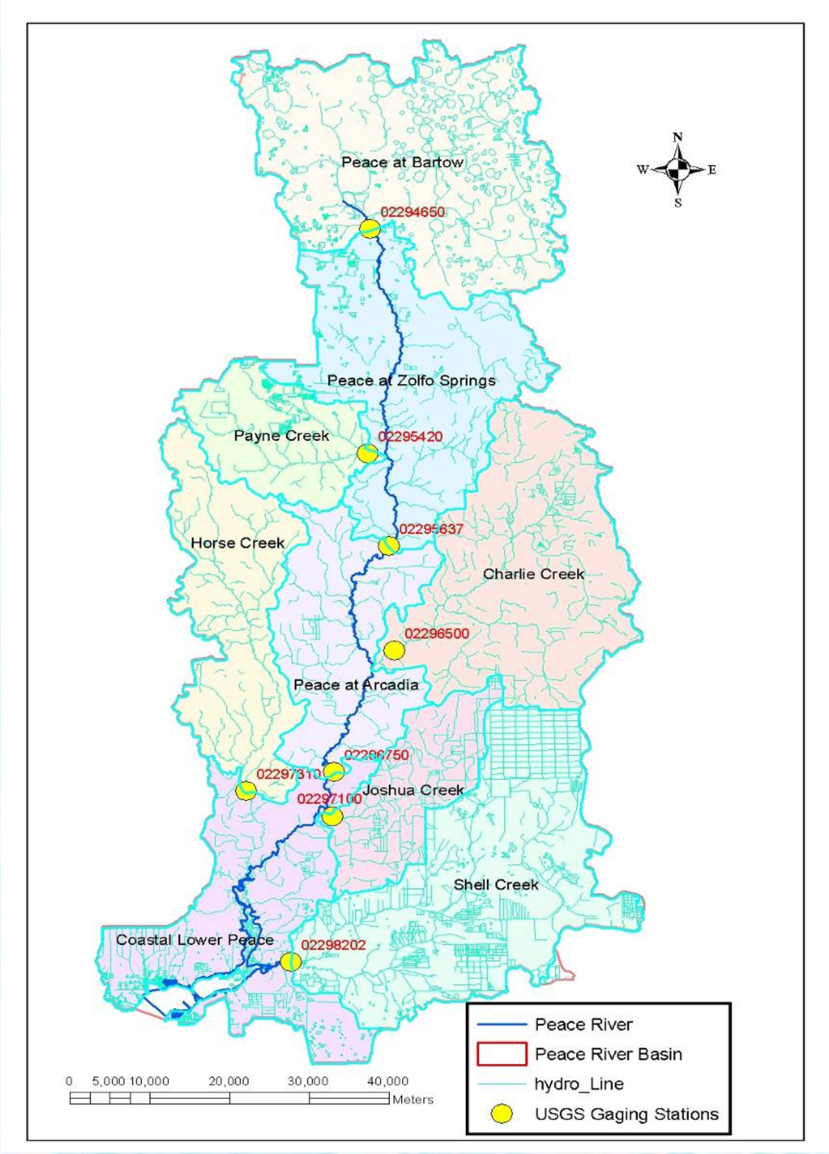
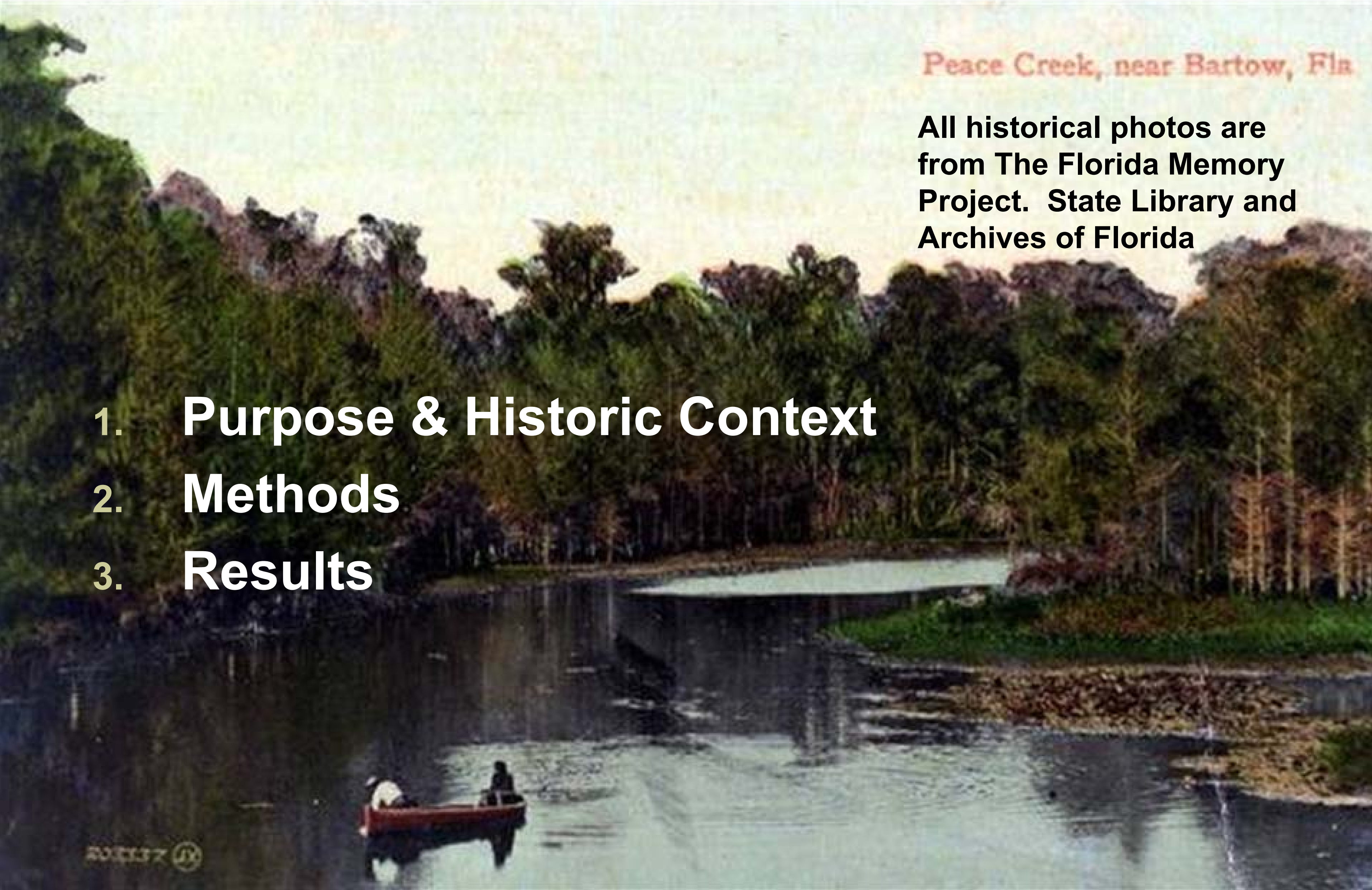
Peace River CIS Water Budgets



Presentation Overview



All historical photos are from The Florida Memory Project. State Library and Archives of Florida

1. Purpose & Historic Context
2. Methods
3. Results

What is a Water Budget?

- **An accounting of all the water flows in a watershed**

- **Basic equation:**

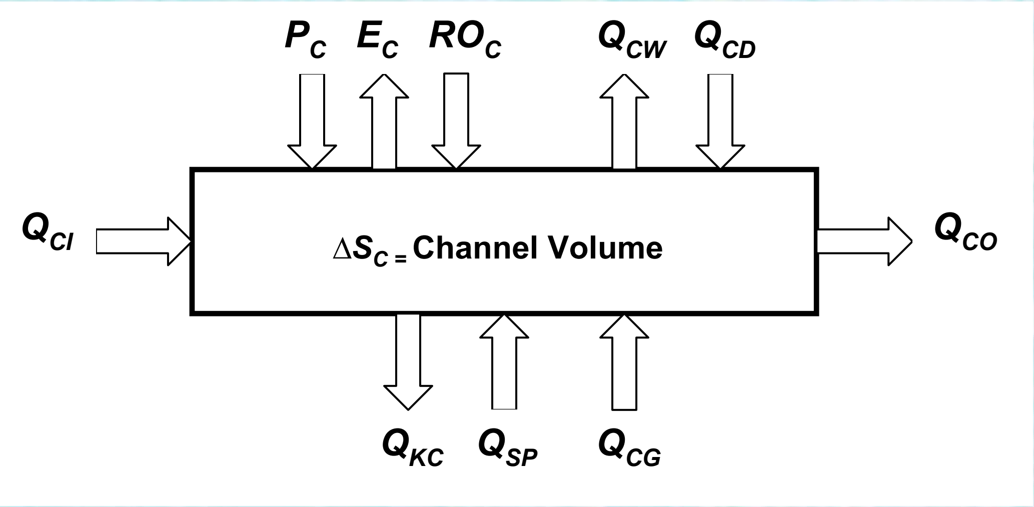
  $$P - ET - R - G = \Delta S$$

  - **P = Rain**
  - **ET = Evapotranspiration**
  - **R = Run off**
  - **G = Groundwater recharge**
  - **ΔS = Change in storage**

PRCIS Water Budget Equations

3 Budgets:

- Channel budget
- Surface budget
- Groundwater budget



What are the Objectives?

Water budgets should:

- **Quantify hydrologic fluxes on at an order-of-magnitude resolution.**
- **Lead to better understanding of the magnitude of natural and anthropogenic fluxes.**
- **Aid understanding of the natural variations in hydrology over time.**

Sub-Basins

Nine Sub-Basins were selected:

- Peace at Bartow
- Peace at Zolfo Springs
- Peace at Arcadia
- Payne Creek
- Charlie Creek
- Joshua Creek
- Horse Creek
- Shell Creek
- Coastal Lower Peace

Water budgets are at “sub-basin scale”

Time Periods

Water budgets for four time periods:

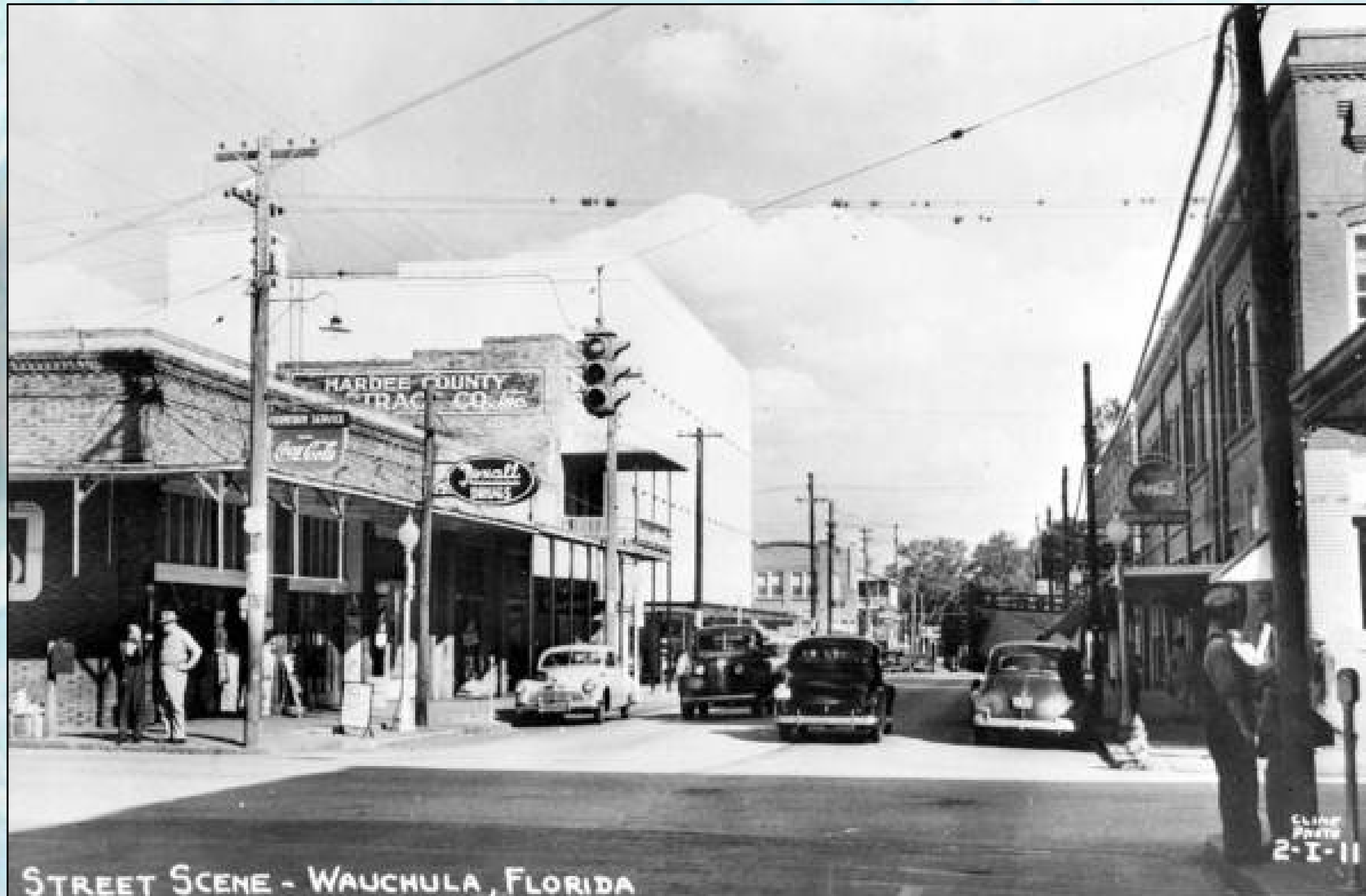
- 1941-1943
- 1976-1978
- 1989-1991
- 1997-1999

- 3-year budgets seek to average inter-annual variability
- 3-year budgets are each associated with a LULC map for that time period

1940's "Pre-Development"

- 1941-1943
- Selected as representative of "pre-development" conditions
- Some development had already taken place
- Pre-1940 hydrologic data is rare
- 1941-1943 period is best compromise to capture "pre-development conditions" and still have data

Wauchula in Late 40's

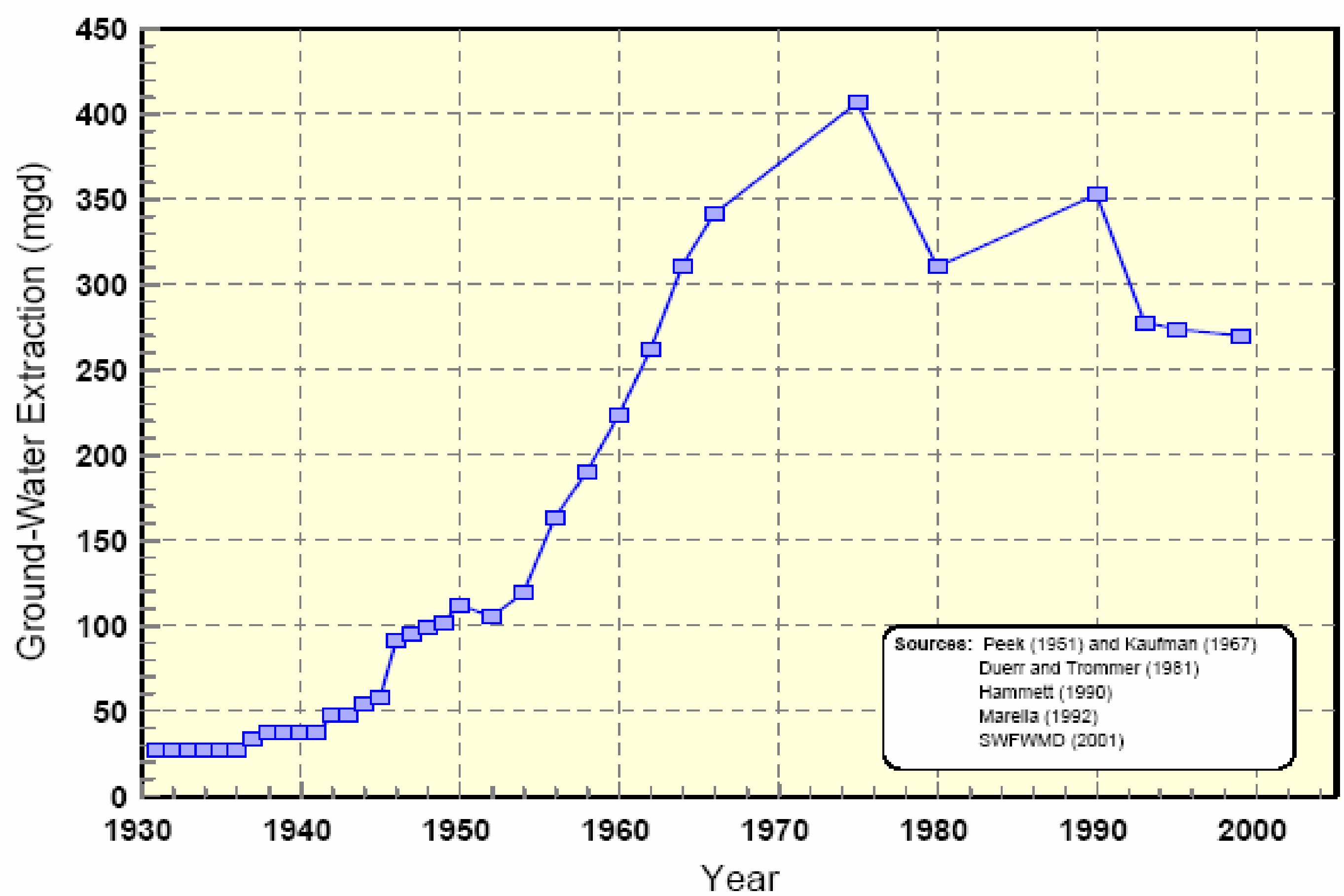


Polk County Artesian Well

Near Eagle Lake, 1911

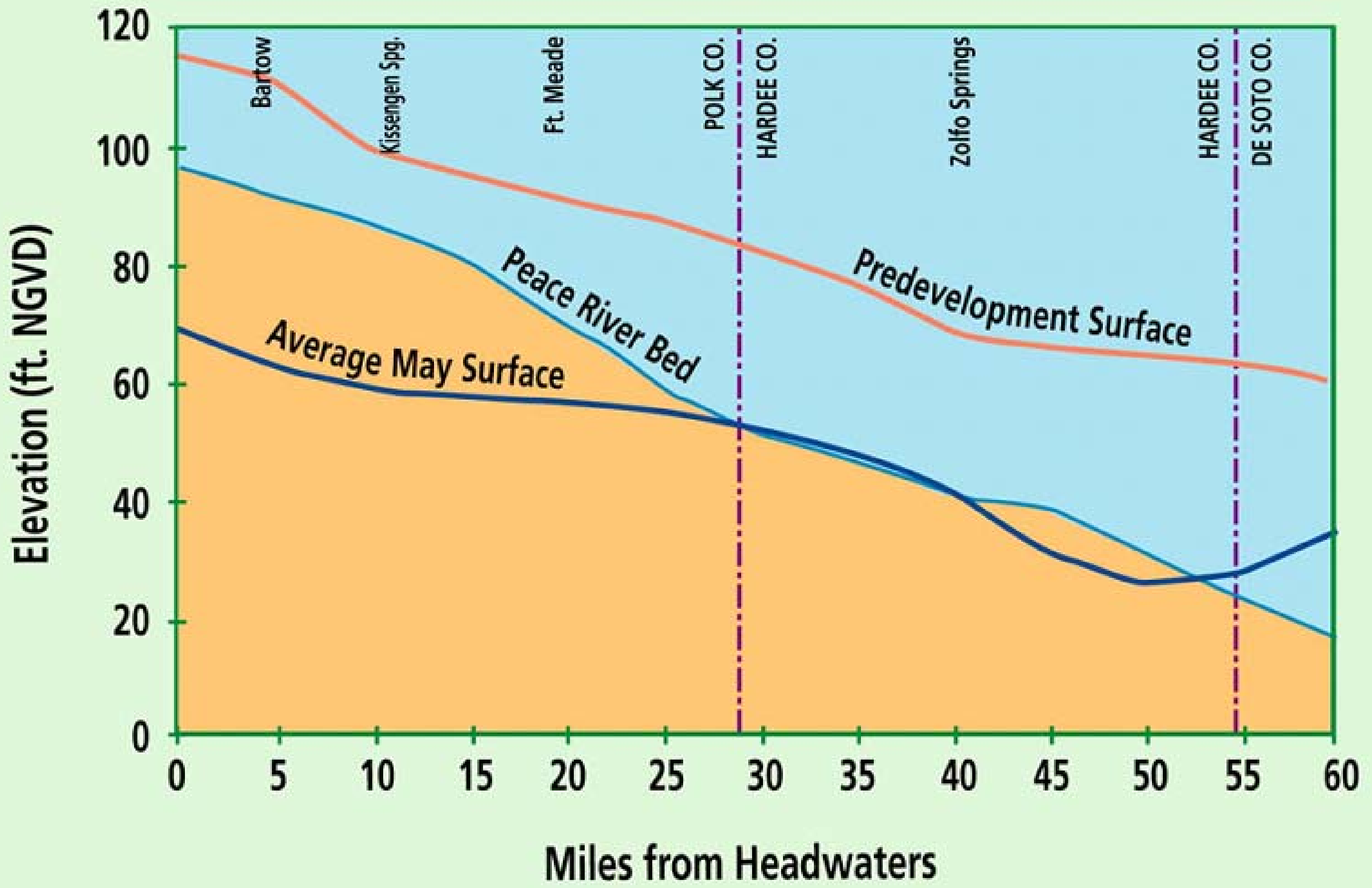
Wauchula 1925

Increasing GW Use in Polk



…Leads to aquifer drawdown.

Recharge / Discharge Trends



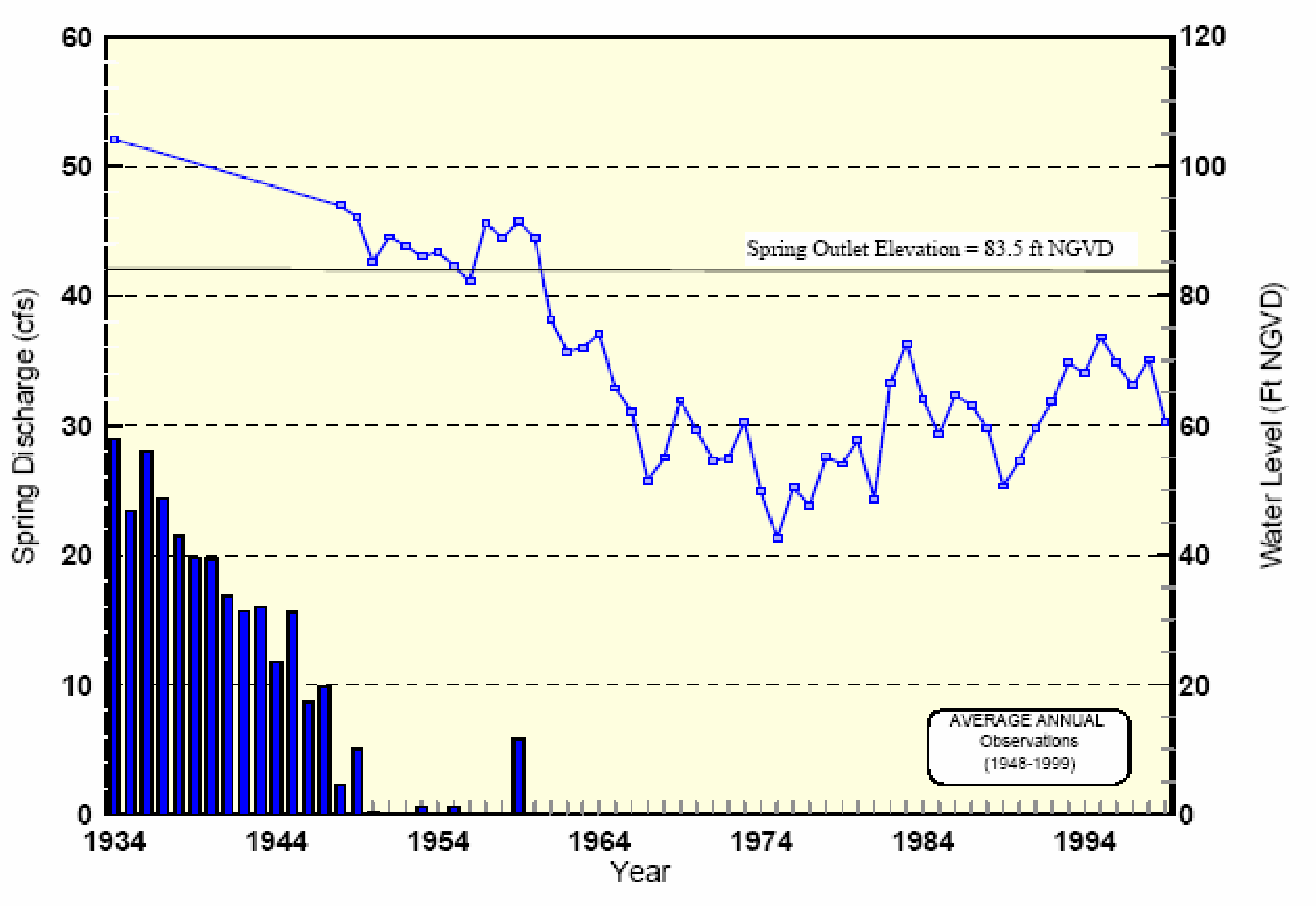
Kissingen Spring

- Flow of approx.15 to 20 Mgd prior to 1940.
- By 1950’s flow was only intermittent.
- Ceased all flow after late 1950’s.

- Kissingen spring is the “canary in the coal mine” for the onset of losing conditions in Upper Peace River.

Kissingen Spring in 1930's

Aquifer Drawdown & Spring Flow



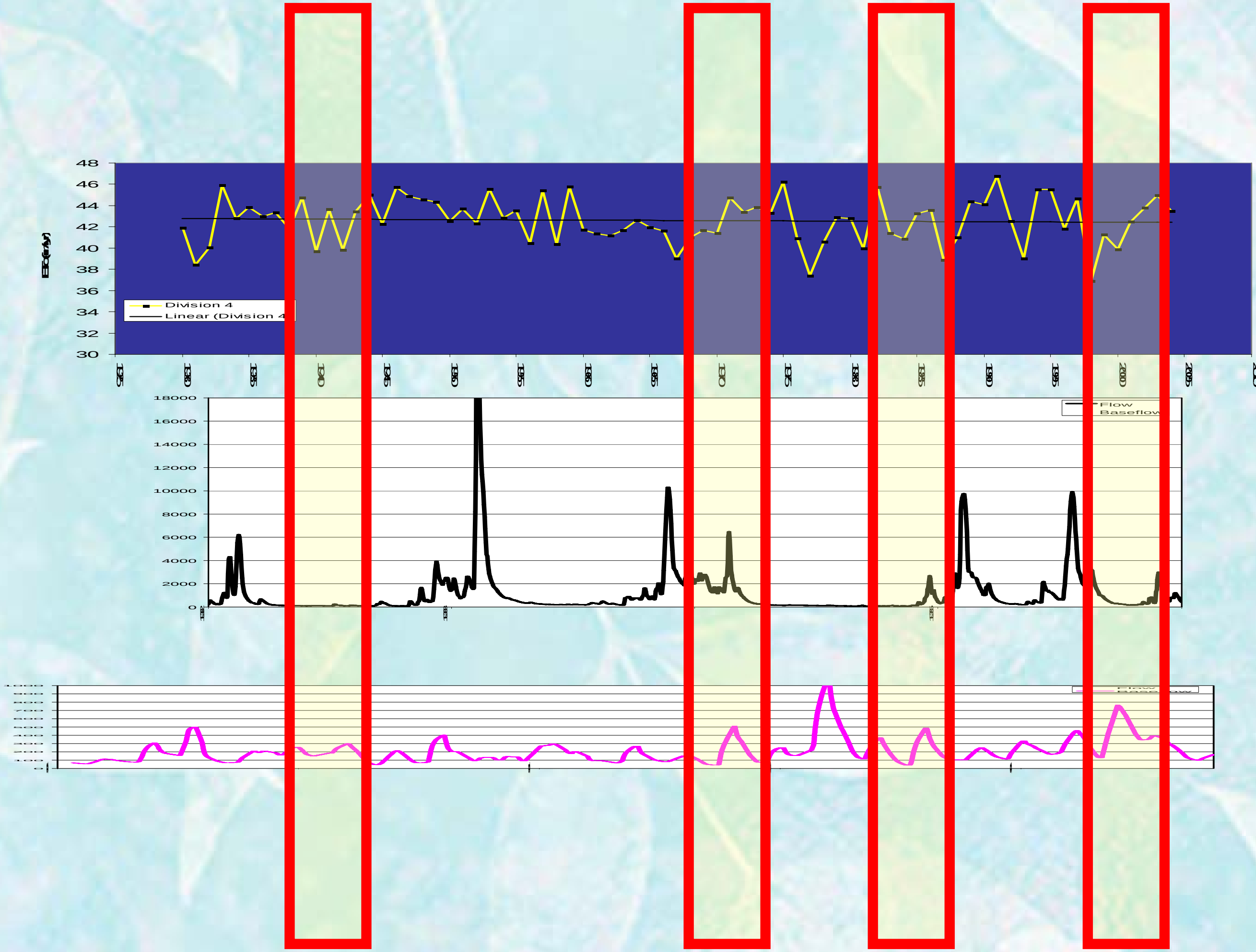
Source: SWFWMD

Methods

- Each water budget parameter (rain, ET, etc) must be directly calculated or estimated as a residual.
- How did we estimate the water budget parameters?

Time Series & Water Budgets

Budget 1 Budget 2 Budget 3 Budget 4

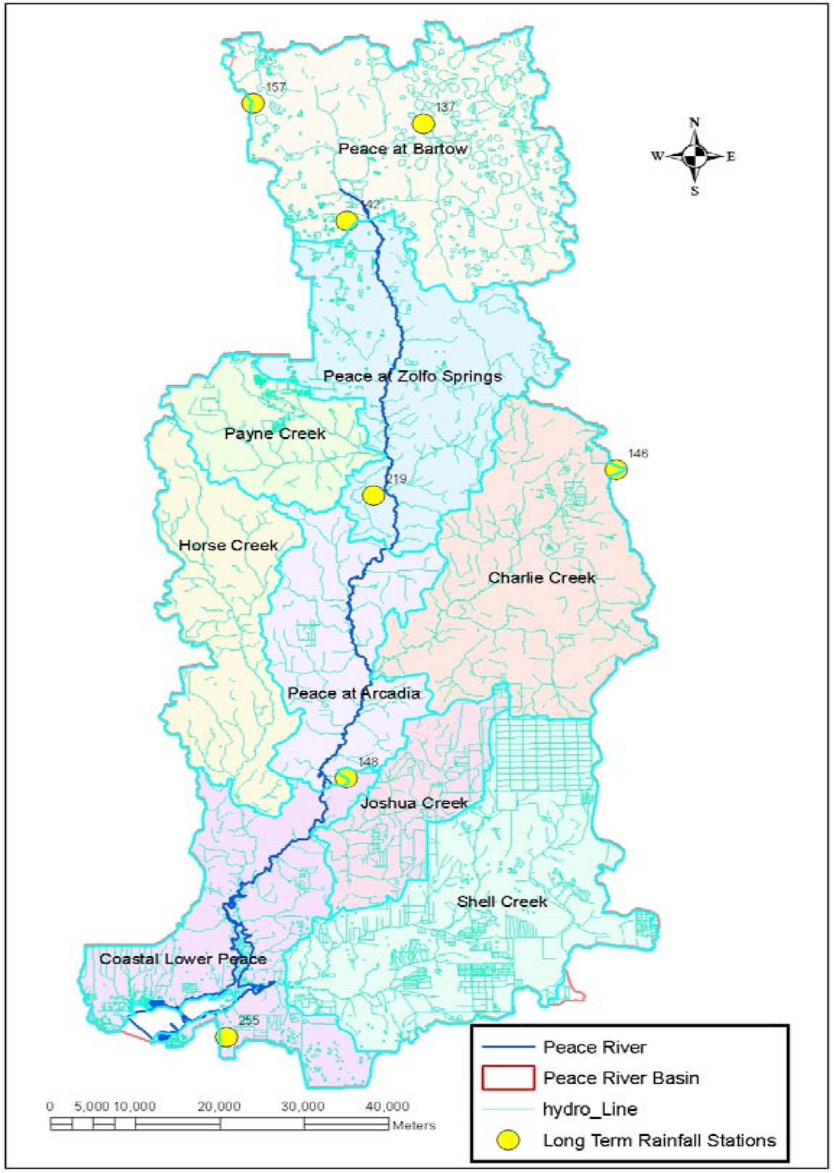


41-43 76-78 89-91 97-99

Rainfall Analysis

Selected long term rainfall stations:

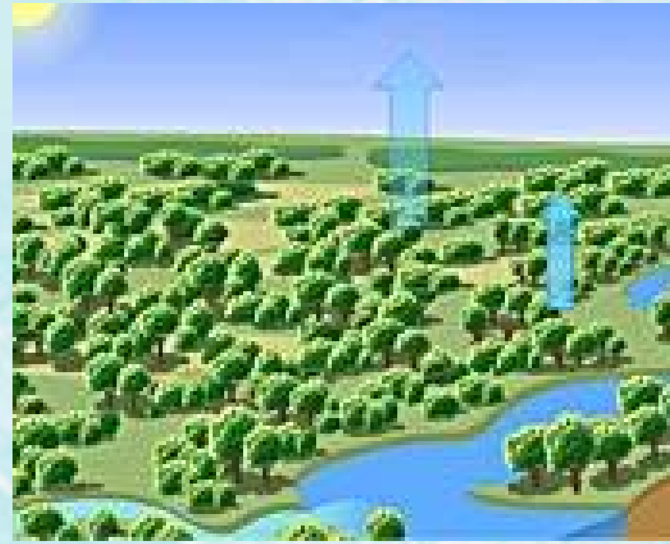
Station ID	Location
137	Winter Haven
142	Bartow
146	Avon Park
148	Arcadia
157	Lakeland
219	Wauchula
255	Punta Gorda



Evapotranspiration Analysis

ET

- Second largest water budget parameter
- Very difficult to estimate
- Varies based on weather and changes in LULC

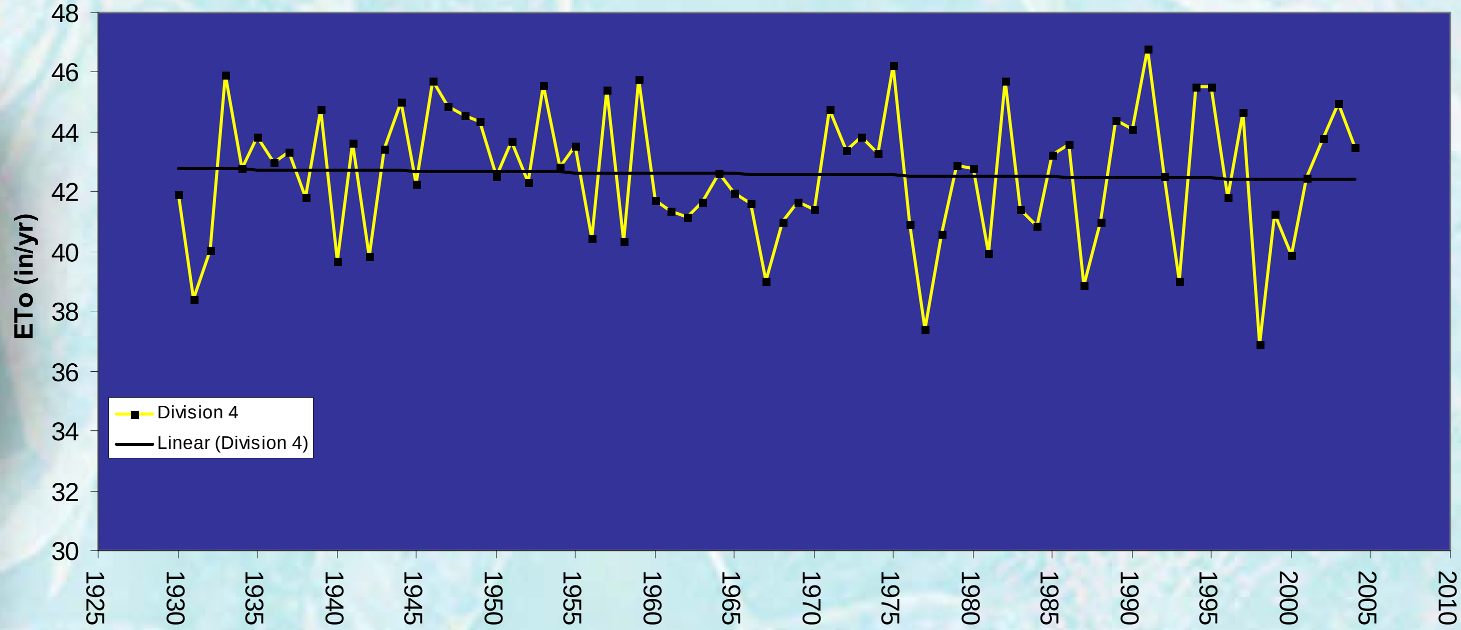


ET Estimates from Literature

- **ET estimates from pervious Central Florida studies range from 34" to 40" per year.**

- **Rieker, et al., (1991) estimated the average ET from water balances of various study watersheds in phosphate mining areas of Central Florida at ~ 38 in/yr.**
- **Knochenmus and Yobbi (2001): ~ 34 in/yr for the Coastal Springs Groundwater Basin of Citrus, Hernando, and Pasco Counties**
- **Knowles (1996): ~38 in/yr for the large springsheds of Rainbow Springs and Silver Springs in northwest central Florida using a water-budget approach.**
- **Cherry et al. (1970): ~39 in/yr for Manatee County**
- **Stewart (1966): 40 in/yr for Peace River basin for the mid-1950's**

Reference ET Record



- Record of reference ET (NWS NCDC)
- Crop coefficients
- Yields estimate of actual ET

ET by Land Use and Land Cover

High ET

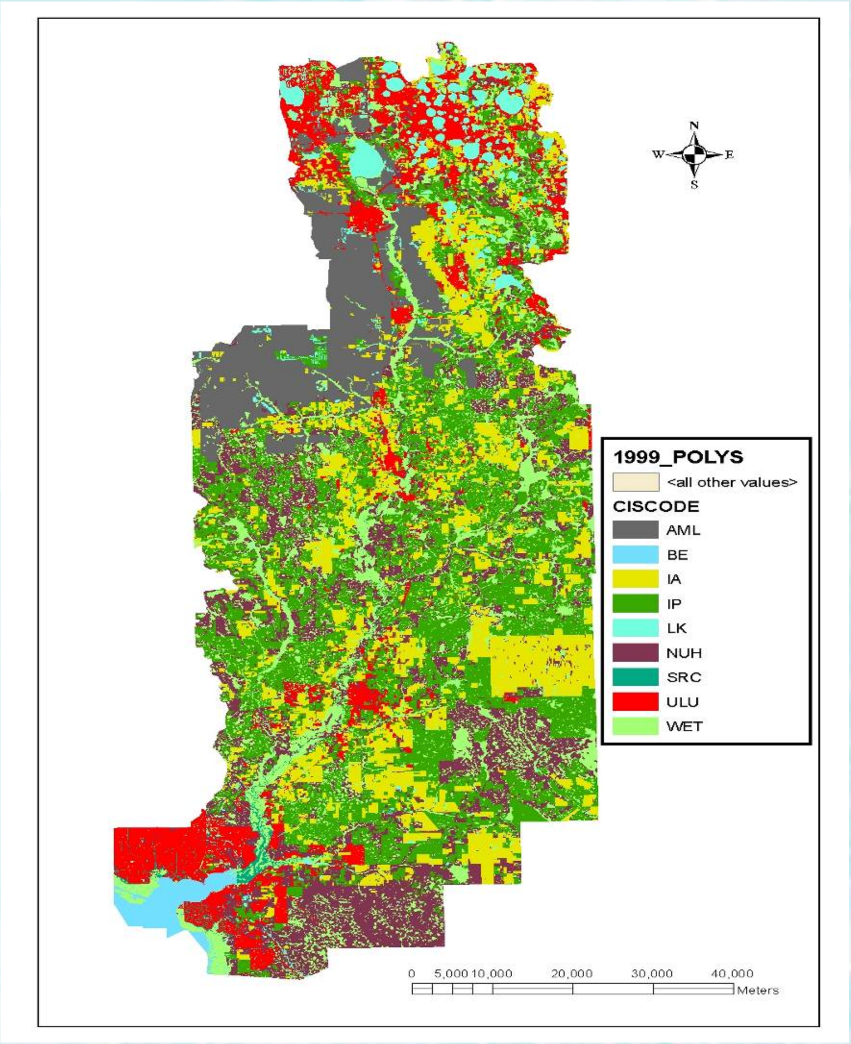
- Open Water
- Irrigated Citrus
- Wetlands

Medium ET

- Native Uplands
- Rangeland
- Low Density Residential

Low ET

- Barren Land
- Dense Urban



ET Trends

- Long term change in ET across PR Basin appears to be small.
- Annual variation in ET due to weather is large.
- Slight decrease in ET associated with change in land use.
  - High ET land cover are lost and replaced with lower ET LULC.
  - Urbanization
  - Loss of wetlands

Groundwater Budget

Utilized SWFWMD's Southern District Model.

Coupled model with historic estimates for aquifer conditions and pumping rates.

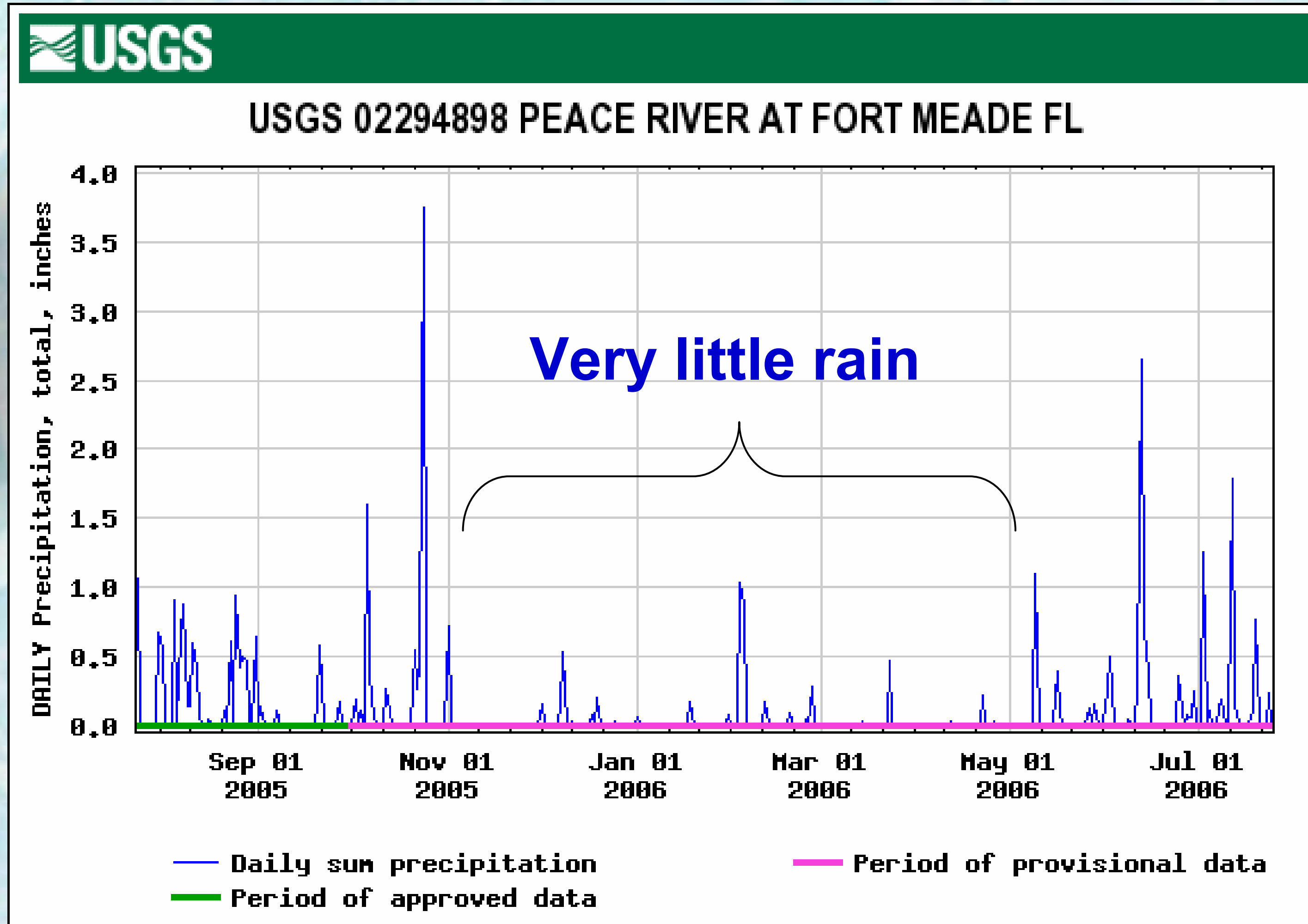
Results are compiled into tables and converted into inch equivalents.

Baseflow

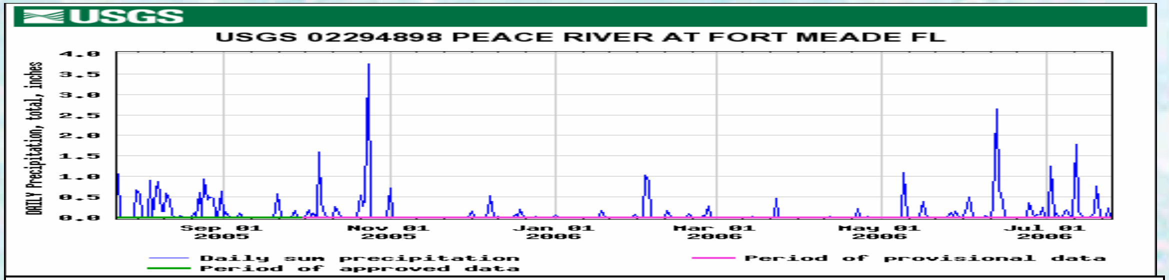
- **Defined as the contribution to stream flow from groundwater or other delayed sources.**

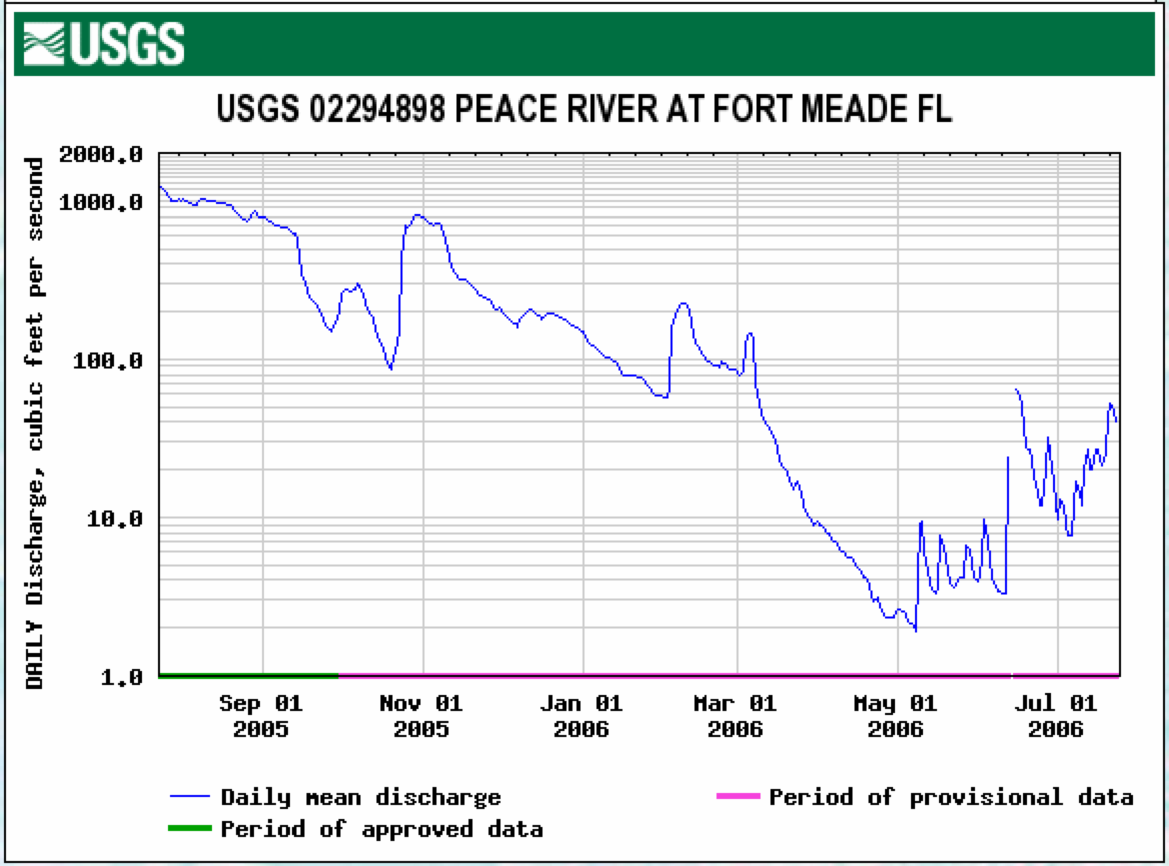



Rain Record at Ft Meade Gauge



Rainfall and Streamflow

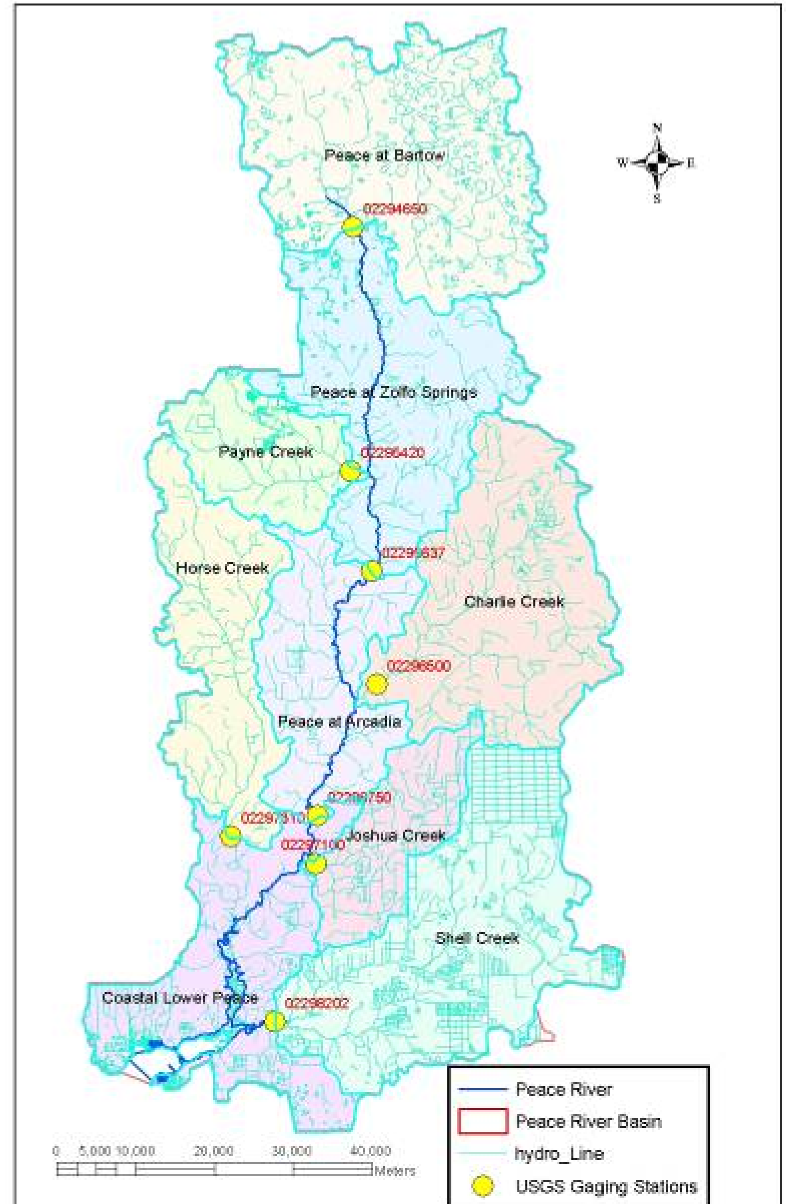




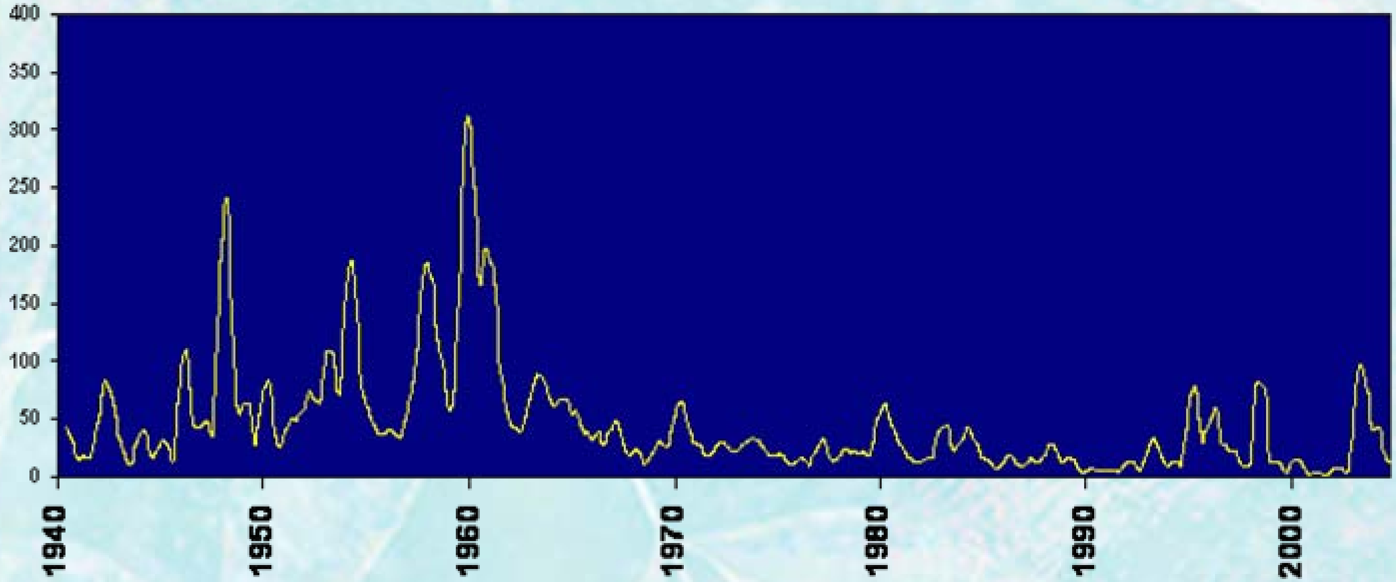
Hydrograph Separation

Selected Flow Gages:

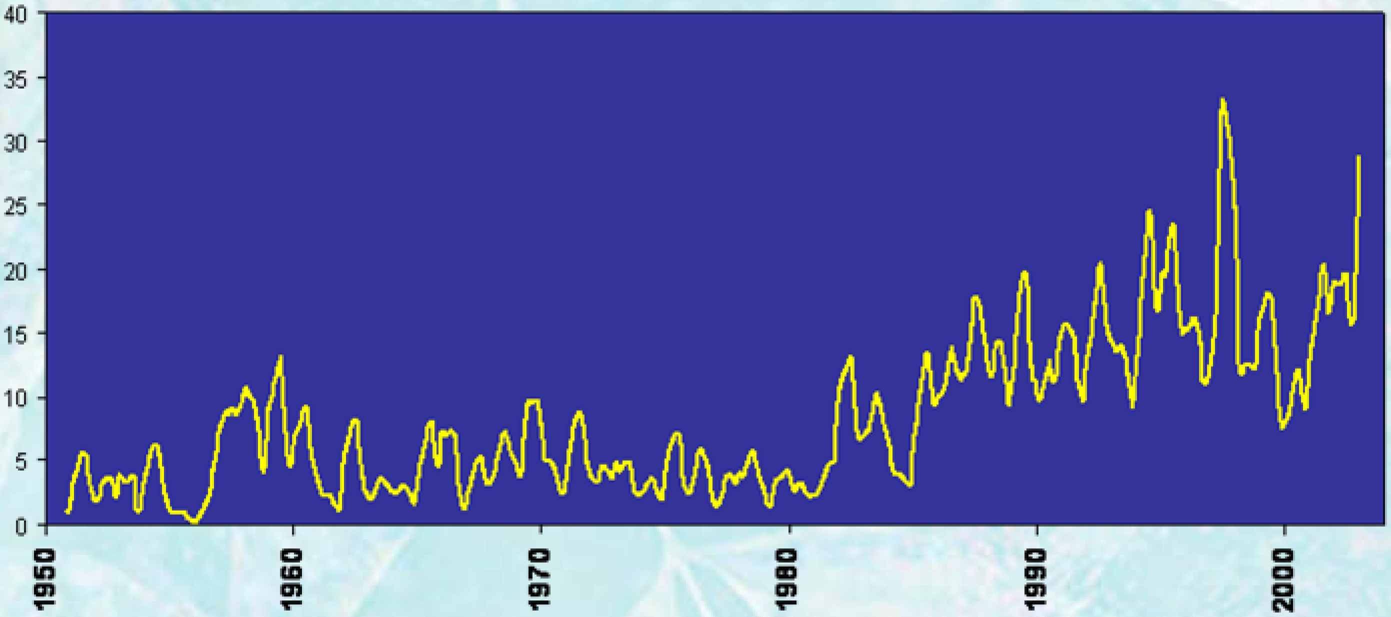
- 2294650 Peace River at Bartow
- 2295637 Peace River at Zolfo Springs
- 2296750 Peace River at Arcadia
- 2295420 Payne Creek
- 2296500 Charlie Creek
- 2297310 Horse Creek
- 2297100 Joshua Creek
- 2298202 Shell Creek



Baseflow at Peace at Bartow



Baseflow at Joshua Creek



Baseflow Trends*

Decreasing

- Peace at Bartow

Increasing

- Joshua Creek

Small or Variable Change

- Peace at Zolfo
- Peace at Arcadia
- Payne Creek
- Charlie Creek
- Horse Creek
- Shell Creek

* For period of record of each gauge

Baseflow by Sub-Basin

- Payne Creek 21%
- PR at Zolfo Springs 17%
- PR at Arcadia 15%
- Joshua Creek 14%
- Shell Creek 12%
- PR At Bartow 11%
- Charlie Creek 8%
- Horse Creek 7%

Baseflow as a percentage of total flow for 1997-1999.

Increased Recharge

- Peace River at Bartow sub-basin.
- Increased recharge in Peace at Bartow sub-basin is not an increase in water input.
- Can be viewed as surficial dewatering.
- As more water moves to replace groundwater withdrawals, less is available as baseflow to Peace River.

Increased Recharge = Less Baseflow

- Peace at Bartow
- Recharge has increased in response to aquifer drawdown from pumping
- Recharge has increased 3” to 5”+ since 1941-1943
- Increase in recharge is more than loss of baseflow

Water Budget Results

Rain	ET	Flow	Recharge
56”	36”	12”	8”

Run Off	Baseflow
10”	2”

GW Use
5”

Composite for all sub-basins upstream of Arcadia 1997-1999.

Note: Some parameters have significant uncertainty and should be interpreted with caution. Water budget results must be viewed as order of magnitude estimates.

Water Budget

Rain

- **56”**

ET

- **36”**

Rain – ET = 20”

- **20”** **(averages about 14”)**
- **10”+ to run off**
- **8” to recharge**

Composite for all sub-basins upstream of Arcadia 1997-1999

Flux Ranking

Biggest

1.)	Rain	56”
2.)	ET	36”
3.)	Total River Flow	12”
4.)	Runoff	10”
5.)	Recharge	8”
6.)	GW Withdrawals	5”
7.)	Baseflow	2”
8.)	Karst Losses	< 1”
9.)	PRMRWSA Extract	< 1”

Smallest

Composite for all sub-basins upstream of Arcadia 1997-1999.

Flux Ranking & Variability

Rain	**56”**	**(46” – 56”)**
ET	**36”**	**(34” - 36”)**
Total River Flow	**12”**	**(5” - 12”)**
Runoff	**10”**	
Recharge	**8”**	
GW Withdrawals	**5”**	
Baseflow	**2”**	**(1” – 2”)**
Karst Losses	**< 1”**	
PRMWSA Extract	**< 1”**	

Composite for all sub-basins upstream of Arcadia 1997-1999.

Parameter range given for the four PRCIS time periods.

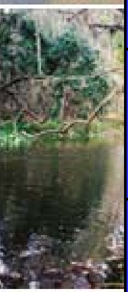
Change in Recharge Above Bartow

Peace River at Bartow Sub-Basin

Time Period	Recharge (in/yr)	Change from 41-43	Baseflow	Change from 41-43
1941-1943	6.9		1.4	
1976-1978	12.3	+5.4	0.7	-0.7
1997-1999	11.1	+4.2	0.9	-0.5

Some water budget parameters have significant uncertainty and should be interpreted with caution.

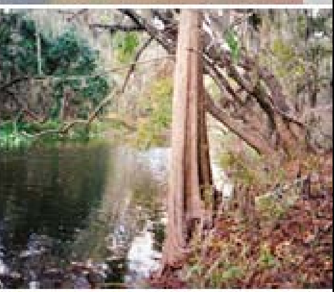
Budget Summary at Bartow



Years	Rain	ET	Total Flow	Run Off	Baseflow	Recharge	GW Use
41-43	51	37	8.7	7.3	1.4	6	3
76-79	49	34	4.1	3.4	0.7	12	9
97-99	54	36	8.8	7.8	0.9	10	8

All values in inch per year

Payne Creek Budget Summary



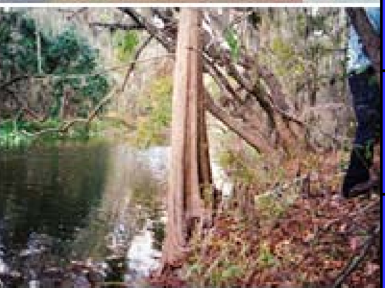
Years	Rain	ET	Total Flow	Run Off	Baseflow	Recharge
65-68*	-	-	8.7	8.0	0.7	-
89-91**	46	37	8.4	6.5	2	3
97-99	57	35	16.3	12.9	3.4	9

All values in inch per year

*6/1/1965 to 6/1/1968

**Values for this year are calculated using LULC mapping that differs from other periods. These values should be interpreted with caution.

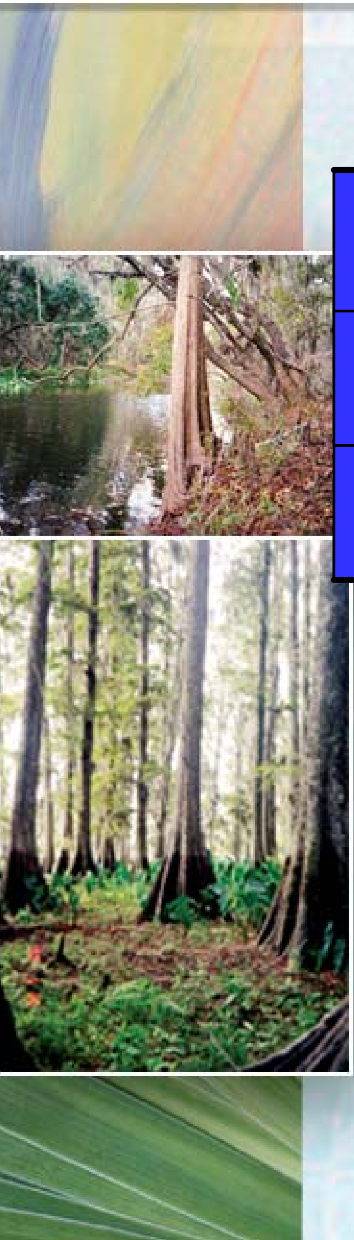
Joshua Creek Budget Summary



Years	Rain	ET	Total Flow	Run Off	Baseflow	Recharge
76-79	43	34	6	5.6	0.4	3
97-99	52	37	13.6	11.8	1.9	3

All values in inch per year

Horse Creek Budget Summary



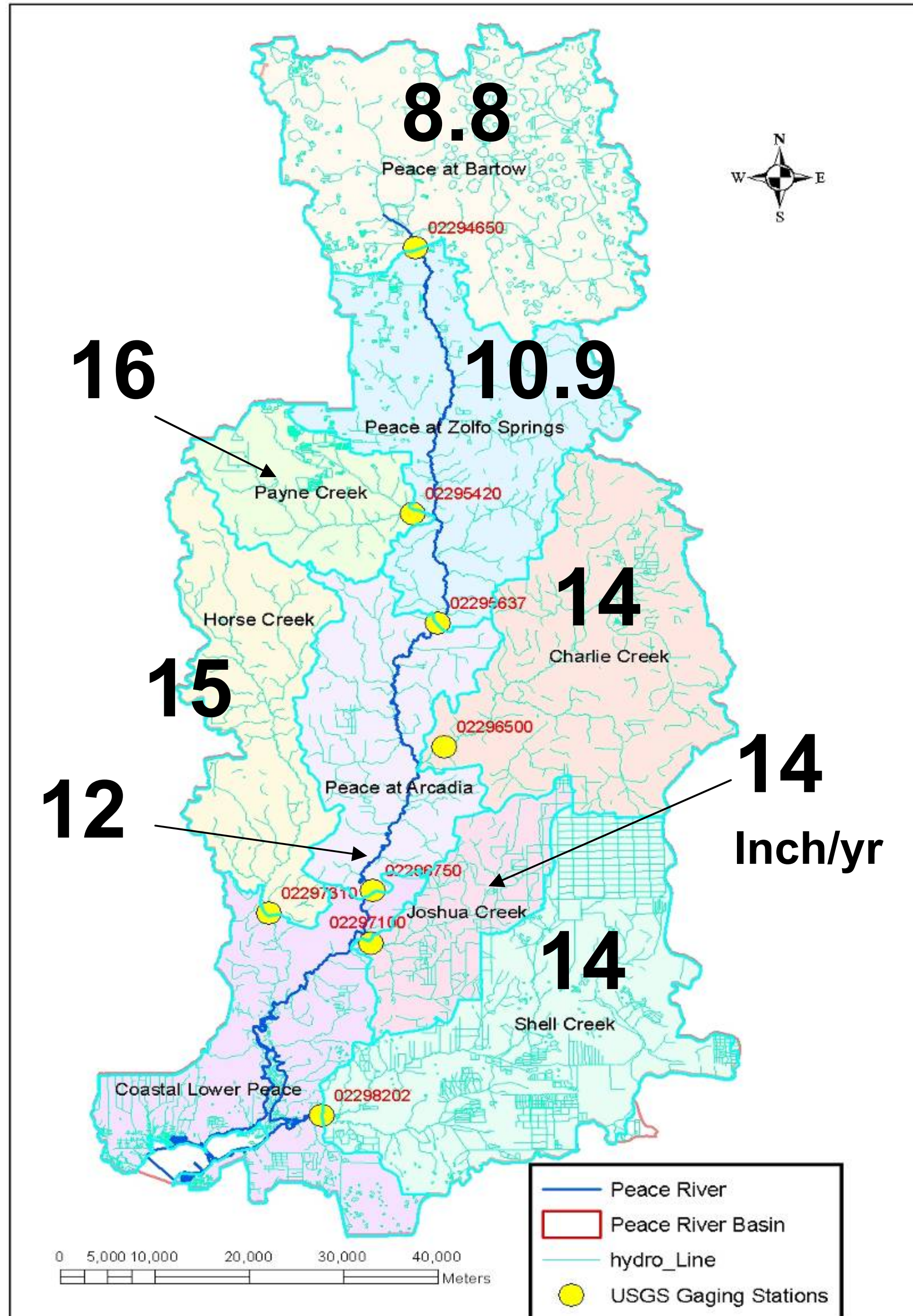
Years	Rain	ET	Total Flow	Run Off	Baseflow	Recharge
76-79	45	34	6.0	5.7	0.3	5
97-99	55	37	15.3	14.3	1.0	3

All values in inch per year

Conclusions

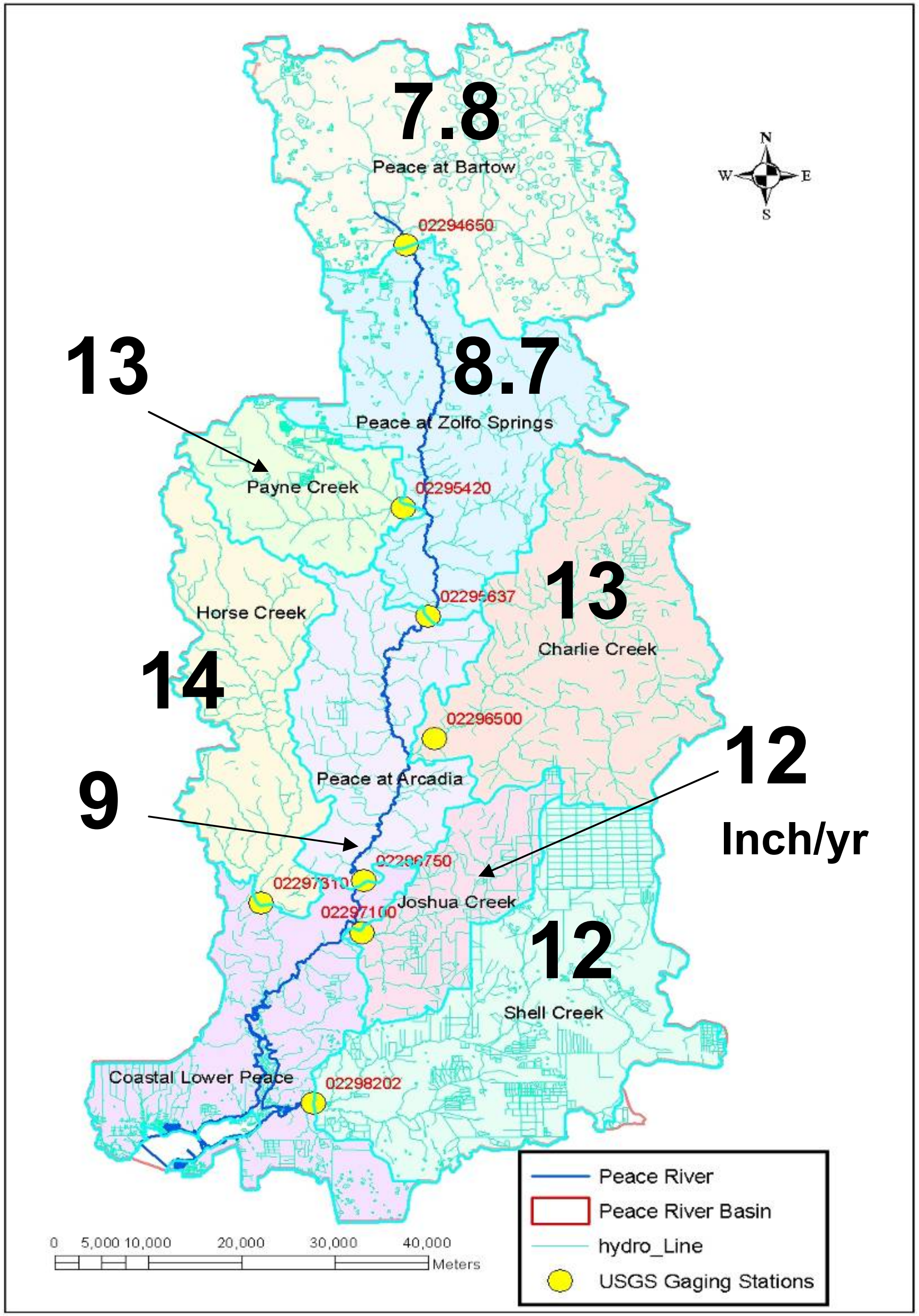
Total Flow

1997-1999



Conclusions

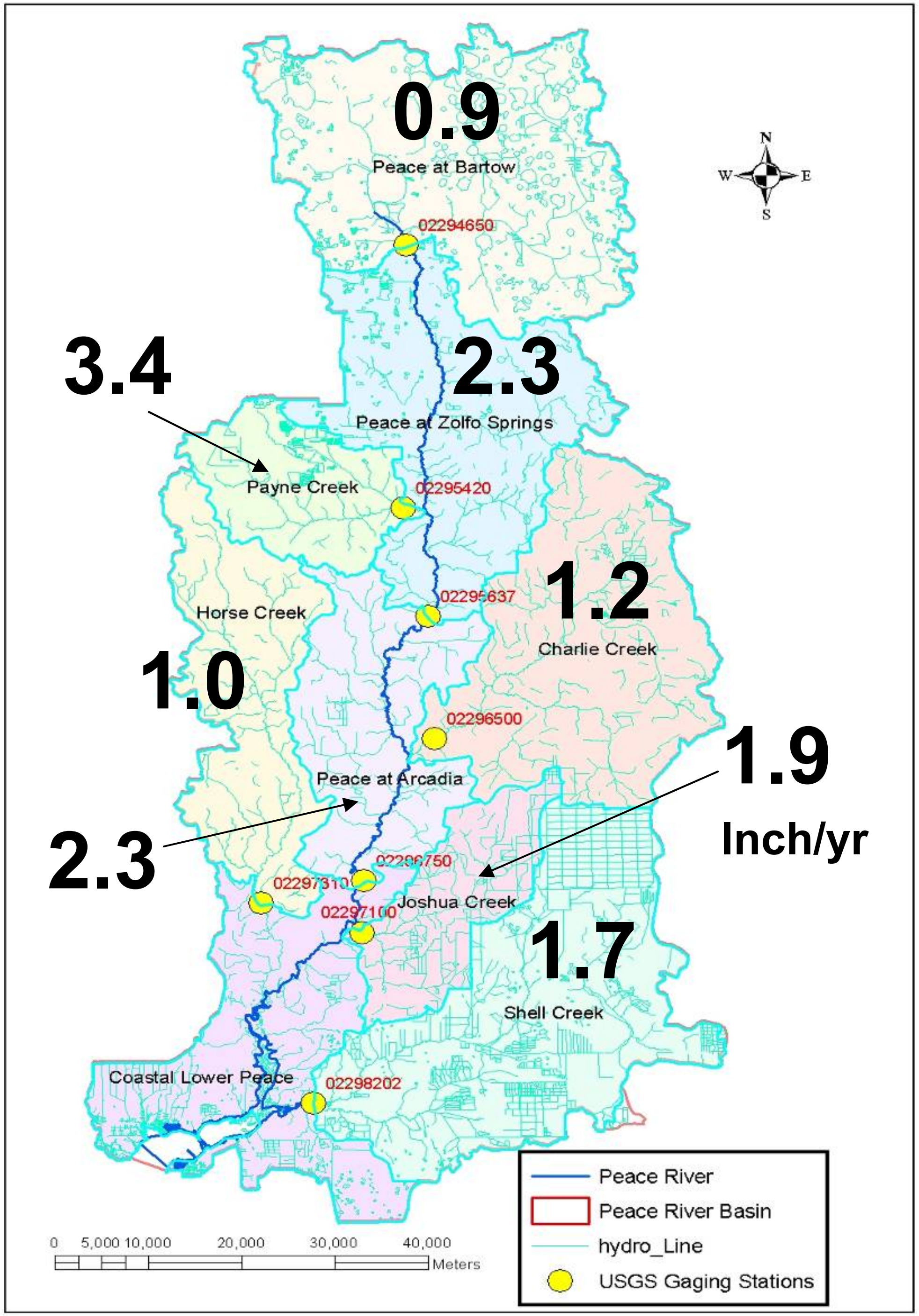
Run Off
1997-1999



Conclusions

Baseflow

1997-1999



Conclusions

- **Withdrawals of groundwater in the Peace River Basin have resulted in lower aquifer heads basin-wide.**
- **The impacts of aquifer drawdown vary across the basin.**
- **In more unconfined areas (above Ft Meade), the surficial aquifer and river are impacted from this effect.**
- **In more confined areas (Lower Basin), the surficial aquifer and river are not significantly impacted from this effect.**

Conclusions

- Baseflow has declined significantly in Peace River at Bartow sub-basin.
- Baseflow has increased significantly in Payne Creek and Joshua Creek.
- Baseflow trends in other sub-basins have been less significant.

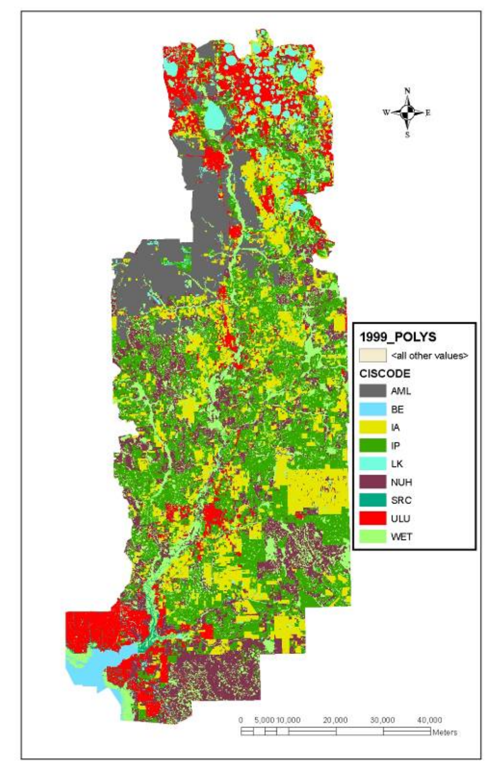
Conclusions

- Recharge to the SAS has increased in certain agricultural areas.
- This has resulted in increased baseflow in Joshua Creek.
- In Upper Peace River Basin recharge to IAS/UFAS has increased in response to drawdown of IAS/UFAS
- This has contributed a decrease in baseflow above Bartow along with other factors.

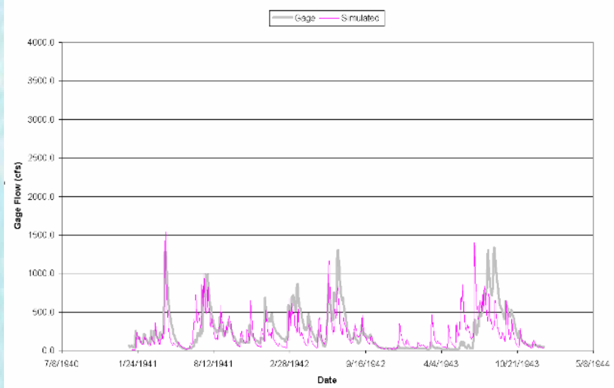
Conclusions

- Aquifer drawdown has changed the nature of baseflow in the Upper Peace.
- Gains from spring discharges (Kissingen) have been replaced by karst losses (sinkholes, etc.).
- Karst losses are important locally under low-flow conditions.
- Karst losses are less significant to overall flows at Arcadia.

Surface Water Budgets



Land Use Map

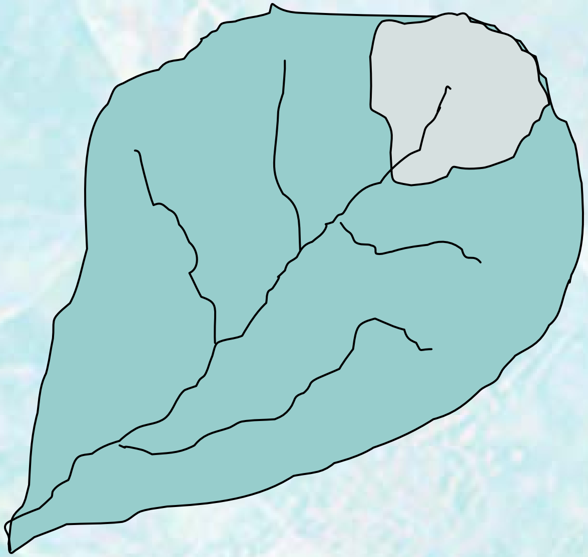


Runoff summary for each basin (in/yr)

	1941-43	1976-78	1997-99
'Bartow'	7.30	3.36	7.81
'Zolfo'	9.32	6.95	8.87
'Payne'	12.63	6.71	12.48
'Charlie'	13.71	8.30	13.07
'Horse'	14.76	5.89	14.70
'Arcadia'	11.25	4.68	9.88
'Joshua'	13.74	5.50	12.84
'Shell'	12.19	5.99	12.23

Storm Water Model

EPA Storm Water Management Model (EPA SWMM)



Precipitation (Rainfall hyetograph)

↓

SWMM Model ← SWMM Input Data Include…

↓

Flows and water levels

SWMM Input Data Include…

PRECIPITATION
Subbasin Areas
Imperviousness (DCIA)
Slope
Roughness
Width (a shape factor)
Depression Storage
Infiltration Parameters
Channel Characteristics

Hydrologic Assessment of Directly Connected Impervious Areas (DCIA)

Runoff summary for each basin (in/yr)

	1941-43	1976-78	1997-99
'Bartow'	7.30	3.36	7.81
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'Charlie'	13.71	8.30	13.07
'Horse'	14.76	5.89	14.70
'Arcadia'	11.25	[illegible]	[illegible]
'Joshua'	13.74	[illegible]	[illegible]
'Shell'	12.19	[illegible]	[illegible]

Estimated DCIA% based on land use

	1940	1970	1999
'Bartow'	37.0	29.9	32.6
'Zolfo'	23.1	17.0	16.1
'Payne'	21.2	17.9	10.7
'Charlie'	18.5	15.8	15.9
'Horse'	20.8	18.6	17.6
'Arcadia'	24.4	20.6	20.9
'Joshua'	16.1	13.9	13.9
'Shell'	18.2	15.0	14.2
"Coastal"	24.7	27.6	29.5

Calibrated DCIA% using flow volume

	1941-43	1976-78	1997-99
'Bartow'	14.44	6.91	14.47
'Zolfo'	16.95	14.00	15.78
'Payne'	23.43	14.20	21.81
'Charlie'	25.43	17.86	22.40
'Horse'		13.06	26.90
'Arcadia'	20.50	10.38	18.06
'Joshua'		13.04	24.90
'Shell'		13.77	23.35

Land Use Change Impacts

Land use change impacts
Assuming urban land uses had remained native upland habitats

1997-1999 versus 1941-1943 condition				
		Runoff (in/yr)		
	Additional ULU (acres)	Actual condition 1997-1999	Assumed condition	Runoff Change (%)*
'Bartow'	53671.2	7.81	6.37	23%
'Zolfo'	11105.4	8.87	8.20	8%
'Payne'	875.7	12.48	12.13	3%
'Charlie'	1382.7	13.07	12.90	1%
'Horse'	1517.4	14.70	14.43	2%
'Arcadia'	3470.8	9.88	9.52	4%
'Joshua'	2368.9	12.84	12.06	6%
'Shell'	3040.6	12.23	11.94	2%

*Percent change from assumed condition to actual condition
ULU--Urban Land Uses; NUH—Native Upland Habitats

Land Use Change Impacts

Land use change impacts
Assuming actively mined lands had remained native upland habitats

1997-1999 versus 1941-1943 condition				
		Runoff (in/yr)		
	Change in Mining Area (acres)	Actual condition 1997-1999	Assumed condition	Runoff Change (%)*
'Bartow'	17526.6	7.81	7.84	-0.5%
'Zolfo'	61111.1	8.87	9.23	-3.9%
'Payne'	49074.1	12.48	13.98	-10.7%
'Horse'	6862.1	14.70	14.79	-0.6%

*Percent change from assumed condition to actual condition
AML—Actively Mined Lands

Land Use Change Impacts

Land use change impacts
Assume improved pastureland had remained wetlands

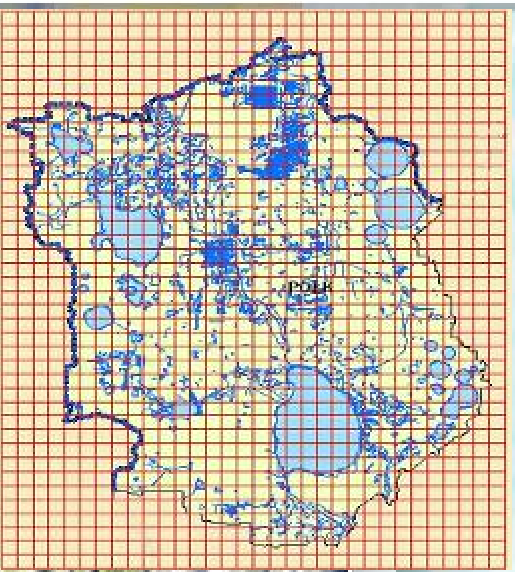
1997-1999 versus 1941-1943 condition						
	Change in Wetland Area (acres)	1997 condition Runoff (in/yr)	Dry Season Runoff (in/yr)	Dry Season Runoff Change (%)*	Wet Season Runoff (in/yr)	Wet Season Runoff Change (%)*
'Bartow'	-28216.9	7.81	7.46	5%	8.91	-12%
'Zolfo'	-24120.5	8.87	8.47	5%	11.21	-21%
'Payne'	-4893.6	12.48	12.28	2%	13.68	-9%
'Charlie'	-12061.1	13.07	12.89	1%	14.20	-8%
'Horse'	-8196.5	14.70	14.52	1%	15.83	-7%
'Arcadia'	-9520.8	9.88	9.65	2%	11.27	-12%
'Joshua'	-5155.1	12.84	12.64	2%	14.01	-8%
'Shell'	-18615.9	12.23	12.00	2%	13.61	-10%

*Percent change from assumed condition to actual condition

PRIM

- PRIM or Peace River Integrated Modeling Project
- Funded by the SWFWMD
- Started in 2004, to be completed in December 2008
- Integrated surface-water and groundwater flow model of the Peace River
- Calibration for 5 –year period 1998 – 2002, and validation for 1994 - 1997
- Better tool for analysis of changes in land-use, climate, and other human impacts.
- Prediction – How minimum flows will be affected under various management options

PRIM Complements the Cumulative Impact Study



Saddle Creek

PRIM

- Focus on hydrology, not water quality
- Focus on 'recent' (1994 – 2002) conditions vs. multi-decade scale changes
- Building a detailed computer simulation model
- 2500x 2500 ft grid size vs sub-basin scale
- Daily time steps vs. average annual water budgets

Questions & Comments