GROUNDWATER/SURFACEWATER INTERACTIONS IN TAMPA BAY

IMPLICATIONS FOR NUTRIENT FLUXES

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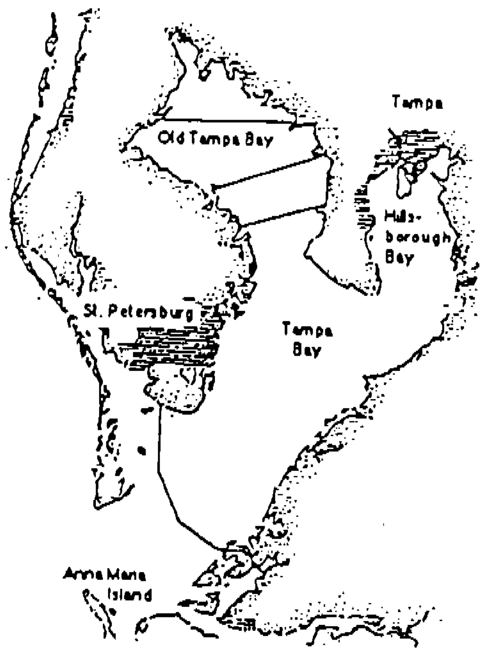

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EXECUTIVE SUMMARY

In developing a framework for bay characterization the Tampa Bay National Estuary Program identified a priority area, which involves the collation and synthesis of existing information on groundwater/surface water interactions in the Tampa Bay Watershed. The primary objective was to establish a rough estimate of the flux rates of nitrogen and phosphorus between these two reservoirs based upon available data and compare them to rates determined for other sources. The purpose was to determine if groundwater may be considered a major mechanism for nutrient input to Tampa Bay, which is critical for management purposes.

Our approach was to initially determine flow rates and directions (whether into or out of the bay) for both wet and dry seasons for the surficial, intermediate and Floridan aquifers. This required the construction and analyses of flow nets. Once estimates of rates were determined flux rates of nitrates and phosphates were calculated based upon their reported concentrations in each of the three aquifers. Once again results are very rough but we attempted to calculate maximum inputs into the bay system.

Results show a total average dry season discharge into the bay of 83-91 Mgal./day from all three aquifers. The total average wet season discharge ranges from 90 to 97.5 Mgal./day. In both cases the bulk of the discharge comes from the Floridan aquifer. Based upon these discharge rates, the flux rate for nitrate was calculated at 5,780 to 6,125 kg./yr. for the dry season and 6,320 to 6,685 kg./yr. for the wet season. Rates for phosphate range from 17,770 to 18,670 kg./yr. for the dry season (October through May) and 21,720

to 22,740 kg./yr. for the wet season (June through September). Comparing these rates with those reported for other sources indicates groundwater probably represents a minor input of nitrates and phosphates into Tampa Bay. Nitrate loads are in the vicinity of 2 orders of magnitude lower than other sources and phosphate loads, while not in the same range, are considerably lower than values reported for other sources. We emphasize the fact that as these are very rough estimates, they are intended to be used for comparative purposes only. On the other hand, we attempted to determine maximum input (ie, we are assuming all water enters Tampa Bay), rates based upon available data therefore rates may be even lower. In order to determine more accurate nitrate and phosphate input rates a project requiring more rigorous data collection and numerical analysis may be required.

INTRODUCTION

Scope

One of the initial issues undertaken by the Tampa Bay National Estuary Program (TBNEP) was the development of a framework, or conceptual model for Bay characterization containing the critical physical, chemical, geological and biological components of the Tampa Bay watershed and the interrelationships of these components. As a result of this Framework for characterization, a priority area of hydrogeologic information was identified as important to assist with future resource management decisions. This priority area, the focus of this project, includes the collation and synthesis of existing information on groundwater/surface water interactions in the Tampa Bay watershed. Specific questions to be addressed include:

1) Is there a hydraulic connection between surface water bodies and underlying aquifers in the watershed?
2) What are the directions and rates of water movement between these two reservoirs?
3) Is there a net input of nitrogen and/or phosphorus from groundwater into Tampa Bay surface waters?
4) If so, at what rate?

Background

Tampa Bay is the largest estuary on Florida's west coast. It covers over 4,600 Km^2 in area and has an average depth of 3-4m. Summers in the Tampa Bay area are hot and humid, whereas winters are mild with the periodic passage of cold fronts averaging every 5-10 days. The average annual rainfall is approximately 124 cm. The rainy season lasts from June through September (Wooten, 1985). Total annual mean freshwater runoff is reported to be approximately 63 m^3/sec. (Galperin, Blumberg and Weisberg, 1991). Typically, May is a low-flow period when stream flow is composed mainly of ground-water outflow from underlying aquifers. Hence, there is little or no surface water contribution to Tampa Bay at the end of the 'dry' season.

Tampa Bay is a drowned river valley that was curved out of the underlying tertiary sedimentary deposits during pleistocene sea-level lowstands, (Brooks and Doyle, 1992). It is these underlying sedimentary rocks whose texture and composition control, to a large extent, the chemical content of the water contained, and rates of groundwater movement. Thickness, areal extent and fracturing of the rocks also influence the rates of groundwater movement (Hutchinson, 1983). Principal Hydrogeologic units in the Tampa Bay area consist of the surficial aquifer, intermediate aquifer system, and upper Floridan aquifer. Each is separated by a confining bed.

The surficial aquifer consists of unconsolidated sands, silts and clays deposited during the Pliocene and Pleistocene (Culbreth, Bretnall, and Stewart, 1985). Thickness of this surficial unit ranges from 0 to greater than 200 ft. in west-central Florida. In the Tampa Bay region it is generally less than 50 ft. thick (Wolansky, et al., 1979).

The intermediate aquifer system and confining units consist of sands, clays and limestone (DeHaven, et al., 1991; Culbreth, Bretnall, and Stewart, 1985). In west-central Florida the intermediate aquifer system is very localized in extent thickening from 0 ft. in the north to greater than 250 ft. in the south (DeHaven, et al., 1991). In the Tampa Bay region the intermediate aquifer system extends approximately halfway up the bay (see appendix 1).

The Floridan aquifer is the principal source of water for consumptive use in the Tampa Bay area. It is composed chiefly of limestone and dolostone that range in age from early Miocene to middle Eocene. In west-central Florida the Floridan thickens from approximately 1,000 ft. in the north to greater than 1,200 ft. in the south (DeHaven, et al., 1991). It is more than 1,000 ft. thick in the Tampa Bay region (Hutchinson, 1983).

METHODS

In order to determine flow rates between groundwater and surface water reservoirs, flow nets were constructed using the same method as Hutchinson (1983), as described by Walton (1970).

Flow nets consist of two sets of lines. One set, referred to as equipotential lines, connect points of equal head and thus represent the elevation of the water table, or the potentiometric surface in the case of a confined aquifer, above some datum plane. The second set, referred to as flow lines depict the idealized path followed by water particles as they move through the aquifer. Since groundwater moves in the direction of the hydraulic gradient, flow lines in isotropic aquifers are perpendicular to equipotential lines (Heath 1987). Flow lines can be chosen at any interval. In order to maintain consistency, flow lines for this project approximate those of Hutchinson (1983), which were originally chosen at random (C. Hutchinson, 1992, Pers. Comm.). Exactly the same flow lines could not be used as equipotential lines change according to hydrologic conditions. Flow zones were defined by two adjacent flow lines and equipotential lines. In this case the 5 ft. and 10 ft. contours were chosen in order to maintain consistency with Hutchinson (1983). Discharge was then computed for each flow zone using Darcy's formula (see Walton, 1970): $Q = 7.48 \times 10^{-6}\ TIL$

Where T = Transmissivity (ft^2/d)

I = Hydraulic gradient (ft/mi)

L = length of Flow zone (mi)

Q = Discharge rate (Mgal/day)

The hydraulic gradient (I) was calculated using the following formula:

$$I = \frac{Ci}{Wa}$$

Where Ci = the contour interval of the flow zone (ft)

$$Wa = \frac{A'}{L}$$

Wa is the average width of the flow zone

A′ is the area of the flow zone (mi^2)

L is the same as above.

In order for this flow net analysis to be valid one must assume strictly lateral flow, which may not be the case (Hutchinson, 1983).

Data for these calculations were obtained from published sources. Transmissivity (T) values for the Floridan aquifer were taken from Hutchinson (1983) in order to maintain consistency. Transmissivities for the surficial and intermediate aquifers were estimated based on geological characteristics (Heath, 1987). Flow lines and flow zones were determined from potentiometric surface maps produced jointly by the U.S. Geological Survey (USGS) and Southwest Florida Water Management District (1992). Discharge rates were calculated for the Floridan, intermediate and surficial aquifers for both wet (September) and dry (May) seasons. For the Floridan and intermediate aquifers calculations were made based on the most recent data available (1990/1991), as well as 1985/1986 data (Southwest Florida Water Management District, 1992). Calculations based on the latter data were included because nitrogen and phosphorus data used here were collected during that time period. For the surficial aquifer 1982 data were used as it was the last year potentiometric maps were produced for this aquifer.

To determine flux rates of nitrogen (N) and phosphorus (P) from ground waters to surface waters, concentrations were averaged for each flow zone for each aquifer and the flux rate calculated. Concentrations were estimated from DeHaven (1991), which consists of a compilation of data collected through the Southwest Florida Water Management District's ambient ground-water monitoring program.

In determining these flux rates it is assumed that all water traveling toward the Bay actually enters the Bay. Therefore, this would result in a maximum value. It is also assumed that the rate of movement of nitrogen and phosphorus is the same as the water itself. In other words their flux is not retarded by chemical interactions, etc. This also represents a maximum input. Hence, based upon available data, these calculations represent the maximum input, ie. a worst case scenario.

RESULTS AND DISCUSSION

Flow Rates

Results of flow net analyses are shown in Appendices I and II. Discharge rates based upon 1985/86 data for the Floridan aquifer during May (the dry season) are in the range of 80 Mgal./day. Due to the depression in the potentiometric surface east of the bay area, probably a result of pumping, much of the ground water becomes trapped and does not enter directly into the Bay. Hence, only approximately 36% of the ground water normally moving toward the bay is used in the calculation. In determing flow rates for the intermediate aquifer during this time period flow zones I, II and III only were used as the intermediate aquifer is present only in these areas. Calculated discharge rates are approximately 3-4 Mgal./day. The total discharge from both the Floridan and intermediate aquifer system for May 1986 therefore, is calculated to be in the range of 83-84 Mgal./day.

Discharge rates for the Floridan aquifer for September 1985, the wet season, are calculated at approximately 85.5 Mgal./day. The slight increase over the dry season rate may be a reflection of increased head gradients experienced during the wet season and/or the lack of the potentiometric surface depression which is believed to keep groundwater from entering the bay during the dry season. Discharge rates for the intermediate aquifer during this time period are in the range of 4-6 Mgal./day. The slight increase here probably reflects the steeper hydraulic gradient during the wet season. Total wet season discharge for the Floridan and intermediate aquifers for September 1985, therefore is approximately 90 Mgal./day.

Discharge rates based upon the most recent data available (1990/91) show a very slight but probably insignificant (compared to the accuracy of the technique) increase over 1985/1986 rates. Discharge rates for the Floridan aquifer for May 1991, the dry season, are calculated to be approximately 84 Mgal./day. Rates for the intermediate aquifer are calculated be between 5-7 Mgal./day. The total for the Floridan and intermediate aquifers for May 1991 are in the range of 89-91 Mgal./day.

Wet season rates, calculated for September 1991, are approximately 89.5 Mgal./day for the Floridan aquifer and 5-7 Mgal./day for the intermediate aquifer. The total 1991 wet season discharge rate is in the range of 94.5 - 96.5 Mgal./day.

Surficial aquifer discharge rates were based upon 1982 data, the most recent data available. Dry season discharge rates for May 1982 are calculated to be approximately 0.08 Mgal./day. Wet season rates calculated for September 1982 range from approximately 0.1 to 1.0 Mgal./day. This one order of magnitude range reflects the range of hydraulic conductivity values (required to estimate transmissivity) assumed for the calculation.

Combining discharge rates for the surficial aquifer, calculated from 1982 data, with 1985 and 1991 data for the Floridan and intermediate aquifers, gives a total dry season discharge range of approximately 83 to 91 Mgal./day and a total wet season discharge ranging from approximately 90 to 97.5 Mgal./day. These rates are based upon the assumption that 1982 surficial aquifer discharge rates have not changed substantially over the past 10 years and can be used in determining total groundwater discharge rates to Tampa Bay for 1985/86 and 1990/91. On the other hand, surficial aquifer discharge rates are so small compared to those of the Floridan and even the intermediate aquifers, that purely from a water volume standpoint they may be insignificant. From a solute transport standpoint however, surficial aquifer discharge may make a significant contribution and therefore, rates, albeit very low, must not be ignored.

Nitrate and Phosphate Flux

The approximate flux of nitrate and phosphate was calculated for each flow zone, for all three aquifers for both wet and dry seasons. Results are shown in Appendix III. In determing flux rates it was determined that salutes were transported at the same rate as the groundwater.

The total flux rate for nitrates for the dry season ranges from approximately 5,780 to 6,125 Kg./yr. (units have been changed for comparison purposes). The rate for phosphorus for the same period ranges from approximately 17,770 to 18,670 kg./yr. Wet season rates range from 6,320 to 6,685 kg./yr. for nitrates and 21,720 to 22,740 kg./yr. for phosphate. The increase in both, from dry to wet season, obviously reflects the calculated increase in flow rate during the wet season. The relatively low flux rate for nitrate compared to phosphate may, at least in part, be a reflection of aquifer geochemistry and input. Generally speaking, since the surficial aquifer is primarily composed of relatively inert of quartz sand and the residence time of the groundwater is relatively short, concentrations of most of the major ions are lowest compared to underlying aquifers (DeHaven, 1991).

This is especially true for phosphate as the geologic formations comprising underlying aquifers are phosphate rich. Nitrate concentrations however, are found to be higher in the surficial aquifer than in underlying aquifers, possibly as a result of the application of nitrate fertilizers (DeHaven, 1991). The implication is that the higher flow rates calculated for the Floridan aquifer contribute a large amount of phosphate rich water, where as the lower flow rates calculated for the surficial aquifer contribute a comparatively small amount of nitrate rich water.

Comparing the flux rates of nitrate and phosphate calculated for ground water reservoirs to other sources of input into Tampa Bay, indicates groundwater probably represents a minor source. Appendix IV lists sources and rates of input of nitrate and phosphate into the bay (Southwest Florida Water Management District, 1992). Nitrate loads for these other sources are in the vicinity of two orders of magnitude higher than those calculated for groundwater. Phosphorus loads for each of the other sources are also considerably higher than those calculated for groundwater. In addition, considering that chemical processes generally act to impede the flux of solutes, especially nitrate (Mandel and Shifton, 1981), as well as the fact that flow rates were calculated to be a maximum, the calculated flux rates of both nitrate and phosphate are quite probably even lower. The conclusion is that, based upon these calculations, the flux of nitrate and phosphate from groundwater into Tampa Bay is minimal compared to other sources. We stress the fact however, that these rates should be regarded as <u>very rough</u> estimates, based upon available data and are meant to be used for comparative purposes only. On the other hand, we have endeavored to structure the calculations such that rates are <u>over</u> estimates if anything.

CONCLUSIONS

Based upon the collation and synthesis of existing information on groundwater/surface water interactions in the Tampa Bay watershed the following conclusions have been reached:

1) The literature review indicated that there is a hydraulic connection between groundwater (in all three aquifers) and surface waters in the Tampa Bay area. Potentiometric surface maps show a depression in northern Tampa Bay and hydraulic gradients that slope toward the depression substantiating that ground water discharges to the bay.
2) Rates and direction of water movement between these reservoirs will vary according to a variety of conditions such as rainfall, tides, groundwater pumping, etc... Rough estimates of groundwater influx into Tampa Bay, based upon flow net analyses using existing data, range from 83-91 Mgal./day for the dry season to 90-97.5 Mgal./day for the wet season, the bulk of which by far is input from the upper Floridan aquifer.
3) Based upon flow net analysis and existing groundwater chemistry data a net input of nitrates and phosphates from groundwater into Tampa Bay's surface waters is indicated.
4) Using the flow rates described above, flux rates calculated for nitrate and phosphate into Tampa Bay are on the order of 5,780 - 6,685 Kg./yr. and 17,770 - 22,740 Kg./yr. respectively. As above, these are very rough estimates but are up to two orders of magnitude lower than rates reported for other sources. Based upon existing data therefore, it appears that groundwater represents a minor source for the input of nitrate and phosphate into Tampa Bay.

As mentioned, results of this study should be used as a rough, first cut approximation of flow rates and nitrate/phosphate flux from groundwaters to surface waters in the Tampa Bay area. For a more accurate determination we suggest using these results as a foundation and conducting a more sophisticated analysis of the system under a variety of conditions, and collecting new data where required. Also, if desired the flux rates of other solutes can easily be determined based upon the same method used here. As flow rates have already been determined, flux rates based upon existing data can be calculated in a relatively straightforward manner.

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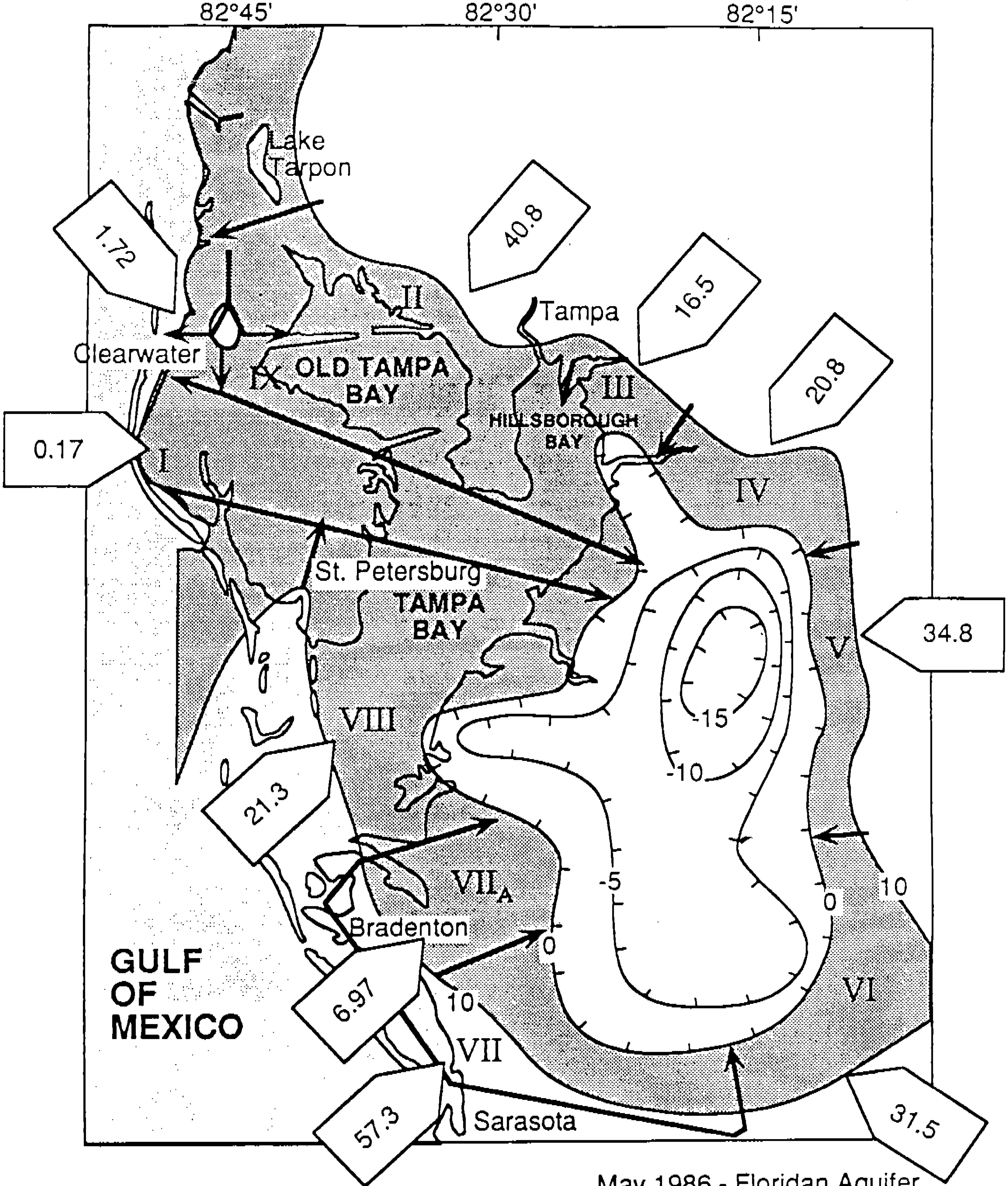
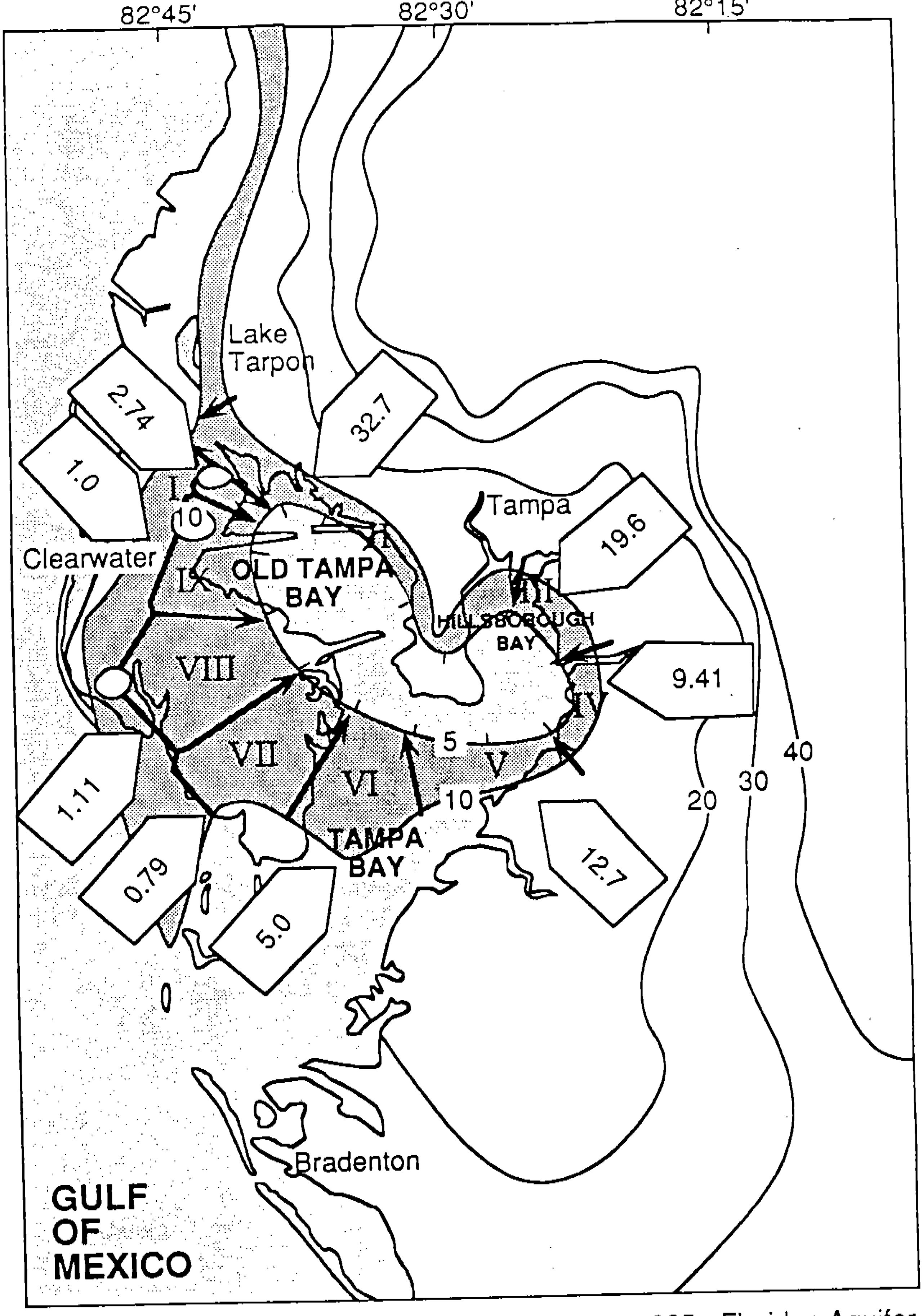
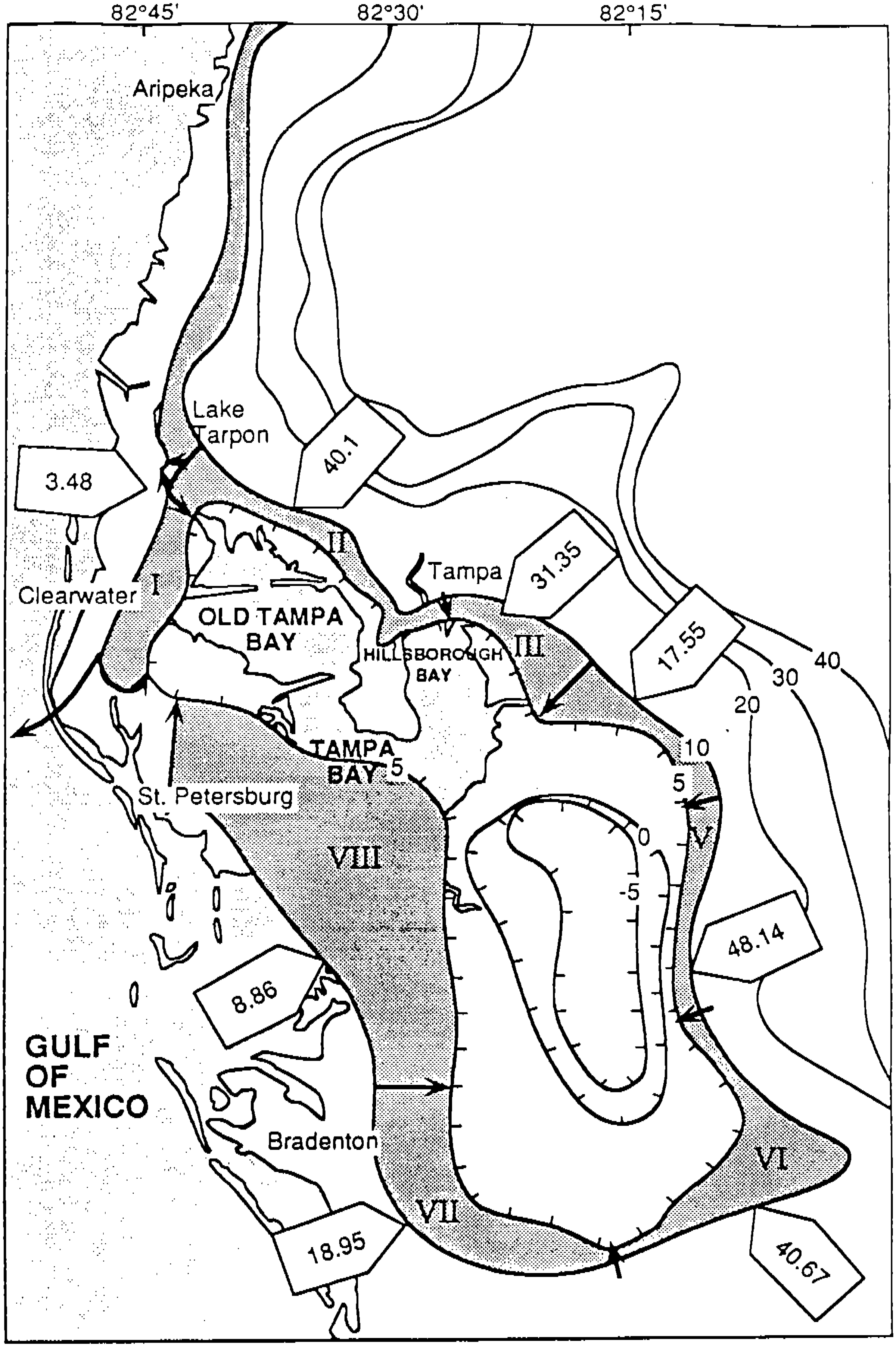
Appendix I. Maps showing the results of flow net analyses. Including flow zones and computed discharge for each. Note, arrows are meant to represent a graphic depiction of flow direction and flow zone boundaries. They do not necessarily represent flow lines and as such may not be normal to equipotential contours.



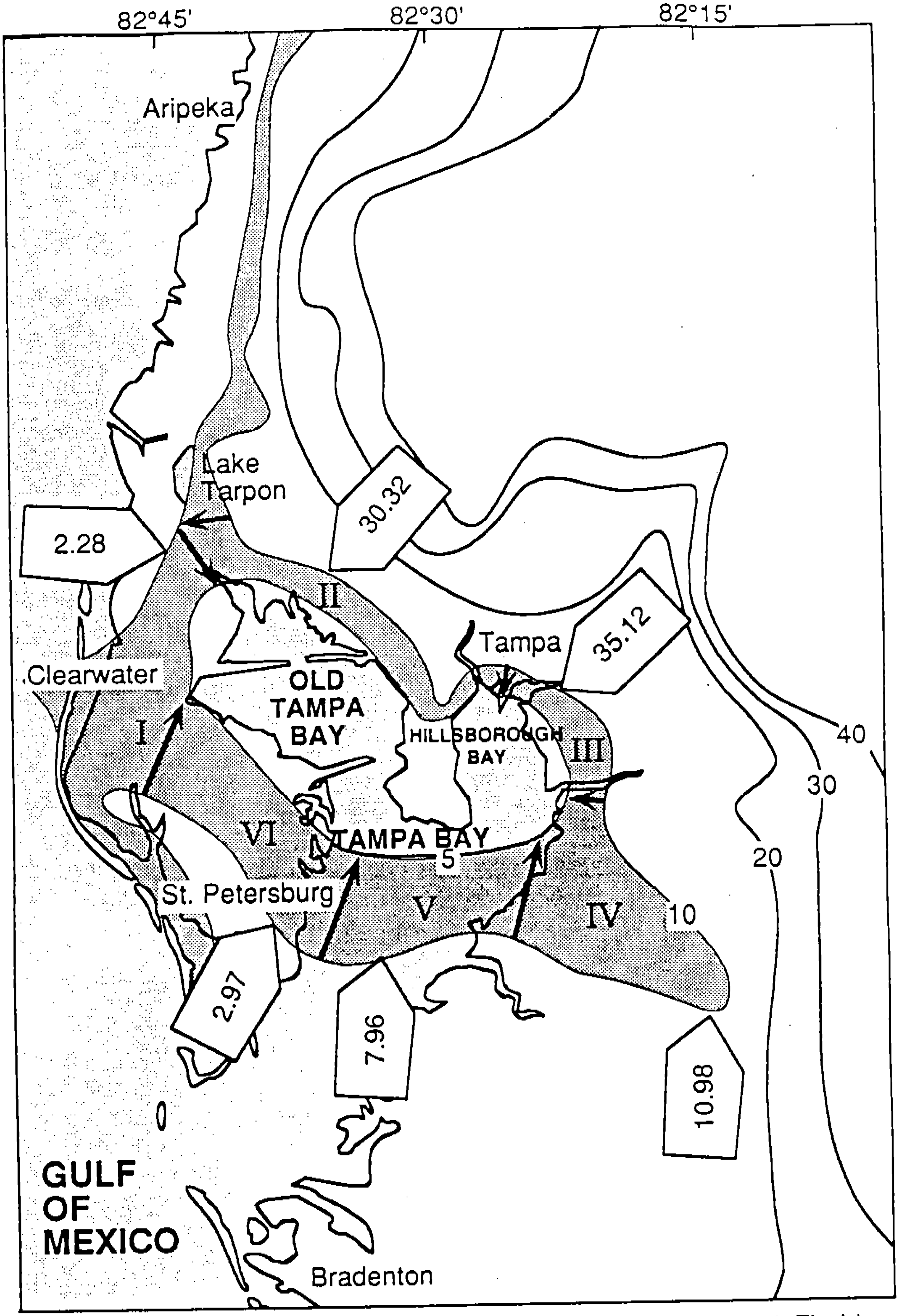
May 1986 - Floridan Aquifer



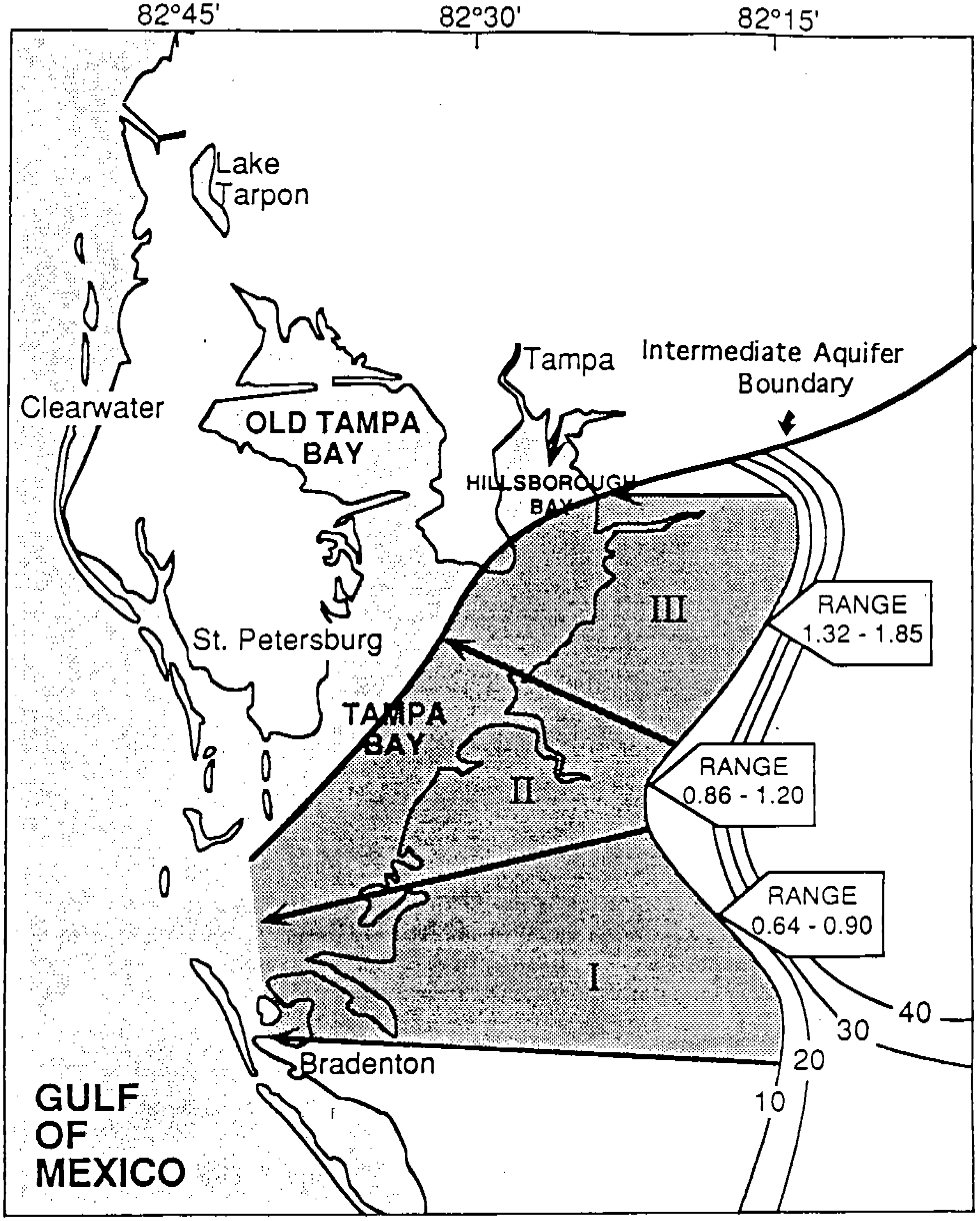
September 1985 - Floridan Aquifer



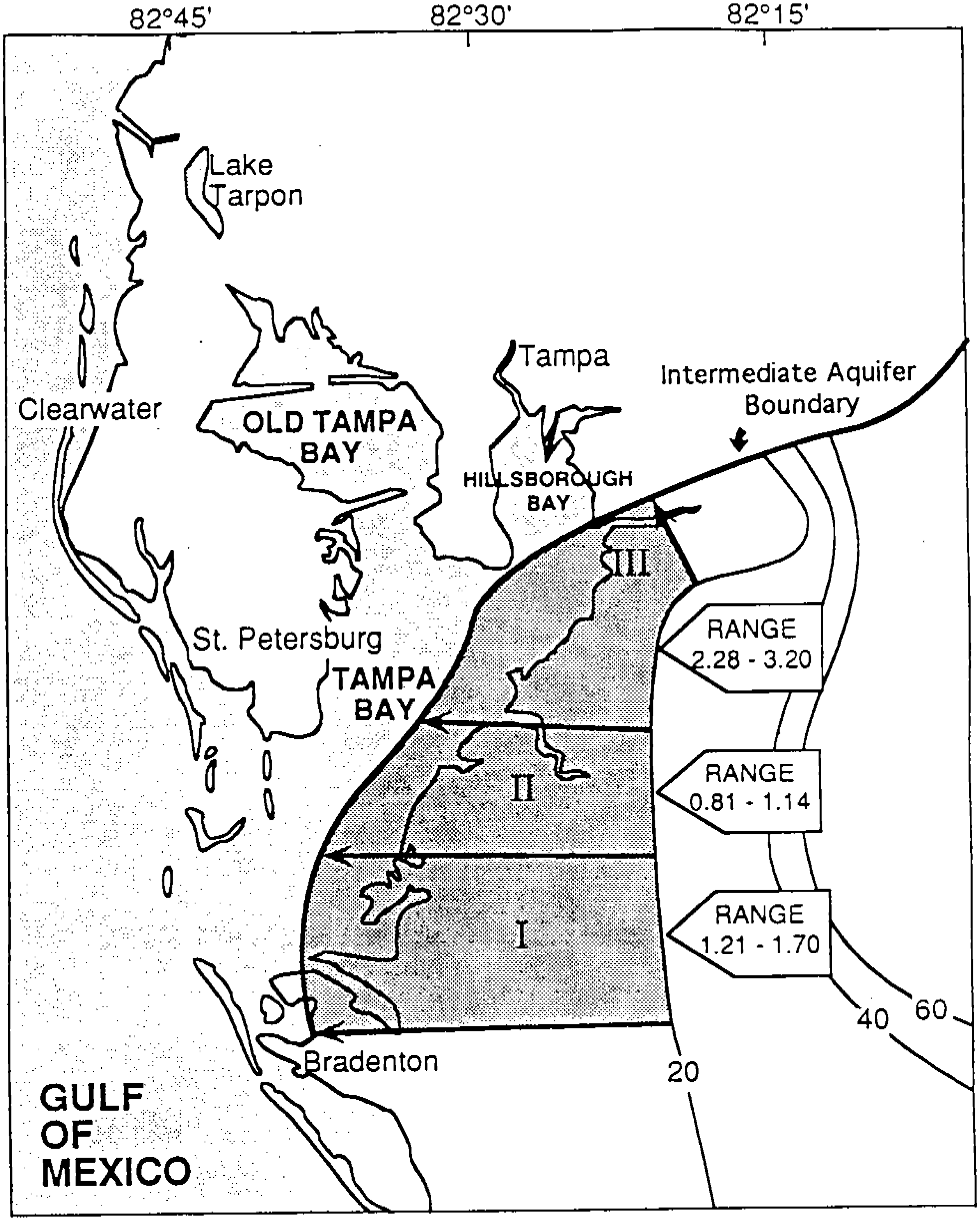
May 1991-Floridan



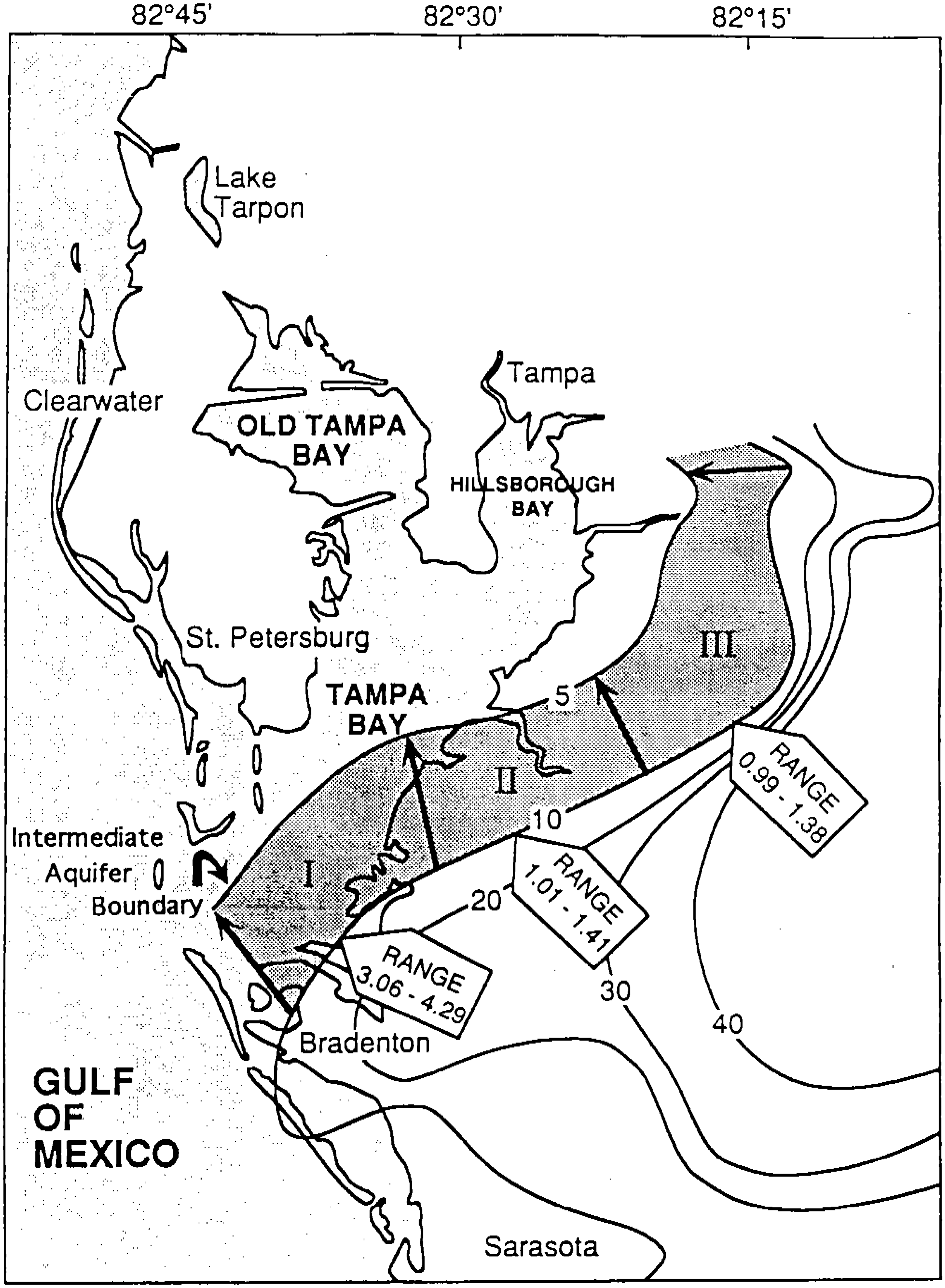
September 1990-Floridan



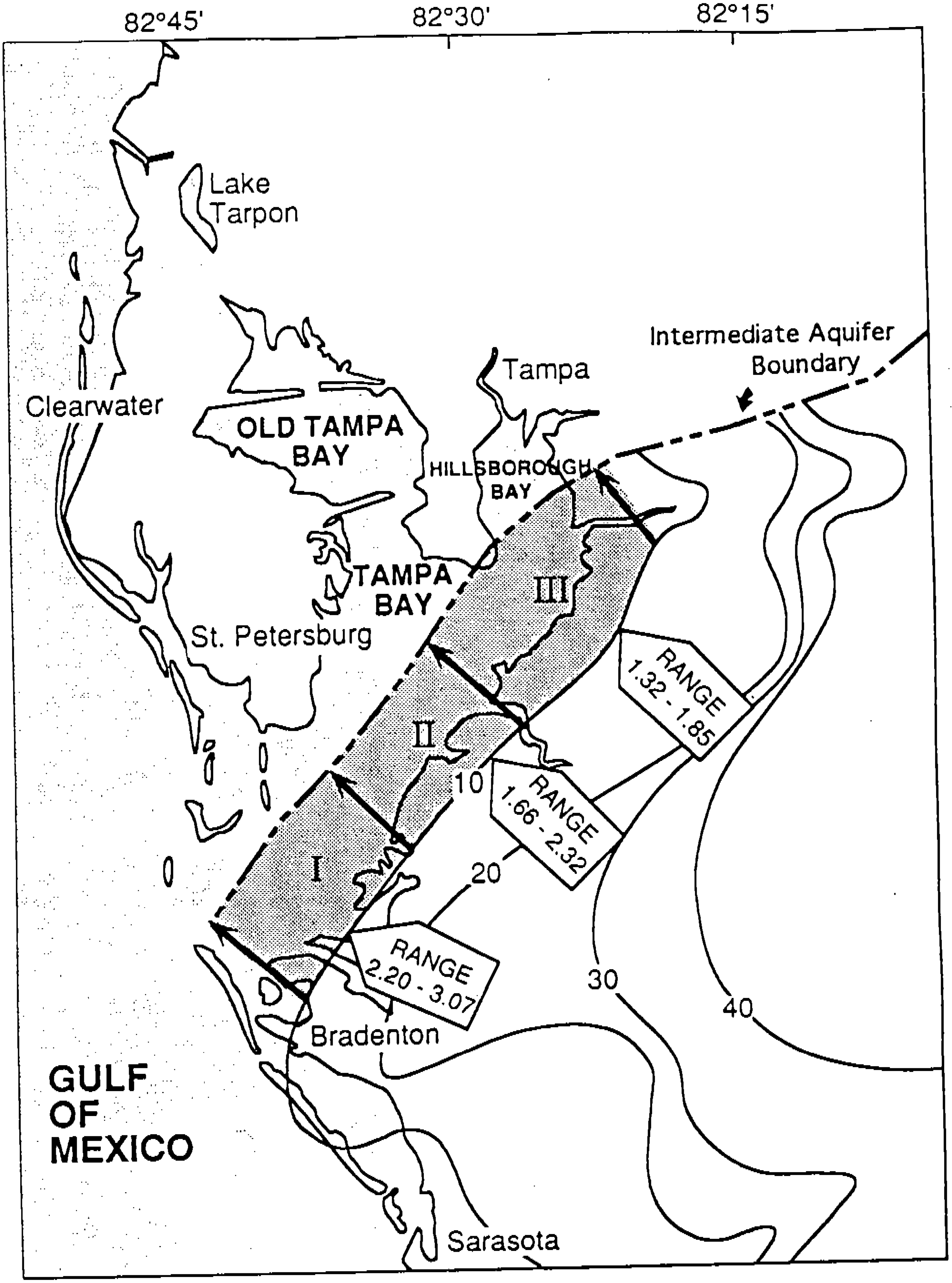
May 1986 - Intermediate Aquifer



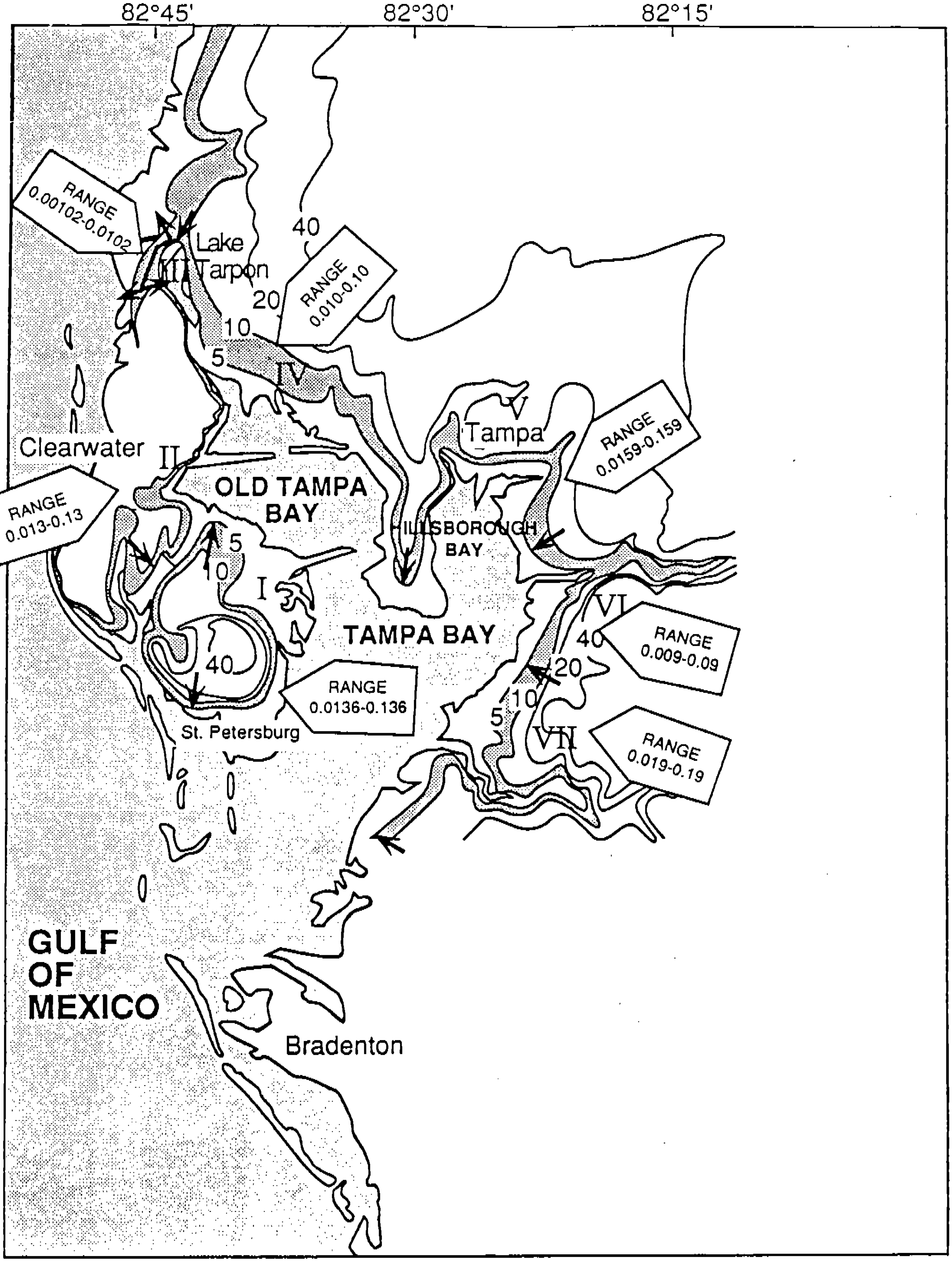
September 1985 - Intermediate Aquifer



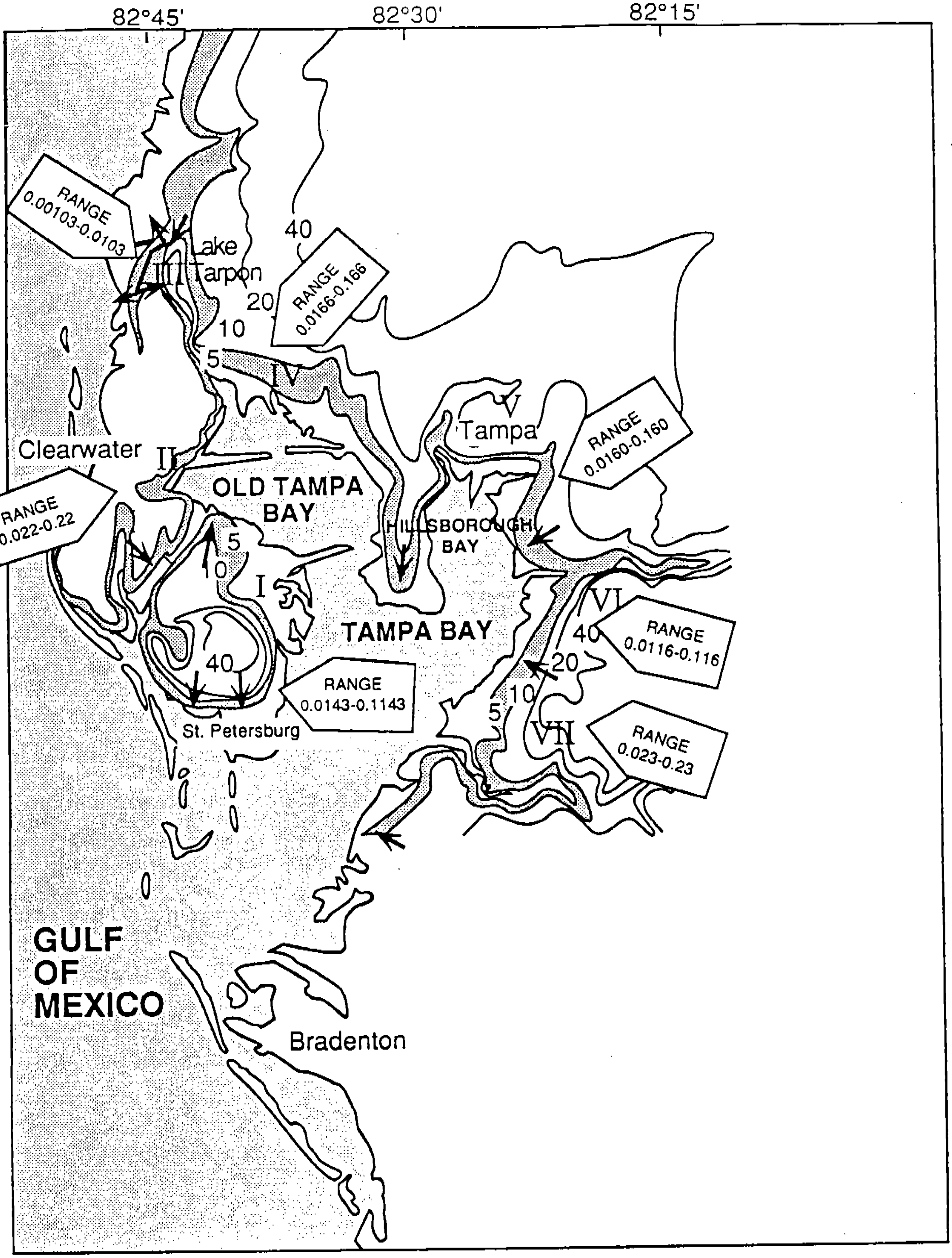
May 1991-Intermediate



September 1990-Intermediate



May 1982-Surficial Aquifer



September 1982-Surficial Aquifer

Appendix II. Tables showing data generated for flow net analyses.

Upper Floridan Aquifer

May, 1986

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
I	30,000	0.2	4	0.2
II	67,000	2.9	28	40.8
III	200,000	1.9	9	16.5
IV	100,000	2.3	12	20.8
V	100,000	2.6	18	34.8
VI	100,000	1.8	23	31.5
VII	100,000	2.3	33	57.3
VIII	67,000	1.6	27	21.3
IX	30,000	2.8	3	1.7

September, 1985

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
I	67,000	3.6	2	2.7
II	67,000	2.8	23	32.7
III	200,000	2.1	6	19.6
IV	100,000	2.0	6	9.4
V	100,000	1.9	9	12.7
VI	100,000	0.8	8	5.0
VII	30,000	0.7	5	0.8
VIII	30,000	0.8	6	1.1
IX	30,000	0.9	5	1.0

Intermediate Aguifer System
May, 1986

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
I	20,000	0.4	10	0.6
	28,000	0.4	10	0.9
II	15,000	0.7	11	0.9
	21,000	0.7	11	1.2
III	10,000	1.1	17	1.3
	14,000	1.1	17	1.9

September, 1985

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
I	20,000	1.0	8	1.2
	28,000	1.0	8	1.7
II	15,000	1.2	6	0.8
	21,000	1.2	6	1.1
III	10,000	2.3	13	2.3
	14,000	2.3	13	3.2

Upper Floridan Aquifer
May, 1991

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
I	30,000	1.1	14	3.5
II	67,000	3.7	22	40.1
III	200,000	1.8	12	31.4
IV	100,000	2.3	10	17.6
V	100,000	3.6	18	48.1
VI	100,000	2.2	24	40.7
VII	100,000	1.2	21	19.0
VIII	67,000	0.6	29	8.9

September, 1990

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
I	30,000	1.2	9	2.3
II	67,000	2.6	23	30.3
III	200,000	2.4	10	35.1
IV	100,000	0.9	15	10.8
V	100,000	1.0	11	8.0
VI	100,000	1.0	14	3.0

Intermediate Aquifer System
May, 1991

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
I	20,000	1.5	13	3.1
	28,000	1.5	13	4.3
II	15,000	0.8	12	1.0
	21,000	0.8	12	1.4
III	10,000	0.8	17	1.0
	14,000	0.8	17	1.4

Semtember, 1990

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
	September 1990 Intermediate Aquifer			
I	20,000	1.5	10	2.2
	28,000	1.5	10	3.1
II	15,000	1.5	10	1.7
	21,000	1.5	10	2.3
III	10,000	1.3	13	1.3
	14,000	1.3	13	1.9

Surficial Aquifer
May, 1992

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
I	25	4.6	16	0.014
	250	4.6	16	0.14
II	25	3.2	22	0.013
	250	3.2	22	0.13
III	25	1.9	3	0.001
	250	1.9	3	0.01
IV	25	2.0	27	0.010
	250	2.0	27	0.10
V	25	3.8	22	0.016
	250	3.8	22	0.16
VI	25	3.0	16	0.009
	250	3.0	16	0.09
VII	25	3.6	28	0.019
	250	3.6	28	0.19

Surficial Aquifer
September, 1982

Flow Zone	T Transmissivity (ft2/d)	I Hydraulic Gradient (ft/mi)	L Length of flow zone (mi)	Q Discharge rate (Mgal/d)
I	25	4.8	16	0.014
	250	4.8	16	0.14
II	25	5.2	23	0.022
	250	5.2	23	0.22
III	25	1.9	3	0.001
	250	1.9	3	0.01
IV	25	2.9	30	0.017
	250	2.9	30	0.17
V	25	3.8	22	0.016
	250	3.8	22	0.16
VI	25	4.0	16	0.012
	250	4.0	16	0.12
VII	25	3.8	33	0.023
	250	3.8	33	0.23

Appendix III. Tables showing data used in determining nitrate and phosphate flux rates.

Upper Floridan Aquifer
May, 1991

Zone	Nitrate value (mg/l)	Nitrate input (Kg/year)
I	0.001	4.8
II	0.046	2555.6
III	0.0565	2452.5
VIII	0.005	61.3
Total		5074.2

Floridan Aquifer
September, 1990

Zone	Nitrate value (mg/l)	Nitrate input (Kg/year)
I	0.001	3.2
II	0.046	1929.8
III	0.056	2744.9
IV	0.056	844.3
V	0.005	55.2
VI	0.005	20.5
Total		5597.9

Intermediate Aquifer System
May, 1991

Zone	Nitrate value (mg/l)	Nitrate input (Kg/year)
I	0.001	423.3 to 593.6
II	0.001	139.7 to 195.1
III	0.001	137.0 to 190.8
Total		700.0 to 979.5

September, 1990

Zone	Nitrate value (mg/l)	Nitrate input (Kg/year)
I	0.001	304.3 to 424.7
II	0.001	229.5 to 320.9
III	0.001	182.6 to 255.9
Total		716.4 to 1001.5

Surficial Aquifer System
May, 1982

Zone	Nitrate value (mg/l)	Nitrate input (Kg/year)
I	0.068	1.28 to 12.8
II	0.068	1.26 to 12.6
III	0.0013	0.002 to 0.02
IV	0.011	0.15 to 1.5
V	0.130	2.86 to 28.6
VI	0.130	1.62 to 16.2
VII	0.002	0.05 to 0.5
Total		7.22 to 72.2

September, 1982

Zone	Nitrate value (mg/l)	Nitrate input (Kg/year)
I	0.068	1.34 to 13.4
II	0.068	2.07 to 20.7
III	0.0013	0.002 to 0.02
IV	0.011	0.25 to 2.5
V	0.130	2.88 to 28.8
VI	0.130	2.09 to 20.9
VII	0.002	0.06 to 0.6
Total		8.69 to 86.9

Floridan Aquifer
May, 1991

Zone	Phosphate value (mg/l)	Phosphate input (Kg/year)
I	0.1	480.7
II	0.1	5555.6
III	0.2	8677.0
VIII	0.1	1224.4
Total		15937.7

September, 1990

Zone	Phosphate value (mg/l)	Phosphate input (Kg/year)
I	0.1	314.3
II	0.1	4195.9
III	0.2	9718.7
IV	0.2	2989.8
V	0.2	2204.0
VI	0.1	409.4
Total		19832.1

Intermediate Aquifer System
May, 1991

Zone	Phosphate value (mg/l)	Phosphate input (Kg/year)
I	0.26	1100.2 to 1542.4
II	0.26	361.8 to 507.2
III	0.26	354.5 to 497.1
Total		1816.5 to 2546.7

September, 1990

Zone	Phosphate value (mg/l)	Phosphate input (Kg/year)
I	0.26	793.1 to 1103.8
II	0.26	595.8 to 833.3
III	0.001	475.2 to 665.2
Total		1864.1 to 2602.3

Surficial Aquifer System

May, 1982

Zone	Phosphate value (mg/l)	Phosphate input (Kg/year)
I	0.2	3.65 to 36.5
II	0.2	3.58 to 35.8
III	0.12	0.17 to 1.7
IV	0.1325	1.83 to 18.3
V	0.01	0.22 to 2.2
VI	0.01	0.12 to 1.2
VII	0.35	9.17 to 91.7
Total		18.74 to 187.4

September 1982

Zone	Phosphate value (mg/l)	Phosphate input (Kg/year)
I	0.2	3.94 to 39.4
II	0.2	6.21 to 62.1
III	0.12	0.17 to 1.7
IV	0.1325	3.04 to 30.4
V	0.01	0.22 to 2.2
VI	0.01	0.16 to 16.0
VII	0.35	11.11 to 11.1
Total		24.85 to 248.5

Total Input in Tampa Bay

Nitrate

May 1991 = 5781.4 kg/year to 6125.9 kg/year

September 1990 = 6323.0 kg/year to 6686.3 kg/year

Phosphate

May 1991 = 17772.9 kg/year to 18671.8 kg/year

September 1990 = 21721.1 kg/year to 22742.9 kg/year

Nitrate

May 1991 = 5.8 x 1000 kg/year
to
6.1 x 1000 kg/year

September 1990 = 6.3 x 1000 kg/year
to
6.7 x 1000 kg/year

Phosphate

May 1991 = 17.8 x 1000 kg/year
to
18.7 x 1000 kg/year

September 1990 = 21.7 x 1000 kg/year
to
22.7 x 1000 kg/year

Appendix IV. Table showing flux rates into Tampa Bay from other sources (Southwest Florida Water Management District, 1992)

TAMPA BAY- ANNUAL BUDGETS
NITROGEN

Inputs	Low Load (kgx1000)	%	High Load (kgx1000)	%	Confidence
	Non-point				
(Lower Watershed)	1940	44.0	1940	26.6	Low
(Upper Watershed)	940	21.3	2620	36.0	Moderate
Atmospheric	640	14.5	1290	17.7	Moderate
	Point				
(Lower Watershed)	470	10.7	470	6.5	High
Fugitive Releases	380	8.6	750	10.3	Moderate
Groundwater	40	0.9	210	2.9	Very Low
Total		4410		7280	

Losses	Low Load (kgx1000)	%	High Load (kgx1000)	%	Confidence
Outflow	980		1200		Moderate
Sediments/Other	3430		6080		Very Low
Total		4410		7280	

TAMPA BAY- ANNUAL BUDGETS
PHOSPHORUS

Inputs	Low Load (kgx1000)	%	High Load (kgx1000)	%	Confidence
Fugitive Release	1250	48.7	2504	53.0	Moderate
Upper Watershed	640	24.7	1450	30.7	Moderate
Point (Lower Watershed)	370	14.4	370	7.8	High
Non-point (Lower Watershed)	260	10.1	260	5 5	Low
Atmospheric	40	1.6	90	1.9	Moderate
Groundwater	8	0.3	50	1.1	Very Low
Total	2568		4724		

Losses	Low Load (kgx1000)	%	High Load (kgx1000)	%	Confidence
Outflow	350		430		Moderate
Sediments/Other	2218		4294		Very Low
Total	2568		4724		