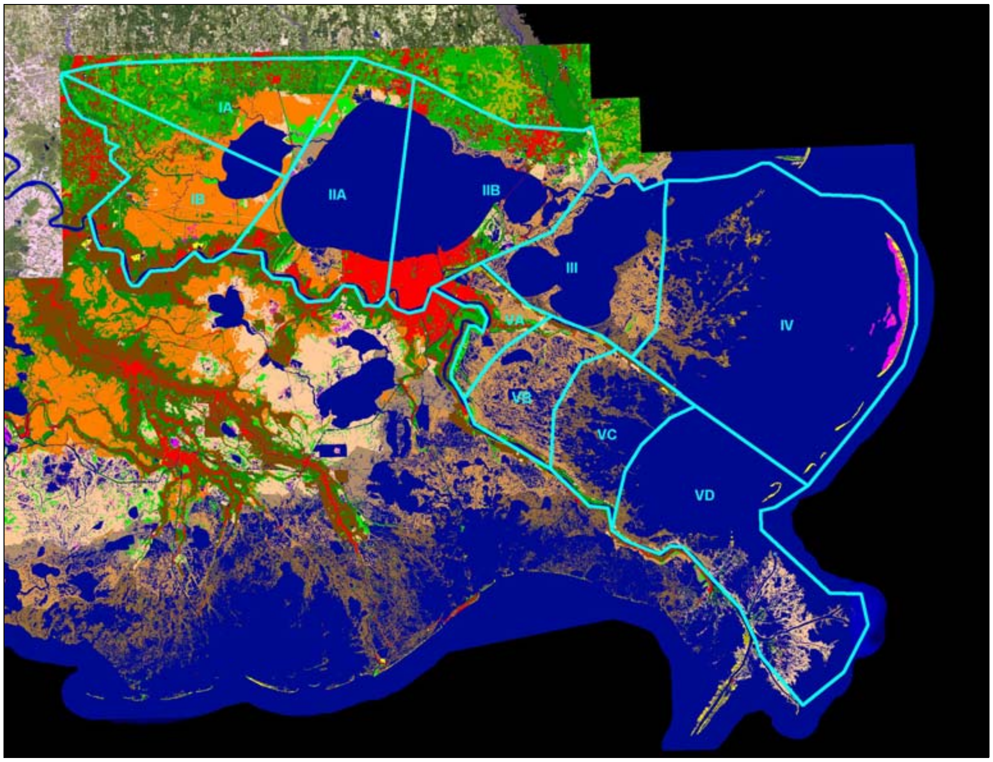

Figure C.11-1 Example of Box distribution and boundaries in subprovince 1 (Breton/Pontchartrain) used to evaluate water quality variables.

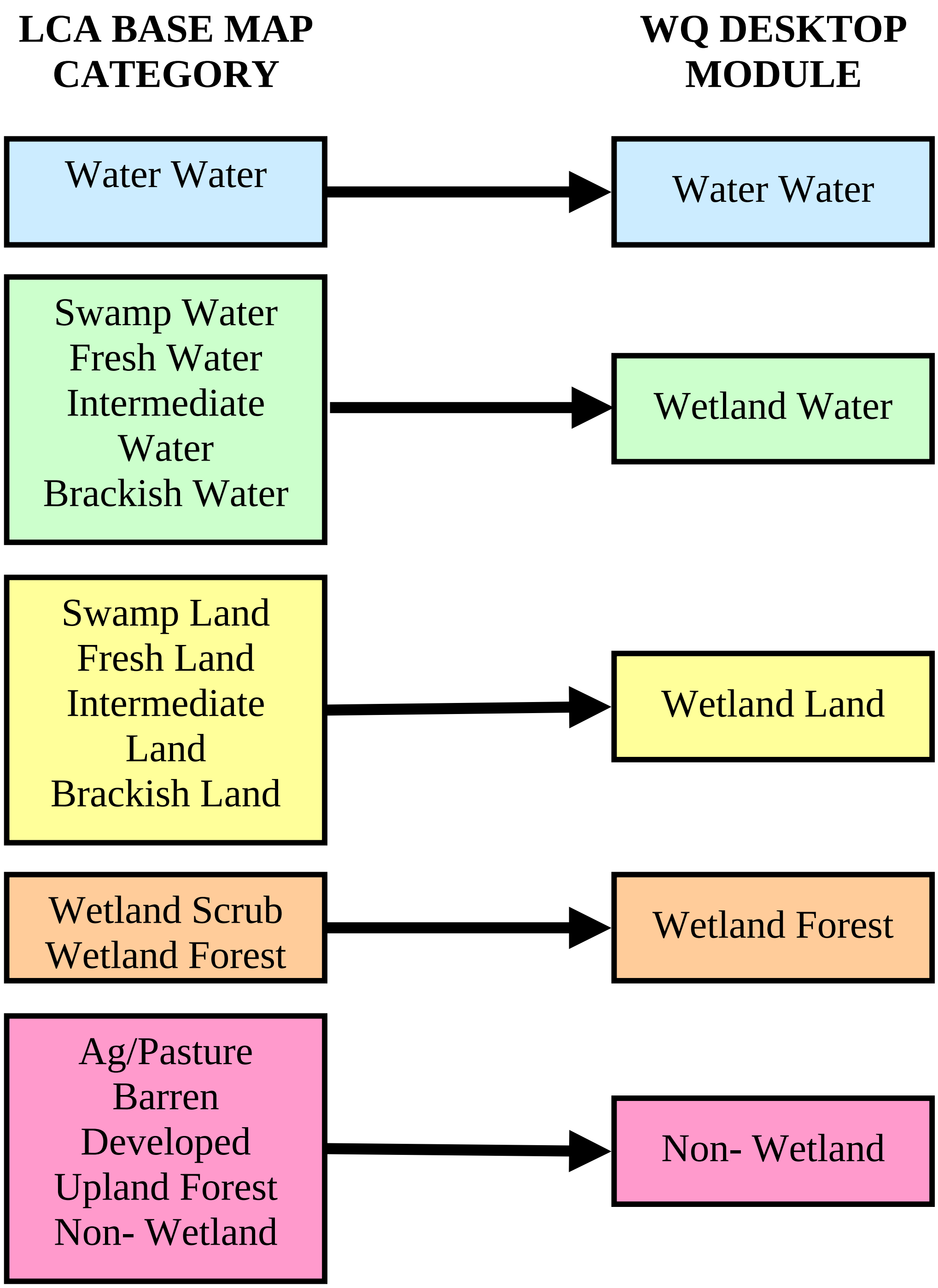

Figure C.11-.2 Initial LCA mapping categories and new categories defined to obtain the land water and volumes for the water quality module.

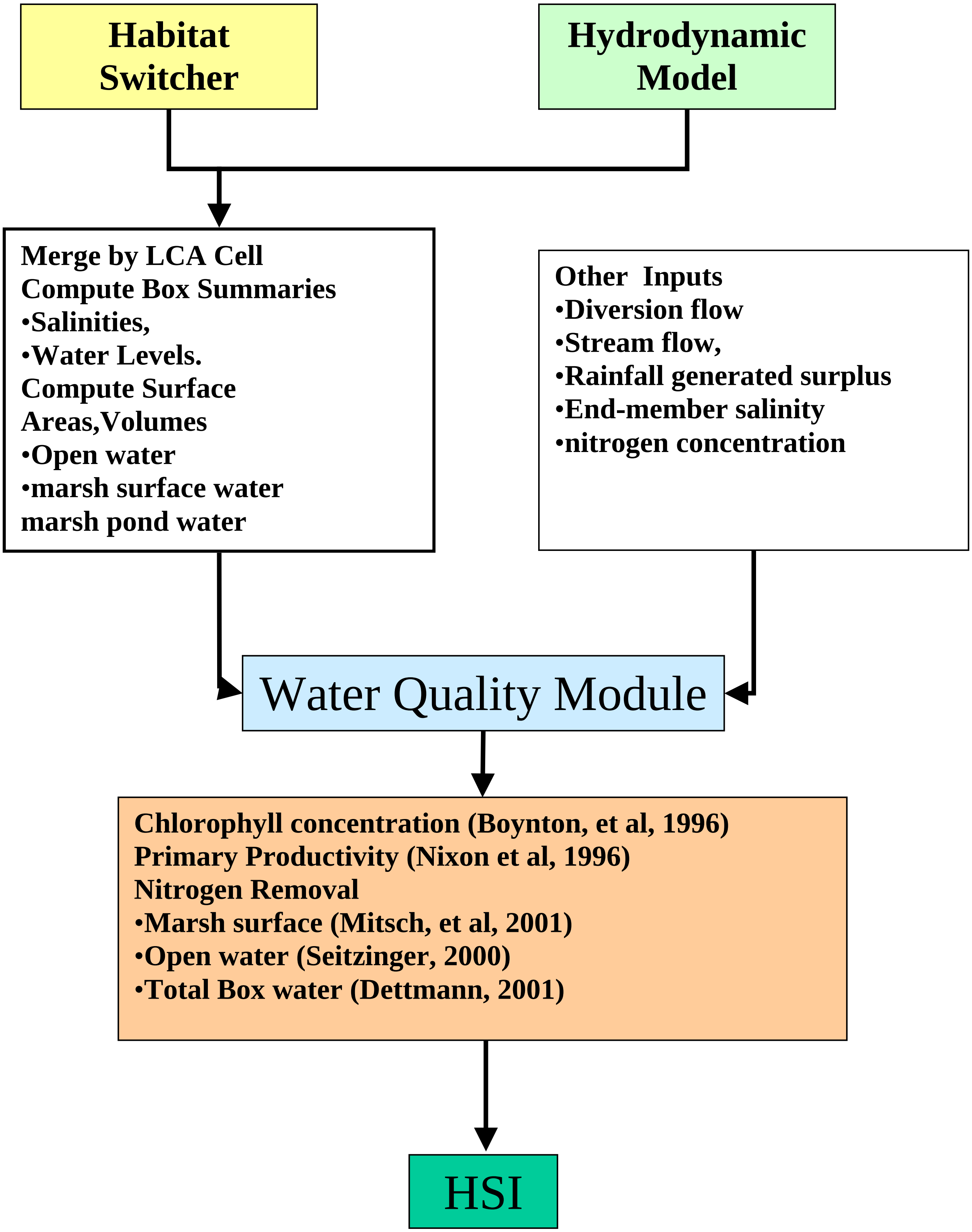

Figure C.11-3 Flow chart of the water quality module to estimate suitability indexes (HSI)

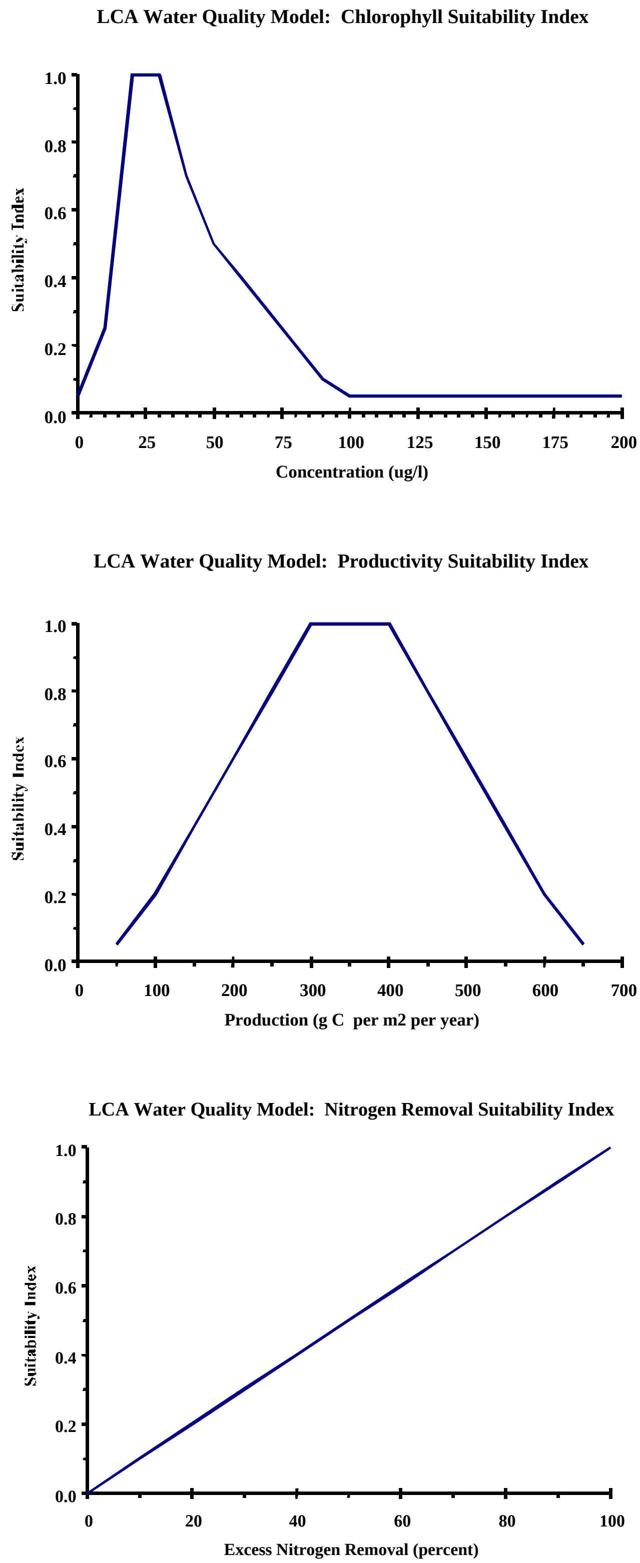

Figure C.11-4 Chlorophyll a, productivity, and nitrogen removal suitability indexes

11.4 Models

11.4.1 Inorganic N and Total Nitrogen Removal

a. Total box water (Dettmann 2001):

This approach is based on a mass balance to estimate annual N export to the sea, internal losses (*e.g.,* denitrification and burial in sediments), and concentration in the water column. This model assumes that the average rate of N loss from the water column is proportional to total nitrogen in the water column (Dettmann 2001). Loading rates are estimated based on the long term TN and inorganic nitrogen concentrations reported by Goolsby *et al.* 2001. Thus, the extent of removal depends on the loading rate of nitrogen, the residence time of freshwater, and the estuary volume. This model uses annual budgets for inorganic and TN and therefore does not estimate seasonal dynamics, for example, as in the case of organic nitrogen that is incorporated into sediments but later remineralized and returned to the water column (Dettmann 2001).

N removal by the water column was estimated using the equations proposed by Dettmann 2001:

[1]

$$F_{E(l)} = \frac{1}{1+\alpha\tau_{fw}}$$

$\alpha = first-order\_loss\_coefficient$ (range 0.23-0.36 mo^{-1})

$\tau_{fw} = freshwater\_replacement\_time$

where,

[2]

$$\tau_{fw} = \frac{S_s - S_n}{S_s}$$

$S_s = salinity\_of\_"seawater"\_entering\_the\_system$

$S_n = mean\_salinity\_in\_the\_system$

The fraction of upland N loading that is lost from the water column within the estuary is

[3]

$$F_{R(l)} = 1 - F_{E(l)}$$

and the fraction that is denitrified is:

[4]

$$F_{D(l)} = \frac{\gamma\alpha\tau_{fw}}{1+\alpha\tau_{fw}}$$

where,

[5]

$\gamma = first - order\_coefficient$ (range 0.69-0.81)

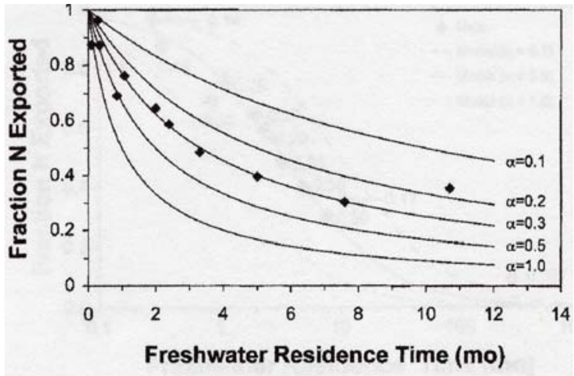

Figure C.11-5 Fraction of upland nitrogen input exported versus freshwater residence time, observation and model predictions for selected values of the first order loss coefficient (from Dettmann 2001).

b. Marsh surface, Mitsch *et al.* 2001

Nitrate removal by wetlands is estimated using the general model proposed by Mitsch *et al.* 2001. This model was developed based on data from constructed wetlands in the midwestern United States. It is assumed that when N-NO_3 is introduced to wetlands and sufficient organic carbon is available to support bacteria, high rates of denitrification can be observed (Mitsch *et al.* 2001).

The empirical model (Figure C.11-6) is:

$$y = -0.45\log(x) + 1.23$$

where, x = NO_3-N loading (g N m^{-2} yr^{-1}), and y = Percent of NO_3-N removal (by concentration)

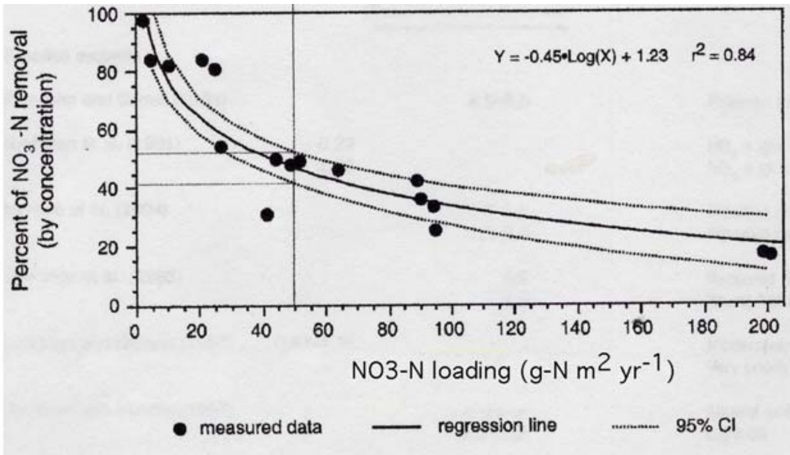

Figure C.11-6 Nitrate-nitrogen removal by mass and concentration versus nitrate-nitrogen loading for constructed wetlands in the midwestern United States (from Mitsch et al. 2001)

The wetland and estuary components are interconnected, thus a total removal rate per region was estimated. The hydrological coupling between the estuarine water column and the adjecent wetland depends on the hydroperiod, which will be affected by the planned water diversions. The frequency and duration of inundation estimated by the Habitat Switch Group was used to determine the loading rate into the wetlands.

c. Open water, Seitzinger 2000

This model assumes that 1) water residence time is an important variable determining changes in the percentage of the TN inputs that are denitrified and 2) benthic metabolism, fueled by organic matter deposition, correlates with denitrification (Figure C.11.7). Therefore, longer water residence times would result in a N molecule passing through the phytoplankton/benthic mineralizaton phytoplankton cycle more times, and thus increase the overall percentage of the N input that is denitrified (Seitzinger 2000).

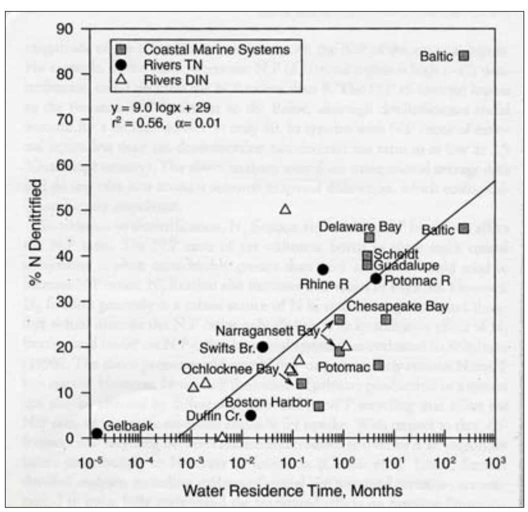

Figure C.11-7 Relationship between percentage of TN loading and removed by denitrification and water residence time in a range of coastal marine ecosystems and rivers (from Seitzinger 2001).

d. Chlorophyll Concentrations (Boynton *et al*. 1996)

Chlorophyll a concentrations were obtained using a functional regression between annual TN load and chlorophyll a concentrations using long term data for coastal bays (Boyton *et al*. 1996) (Figure C.11-8). Boyton *et al*. 1996 suggested that this type of model could be used as quantitative management tool to relate habitat conditions to nutrient loading rates. This relationship also indicates the magnitude of nitrogen loading rate reductions to potentially achieve lower chlorophyll a levels.

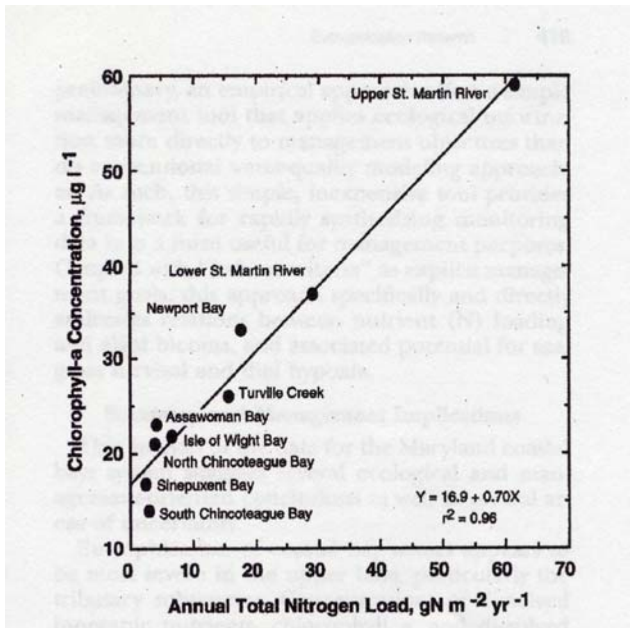

Figure C.11-8 Scatter plot relating annual areal TN loads to annual average chlorophyll *a* concentrations for several regions of the Maryland coast (from Boynton et al. 1996).

e. Primary Production (Nixon *et al.* 1996)

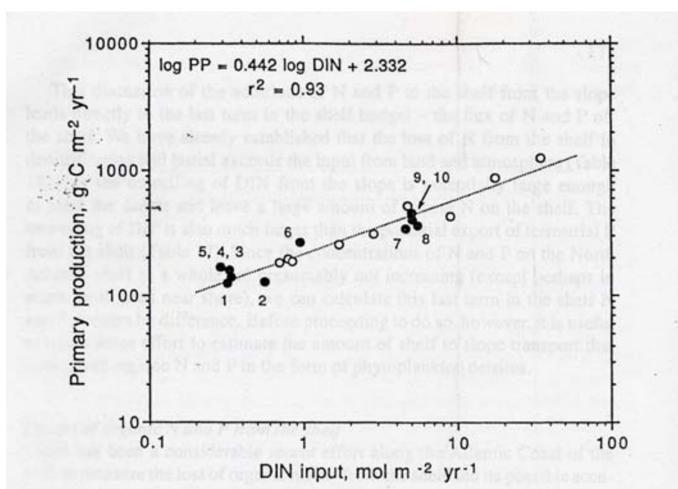

Figure C.11-9 Relationship to estimate primary production in the water column (from Nixon et al. 1996).

11.4.2 Freshwater Flushing and Depth and Elevation Variables

a. Freshwater Flushing

The flushing times estimated for the boxes in each province assume a) complete mixing of water masses and b) water that escapes during the ebb returns on the next flood tide. Thus, the flushing estimates represent "first order" estimates of the long term mean behavior of the system. Table 11-1 shows flushing times for various systems in the USA including Louisiana for comparison. Fraction of freshwater was estimated as:

$F = (S_s - S_n) / S_n$ (Freshwater fraction, Dyer 1973)

$Q_f = Q_t F$ (Freshwater volume)

where:

Q_f = Fresh Water Volume (m^3)

Q_t = Total Water Volume (m^3)

F = Fresh Water Fraction

S_s = Salinity of seawater endpoint (end member)

S_n = Mean salinity of system

Freshwater flushing rate is:

$T = Q_f / R$

Where:

T = Flushing time (seconds)

Q_f = Fresh Water Volume (m^3)

R = Fresh Water Input (m^3/s; e.g. diversion, rain, seepage)

Table C.11-1 Flushing Times in Several Coastal Systems

Study Area	Flushing	Citation	Months
Narragansett Bay, RI	0.85	Pilson 1985	
Chesapeake Bay	7.6	Nixon *et al.* 1996	
Guadalupe Estuary	1-10	Brock (as cited in Dettmann 2001	
Louisiana Estuaries			
Upper Barataria	1.3	Wiseman & Swenson 1989	
Terrebonne	2.0	Wiseman & Swenson 1989	
Barataria Bay	0.5	Park 1998	
Breton Sound	1.5	Swenson *et al.* 2002	

b. Water Distribution Among Compartments: Depth and Elevation Variables

One of the major assumptions to estimate depth and elevation was to assume that the volume flowing through the wetlands is given by the depth of water in the wetlands as estimated by the hydrodynamic models for each scenario; this approach also took into account the volume of diversion water that flows into the wetlands. Yet, how the water is actually flowing through the wetland is beyond the capability of the box model approach since it is necessary to define spatially-explicit criteria hydrologial patterns which are not included in the present modeling effort.

Figure C.11-10 shows how water level at and above marsh elevation were considered in the calculations. Previous to "flooding" "wetland water" base depth was assumed to be 30 cm. This number was modified as inundation occurred based on results from the hydrodynamic model simulations. This assumption is critical because water was above the marsh elevation, and the N removal rate was estimated using the model proposed by Seitzinger 2001; this model relates water residence time with percentage of TN loading removed by denitrification.

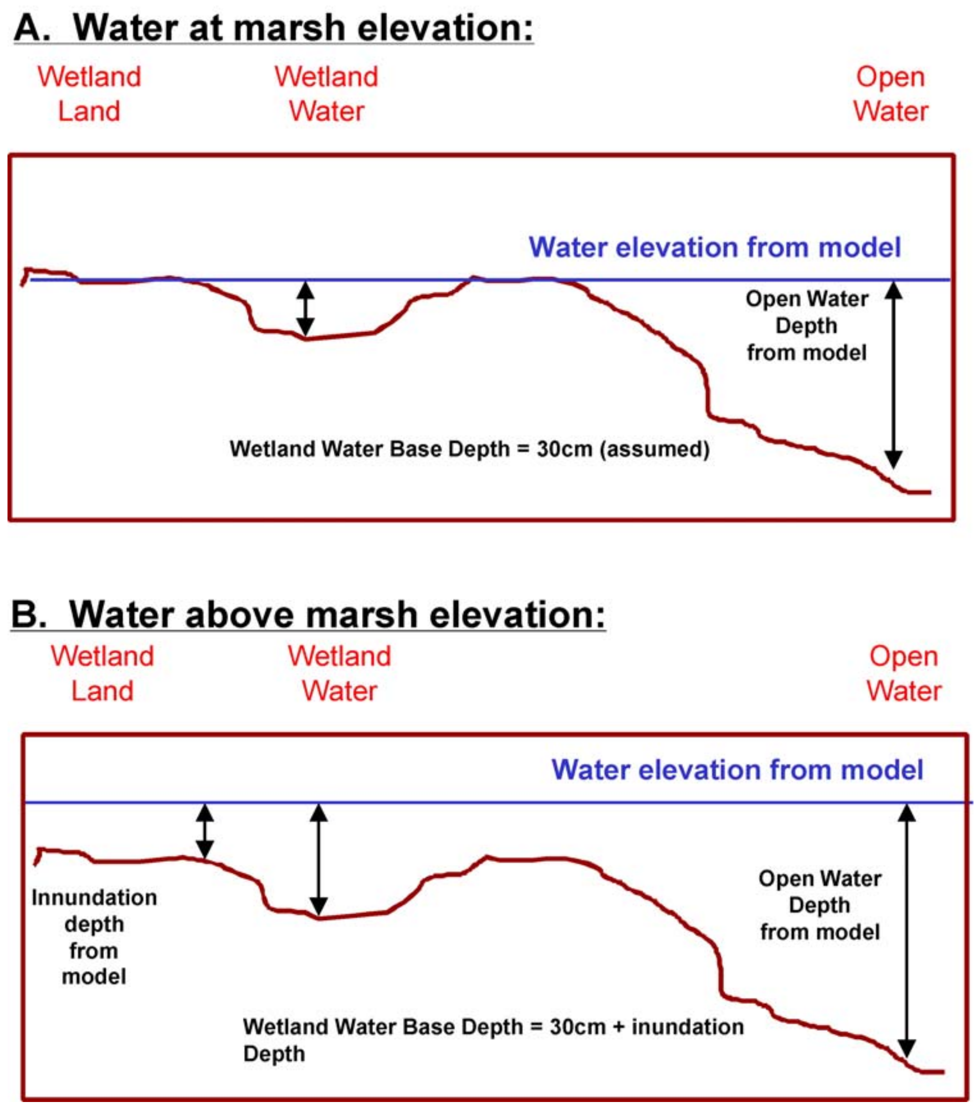

Figure C.11-10 Schematic showing changes in 'wetland water" base depth before and after inundation.

11.4.3 Subprovince Total Percentage of N Removal

Figure C.11-11 shows the overall protocol for estimation of N removal by subprovince. N removal is estimated for all boxes in relation to the actual N exported by the system. Potential evapotranspiration and stream flow was included in the hydrological calculations to correctly account for the effect of freshwater diversion in the water budget for each region.

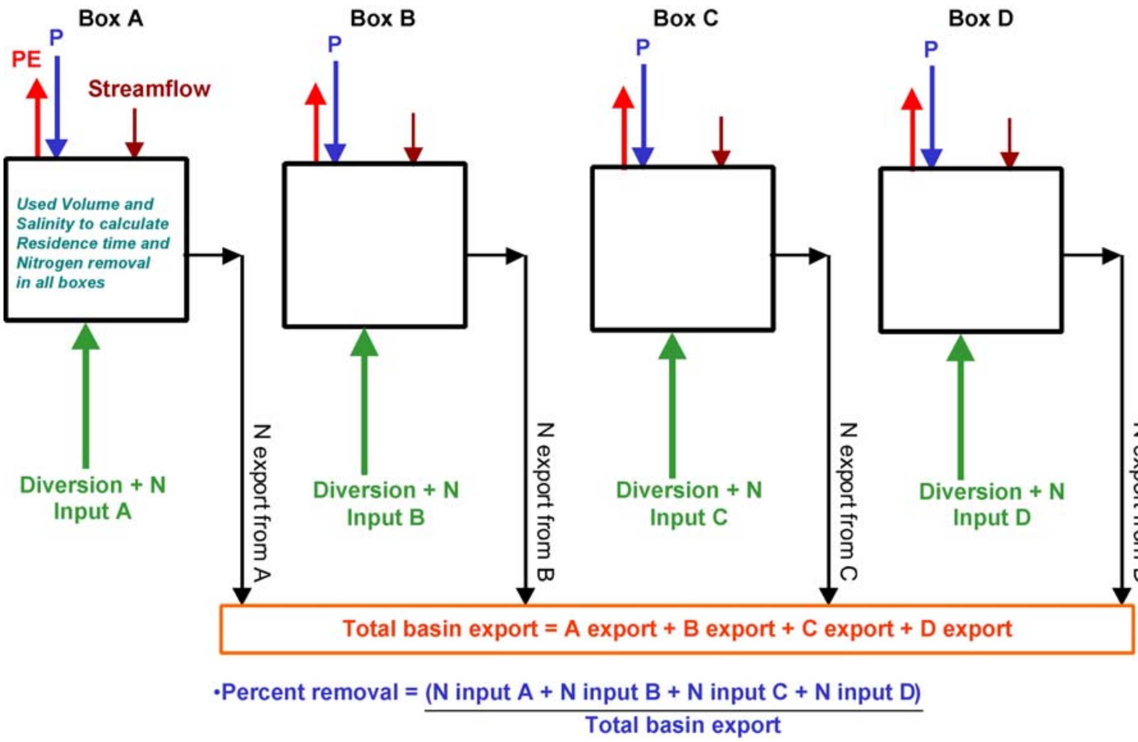

Figure C.11-11 Conceptual diagram showing the overall calculation of N removal for each subsystem (boxes) within each subprovince.

11.5 Results

Tables C.11-2 and C.11-3 show final results for Subprovinces 1 and 2. Although the suitability indexes were estimated for each box within each province, a geometric mean was computed to weight all values and obtain a single index per diversion scenario (TableC.11-4). Figure C.11-12 indicates the percentage of total wetland nitrogen removal per province and scenario. The total N removal was estimated using Mitsch *et al*. 2001 and Seitzinger 2001 models.

These results are discussed in the context of the Benefits Work Group (see respective chapter).

Table C.11-2 Suitability Indices for Subprovince 1 (Mississippi East (Breton))

Alternative Information			Desktop Model Predictions						Suitability Indices (0-1)					Geometric Mean Suitability Indices (0-1)				
Prov	Sceanario	Box	Desktop WQ model Total nitrogen load (metric t/yr)	Nixon et al (1996) Open water Primary Production (g C m-2 yr-1)	Boynton et al (1996) Open water Chl_a (µg L-1)	Mitsch et al (1999) Wetland water nitrogen removal (%/yr)	Dettmann (2002) Total box nitrogen removal (%/yr)	Seitzinger (2000) Open water nitrogen removal (%/yr)	Primary Prod	Chlor	Wetland water nitrogen removal	Total box water nitrogen removal	Open water nitrogen removal	Primary Prod	Chlor	Wetland water nitrogen removal	Total box water nitrogen removal	Open water nitrogen removal
1	BASE	IA	233	39.4	17.1	156.4	79.3	36.4	0.05	1.00	1.56	0.79	0.36	0.12	0.65	1.16	0.65	0.36
1	BASE	IB	2,944	89.5	18.3	120.1	45.3	31.5	0.20	1.00	1.20	0.45	0.31					
1	BASE	IIA	2,821	120.2	19.5	107.1	80.8	38.6	0.40	1.00	1.07	0.81	0.39					
1	BASE	IIB	359	54.5	17.3	142.0	97.6	41.5	0.20	1.00	1.42	0.98	0.42					
1	BASE	IIIA	20,670	526.9	91.5	41.7	22.2	28.4	0.20	0.05	0.42	0.22	0.28					
1	BASE	IIIB	153	41.0	17.1	154.6	93.9	40.8	0.05	1.00	1.55	0.94	0.41					
1	BASE	IV	154	38.0	17.1	158.0	82.6	39.7	0.05	1.00	1.58	0.83	0.40					
1	R01	IA	233	39.4	17.1	156.4	79.4	36.4	0.05	1.00	1.56	0.79	0.36	0.08	0.42	0.58	0.59	0.36
1	R01	IB	7,090	132.0	20.2	102.9	30.7	29.2	0.20	1.00	1.03	0.31	0.29					
1	R01	IIA	12,662	233.5	28.7	77.7	53.7	34.1	0.05	0.05	0.01	0.54	0.34					
1	R01	IIB	359	54.5	17.3	142.0	98.0	41.6	0.05	1.00	1.42	0.98	0.42					
1	R01	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	R01	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	R01	IV	154	38.0	17.1	158.0	90.7	41.3	0.05	1.00	1.58	0.91	0.41					
1	R02	IA	233	39.4	17.1	156.4	79.5	36.4	0.05	1.00	1.56	0.80	0.36	0.08	0.28	0.57	0.57	0.36
1	R02	IB	13,956	178.0	23.3	89.7	21.0	27.1	0.05	0.05	0.90	0.21	0.27					
1	R02	IIA	12,662	233.5	28.7	77.7	53.8	34.1	0.05	0.05	0.01	0.54	0.34					
1	R02	IIB	359	54.5	17.3	142.0	98.1	41.6	0.20	1.00	1.42	0.98	0.42					
1	R02	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	R02	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	R02	IV	154	38.0	17.1	158.0	107.2	45.4	0.05	1.00	1.58	1.07	0.45					
1	R03	IA	233	39.4	17.1	156.4	79.5	36.4	0.05	1.00	1.56	0.80	0.36	0.17	0.62	0.58	0.64	0.37
1	R03	IB	8,188	140.6	20.7	100.1	28.9	28.8	1.00	0.70	1.00	0.29	0.29					
1	R03	IIA	2,567	115.3	19.3	108.9	82.7	39.0	0.40	1.00	0.01	0.83	0.39					
1	R03	IIB	359	54.5	17.3	142.0	97.8	41.6	0.20	1.00	1.42	0.98	0.42					
1	R03	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	R03	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	R03	IV	154	38.0	17.1	158.0	107.9	45.5	0.05	1.00	1.58	1.08	0.45					
1	M01	IA	233	39.4	17.1	156.4	79.4	36.4	0.05	1.00	1.56	0.79	0.36	0.07	0.42	0.58	0.60	0.36
1	M01	IB	7,090	132.0	20.2	102.9	30.7	29.2	0.05	1.00	1.03	0.31	0.29					
1	M01	IIA	12,662	233.5	28.7	77.7	53.7	34.1	0.05	0.05	0.01	0.54	0.34					
1	M01	IIB	359	54.5	17.3	142.0	98.0	41.6	0.05	1.00	1.42	0.98	0.42					
1	M01	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	M01	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	M01	IV	154	38.0	17.1	158.0	107.2	45.4	0.05	1.00	1.58	1.07	0.45					
1	M02	IA	233	39.4	17.1	156.4	79.6	36.4	0.05	1.00	1.56	0.80	0.36	0.09	0.42	0.58	0.61	0.36
1	M02	IB	9,810	152.3	21.4	96.6	26.0	28.3	0.05	0.05	0.97	0.26	0.28					
1	M02	IIA	2,567	115.3	19.3	108.9	82.7	39.0	0.40	1.00	0.01	0.83	0.39					
1	M02	IIB	359	54.5	17.3	142.0	97.8	41.6	0.05	1.00	1.42	0.98	0.42					
1	M02	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	M02	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	M02	IV	154	38.0	17.1	158.0	90.7	41.3	0.05	1.00	1.58	0.91	0.41					
1	M03	IA	233	39.4	17.1	156.4	79.9	36.5	0.05	1.00	1.56	0.80	0.36	0.13	0.40	0.58	0.58	0.36
1	M03	IB	8,188	140.6	20.7	100.1	29.1	28.9	1.00	0.70	1.00	0.29	0.29					
1	M03	IIA	27,804	330.5	42.9	62.3	36.6	31.5	0.05	0.05	0.01	0.37	0.31					
1	M03	IIB	359	54.5	17.3	142.0	100.3	42.1	0.20	1.00	1.42	1.00	0.42					
1	M03	IIIA	20,670	526.9	91.5	41.7	25.7	29.0	0.40	0.05	0.42	0.26	0.29					
1	M03	IIIB	153	41.0	17.1	154.6	95.1	41.9	0.05	1.00	1.55	0.95	0.42					
1	M03	IV	154	38.0	17.1	158.0	110.6	46.1	0.05	1.00	1.58	1.11	0.46					
1	E01	IA	233	39.4	17.1	156.4	79.8	36.4	0.05	1.00	1.56	0.80	0.36	0.08	0.28	0.58	0.56	0.36
1	E01	IB	11,236	161.7	22.1	94.0	24.0	27.8	0.05	0.05	0.94	0.24	0.28					
1	E01	IIA	27,804	330.5	42.9	62.3	36.2	31.4	0.05	0.05	0.01	0.36	0.31					
1	E01	IIB	359	54.5	17.3	142.0	99.5	41.9	0.20	1.00	1.42	1.00	0.42					
1	E01	IIIA	20,670	526.9	91.5	41.7	23.7	28.7	0.40	0.05	0.42	0.24	0.29					
1	E01	IIIB	153	41.0	17.1	154.6	95.0	41.4	0.05	1.00	1.55	0.95	0.41					
1	E01	IV	154	38.0	17.1	158.0	108.5	45.6	0.05	1.00	1.58	1.08	0.46					
1	E02	IA	116	39.4	17.1	156.4	80.2	36.5	0.05	1.00	1.56	0.80	0.37	0.08	0.28	0.56	0.51	0.35
1	E02	IB	12,483	230.2	28.4	78.3	12.3	25.0	0.05	0.05	0.78	0.12	0.25					
1	E02	IIA	27,804	330.5	42.9	62.3	37.0	31.5	0.05	0.05	0.01	0.37	0.32					
1	E02	IIB	359	54.5	17.3	142.0	101.8	42.4	0.20	1.00	1.42	1.02	0.42					
1	E02	IIIA	20,670	526.9	91.5	41.7	27.4	29.4	0.40	0.05	0.42	0.27	0.29					
1	E02	IIIB	153	41.0	17.1	154.6	91.2	42.3	0.05	1.00	1.55	0.91	0.42					
1	E02	IV	154	38.0	17.1	158.0	102.5	44.1	0.05	1.00	1.58	1.02	0.44					
1	E03	IA	233	39.4	17.1	156.4	79.9	36.5	0.05	1.00	1.56	0.80	0.36	0.09	0.28	0.57	0.55	0.36
1	E03	IB	15,382	185.8	24.0	87.8	19.8	26.8	0.05	0.05	0.88	0.20	0.27					
1	E03	IIA	27,804	330.5	42.9	62.3	36.6	31.5	0.05	0.05	0.01	0.37	0.31					
1	E03	IIB	359	54.5	17.3	142.0	100.4	42.1	0.30	1.00	1.42	1.00	0.42					
1	E03	IIIA	20,670	526.9	91.5	41.7	25.7	29.0	0.40	0.05	0.42	0.26	0.29					
1	E03	IIIB	153	41.0	17.1	154.6	95.1	41.9	0.05	1.00	1.55	0.95	0.42					
1	E03	IV	154	38.0	17.1	158.0	110.6	46.1	0.05	1.00	1.58	1.11	0.46					

Table C.11-3 Suitability indexes Indices for Subprovince 1 West (Pontchartrain)

Alternative Information			Desktop Model Predictions						Suitability Indices (0-1)					Geometric Mean Suitability Indices (0-1)				
Prov	Sceanario	Box	Desktop WQ model Total nitrogen load metric t/yr	Nixon et al (1996) Open water Primary Production (g C m-2 yr-1)	Boynton et al (1996) Open water Chl_a (µg L-1)	Mitsch et al (1999) Wetland water nitrogen removal (%/yr)	Dettmann (2002) Total box nitrogen removal (%/yr)	Seitzinger (2000) Open water nitrogen removal (%/yr)	Primary Prod	Chlor	Wetland water nitrogen removal	Total box water nitrogen removal	Open water nitrogen removal	Primary Prod	Chlor	Wetland water nitrogen removal	Total box water nitrogen removal	Open water nitrogen removal
1	BASE	IA	233	39.4	17.1	156.4	79.3	36.4	0.05	1.00	1.56	0.79	0.36	0.12	0.65	1.16	0.65	0.36
1	BASE	IB	2,944	89.5	18.3	120.1	45.3	31.5	0.20	1.00	1.20	0.45	0.31					
1	BASE	IIA	2,821	120.2	19.5	107.1	80.8	38.6	0.40	1.00	1.07	0.81	0.39					
1	BASE	IIB	359	54.5	17.3	142.0	97.6	41.5	0.20	1.00	1.42	0.98	0.42					
1	BASE	IIIA	20,670	526.9	91.5	41.7	22.2	28.4	0.20	0.05	0.42	0.22	0.28					
1	BASE	IIIB	153	41.0	17.1	154.6	93.9	40.8	0.05	1.00	1.55	0.94	0.41					
1	BASE	IV	154	38.0	17.1	158.0	82.6	39.7	0.05	1.00	1.58	0.83	0.40					
1	R01	IA	233	39.4	17.1	156.4	79.4	36.4	0.05	1.00	1.56	0.79	0.36	0.08	0.42	0.58	0.59	0.36
1	R01	IB	7,090	132.0	20.2	102.9	30.7	29.2	0.20	1.00	1.03	0.31	0.29					
1	R01	IIA	12,662	233.5	28.7	77.7	53.7	34.1	0.05	0.05	0.01	0.54	0.34					
1	R01	IIB	359	54.5	17.3	142.0	98.0	41.6	0.05	1.00	1.42	0.98	0.42					
1	R01	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	R01	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	R01	IV	154	38.0	17.1	158.0	90.7	41.3	0.05	1.00	1.58	0.91	0.41					
1	R02	IA	233	39.4	17.1	156.4	79.5	36.4	0.05	1.00	1.56	0.80	0.36	0.08	0.28	0.57	0.57	0.36
1	R02	IB	13,956	178.0	23.3	89.7	21.0	27.1	0.05	0.05	0.90	0.21	0.27					
1	R02	IIA	12,662	233.5	28.7	77.7	53.8	34.1	0.05	0.05	0.01	0.54	0.34					
1	R02	IIB	359	54.5	17.3	142.0	98.1	41.6	0.20	1.00	1.42	0.98	0.42					
1	R02	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	R02	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	R02	IV	154	38.0	17.1	158.0	107.2	45.4	0.05	1.00	1.58	1.07	0.45					
1	R03	IA	233	39.4	17.1	156.4	79.5	36.4	0.05	1.00	1.56	0.80	0.36	0.17	0.62	0.58	0.64	0.37
1	R03	IB	8,188	140.6	20.7	100.1	28.9	28.8	1.00	0.70	1.00	0.29	0.29					
1	R03	IIA	2,567	115.3	19.3	108.9	82.7	39.0	0.40	1.00	0.01	0.83	0.39					
1	R03	IIB	359	54.5	17.3	142.0	97.8	41.6	0.20	1.00	1.42	0.98	0.42					
1	R03	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	R03	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	R03	IV	154	38.0	17.1	158.0	107.9	45.5	0.05	1.00	1.58	1.08	0.45					
1	M01	IA	233	39.4	17.1	156.4	79.4	36.4	0.05	1.00	1.56	0.79	0.36	0.07	0.42	0.58	0.60	0.36
1	M01	IB	7,090	132.0	20.2	102.9	30.7	29.2	0.05	1.00	1.03	0.31	0.29					
1	M01	IIA	12,662	233.5	28.7	77.7	53.7	34.1	0.05	0.05	0.01	0.54	0.34					
1	M01	IIB	359	54.5	17.3	142.0	98.0	41.6	0.05	1.00	1.42	0.98	0.42					
1	M01	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	M01	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	M01	IV	154	38.0	17.1	158.0	107.2	45.4	0.05	1.00	1.58	1.07	0.45					
1	M02	IA	233	39.4	17.1	156.4	79.6	36.4	0.05	1.00	1.56	0.80	0.36	0.09	0.42	0.58	0.61	0.36
1	M02	IB	9,810	152.3	21.4	96.6	26.0	28.3	0.05	0.05	0.97	0.26	0.28					
1	M02	IIA	2,567	115.3	19.3	108.9	82.7	39.0	0.40	1.00	0.01	0.83	0.39					
1	M02	IIB	359	54.5	17.3	142.0	97.8	41.6	0.05	1.00	1.42	0.98	0.42					
1	M02	IIIA	20,670	526.9	91.5	41.7	22.7	28.5	0.40	0.05	0.42	0.23	0.28					
1	M02	IIIB	153	41.0	17.1	154.6	94.2	41.1	0.05	1.00	1.55	0.94	0.41					
1	M02	IV	154	38.0	17.1	158.0	90.7	41.3	0.05	1.00	1.58	0.91	0.41					
1	M03	IA	233	39.4	17.1	156.4	79.9	36.5	0.05	1.00	1.56	0.80	0.36	0.13	0.40	0.58	0.58	0.36
1	M03	IB	8,188	140.6	20.7	100.1	29.1	28.9	1.00	0.70	1.00	0.29	0.29					
1	M03	IIA	27,804	330.5	42.9	62.3	36.6	31.5	0.05	0.05	0.01	0.37	0.31					
1	M03	IIB	359	54.5	17.3	142.0	100.3	42.1	0.20	1.00	1.42	1.00	0.42					
1	M03	IIIA	20,670	526.9	91.5	41.7	25.7	29.0	0.40	0.05	0.42	0.26	0.29					
1	M03	IIIB	153	41.0	17.1	154.6	95.1	41.9	0.05	1.00	1.55	0.95	0.42					
1	M03	IV	154	38.0	17.1	158.0	110.6	46.1	0.05	1.00	1.58	1.11	0.46					
1	E01	IA	233	39.4	17.1	156.4	79.8	36.4	0.05	1.00	1.56	0.80	0.36	0.08	0.28	0.58	0.56	0.36
1	E01	IB	11,236	161.7	22.1	94.0	24.0	27.8	0.05	0.05	0.94	0.24	0.28					
1	E01	IIA	27,804	330.5	42.9	62.3	36.2	31.4	0.05	0.05	0.01	0.36	0.31					
1	E01	IIB	359	54.5	17.3	142.0	99.5	41.9	0.20	1.00	1.42	1.00	0.42					
1	E01	IIIA	20,670	526.9	91.5	41.7	23.7	28.7	0.40	0.05	0.42	0.24	0.29					
1	E01	IIIB	153	41.0	17.1	154.6	95.0	41.4	0.05	1.00	1.55	0.95	0.41					
1	E01	IV	154	38.0	17.1	158.0	108.5	45.6	0.05	1.00	1.58	1.08	0.46					
1	E02	IA	116	39.4	17.1	156.4	80.2	36.5	0.05	1.00	1.56	0.80	0.37	0.08	0.28	0.56	0.51	0.35
1	E02	IB	12,483	230.2	28.4	78.3	12.3	25.0	0.05	0.05	0.78	0.12	0.25					
1	E02	IIA	27,804	330.5	42.9	62.3	37.0	31.5	0.05	0.05	0.01	0.37	0.32					
1	E02	IIB	359	54.5	17.3	142.0	101.8	42.4	0.20	1.00	1.42	1.02	0.42					
1	E02	IIIA	20,670	526.9	91.5	41.7	27.4	29.4	0.40	0.05	0.42	0.27	0.29					
1	E02	IIIB	153	41.0	17.1	154.6	91.2	42.3	0.05	1.00	1.55	0.91	0.42					
1	E02	IV	154	38.0	17.1	158.0	102.5	44.1	0.05	1.00	1.58	1.02	0.44					
1	E03	IA	233	39.4	17.1	156.4	79.9	36.5	0.05	1.00	1.56	0.80	0.36	0.09	0.28	0.57	0.55	0.36
1	E03	IB	15,382	185.8	24.0	87.8	19.8	26.8	0.05	0.05	0.88	0.20	0.27					
1	E03	IIA	27,804	330.5	42.9	62.3	36.6	31.5	0.05	0.05	0.01	0.37	0.31					
1	E03	IIB	359	54.5	17.3	142.0	100.4	42.1	0.30	1.00	1.42	1.00	0.42					
1	E03	IIIA	20,670	526.9	91.5	41.7	25.7	29.0	0.40	0.05	0.42	0.26	0.29					
1	E03	IIIB	153	41.0	17.1	154.6	95.1	41.9	0.05	1.00	1.55	0.95	0.42					
1	E03	IV	154	38.0	17.1	158.0	110.6	46.1	0.05	1.00	1.58	1.11	0.46					

Table C.11-4 Data Summary. Total nitrogen load, average suitability index per province and total wetland nitrogen removal

				Average Index (geometric mean)						
Prov	Sceanario	Basin	Total nitrogen load (tons/yr)	Nixon et al (1996) Primary Productivity	Boynton et al (1996) Chlorophyll	Mitsch et al (1999) Wetland water nitrogen removal	Dettmann (2002) Marsh water and open water nitrogen removal	Seitzinger (2000) Open water nitrogen removal	Total wetland nitrogen removal (tons/yr)	Mitsch + Seitzinger Total wetland nitrogen removal (tons/yr)
1	BASE	Breton	1,265	0.09	1.00	1.45	0.74	0.37	1,829	1,138
1	R01	Breton	765	0.07	1.00	1.51	0.85	0.38	1,154	689
1	R02	Breton	29,871	0.12	0.79	0.46	0.23	0.35	13,613	23,989
1	R03	Breton	445,342	0.14	0.24	0.23	0.19	0.27	101,815	223,837
1	M01	Breton	74,181	0.08	0.40	0.85	0.50	0.33	63,067	66,763
1	M02	Breton	204,537	0.17	0.48	0.47	0.39	0.32	95,657	160,394
1	M03	Breton	725,446	0.09	0.17	0.16	0.28	0.26	115,980	308,089
1	E01	Breton	98,358	0.15	0.48	0.71	0.48	0.31	69,501	88,522
1	E02	Breton	55,430	0.09	0.55	0.33	0.18	0.26	18,057	32,225
1	E03	Breton	617,508	0.17	0.24	0.23	0.07	0.22	140,117	275,421
1	BASE	Pontchartrain	27,334	0.12	0.65	1.16	0.65	0.36	31,843	24,600
1	R01	Pontchartrain	41,320	0.12	0.65	0.58	0.59	0.36	24,152	37,188
1	R02	Pontchartrain	48,186	0.13	0.65	0.57	0.57	0.36	27,617	43,368
1	R03	Pontchartrain	32,323	0.12	0.65	0.58	0.64	0.37	18,819	29,091
1	M01	Pontchartrain	41,320	0.13	0.65	1.09	0.60	0.36	44,981	37,188
1	M02	Pontchartrain	33,946	0.12	0.65	1.13	0.61	0.36	38,427	30,551
1	M03	Pontchartrain	57,560	0.15	0.59	0.58	0.58	0.36	33,511	51,804
1	E01	Pontchartrain	60,608	0.16	0.62	0.58	0.56	0.36	34,966	54,547
1	E02	Pontchartrain	61,739	0.16	0.59	0.56	0.51	0.35	34,706	55,565
1	E03	Pontchartrain	64,754	0.15	0.62	0.57	0.55	0.36	36,999	58,279
1	BASE	All	28,598	0.10	0.83	1.31	0.70	0.37	33,671	25,738
1	R01	All	42,085	0.09	0.83	1.05	0.72	0.37	25,306	37,877
1	R02	All	78,058	0.12	0.72	0.51	0.40	0.35	41,230	67,357
1	R03	All	477,666	0.13	0.44	0.41	0.41	0.32	120,634	252,928
1	M01	All	115,501	0.11	0.52	0.97	0.55	0.35	108,048	103,951
1	M02	All	238,483	0.14	0.57	0.80	0.50	0.34	134,084	190,945
1	M03	All	783,006	0.12	0.38	0.37	0.43	0.31	149,491	359,893
1	E01	All	158,966	0.15	0.55	0.64	0.52	0.33	104,467	143,069
1	E02	All	117,168	0.12	0.57	0.44	0.35	0.30	52,763	87,790
1	E03	All	682,262	0.16	0.43	0.40	0.31	0.29	177,116	333,700
2	BASE	Barataria	10,387	0.07	1.00	1.57	0.85	0.37	16,359	9,349
2	R01	Barataria	171,208	0.14	0.69	1.06	0.49	0.33	182,213	154,088
2	R02	Barataria	429,554	0.13	0.62	0.92	0.46	0.32	393,267	386,599
2	R03	Barataria	291,273	0.09	0.43	0.97	0.40	0.32	282,784	262,145
2	M01	Barataria	171,208	0.13	0.43	1.06	0.49	0.33	182,213	154,088
2	M02	Barataria	377,821	0.15	0.53	0.93	0.44	0.32	352,851	340,039
2	M03	Barataria	300,971	0.13	0.49	0.89	0.34	0.30	268,440	270,874
2	E01	Barataria	427,348	0.09	0.49	0.91	0.37	0.31	389,263	384,613
2	E02	Barataria	660,981	0.10	0.40	0.77	0.35	0.30	512,058	594,883
2	E03	Barataria	158,872	0.10	0.66	1.17	0.58	0.34	185,281	142,985
3	BASE	Terr-Verm	476,450	0.05	0.72	1.30	0.55	0.33	621,555	428,805
3	M01	Terr-Verm	666,358	0.06	0.51	0.97	0.30	0.29	646,349	599,722
3	R01	Terr-Verm	482,698	0.06	0.72	1.19	0.41	0.32	575,462	434,428
3	R02	Terr-Verm	660,111	0.05	0.51	1.06	0.37	0.31	700,296	594,100
3	R03	Terr-Verm	478,851	0.06	0.72	1.25	0.49	0.32	597,287	430,966

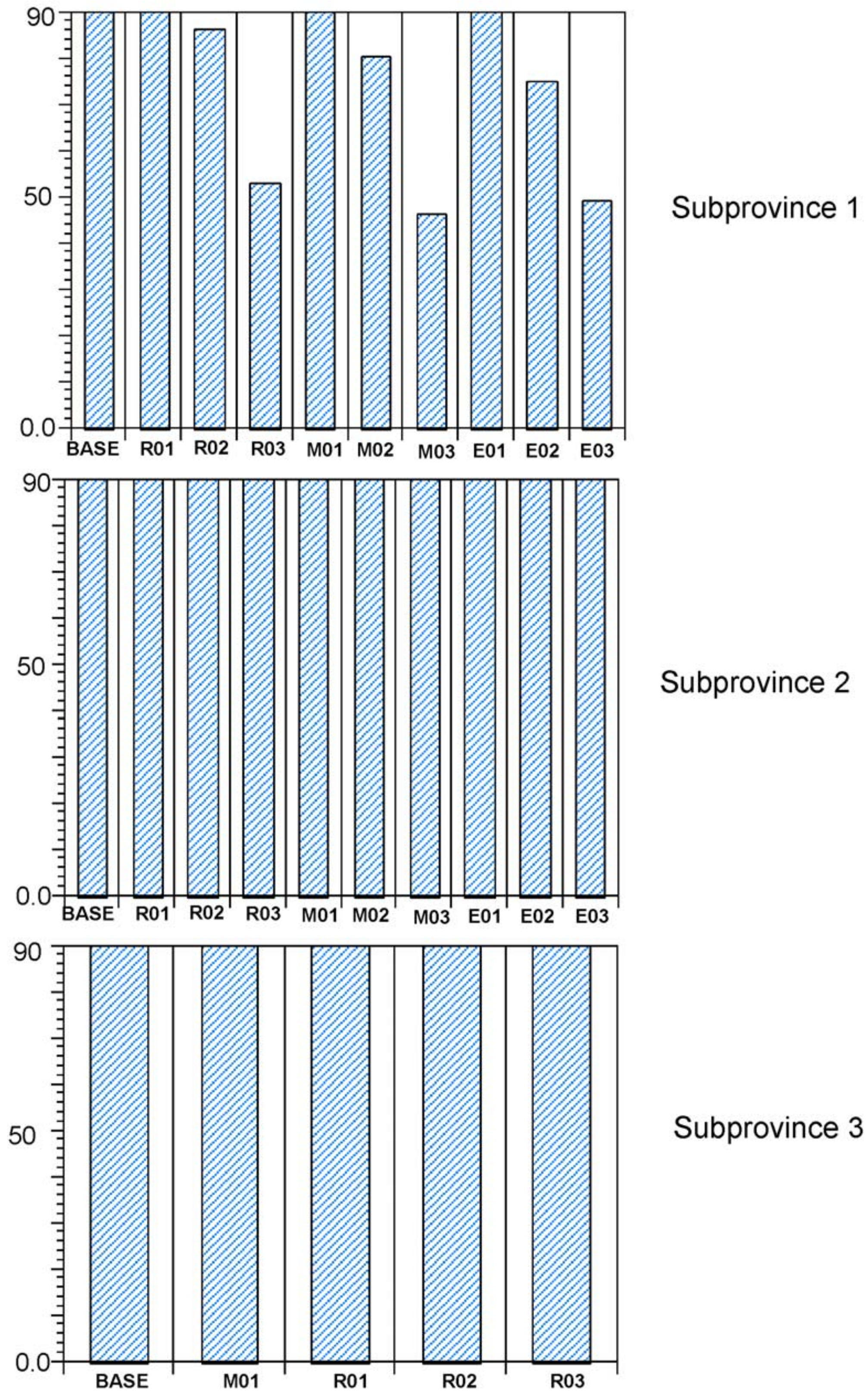

Figure C.11-12 Percentage of total nitrogen removal for each framework by subprovince