HYDROMORPHOLOGY OF THE ECONLOCKHATCHEE RIVER

by

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ABSTRACT

Climate change and human activities alter the hydrologic systems and exerted global scale impacts on our environment with significant implications for water resources. Climate change can be characterized by the change of precipitation and temperature, and both precipitation pattern change and global warming are associated with the increase in frequency of flooding or drought and low flows. With increasing water demand from domestic, agricultural, commercial, and industrial sectors, humans are increasingly becoming a significant component of the hydrologic cycle. Human activities have transformed hydrologic processes at spatial scales ranging from local to global. Human activities affecting watershed hydrology include land use change, dam construction and reservoir operation, groundwater pumping, surface water withdrawal, irrigation, return flow, and others.

In this thesis, the hydromorphology (i.e., the change of coupled hydrologic and human systems) of the Econlockhatchee River (Econ River for short) is studied. Due to the growth of the Orlando metropolitan area the Econ basin has been substantially urbanized with drastic change of the land cover. The land use / land cover change from 1940s to 2000s has been quantified by compiling existing land cover data and digitizing aerial photography images. Rainfall data have been analyzed to determine the extent that climate change has affected the river flow compared to land use change. The changes in stream flow at the annual scale and low flows are analyzed. The Econ River has experienced minimal changes in the amount of annual streamflow but significant changes to the amount of low flows. These changes are due to urbanization and other human interferences.

I dedicate this thesis to my loving family.

ACKNOWLEDGMENTS

I would like to thank my academic advisor Dr. Dingbao Wang. He has been a great advisor, sharing ideas and concepts and teaching me how to do research. He has been an excellent mentor throughout the entire project and I cannot thank him enough for all the guidance and support he has given me. I would also like to thank my thesis committee members Dr. Scott Hagen and Dr. Manoj Chopra for the support and knowledge they have shared with me.

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CHAPTER 1 : INTRODUCTION

1.1 The Econlockhatchee River

The Econlockhatchee River (Econ River for short) is located in Central Florida just east of Orlando. The Econ River is the second largest tributary to the St. Johns River (http://www.sjrwmd.com/middlestjohnsriver/econriver.html) and has a watershed area of roughly 705 square kilometers. Its watershed covers parts of Orange, Seminole and Osceola County. The Econ River is made up of the Little and Big Econ Rivers. The Little Econ River is located on the west side of the watershed and extends towards east Orlando. The mean annual precipitation in the Econ River basin is 1,254 millimeters per year, and the mean annual flow is roughly 292 million cubic meters (i.e., 414 millimeters) per year. Figure 1.1 below illustrates the Econ River watershed's location relative to Orlando and the University of Central Florida (UCF).

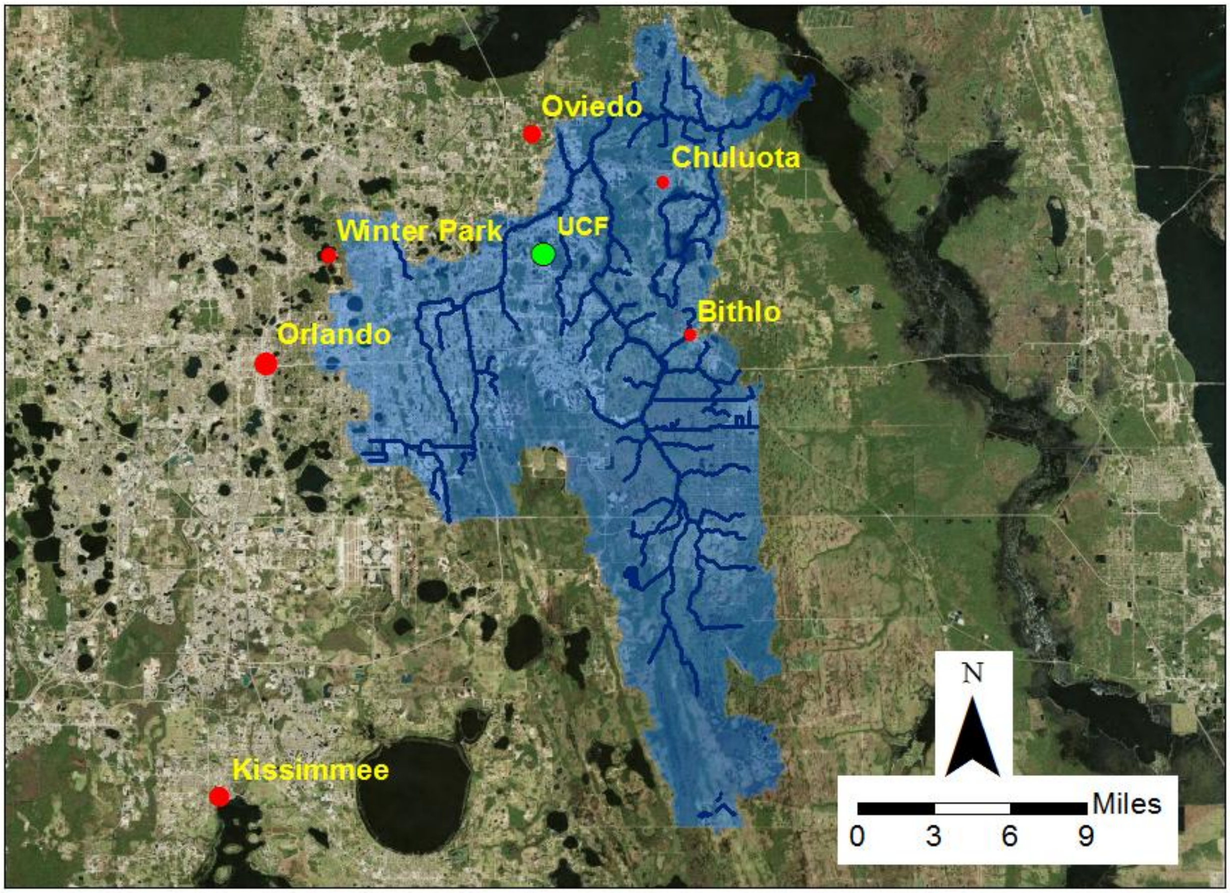

Figure 1.1 Map of the Econlockhatchee watershed and surrounding cities.

1.2 Human and Climate Interferences

The Econ River Basin has undergone substantial land use change since the 1970's. This land use change is the result of development and growth of the greater Orlando area. Prior to development, the watershed was made up of wetland, forest land and upland non-forested areas. The change in land use has impacted the flow regime of the Econ River. This thesis research will analyze the different ways human development has impacted the Econ River.

Watersheds and river systems are not only affected by human development but also by climate variations and changes. Each watershed has a different degree and frequency of variations which is characteristic of the watershed. This thesis will investigate different climate variables and analyze their change to evaluate how the climate variation affects the flow regime.

1.3 Background

Each watershed is unique and has different characteristics such as drainage area, location, land use etc. Because of these characteristics there are so many complexities that can cause the flow regime to change. Human interferences and climate change are two major attributions to flow regime changes. In terms of flow regime changes, human interference is a general term that means the changing of a watershed due to human practices. Human interferences can take on many different forms such as channelization, water withdrawal, effluent discharge, land use change, etc. The different forms of human interferences can change the flow regime in different ways. When looking at changes in a watershed and human development it is important to consider all the factors at hand and how they relate with one another to determine how they may impact the watershed.

Some watersheds change due to climate change even when there is no human interference at all. Climate variations are any fluctuations in the climate that can cause the flow regime to change such as droughts, floods, etc. Most climates have some degree of fluctuations throughout the year that are normal.

Human interferences and climate variations can interact with one another to cause changes in flow regimes. Human interferences can amplify climate change and also minimize climate change. Each watershed is unique and the characteristics and conditions of the watershed should be carefully analyzed to determine what factors are involved in changes to the flow regime.

1.4 Objectives

Below are the research objectives of this case study of the Econ River.

I. Analyze and quantify trends in the climate that relate to the Econ River flow regime.

II. Analyze and quantify land use change over time.

III. Analyze other human interferences such as groundwater pumping, effluent discharge, and storm water management practices.

IV. Discuss the relationship between human and climate interferences and how they relate to the flow regime change in the Econ River basin.

1.5 Organization of the Thesis

This thesis is broken down into 5 chapters to provide the framework of the research goals.

- Chapter 1: Introduction – This chapter contains the abstract as well as base information about the Econlockhatchee River basin. Also discussed are the general concepts of human and climate interferences and how they can affect watersheds.

- Chapter 2: Climate variability and changes in the Econ River basin – This chapter explains methods used to analyze climate data for the Econ River basin.
- Chapter 3: Hydrologic changes and variability in the Econ River basin – This chapter presents methods used to analyze stream flow data and groundwater data for the Econ River basin. Findings and results are discussed to determine common trends.
- Chapter 4: Human interferences in the Econ River basin – This chapter presents methods used to analyze land use, population and water withdrawal data. Storm water regulations and effluent discharge are explored to determine relationships with streamflow analyses.
- Chapter 5: Conclusions and future work – Overall conclusions are summarized and presented. Recommendations of future work and analyses are discussed.

CHAPTER 2 : CLIMATE VARIABILITY AND CHANGES IN THE ECON RIVER BASIN

The Econ River basin is located in a subtropical climate. The summers are hot and humid and winters are mild and warm. The climate aridity index (E_p/P) is 0.93. The average precipitation is 1,254 millimeters per year. During the summer afternoon thunderstorms are frequent and regular. Many northerners come down for the winter every year to enjoy the warmer temperatures and plentiful sunshine.

2.1 Precipitation

There are many different factors in a water balance for a watershed. Precipitation is one of the most important factors because it is the main input into the system. Precipitation recharges the aquifers, provides water sources for evaporation and produces runoff that turns into stream flow. Fluctuation in precipitation can significantly change the stream flow over time. Different climate systems have different rainfall patterns and volumes over time. The stream flow in the Econ watershed is greatly made up of runoff and the discharge of shallow aquifers. Both of which are directly affected by the amount of precipitation.

Data was gathered from several rain stations around the Econ River basin vicinity to compile rain data dating as far back as the 1940's. Data was gathered from NOAA National Climatic Data Center of (http://www.ncdc.noaa.gov/cdo-web/) . This data was pieced together since there was no one rain station that had a complete data set that covered the study period without significant gaps in the data.

Table 2.1 Gauge stations used to piece together the Econ River climate data set.

Climate Data		
Year	Station Name	Station ID
1/1/1940-12/31/1952	Lake Hiawassee	84771
1/1/1953-2/1/1959	Orlando Int. Airport	86628
2/2/1959 - 12/31/1963	Bithlo	80758
1/1/1964 - 12/31/1970	Orlando Int. Airport	86628
1/1/1971 - 1/31/1974	Bithlo	80758
2/1/1974 - 10/31/2010	Orlando Int. Airport	86628

Although precipitation does vary in different areas, it was determined in the case of this study that piecing together a data set was acceptable to gather a large enough data set and get a general idea of the annual rainfall trends in the area. Table2.1 shows the different gauge stations that were used and the time period of the data that was used. Looking at annual values of long time periods help to determine drought periods and periods of abnormal precipitation amounts.

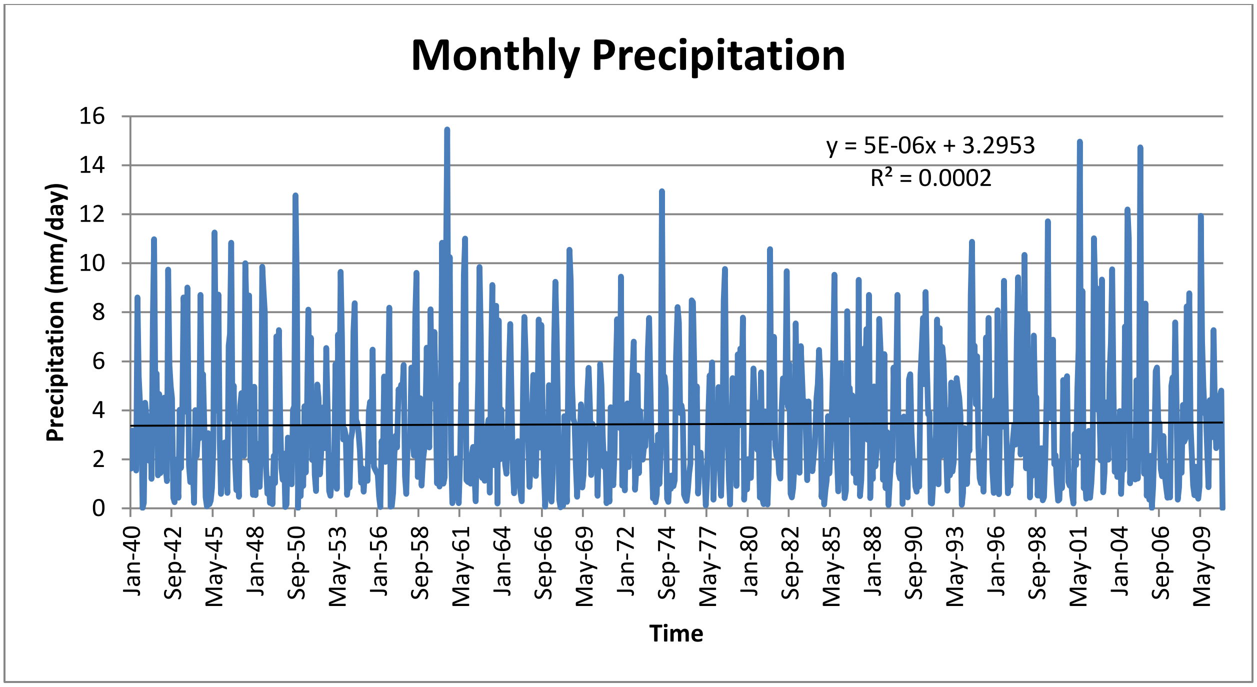

Figure 2.1 Monthly precipitation of the Econ River basin.

The monthly precipitation is the total precipitation of the month divided by the number of days in that month. Figure 2.1 show the mean monthly precipitation of each month plotted out over time. Each year there are dry seasons and rainy seasons which cause the graph to move up and down. The peaks vary greatly from year to year with some years the highest monthly average reaching nearly 16 mm/day. Overall there does not appear to be a significant increase over time in the mean monthly precipitation.

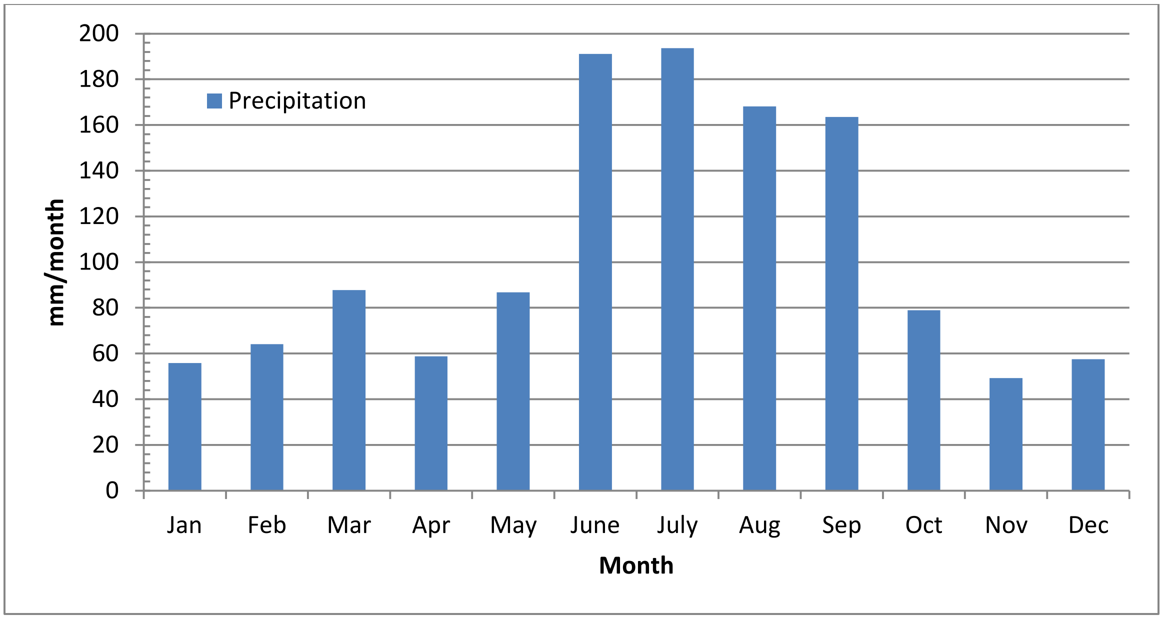

Figure 2.2 Mean monthly rainfall for the Econ basin area.

Figure 2.2 show the average rainfall for the different months of the year for the Econ watershed. The wet season is June through September which shows a monthly rainfall total of 160 mm to about 190 mm. The other months of the year have totals between 50 mm to just over 80 mm.

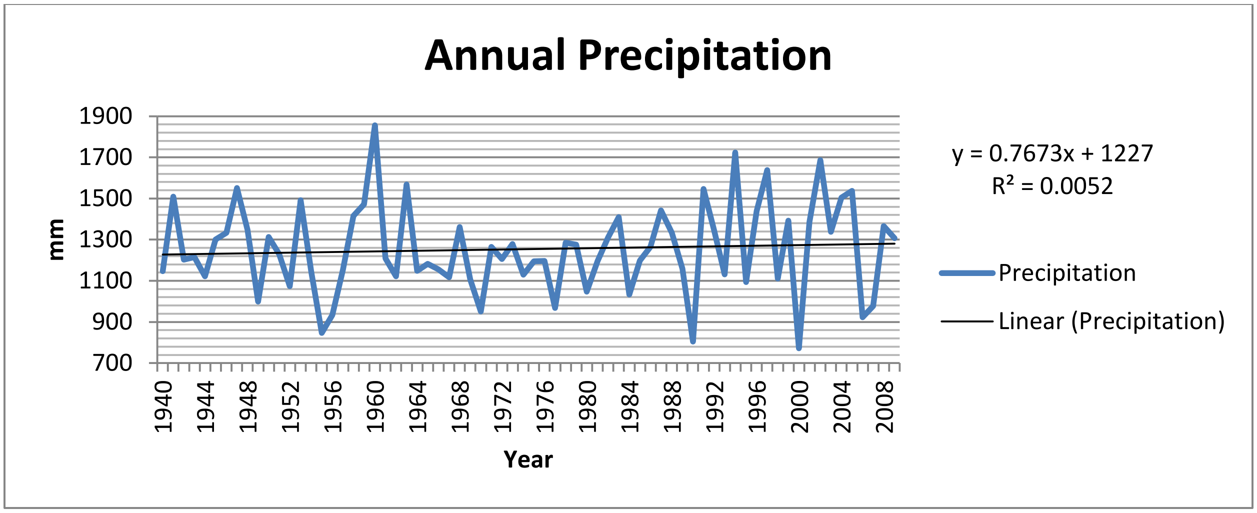

Figure 2.3 Annual precipitation in the Econ River basin.

Figure 2.3 shows the annual precipitation and runoff for the Econ river basin. There are many peaks and valleys for the precipitation and the peak years can differ from the drought years by almost five hundred millimeters. The average precipitation rate is 1254 mm per year.

2.2 Temperature Trend

Temperature variations in a watershed are indicators of drought and high amounts of evaporation. Generally high temperatures result in an increased amount of evaporation.

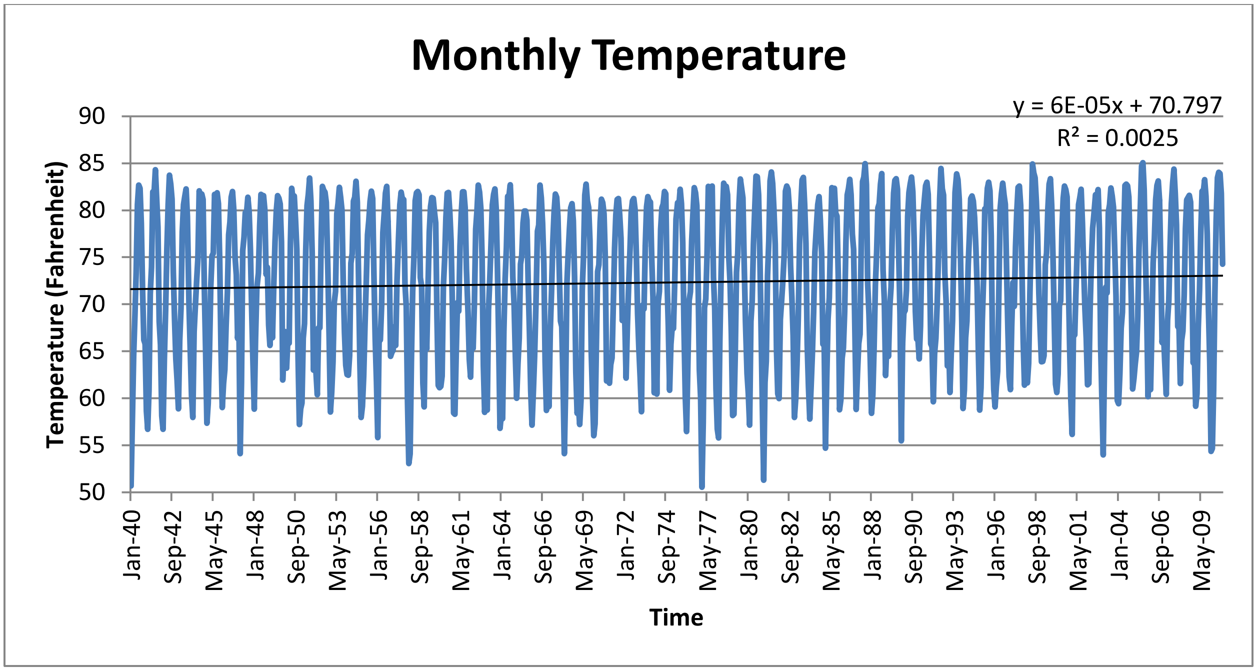

Figure 2.4 Monthly temperature of the Econ River basin.

The mean monthly temperature varies from month to month depending on the time of year. Figure 2.4 shows the mean monthly temperatures over time. There is a regular cycle as the seasons progress throughout the year. Peak times are during the summer and average around 82.5 degrees and the lows during the winter averaging around 60 degrees. There does not appear to be any significant overall trend although the trend line shows a slight increasing trend.

2.3 Potential Evaporation Trend

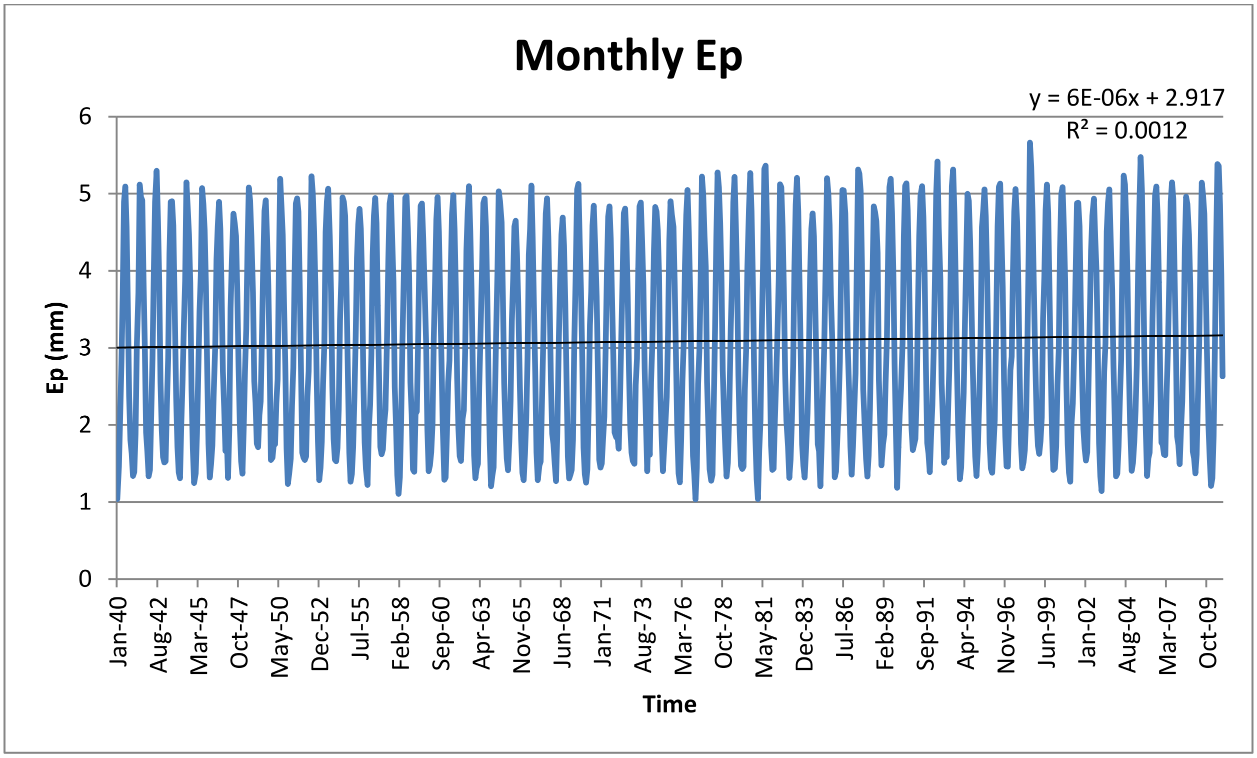

Figure 2.5 Monthly potential evapotranspiration of the Econ River basin.

The mean monthly evapotranspiration follows the trend of the mean monthly temperature. The graph is very cyclical because of the time of year. The peaks average around 5 mm per day and the valleys average just over 1mm per day. There is a slight increasing trend that follows the trend of the temperature.

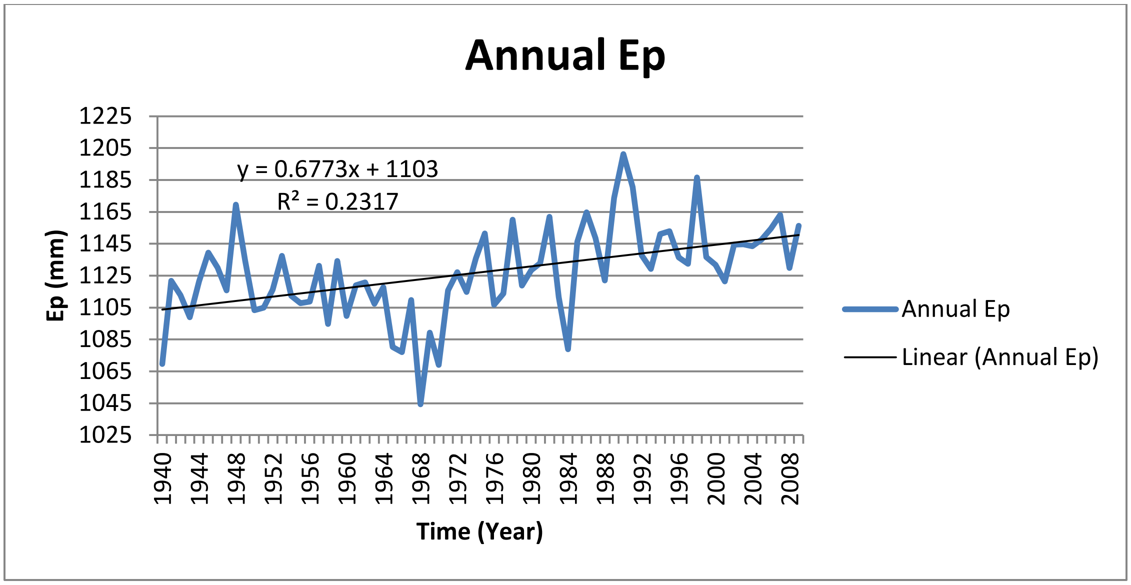

Figure 2.6 Annual evapotranspiration of the Econ River basin.

Figure 2.6 shows the total evapotranspiration per year over time. The figure shows many peaks and valleys over time. There is one drop from about 1962 to about 1970. This drop was most likely caused by a stretch of slightly colder temperatures. Overall, the figure shows an increasing trend. This dramatic increasing trend follows the very slight increasing trend of the temperature.

CHAPTER 3 : HYDROLOGIC VARIABILITY AND CHANGES IN THE ECON RIVER BASIN

This chapter will discuss the hydrologic variability and changes of the Econ River basin over time. The Econ River basin has been developed, had substantial land use change and population growth since 1960s. These changes have induced change of hydrologic regimes in the Econ River and groundwater table. This chapter will analyze the changes in the flow regime and explain the methods used to determine the changes.

3.1. Annual Stream Flow Trend

Data was gathered from the USGS website of (http://waterdata.usgs.gov/fl/nwis/nwisman/?site_no=02233500/). The stream flow data at the gauge station located in Chuluota (gauge number is 02233500) is downloaded. The streamflow data ranges from 1940 to 2009. This long period of time is needed to determine any changes from its natural state. During the 1940's the population was small in the watershed which means the human interferences to the streamflow was at a minimum. It will be shown that the increasing population over the years has changed the water cycle in the Econ River basin.

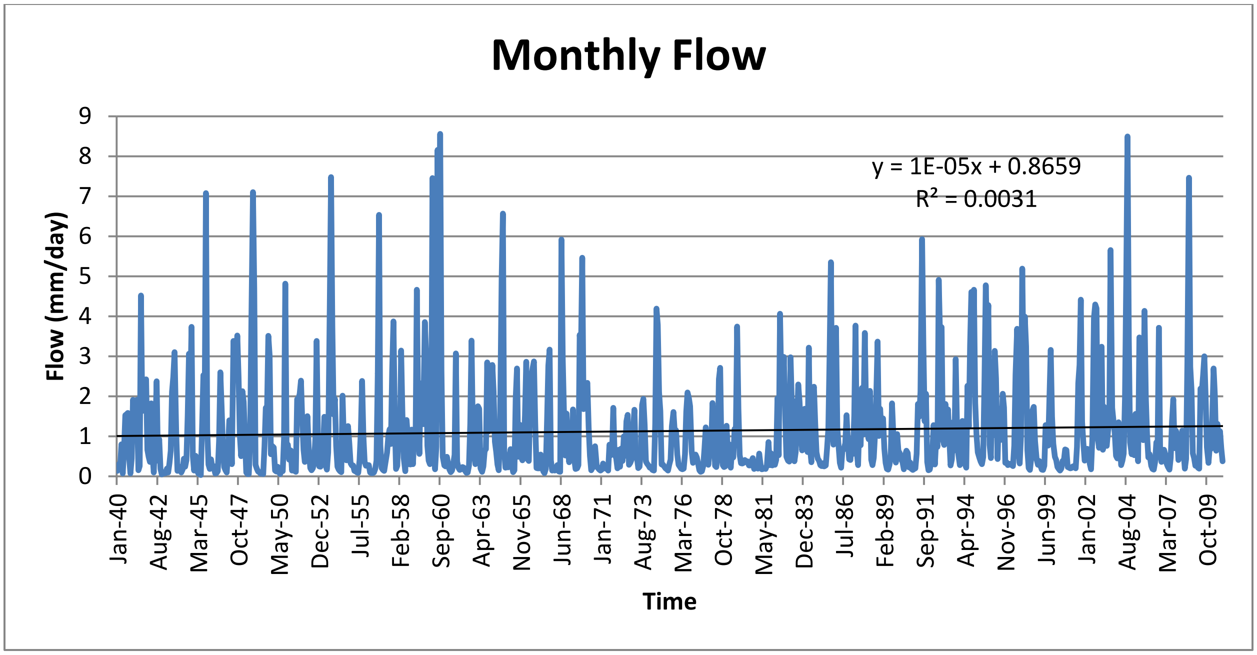

Figure 3.1 Monthly flow of the Econlockhatchee River

Figure 3.1 shows the monthly stream flow of the Econ River over the past 70 years. There are distinct peaks across the figure. From about 1965 to 2003 the peaks are less than 6 mm/day. This may be due to a drought or some type of water management flood control. There are only two peaks after 2003 that are about 6 mm/day. These peaks can be attributed to hurricane Charley (2004) and Tropical Storm Fay (2008). The low flow has a somewhat noticeable increase over time. This is also indicated by the trend line that shows a positive increase.

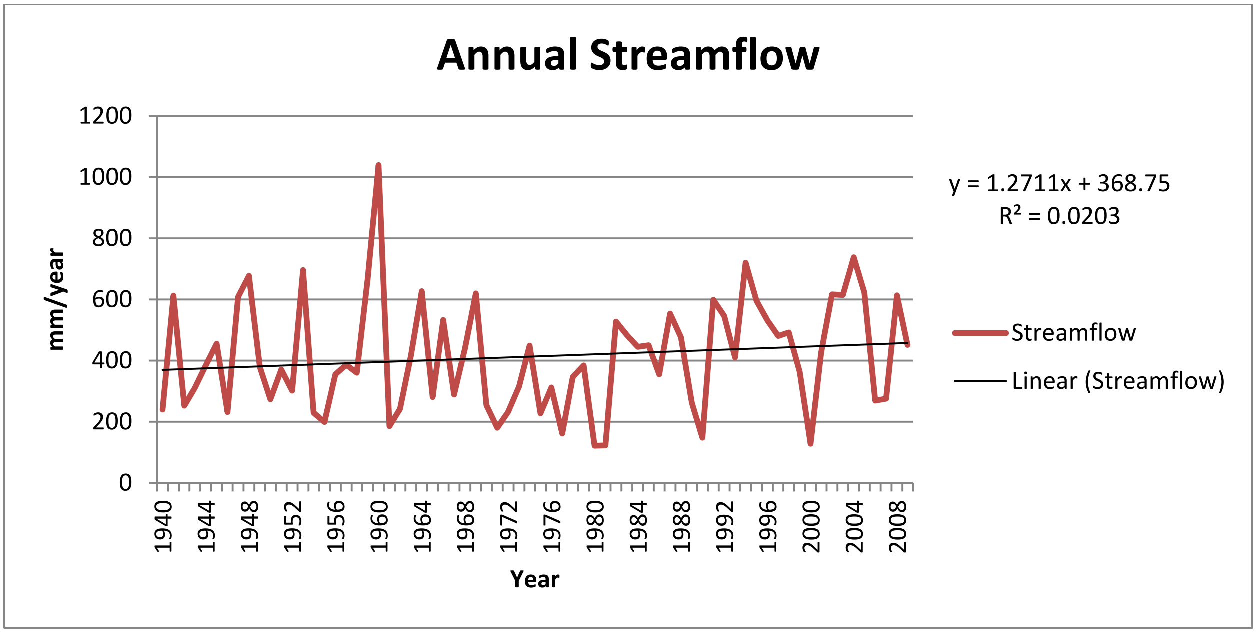

Figure 3.2 Annual streamflow of the Econ River.

Figure 3.2 shows the annual streamflow of the Econ River over time. The trend line shows a slight increase over time. The increase in annual streamflow is most likely caused by increased development and impervious surface over the basin. There are far fewer low valleys after 1981. This indicates an increasing low flow which corresponds to Figure 3.1 of the monthly flow. There was a spike in 1960 that was a result of a large increase in rainfall that caused extreme flooding throughout Florida.

3.2 Annual Minimum Streamflow Trend

The minimum streamflow of the Econ River is mostly made up of base flow from the recession event. This is when water is released from the shallow aquifer into the river. Human interferences that could cause the low flow to change such as effluent discharge, water withdrawal, and water storage. Using the streamflow data the annual minimum flows were determined for each year and plotted.

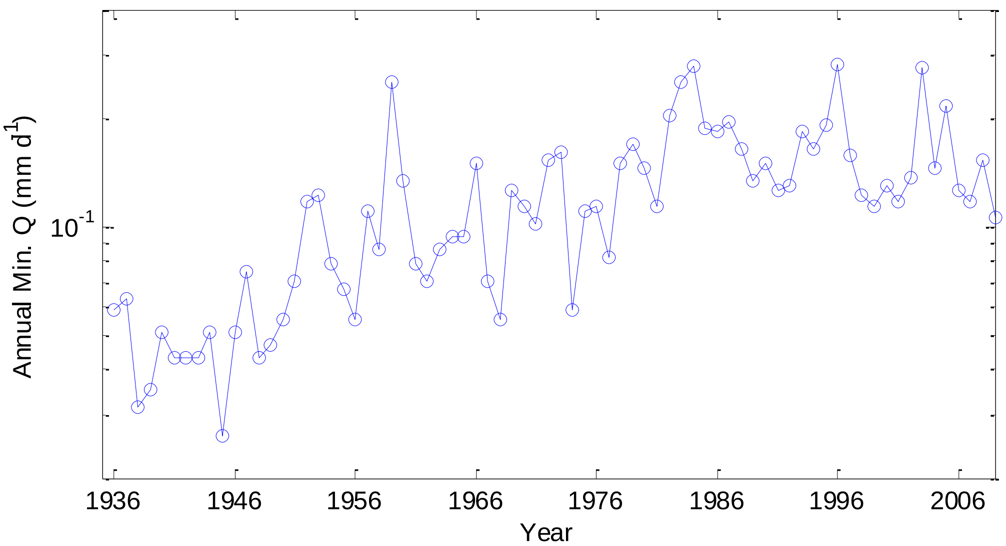

Figure 3.3 Annual minimum stream flow of the Econ River over time.

Figure 3.3 above shows an increasing annual minimum stream flow for the Econ River over time. This increase is most likely due to some type of human interference. Increasing population and increasing development are two factors that can cause the increase in the low flow.

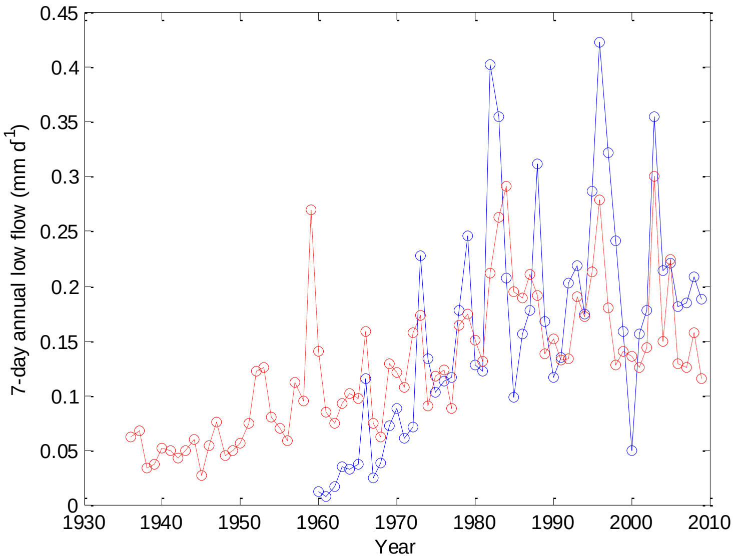

Figure 3.4 Seven day annual low flow of the Econ River.

Figure 3.4 shows the seven day low flow for two different gauge stations on the Econ River. The blue represents USGS gauge number 02233200, which measures the flow for the Little Econ River. The red represents the USGS gauge number 02233500, which measures the flow for the entire Econ River. Both stations show an increasing low flow. The Little Econ River gauge shows slightly higher increases. This could be due to the fact that the percentage of development in that basin was greater compared to the percentage of development in the entire Econ River basin.

3.3 Annual Maximum Streamflow Trend

The annual maximum streamflow is the maximum streamflow each year plotted over time. Looking at the annual maximum streamflow can give indications of human interferences or increased precipitation events. Maximum streamflow is caused by large precipitation events and the runoff due to the large volume of precipitation. Channelization is a type of human interference that can cause the annual maximum streamflow to increase because it can convey more runoff into the river which will increase the streamflow. Human interference can also cause a decrease in maximum streamflow because of stormwater ponds holding back flood waters to release them at a later time after the storm event has past.

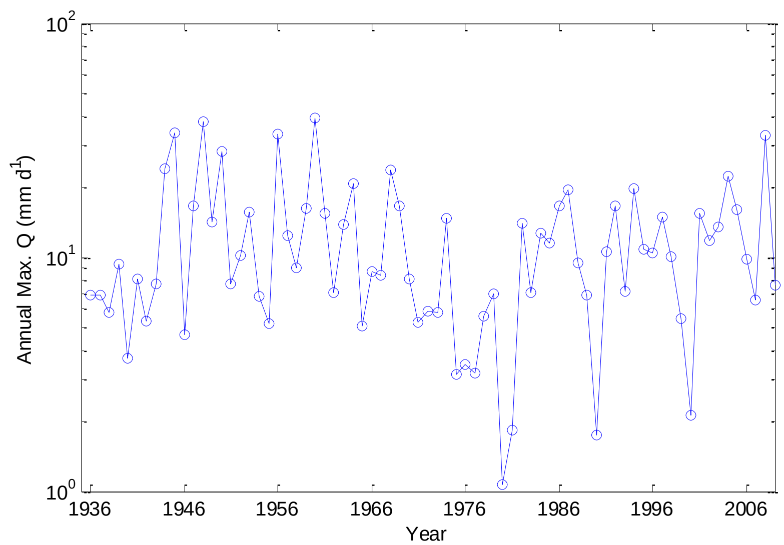

Figure 3.5 Annual maximum flow of the Econ River.

Figure 3.5 shows the annual maximum flow for the river over time. The figure has many peaks and valleys. There appears to be no overall trend in the annual maximum flow. There are a few valleys after 1976 that can be attributed to drought years during that time.

3.4 Groundwater Level Trend

The groundwater is an important aspect of a watershed and its streamflow. Land use change and climate change can both cause changes in groundwater quantity which can affect the low flow of the river. Groundwater is a natural resource that is very important because it is a primary source of potable water for the Central Florida population.

The Florida aquifer is a confined aquifer deep underground that covers large areas of Florida. The depth and confinement of this aquifer make it much more resistant to drought. The Florida aquifer is not directly connected to the Econ River. This aquifer is recharged through infiltration of the surficial aquifer or recharge zones.

Surficial aquifers are shallow and may be directly connected to the Econ River. These types of aquifers are greatly influenced by precipitation patterns and human interferences. Channelization and large amounts of impervious areas decrease infiltration rates and can affect the water level in surficial aquifers.

Groundwater levels around the Econ River basin were analyzed to better understand the interactions between the groundwater and the flow regime. Figure 3.6 shows a map of a few of the groundwater monitoring wells that were analyzed. When determining which well to analyze it was important to find wells that were near the watershed and also had a substantial time period. Six wells were chosen that had data from the late 60’s to early 70’s.

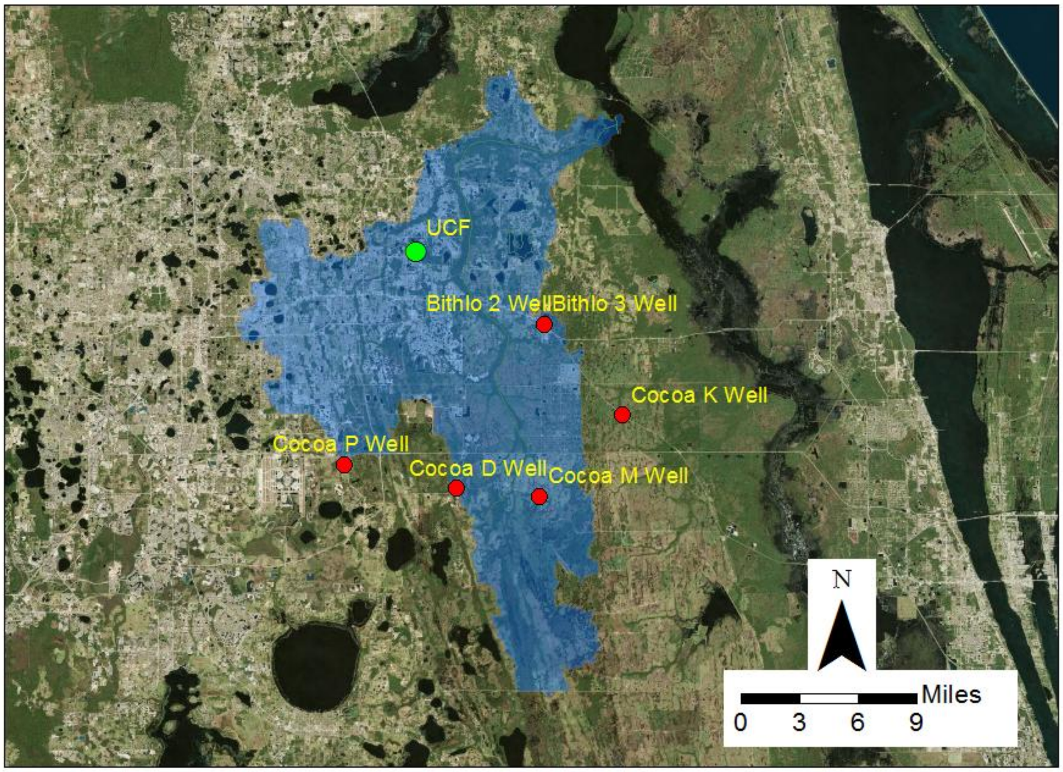

Figure 3.6 Groundwater monitoring wells in and around the Econ River watershed (shown in blue).

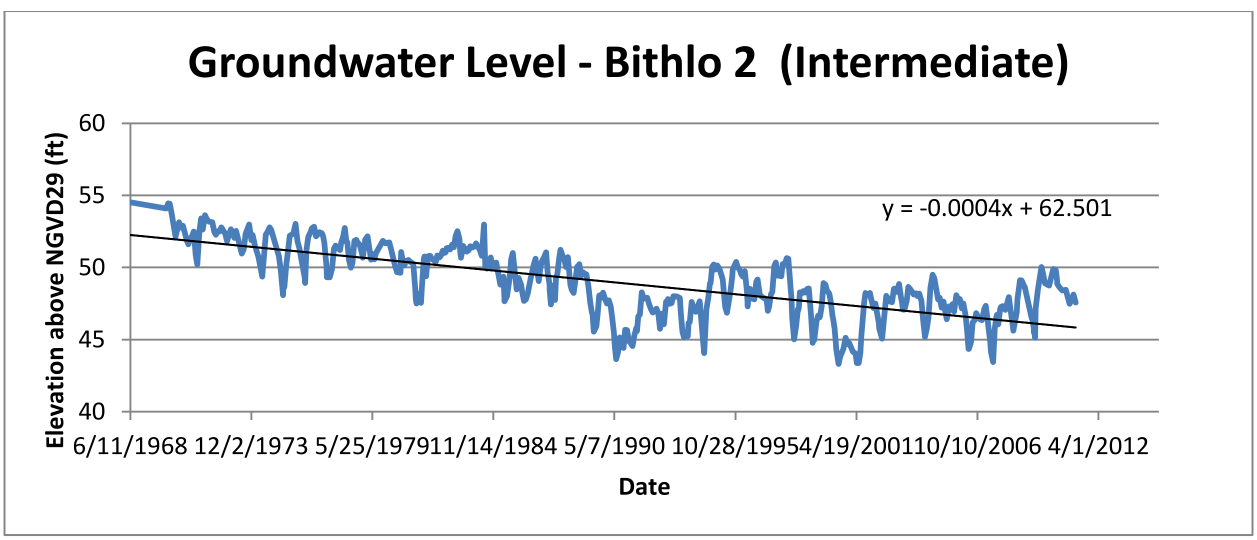

Figure 3.7 Floridan groundwater level for the Bithlo 2 Well at Bithlo.

The Bithlo 2 Well at Bithlo is from USGS gauge number 283249081053202 (http://nwis.waterdata.usgs.gov/fl/nwis/dv/?site_no=283249081053202&agency_cd=USGS&referred_module=gw). This well is a 75 foot deep well located on the east side of the Econ basin. Figure 3.7 shows the elevation of the water in the well over time. There is a clear decrease in elevation over time from the late 70's on.

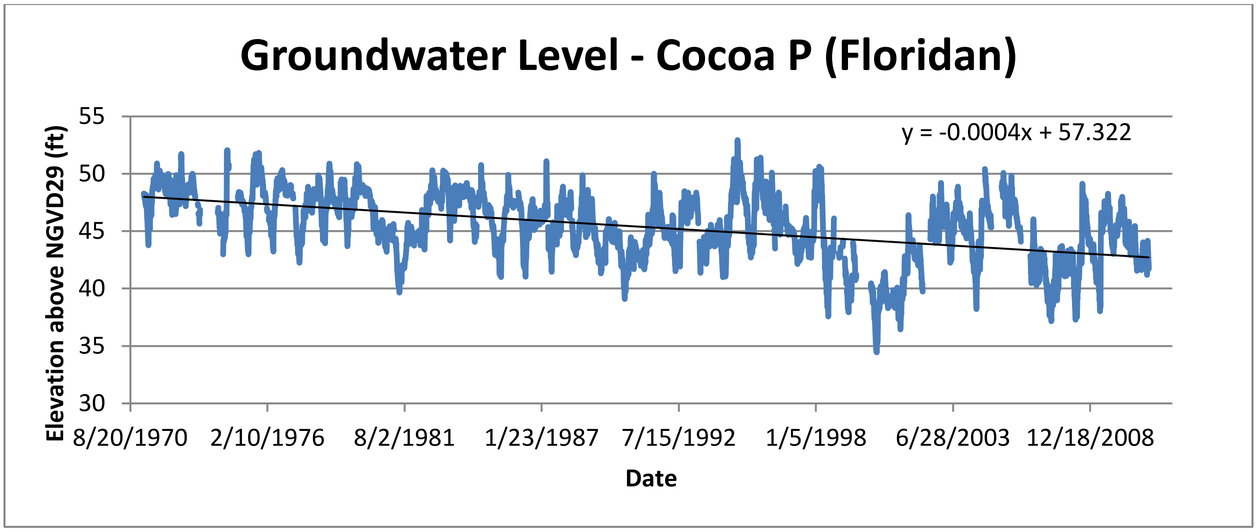

Figure 3.8 Groundwater level for the Cocoa P well near Taft.

The Cocoa P well near Taft is from USGS gauge 282623081153801. http://nwis.waterdata.usgs.gov/fl/nwis/dv/?site_no=282623081153801&agency_cd=USGS&referred_module=gw This well is 439 feet deep and located on the south side of the Little Econ River watershed. Figure 3.8 shows the water level in the well over time. There appears to be a decreasing trend from around 1995 on. There are some low valleys that could be due to ground water pumping in the area. This well is very deep and in the Florida aquifer system.

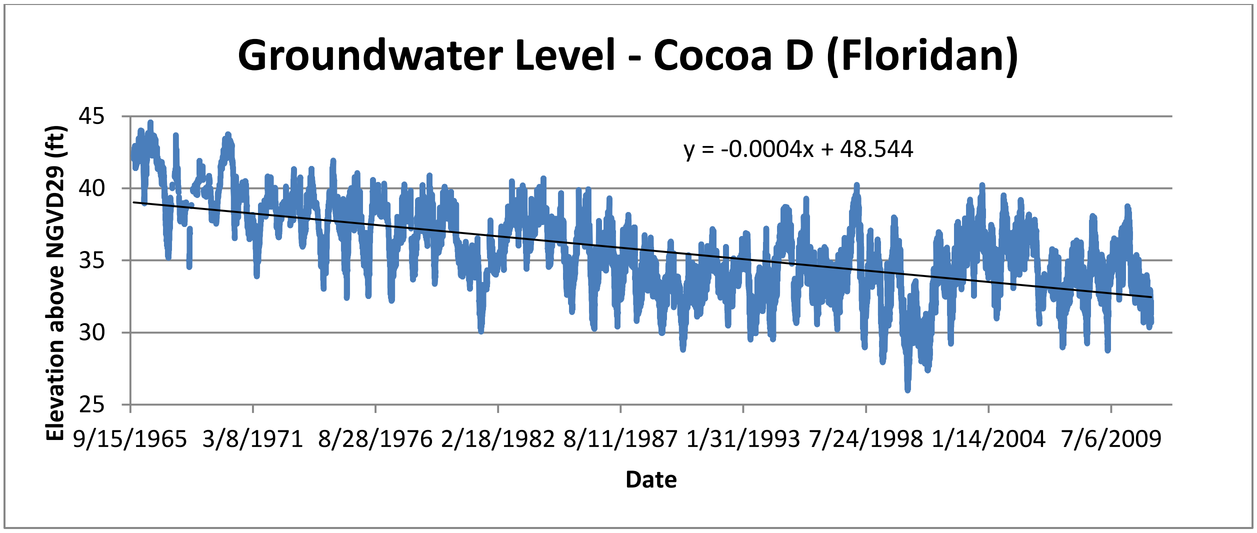

Figure 3.9 Groundwater level for the Cocoa D well near Narcoossee.

The Cocoa D well near Narcoossee is from USGS gauge 282531081095701. http://nwis.waterdata.usgs.gov/fl/nwis/dv/?site_no=282531081095701&agency_cd=USGS&referred_module=gw This well is 300 feet deep and located on the west side of the Econ River watershed. Figure 3.9 shows the water level in the well over time. There appears to be a significant decreasing trend. This well is also in the Florida aquifer system.

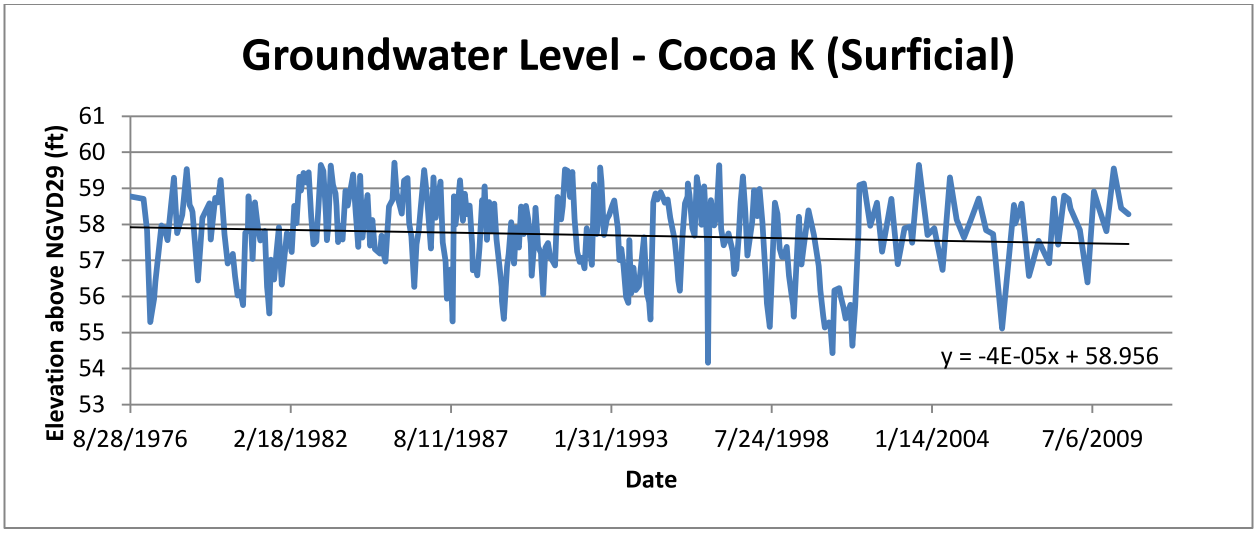

Figure 3.10 Groundwater level for the Cocoa K well.

The Cocoa K well is from the USGS gauge 282847081013702. http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=282847081013702 This well is 8 feet deep and located just east of the Econ River watershed. There appears to be a slight decreasing trend over time. This well is located in the surficial aquifer system.

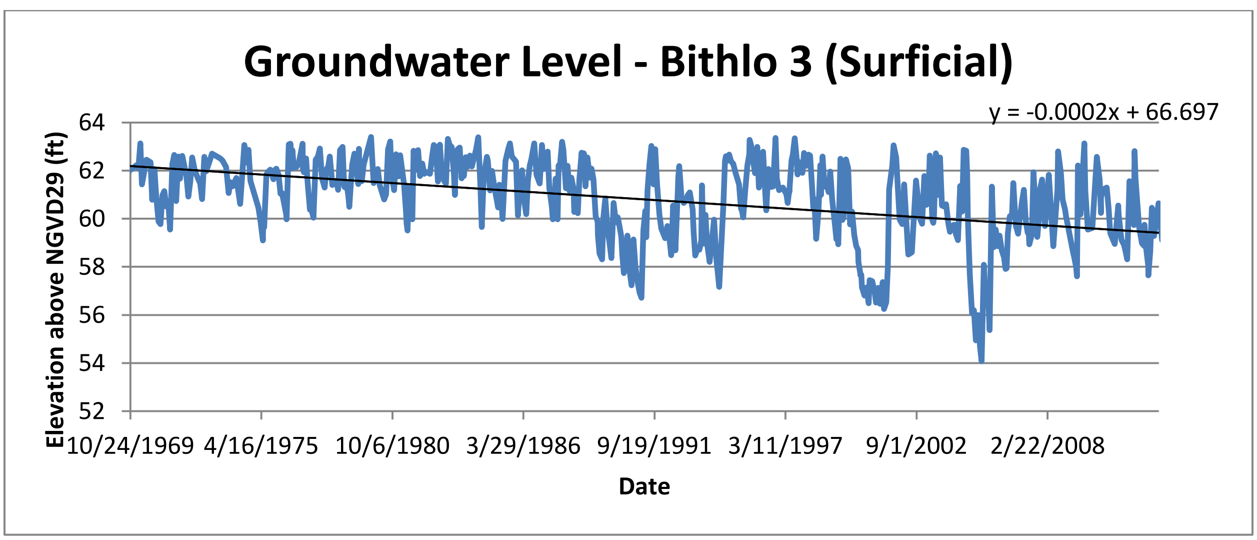

Figure 3.11Groundwater level from the Bithlo 3 well.

The Bithlo 3 well is from the USGS gauge 283249081053203. http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=283249081053203 This well is 15 feet deep and located on the east side of the watershed near Bithlo. This figure shows a decrease over time starting from the mid 80's. There are large valleys that may be the result of droughts compounded by human impacts. This well is located in the surficial aquifer system.

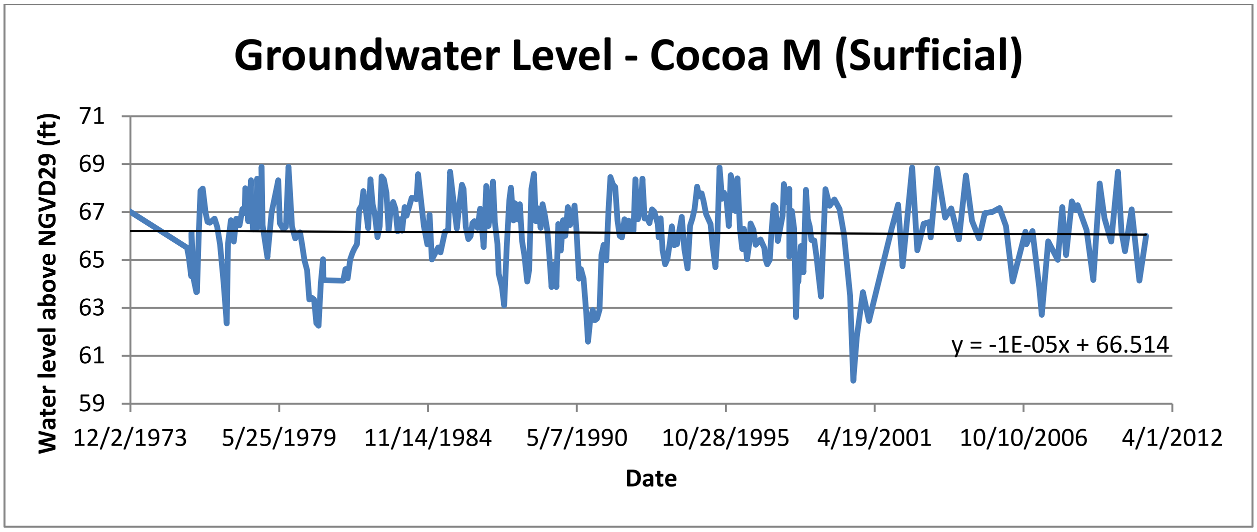

Figure 3.12 Groundwater level from the Cocoa M well.

The Cocoa M well is from the USGS gauge 282510081054502. http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=282510081054502 This well is 10 feet deep and located on the south end of the Econ River watershed. This figure shows a few low levels but overall no significant trend. This well is also located in the surficial aquifer system. The southern end of the watershed is relatively untouched which is most likely why we do not see any significant changes.

Of the six wells presented most show a slight decrease over time. The well that does not show a decrease is located in the most undeveloped portion of the watershed. This indicates that the human impacts likely have decreased the groundwater levels. Since the low flow of the Econ River is largely controlled by the surficial aquifer levels. It is important to look at those wells separately from the Florida aquifer wells. Two of the three surficial aquifer wells show a decrease over time. As stated above the third well likely shows no decrease since it is located in a relatively untouched area of the watershed. Although the wells show a decrease over time the low flow shows an increase over time. Typically lower surficial groundwater levels will lower the low flow because the relative flow into the river from the aquifer will be less. In this case the opposite has happened. This is most likely due to other human impacts that can increase the low flow such as effluent discharge and stormwater management regulations. These characteristics will be discussed in chapter 4.

3.5 Water Balance

When looking at the hydrologic changes in a watershed it is important analyze the entire water balance to understand any changes. Changes in the climate can affect streamflow as can human interferences. One way to look at the differences is using the Budyko method. The Budyko method is a conceptual method that can be used to determine if changes are climate impacts or human impacts or both. Budyko determined that the mean annual evaporation can be calculated using the mean annual precipitation and potential evaporation. The Budyko method assumes that the change in storage is negligible over a long period of time. For our case study the annual precipitation data and annual runoff data were used to determine the evaporation (E=P-Q). This method assumes that for each year the excess precipitation that is not runoff is evaporation. In other words there is no change of storage and all precipitation is evaporated or runoff into the stream. This allows for the determination of the evaporation ratio at an annual scale.

The temperature data was used to calculate the potential evaporation using the Hamon method. Temperature data that was compiled using the same gauges as the precipitation data. These gauges consisted of daily minimum and maximum temperature values. The values were averaged together to determine the average temperature for each day over the entire data set. Along with the latitude, these temperatures were used in the Hamon method to calculate the evapotranspiration each day of the data set.

In order to look more at long term averages a 10 year moving average was calculated using mean annual values of precipitation, evaporation and potential evaporation. This helps to reduce the effects of short term droughts and other anomalies. The dryness index (Ep/P) and the evaporation ratio (E/P) were calculated. Budyko proposed that the points would move along the curve if there were no human impacts on the system. If the climate became drier, the subsequent evaporation ratio would adjust as well and this change would follow the Budyko curve.

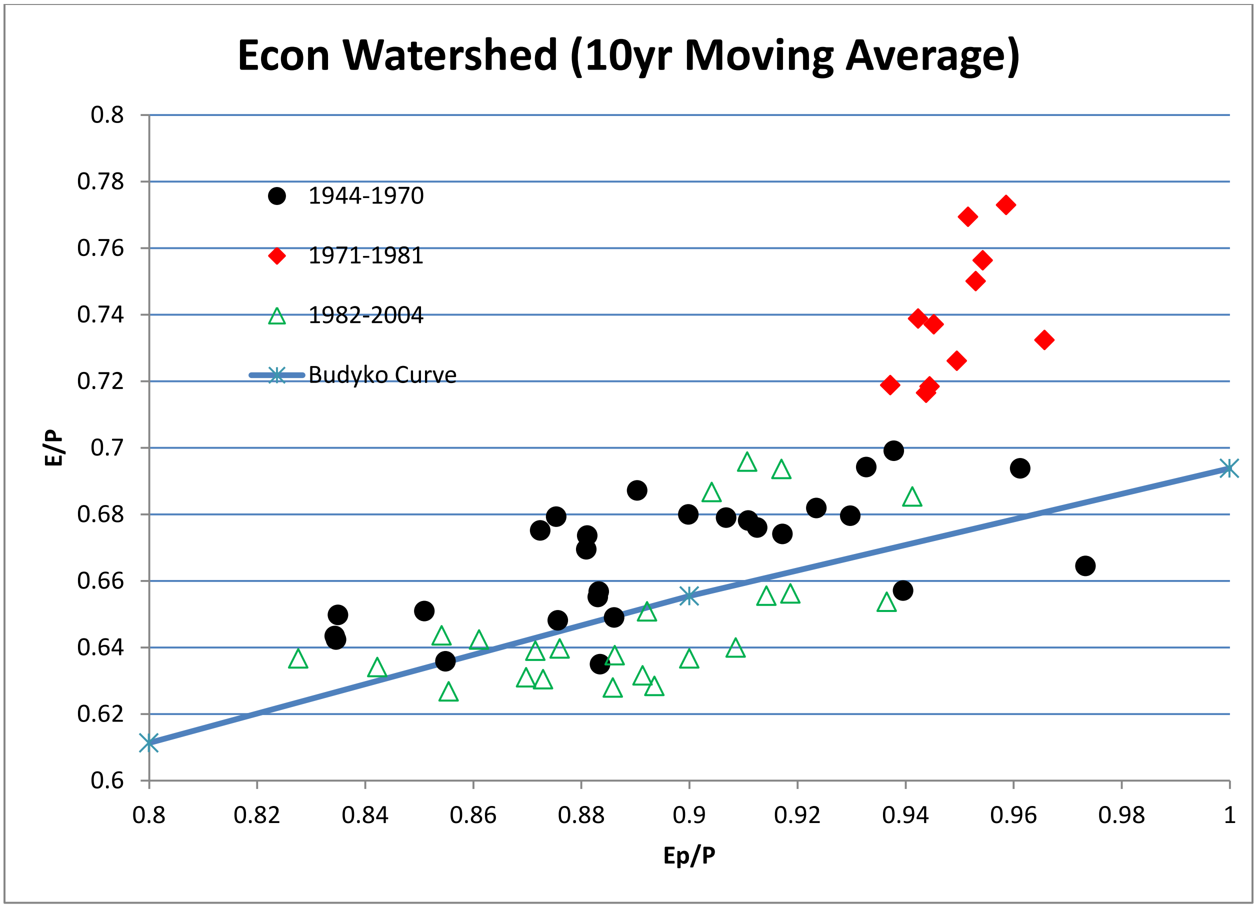

Figure 3.13 E/P vs. Ep/P for the Econ watershed using a ten year moving average.

Figure 3.13 shows the 10 year moving average of the Econ Watershed plotted along with the Budyko curve. In this figure the 1944 – 1970 values and the 1982-2004 values are along the Budyko curve and the 1971-1981 values are above the curve. The values from 1944 to 1970 reflect a time in the watershed where there were relatively no human interferences. As proposed by the Budyko method the values fall along the curve. The values from 1971 – 1981 are above the curve showing that there is some sort of human interferences during this time that have altered the evaporation ratio relative to the climatic dryness index. This time period is right around the start of major development in the Greater Orlando area which is most likely the cause of the variation. In the years 1982 to 2004 the values fall back on the Budyko curve. Although the values fall along the curve it does not mean that the watershed has been restored to its natural state. In contrast we will see in chapter 4 that the watershed is further developed over time. The reason the points fall back along the curve is most likely due to a human interference that has changed the flow regime to counter act previous interferences. Examples of this may be stormwater management practices changing the way development deals with stormwater. Another example may be the development of a regional water treatment facility. Both of these examples can change a flow regime and the values plotted along the Budyko curve.

CHAPTER 4 HUMAN INTERFERENCES IN THE ECONLOCKHATCHEE RIVER BASIN

4.1 Population Growth

Population growth in an area is an indicator of human interferences such as water withdrawal, channelization, effluent discharge and others. These types of human interferences can affect the water cycle in different ways depending on the watershed properties. Substantial population in a short time period will most likely change the watershed in a significant way.

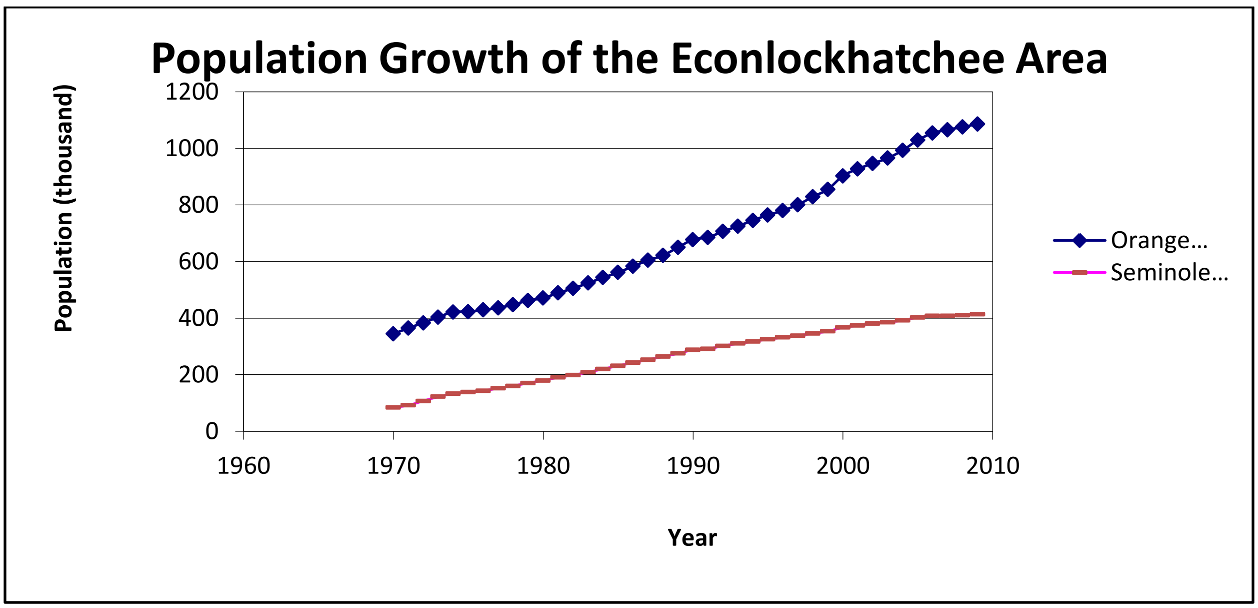

Figure 4.1 Population growth of the Econ area over time.

The population growth for the Econ River basin can be generally determined by looking at the population growth of the counties the watershed is located in. Figure 4.1 shows the population growth over time in the Orange and Seminole counties. This figure shows the population in the

Orange and Seminole counties nearly triples from 1970 to 2010. This growth from the Orlando area indicates that the Econ River Basin has some significant human interferences.

4.2 Land Use/ Land Cover Change

The Econ River basin has had significant changes in land use and land cover. Prior to the 1970's the basin was primarily made up of upland non-forested and wetland areas, since then significant parts of the basin have been paved and developed. This section will focus on the land use change over time and what methods were used to gather this data.

When looking at a basin to see how human interferences have affected it, it is important to gather a base point of what the basin was like before there was substantial human development. Land use and land cover data is not widely available before the 1970's. To determine the land cover at the basin's natural state, aerial imageries from the 1940's were digitized and geo-referenced in the software of ArcGIS to determine general percentages of the different types of land cover. The aerial imageries were gathered from the University of Florida's historical imagery department. The hard copy of the images were scanned and digitized and then made available on the University of Florida's historical imagery website (ufdc.ufl.edu/aerials). On the website each flight had meta-data available which gave the latitude and longitude of each image. Due to the size of the Econ River basin there was not one flight that contained all the images that covered the entire basin. Multiple flights from different years in the 1940's were used to piece together an image of the basin during that time. These images were geo-referenced into ArcGIS by importing each image separately. Once the image was on the map it was placed in the correct location using the ArcGIS georeferencing tool. This tool allows images to be referenced using a point and assigning the latitude and longitude for each corner of the image. Since the images were scanned most of the images edges were out of focus. This made the corners of the images difficult to pick and assign the correct coordinates to. For the purposes of this project assigning the coordinates to the best guess of the corner of the images was determined to be acceptable. This procedure places the images in the most accurate location possible. Once all the images were geo-referenced into ArcGIS they were aggregated together to form a composite image of the basin.

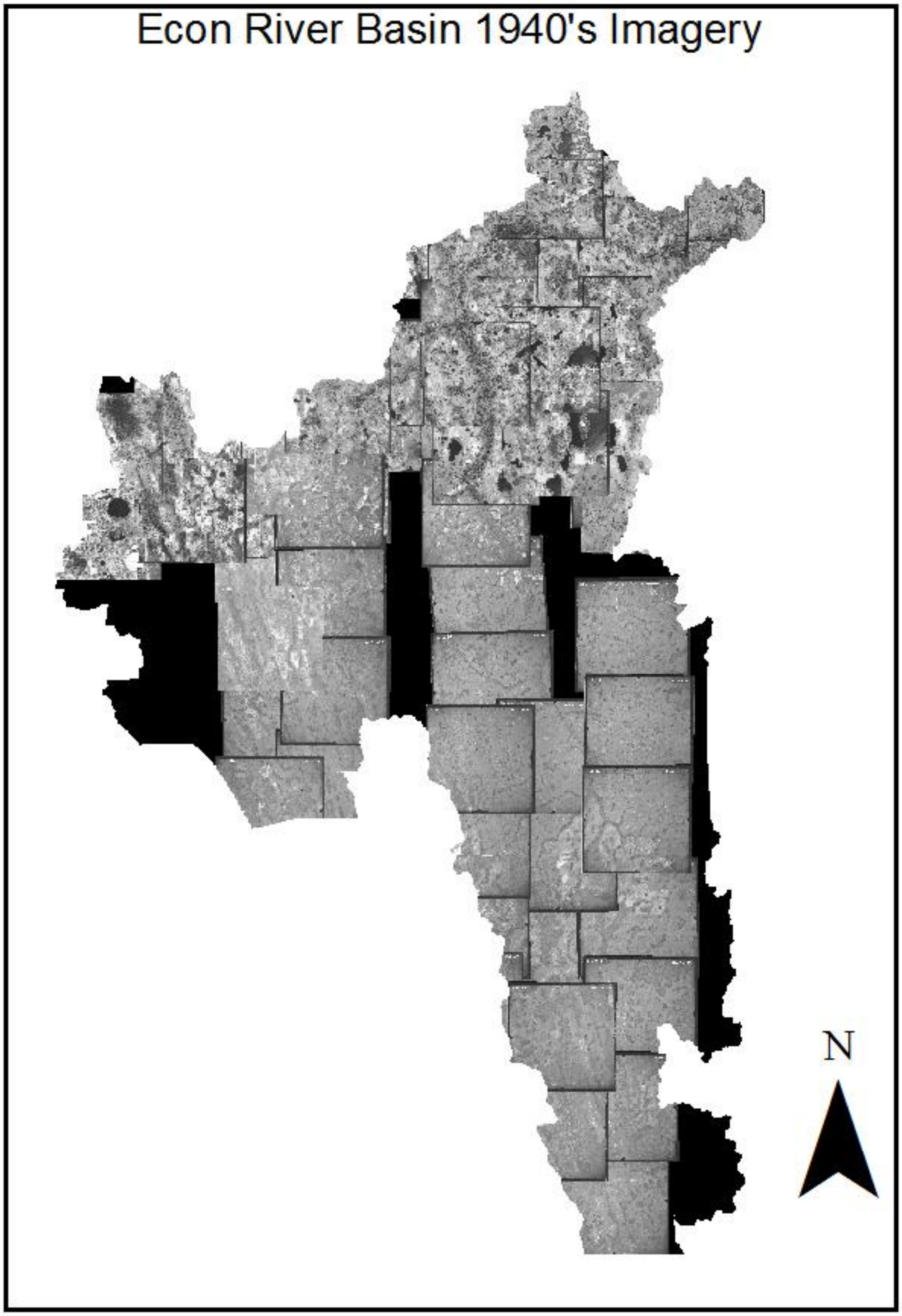

Figure 4.2 1940’s Econ River basin aerial imagery map.

Although multiple flights were used during the 1940's there were not enough images to cover the entire Econ River basin. Enough imagery was gathered to cover about 84% of the basin. It was determined this was enough coverage to give a general picture of what the basin was like during the 1940's. The image was then digitized by creating 6 different categories. The categories that were made were upland non-forested, forest, wetland, water, agricultural, and urban. These categories were digitized using ArcGIS. A layer was made for each land cover category. Each layer was then used to trace out the different land cover on the map by using the ArcGIS layer editing tools. Polygons were roughly drawn over the associated land type. Once the layers were saved they could then be used to determine the areas and percentages.

Additional maps were made to look at the Econ River basin and how it changes over time. These maps were made using data from the St. Johns River Water Management District (http://www.sjrwmd.com/gisdevelopment/docs/themes.html). The data for this area was available for the years 1973, 1995 and 2004. This data consisted of many detailed land use / land cover classifications.

For the purposes of this project it was determined it was better to generalize the data into 9 categories, Urban, Industrial, Recreational, Transportation & Utilities, Agricultural, Water, Wetland, Forest, and Upland Non-forested. These categories were made to better understand the general land uses and compare them with the 1940's map. See table 4.1, 4.2 and 4.3 for the land use / land cover classifications and how they were more generally categorized.

Table 4.1 1973 SJRWMD land use classification table.

1973 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Upland Non-Forested	0	No Data
	1	Open Land
	18	Clear-cut Areas
	20	Grassy Scrub
	21	Sand Pine Scrub
	22	Sandhill Communities
	23	Pine Flatwood
	24	Xeric Hammock
Recreation	2	Recreation
Urban	3	Residential Low-Density
	4	Residential Medium Density
	5	Residential High Density
	8	Commercial & Service
Industrial	6	Industrial
	7	Mining
	9	Institutional
	36	Borrow Pit
	42	Spoil Bank

1973 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Transportation, Communications & Utilities	10	Transportation
	11	Utilities & Communications
Agriculture	12	Improved Pasture
	13	Cropland
	14	Citrus Groves
	15	Nurseries & Special Crops
	16	Confined Feeding
	17	Planted Pine
	19	Agriculture Other
Forest	25	Mesic Hammock
	29	Cypress Dome
Wetlands	26	Hydric Hammock
	27	Hardwood Swamp (Riverine)
	28	Riverine Cypress
	30	Bayheads & Bogs
	31	Wet Prairies
	32	Fresh Water Marsh
	37	Tidal Flat
	40	Salt Marsh

1973 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Wetlands	41	Mangroves
	43	M. Salt Plankton Estuary
	44	Oligohaline System
	45	Neutral Embayment
	46	Marine Meadow
	47	Costal Plankton
Water	33	Rivers
	34	Lakes & Ponds
	35	Reservoir
	48	High Velocity Channel

Table 4.2 1995 SJRWMD land use classification table.

1995 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Upland Non-Forested	3100	Herbaceous
	3200	Shrub and Brushland
	3300	Mixed Rangeland
	4100	Upland Coniferous Forests
	4110	Pine Flatwoods
	7100	Beaches Other Than Swimming Beaches
	7200	Sand Other Than Beaches
	7300	Exposed Rocks
	7400	Disturbed Land
	7410	Rural Land in Transition without Positive Indicators of Intended Activity
	7420	Borrow Areas
	7430	Spoil Areas
Recreation	1810	Swimming Beach
	1820	Golf Course
	1830	Race Tracks
	1840	Marinas and Fish Camps
	1850	Parks and Zoos
	1870	Stadiums: Those Facilities Not Associated with High Schools, Colleges or Universities

1995 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Urban	1100	Residential, Low Density - Less than two dwelling units per acre
	1200	Residential, Med. Density - Two to five dwelling units per acre
	1300	Residential, High Density
	1400	Commercial and Services. Condominiums and Motels combined.
	1460	Oil and gas storage: except those areas associated with industrial use or manufacturing
	1480	Cemeteries
	1920	Inactive land with street pattern but without structures
Industrial	1510	Food Processing
	1520	Timber Processing
	1523	Pulp and Paper Mills
	1530	Mineral Processing
	1540	Oil and Gas Processing
	1550	Other light Industry
	1560	Other heavy Industrial
	1561	Ship building and repair
	1562	Prestressed concrete plants
	1563	Metal Fabrication Plants

1995 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Industrial	1610	Strip Mines
	1611	Clays
	1612	Peat
	1613	Heavy Metals
	1620	Sand and Gravel Pits
	1630	Rock Quarries
	1632	Limerock or Dolomite
	1633	Phosphates
	1634	Heavy Minerals
	1640	Oil and Gas Fields
	1650	Reclaimed Lands
	1660	Holding Ponds
	1670	Abandoned Lands
	1730	Military
	1750	Governmental
Transportation, Communications & Utilities	8100	Transportation
	8110	Airports
	8120	Railroads
	8130	Bus and Truck Terminals
	8140	Roads and Highways
	8150	Port Facilities

1995 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Transportation, Communications & Utilities	8160	Canals and Locks
	8180	Auto Parking Facilities - when not directly related to other land uses
	8190	Transportation Facilities Under Construction
	8191	Highways
	8192	Railroads
	8193	Airports
	8194	Port Facilities
	8200	Communications
	8300	Utilities
	8310	Electrical Power Facilities
	8320	Electrical Power Transmission Lines
	8330	Water Supply Plants
	8340	Sewage Treatment Plants
	8350	Solid Waste Disposal
	8360	Treatment Ponds (Non-Sewage)
	8390	Utilities Under Construction
Agriculture	2100	Cropland and Pastureland
	2110	Improved Pastures
	2120	Unimproved Pastures
	2130	Woodland Pastures

1995 SJRWMD Land Use Data		
	SJRWMD Classification	
General Classification	Land Use Code	Description
Agriculture	2140	Row Crops
	2141	Potatoes and Cabbage
	2150	Field Crops
	2160	Mixed Crops: Used if crop type cannot be determined
	2200	Tree Crops
	2210	Citrus Groves
	2240	Abandoned Tree Crops
	2300	Feeding Operations
	2310	Cattle Feeding Operations
	2320	Poultry Feeding Operations
	2400	Nurseries and Vineyards
	2410	Tree Nurseries
	2430	Ornamentals
	2431	Shade Ferns
	2432	Hammock Ferns
	2450	Floriculture
	2500	Specialty Farms
	2510	Horse Farms
	2520	Dairies
	2540	Aquaculture
	2600	Other open lands - Rural

1995 SJRWMD Land Use Data		
	SJRWMD Classification	
General Classification	Land Use Code	Description
Agriculture	2610	Fallow Cropland
Forest	4120	Longleaf Pine - Xeric Oak
	4130	Sand Pine
	4200	Upland Hardwood Forest (4200 - 4399)
	4210	Xeric Oak
	4300	Upland Mixed Forest
	4340	Upland Mixed Coniferous/Hardwood
	4370	Australian Pine
	4400	Tree Plantations
	4410	Coniferous Pine
	4430	Forest Regeneration
Wetlands	6100	Wetland Hardwood Forests
	6110	Bay Swamps
	6120	Mangrove Swamps
	6150	River/Lake Swamp (bottomland)
	6170	Mixed Wetland Hardwoods
	6180	Cabbage Palm Savanna
	6200	Coniferous Forest
	6210	Cypress
	6220	Forested Depressional Pine
	6300	Wetland Forested Mixed

1995 SJRWMD Land Use Data		
	SJRWMD Classification	
General Classification	Land Use Code	Description
Wetlands	6400	Vegetated Non-Forested Wetlands
	6410	Freshwater Marshes
	6420	Saltwater Marshes
	6430	Wet Prairies
	6440	Emergent Aquatic Vegetation
	6450	Submergent Aquatic Vegetation
	6460	Mixed Scrub-Shrub Wetland
Water	5100	Streams and Waterways
	5200	Lakes
	5300	Reservoirs
	5340	Reservoirs Less than 10 Acres (4 hectares) which are Dominant Features
	5400	Bays and Estuaries
	5500	Major Springs
	5600	Slough Waters

Table 4.3 2004 SJRWMD land use classification table.

2004 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Upland Non-Forested	1900	There are none
	2600	Other Open Lands - Rural
	3100	Herbaceous Upland Nonforested
	3200	Shurb and Brushland
	3300	Mixed Upand Nonforested
	4110	Pine Flatwoods
	7100	Beaches other than Swimming Beaches
	7200	Sand other than Beaches
	7400	Disturbed Land
	7410	Rural Land in Transition without positive indicators of intended activity
	7420	Borrow Areas
	7430	Spoil Areas
Recreation	1800	Recreational
	1810	Swimming Beach
	1820	Golf Course
	1830	Race Tracks
	1840	Marinas and Fish Camps

2004 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Recreation	1850	Parks and Zoos
	1860	Community Recreational Facilities
	1870	Stadiums: Those facilities not associated with High Schools, Colleges or Universities
	1890	Other Recreational
Urban	1100	Residential, Low Density - Less than 2 dwelling units per acre
	1180	Residential, Rural - Less than or equal to 0.5 dwelling units per acre (one unit on 2 or more acres)
	1190	Low Density under Construction
	1200	Residential, Med. Density - Two to five dwelling units per acre
	1290	Medium Density under Construction
	1300	Residential, High Density
	1390	High Density under construction
	1400	Commercial and Services
	1460	Oil and gas storage: except those areas associated with Industrial use or Manufacturing
	1480	Cemeteries
	1490	Commercial and Services under Construction
	1920	Inactive Land with Street Pattern but without structures

2004 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Industrial	1510	Food Processing
	1520	Timber Processing
	1523	Pulp and Paper Mills
	1530	Mineral Processing
	1540	Oil and Gas Processing
	1550	Other Light Industry
	1560	Other Heavy Industrial
	1561	Ship Building and Repair
	1562	Prestressed Concrete Plants
	1563	Metal Fabrication Plants
	1590	Industrial Under Construction
	1600	Extractive
	1610	Strip Mines
	1611	Clays
	1612	Peat
	1613	Heavy Metals
	1620	Sand and Gravel Pits
	1630	Rock Quarries
	1632	Limerock or Dolomite
	1633	Phosphates
	1640	Oil and Gas Fields

2004 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Industrial	1650	Reclaimed Lands
	1670	Abandoned Mining Lands
	1700	Institutional
	1730	Military
	1750	Governmental (to be used for KSC only)
Transportation, Communications & Utilities	8100	Transportation
	8110	Airports
	8120	Railroads
	8130	Bus and Truck Terminals
	8140	Roads and Highways
	8150	Port Facilities
	8180	Auto Parking Facilities - when not directly related to other land uses
	8190	Transportation Under Construction
	8200	Communications
	8290	Communications Under Construction
	8300	Utilities
	8310	Electrical Power Facilities
	8320	Electrical Power Transmission Lines
	8330	Water Supply Plants
	8340	Sewage Treatment Plants

2004 SJRWMD Land Use Data		
	SJRWMD Classification	
General Classification	Land Use Code	Description
Transportation, Communications & Utilities	8350	Solid Waste Disposal
	8390	Utilities Under Construction
Agriculture	2110	Improved Pastures
	2120	Unimproved Pastures
	2130	Woodland Pastures
	2140	Row Crops
	2143	Potatoes and Cabbage
	2150	Field Crops
	2160	Mixed Crops
	2200	Tree Crops
	2210	Citrus Groves
	2240	Abandoned Tree Crops
	2300	Feeding Operations
	2310	Cattle Feeding Operations
	2320	Poultry Feeding Operations
	2400	Nurseries and Vineyards
	2410	Tree Nurseries
	2420	Sod Farms
	2430	Ornamentals
	2431	Shade Ferns

2004 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Agriculture	2432	Hammock Ferns
	2450	Floriculture
	2500	Specialty Farms
	2510	Horse Farms
	2520	Dairies
	2540	Aquaculture
	2610	Fallow Cropland
Forest	4120	Longleaf Pine - Xeric Oak
	4130	Sand Pine
	4200	Upland Hardwood Forest
	4210	Xeric Oak
	4280	Cabbage Palm
	4300	Upland Mixed Forest
	4340	Upland Mixed Coniferous/Hardwood
	4370	Australian Pine
	4400	Tree Plantations
	4410	Coniferous Pine
	4430	Forest Regeneration
Wetlands	6100	Wetland Hardwood Forests
	6110	Bay Swamps
	6120	Mangrove Swamp

2004 SJRWMD Land Use Data		
	SJRWMD Classification	
General Classification	Land Use Code	Description
Wetlands	6170	Mixed Wetland Hardwoods
	6180	Cabbage Palm Wetland
	6181	Cabbage Palm Hammock
	6182	Cabbage Palm Savannah
	6200	Wetland Coniferous Forest
	6210	Cypress
	6220	Pond Pine
	6250	Hydric Pine Flatwoods
	6300	Wetland Forested Mixed
	6400	Vegetated Non-Forested Wetlands
	6410	Freshwater Marshes
	6420	Saltwater Marshes
	6430	Wet Prairies
	6440	Emergent Aquatic-Vegetation
	6460	Mixed Scrub-Shrub Wetland
	6500	Non-Vegetated Wetland
Water	1660	Holding Ponds
	5100	Streams and Waterways
	5200	Lakes
	5250	Marshy Lakes
	5300	Reservoirs

2004 SJRWMD Land Use Data		
General Classification	SJRWMD Classification	
	Land Use Code	Description
Water	5400	Bays and Estuaries
	5430	Enclosed Saltwater Ponds within a Salt Marsh
	5500	Major Springs
	5600	Slough Waters
	8160	Canals and Locks
	8360	Other Treatment Ponds
	8370	Surface Water Collection Basin

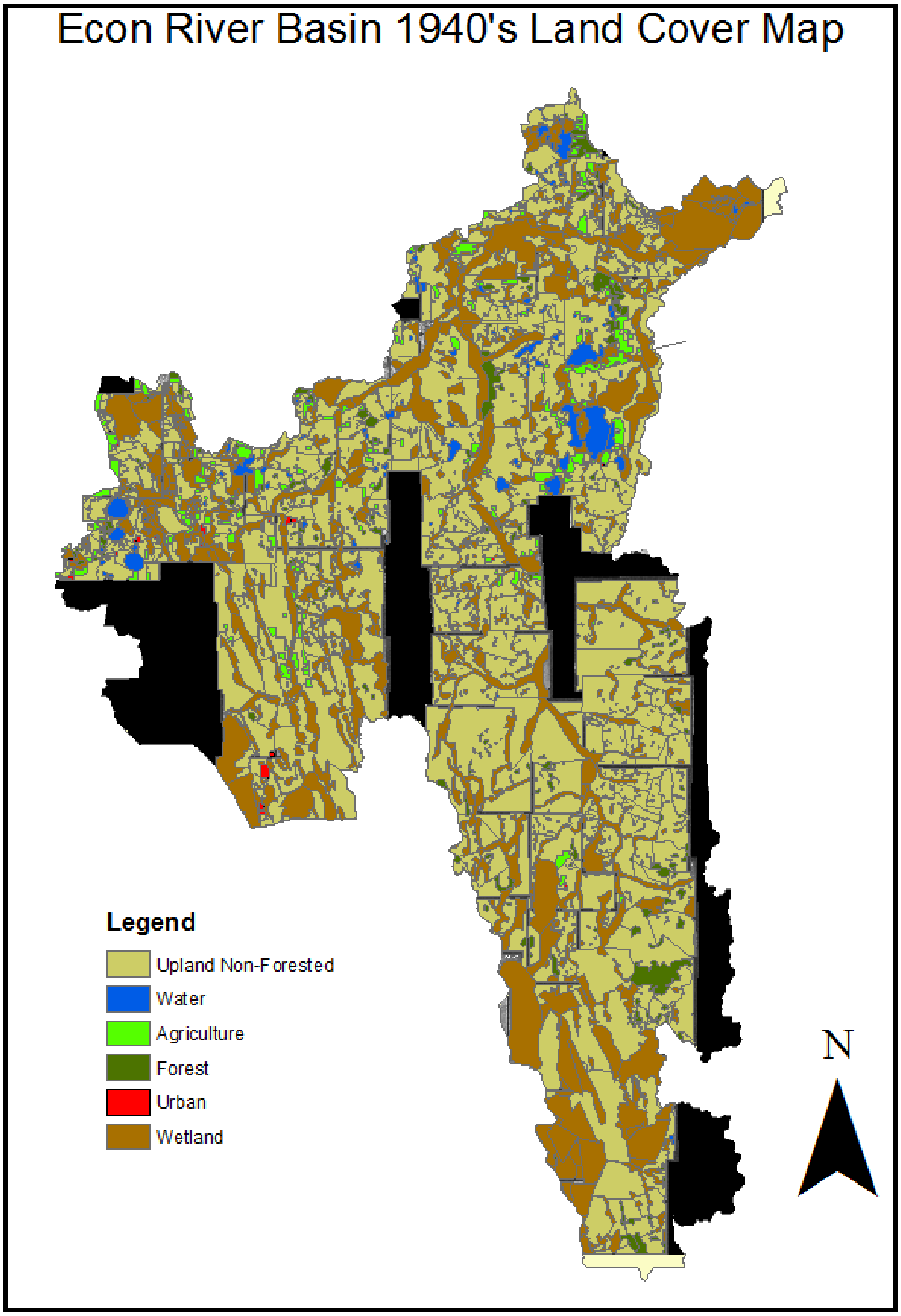

Figure 4.3 Land cover map of the Econ River Basin in the 1940's.

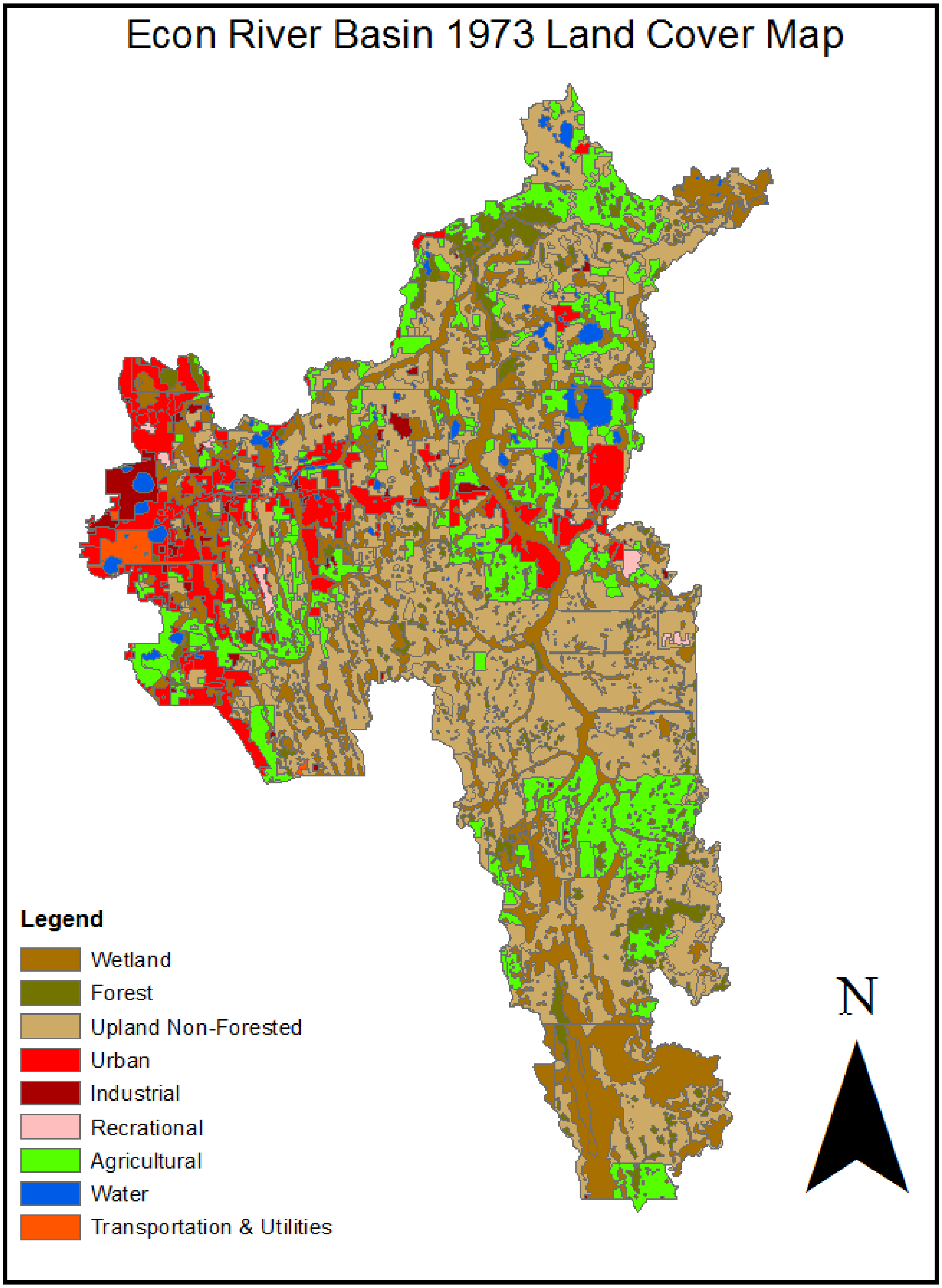

Figure 4.4 Land cover map of the Econ River Basin in 1973.

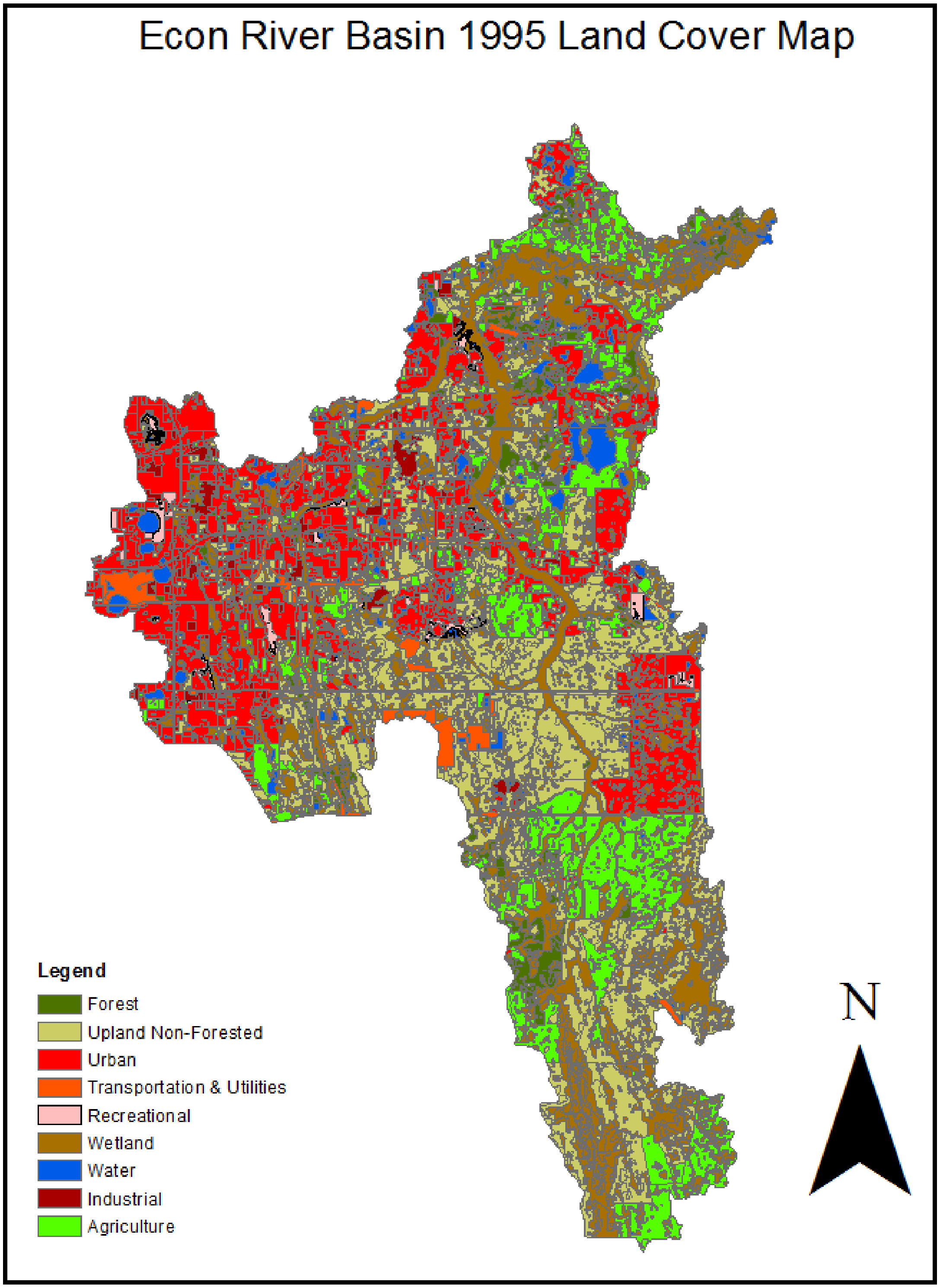

Figure 4.5 Land cover map of the Econ River Basin in 1995.

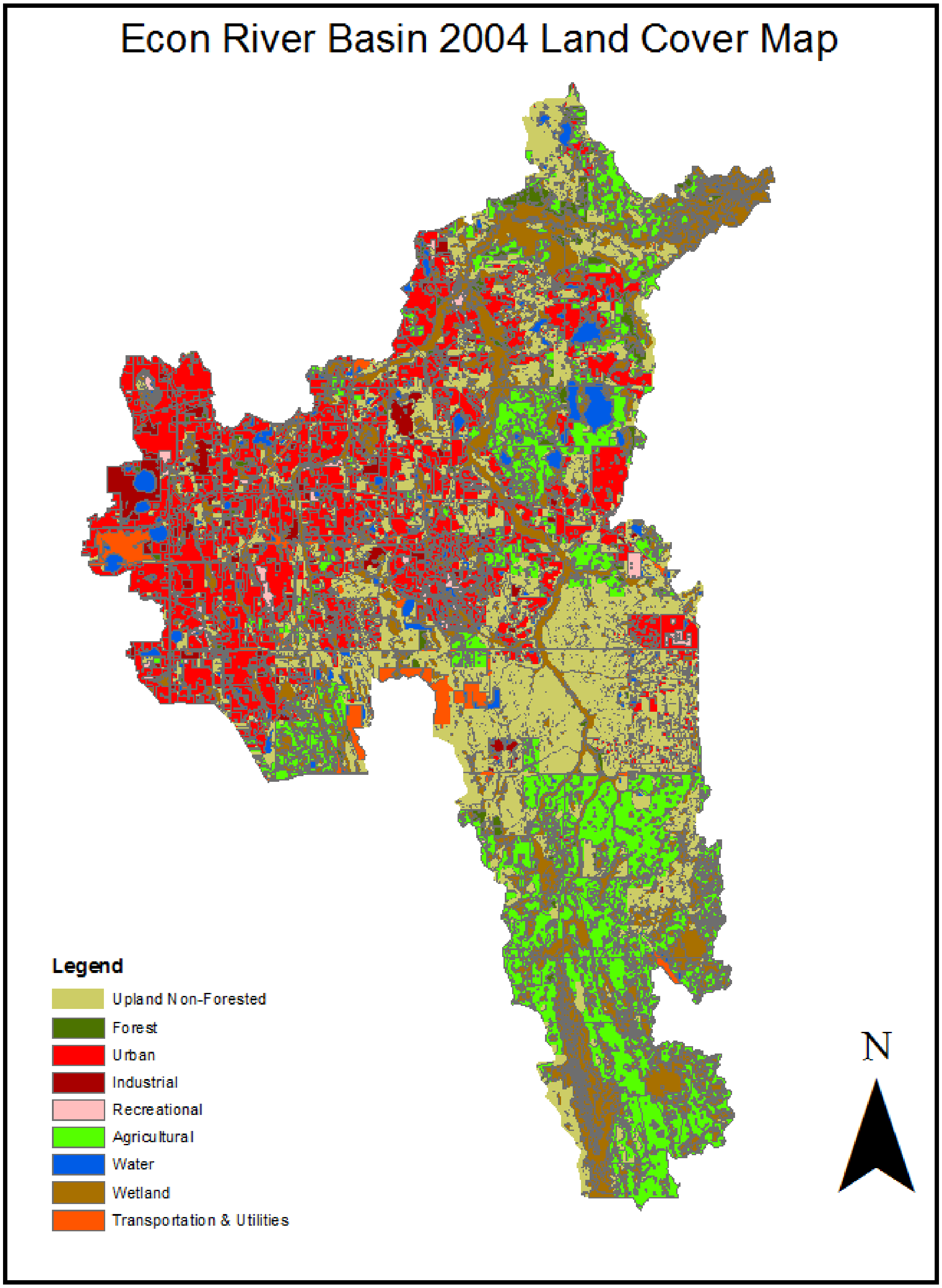

Figure 4.6 Land cover map of the Econ River Basin in 2004.

Table 4.4 Percentages of land cover over the Econ River basin.

Land Cover of the Econ River Basin				
Year	**1940's**	**1973**	**1995**	**2004**
Wetland	33.2%	21.5%	25.9%	25.9%
Forest	3.0%	6.0%	3.9%	2.2%
Upland Non-Forested	58.6%	42.5%	25.8%	18.0%
Urban	0.2%	9.4%	22.6%	24.3%
Industrial	0.0%	1.4%	1.6%	2.3%
Recreational	0.0%	0.4%	1.0%	1.0%
Agricultural	2.6%	16.1%	12.6%	18.3%
Water	2.4%	2.0%	3.7%	4.4%
Transportation	0.0%	0.6%	3.1%	3.5%

As illustrated in the maps the urban population increases over time. There is a significant increase in urban area between 1973 and 1995 which caused the upland non-forested area to decrease significantly over time. There was a decrease in wetland area from 1940's to 1973 and then a slight increase from 1973 to 1995 and then maintained from 1995 to 2004. The decrease from 1940's to 1973 was most likely from development. The increase from 1973 to 1995 could be from some wetland conservation that led to the formation of new wetlands or reclassified areas to be wetlands that weren't classified that way before. The forest area increased in 1973 and then decreased to 2004. The increase in forest area may be an artificial increase due to miss-identification between wetland and forest area in the 1940's. Due to the quality of the imagery it was hard to differentiate forest and wetland. This could have lead to small amounts of miss-identification.

Industrial, recreational & Transportation categories steadily increased overtime. This increase was expected due to the increasing population and urban area. Agriculture increased significantly from the 1940's to 1973, then decrease in 1995 and again increased in 2004. The increase in 1973 was most like due to the increased population and the need for more produce. The decrease in 1995 and then increase in 2004 may be because farmers moving away from the city to other areas because of freezes in the 1980's and then returning years later.

The water area decreased from the 1940's to 1973 and then steadily increased to 2004. The decrease in water area may be an artificial decrease due to not having an entire map of the 1940's. Since the water area is such a small portion, the percentage of water area may have been slightly skewed by leaving out upland areas. The significant increase from 1973 to 2004 is most likely because of increased channelization due to urbanization. The urbanization causes vast areas to be paved and decreased infiltration into the soil. Since the runoff cannot infiltrate it is directed into manmade ponds which then flow into the river. The increase in development increases the number and sizes of the ponds thus causing the water area to increase.

4.3 Water Withdrawals

Many populated areas withdraw water from lakes, streams and groundwater to consume or use for irrigation or other industries. Population growth in the Econ River basin points towards increased groundwater pumping and water withdrawal. Much of the groundwater pumped is from the Florida Aquifer that is deep underground. This encompasses many watersheds, and fluctuations in this aquifer will most likely not affect the stream flow of the Econ River. Shallow wells are used to pump water from the surficial aquifer. The surficial aquifer is much more shallow than the Florida aquifer and is much more sensitive to short term droughts and flooding. Base flow from the Econ River is largely a factor of the surficial aquifer and its discharge.

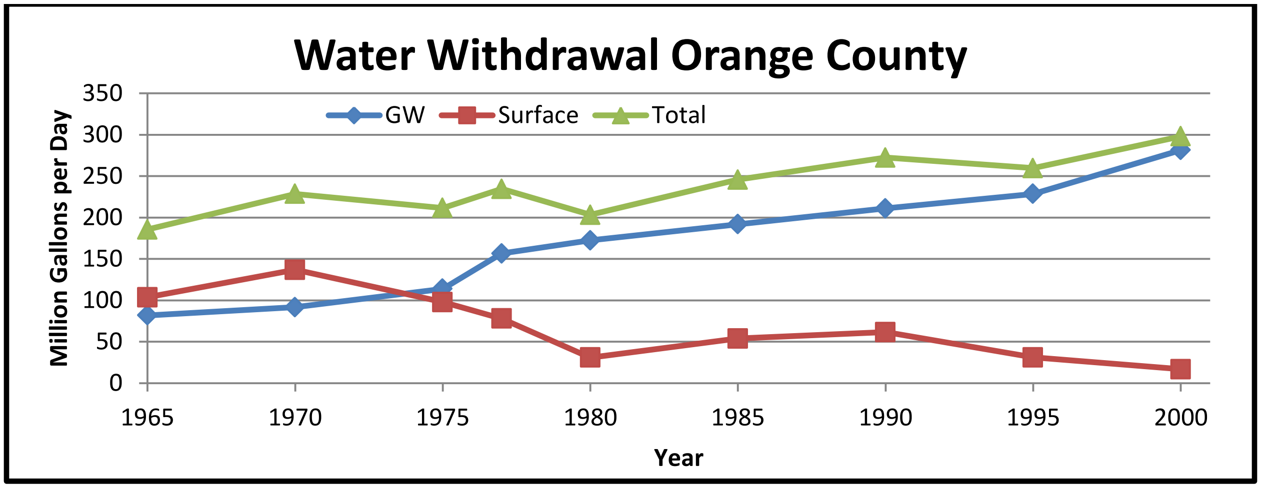

Figure 4.7 Water withdrawal in Orange County over time.

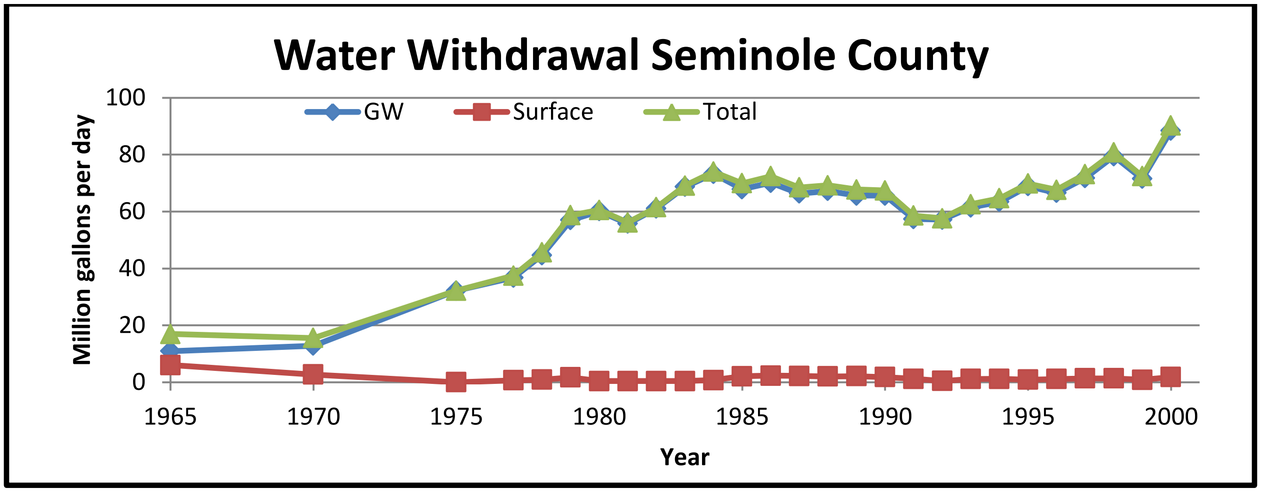

Figure 4.8 Water withdrawal in Seminole County over time.

Figures 4.7 and 4.8 show the water withdrawal from Orange and Seminole Counties over time. (http://water.usgs.gov/watuse/). In Orange County before 1975 surface water withdrawal was slightly greater than ground water withdrawal. After 1975 ground water withdrawal is significantly greater with an average pumping rate around 200 million gallons per day while surface water withdrawal steadily decreased. In Seminole County the ground water withdrawal was always greater than the surface water withdrawal. Like Orange County, Seminole County had a significant growth in ground water pumping and surface water withdrawal declined to become almost negligible.

The total pumping rate for each county grew over time showing an increase in population growth. During population growth there are more people in a smaller area causing a greater water demand. The water that is pumped out from the deep and shallow aquifers reduces the groundwater available for streams and rivers to maintain water levels and flows. Land use and land cover change also point towards increased pumping because of the landscaping water demand. Landscaped areas need to be watered regularly. This water comes from potable water and reclaimed water and also wells. Increasing population in the Econ River basin has changed the land use and water demand which has in turn increased water withdrawals.

4.4 Effluent Discharge

Effluent discharge is a contributing factor to the Econ River and its flow regime. This discharge from water treatment plants can increase low flows in the river and also decrease the water quality. The Iron Bridge wastewater treatment plant (Iron Bridge WWTP for short) is a regional facility located in the Econ River basin. See Figure 4.9 for its discharge locations in the watershed. The Iron Bridge plant is owned by the City of Orlando but also serves Winter Park, Maitland, Casselberry and unincorporated portions of Orange and Seminole Counties. The facility was built in three phases. The first phase of the facility began operating in 1982 and was designed to treat 24 mgd. The second phase began operating in 1989 and was designed to treat 12 mgd. The third phase began operation in 1991 and was designed to treat 12 mgd. After all the phases were completed the facility had a total treatment capacity of 40 mgd.

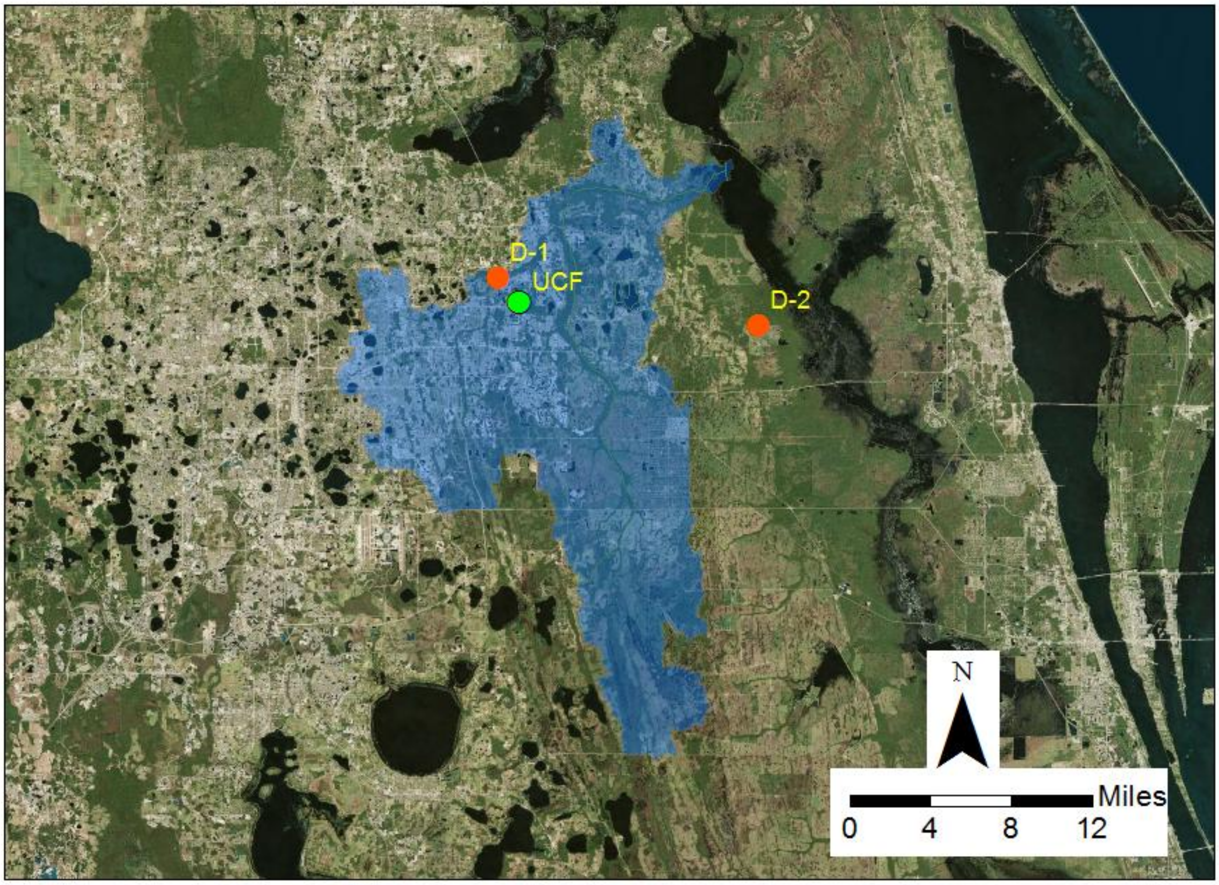

Figure 4.9 Iron Bridge effluent discharge locations.

The Iron Bridge WWTP has two effluent discharge locations, the Little Econ River and the man made Orlando Easterly Wetlands. The discharge limit for the Little Econ River is 28 mgd and the limit for the wetlands is 20 mgd. The Orlando Easterly Wetlands was originally natural wetlands turned into cattle pasture and then transformed into manmade wetlands for the Iron Bridge facility to discharge to. The wetlands are 1,250 acres located outside the Econ River basin. The wetlands consist of bermed cells which the water flows through. The wetland began receiving flows from the facility in 1987 ("Iron bridge regional,").

Data was gathered from City of Orlando to determine the effluent discharge over time into the Econ River. This data was plotted on Figure 4.10.

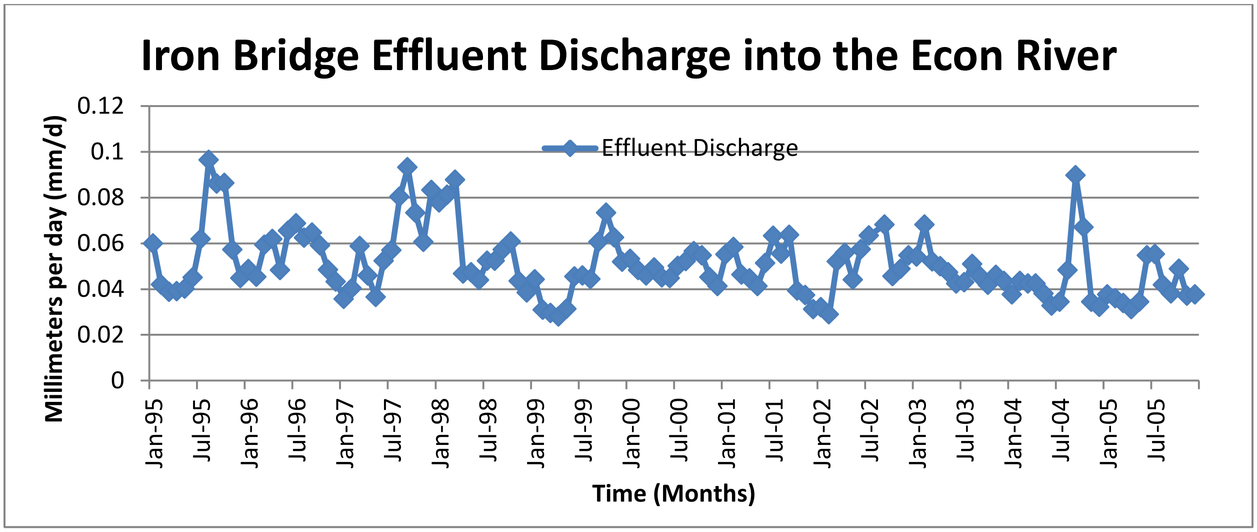

Figure.4.10 Effluent discharge from the Iron Bridge facility into the Econ River.

The average effluent discharge into the Econ River is 0.05 mm per day. The plot shows a few peaks around 0.09 mm per day.

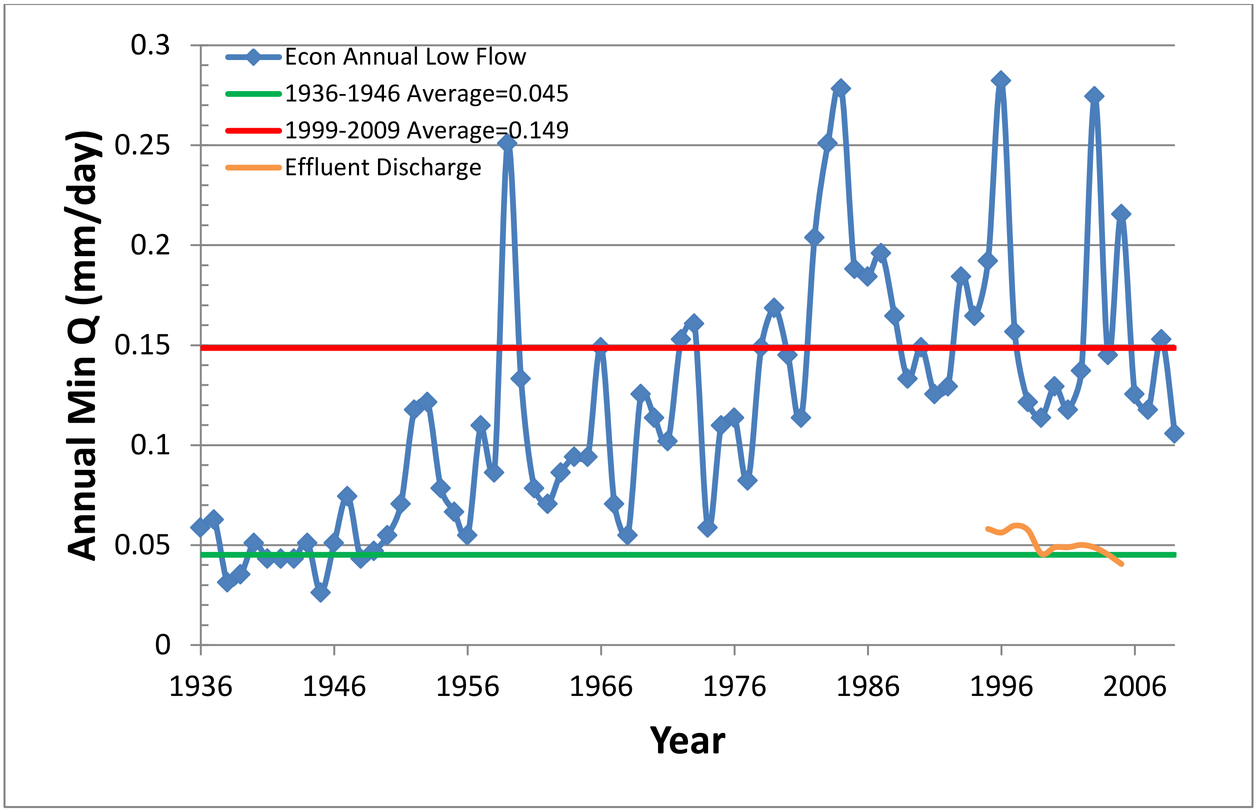

Figure 4.11 Effluent discharge into the Econ River plotted with the annual minimum flow of the river.

Figure 4.11 shows the scale of the effluent discharge in relation to the annual low flow. From the low flow data an average was taken from the first 10 years which equals 0.045 mm per day. This number is the average minimum annual flow before significant human development. A second average was taken from the last 10 years which equals 0.149 mm per day. This number is the average minimum annual flow after significant human development. The difference between the two averages is 0.104 mm which equals the net increase in annual minimum flows between the two periods. Figure 4.11 shows an average effluent discharge into the Econ River of about 0.05 mm per day. This accounts for nearly half of the increase in low flow into the river. Although the effluent discharge does not account for the total net increase it accounts for a significant portion. The remainder of the increase in low flow is likely due to storm water management regulations.

4.5 Stormwater Management Regulations

Development in Florida has caused the need for stormwater management to manage flood waters and maintain the health of the water systems. Florida's water management practices have evolved over the years as researchers have improved their knowledge on what regulations work best. In the beginning most water management was mainly about managing flood waters. Channels and pipe networks were built to convey flood waters away from developments to prevent flooding and damage to property. Declining water quality later caused the need for management practices to improve and maintain the water bodies.

The Water Pollution Control Act of 1948 was the first water quality legislation. This law established the framework in which states and the federal government would develop cooperative programs. Later the Federal Water Pollution Control Act in 1956 and the Water Quality Act of 1965 directed the states to develop their own water quality standards to accommodate their specific water quality goals. In 1972 the Federal Water Pollution Control Act Amendments also called the Clean Water Act created a National Pollutant Discharge Elimination System (NPDES). This system requires each point source discharge to obtain a permit. This system made water quality standards easier to enforce. ("Water quality standards," 2012)

In the late 70's the St. John's River Water Management District (SJRWMD) was establishing itself and its water management needs. Before the late 70's permits were handled thorough the FDEP. The SJRWMD established its own permitting system and rules, requiring developers to obtain permits through them.

Current SJRWMD regulations have different requirements for different types of stormwater treatment systems. The following is a summary of some of the main criteria that is applicable for this discussion. Refer to the SJRWMD Environmental Resource Permits: Regulation of Stormwater Management Systems for all requirements. Retention systems require off-line retention of the first one half inch of runoff or 1.25 inches of runoff from the impervious area, whichever is greater. For on-line retention systems an additional one half inch of treatment of runoff is required. If discharging into an impaired water body an additional 50% of volume is required. Wet and dry detention systems require a treatment volume of the first one inch of runoff or 2.5 inches of runoff volume from the impervious area, whichever is greater. It must be designed so that the pond will bleed down one-half of the volume within 24-30 hours following a storm event, but no more than one- half of this volume will be discharged within the first 24 hours. The system must contain a permanent pool volume to achieve a residence time of at least 14 days during the wet season (June-October). If discharging into an impaired water body an additional 50% of volume is required. Dry detention systems must contain areas of standing water for no longer than three days following a rainfall event.

The volumes of these systems are also controlled by the required attenuation. SJRWMD requires that the pond attenuate the 25 year 24 hour storm and the mean annual 24 hour storm.

This means that the post-development flow coming off the site must not exceed the pre-development flow. The attenuation is designed to hold back stormwater to prevent flooding. Attenuation requires most pond volumes to be increased because the increase in impervious increases the amount of runoff coming from the site.

Developed sites and increased impervious areas require treatment ponds that provide for treatment and attenuation. These ponds are different sizes and function differently depending on the pre-development conditions, type of use, type of soil, elevations, etc. Stormwater ponds collect the stormwater and release it gradually to prevent flooding. Systems attenuate the rate of runoff from the site but not the total volume. The larger amount of impervious area in the post development condition results in a larger amount of runoff because the runoff cannot infiltrate into the soil as easily as the pre development condition. This additional amount of runoff is released after the storm event through bleed down structures to bring the pond back to its normal water level. The slow release of the additional stormwater after the storm event can increase the low flows between storm events. This means the maximum flows will not increase because the ponds are holding back the peak flows, but the minimum flow will increase because of the runoff being released gradually after the storms.

CHAPTER 5 : CONCLUSIONS AND FUTURE WORK

The Econ watershed is a dynamic watershed that has endured changes over time. This thesis analyzes the hydrologic changes, climatic changes and human interferences of the Econ watershed. Through this analysis hydrologic changes were determined to be a slight increase in annual stream flow and a significant increase in low flow. These changes are the result of human impacts on the watershed. Ground water levels in wells around the watershed were also analyzed and showed a decrease around the areas with substantial land use change.

In order to look at all of the factors that can play a part in the hydrologic changes in the watershed the climatic changes were analyzed. The annual precipitation had no uniform trend. There was a slight increase in temperature but it does not appear to yield significant changes to the watershed. The potential evaporation increased similarly to the temperature trend. This was expected since the potential evaporation was calculated using the Hamond Method which uses the temperature. Based on these results it was determined that there were significant changes in the potential evaporation but no other significant changes to the climate over the study period.

Human interferences are the primary reason for the hydrologic changes in the watershed. Population growth from the Greater Orlando area has resulted in significant land use change since the 1970's. This land use change has increased runoff by increasing the impervious area in the watershed. Effluent discharge has also played a part in increasing the low flow of the Econ River. The Iron Bridge facility is a large wastewater facility that discharges into the Econ River. This discharge seems to play a significant role in the low flow event. Other changes to the watershed are storm water management regulations. These regulations require developments to capture runoff in ponds to increase water quality of runoff and decrease flooding. These systems are also required to attenuate the flow off the site. This means peak runoff from the site is held back to be released at a later time. When this runoff is released it is after the peak storm event and can cause an increase in low flow. Human interferences such as effluent discharge, land use change, and storm water management regulations have played a part in changing the hydrologic cycle of the Econ River watershed.

This thesis showed a numerical analysis of the change in land use and the effluent discharge into the Econ River. Future work should include a numerical analysis on the effects of the stormwater management practices on the watershed. This analysis may include determining the volumes of runoff over the watershed that is collected in storm water systems and a time analysis on how the systems across the watershed hold back the runoff. Quantifying the effects of the stormwater management practices will help to complete the overall water budget analysis of the Econ River flow regime.

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