4. WATER BUDGET

Appendix L of the August 2011 Annual Report (FPL 2011b) documented a preliminary water and salt budget for the period of September 2010 to May 2011. The water budget quantifies exchanges between the CCS and the groundwater, freshwater surface waters, Biscayne Bay waters, and the atmosphere. The salt budget quantifies these exchanges with regard to salt mass. The preliminary water and salt budget presented in Appendix L of the Annual Report showed the conceptual model of the CCS exchanges, the methodology for performing calculations using the monitoring data to quantify these exchanges, and preliminary results that were computed on a daily time step and summarized monthly.

To help clarify some questions or misunderstandings by the Agencies regarding the water budget, a brief overview of the conceptual model and previous water budget results are provided below along with pending efforts.

4.1 Conceptual Model

The conceptual model of the CCS, as modeled in the water and salt budget, is described below. The conceptual model considers three related variables (flow, concentration, and temperature) which are controlled by physical processes such as water elevation differences, mixing, precipitation, and evaporation. The description begins with the exit of approximately 1,728 million gallons per day (MGD) of warm hypersaline water from the power plant as it enters the CCS. The water enters the CCS via a single east-west running canal that serves as a header that distributes water into a series of 32 north-south running discharge canals. The water flows in this direction because the addition of the water raises the water elevation in the CCS locally. This water then runs in a southerly direction for about 5 miles, where the north-south running canals terminate and intercept a single west-east running canal that collects the flow.

Within the side of the CCS described above, which pertains to what is called the discharge canals, the water goes through several processes that alter its flow, concentration, and temperature. A small portion of water running through the canals is lost from the CCS through the sides and base of the CCS as seepage. This loss is primarily due to the water elevation difference that exists between the CCS and the regional groundwater. In general, the loss occurs in the northern part of the CCS where the water elevation in the CCS is higher than regional groundwater. This water elevation difference between the CCS and groundwater dissipates to the south and, hence, the loss decreases to the south. During some times of the year, the water elevation in the CCS is less than regional groundwater and the CCS gains water from groundwater as seepage. The extent and amount of gains from and losses to groundwater are affected by the differences in water elevations in the CCS and regional groundwater. These differences change seasonally and spatially. Water elevation changes may be caused by factors that include precipitation, evaporation, regional canal management, regional water supply pumping, and power plant operations.

The discharge side of the CCS acts as a giant radiator because a large surface area is created (32 shallow, 5-mile-long canals). The large surface area allows considerable evaporation to occur, which cools the water up to 8°C. The cooling process is illustrated in the thermal image presented as Figure 4.1-1 (Garrett, 2001). Note that much of the cooling takes place in the northern part of the CCS. Evaporation removes only water, such that dissolved solids (salt) are left behind in the CCS water. The concentration of this water increases downstream because there is less water but the same amount of salt than there was upstream. The concentration of water in the CCS is prevented from increasing in an unbounded fashion because fresher water is added along the traverse through the discharge canal system via rainwater and groundwater seepage. Both of these waters have concentrations less than the hypersaline conditions in the CCS and, hence, tend to cause the CCS concentrations to equilibrate to a concentration that is consistent with the mixing of these three types of water.

Much of the cooling has occurred by the time the canal water has reached the southern end of the CCS. The water runs easterly, is redistributed into a series of six south-north running canals, and then heads back to the plant. These canals are referred to as return canals. The water runs north back to the plant because water elevations in the CCS are depressed at the plant as the water is pumped back through the plant. There may be some loss of CCS water to groundwater in the southerly part of the return canals, again due to the water elevation difference, but this loss decreases and becomes a gain (into the CCS) as the water heads north in the return canals. The extent and amount of gains from and losses to groundwater are affected by the water elevations in the CCS and regional groundwater. A large component of the water that is gained by the CCS is in the north, near the depressed water elevations caused by the pumping. This gained water comes from beneath Biscayne Bay and, as such, is saline. Though the water is saline, it is of lower concentration than the hypersaline CCS water and tends to cause the CCS concentration to equilibrate to a concentration that is lower than it would be without the addition of saline water.

As water re-enters the plant, its flow volume is essentially the same as when it left the plant, with water that was lost to evaporation and outflowing groundwater seepage having been made up by inflowing groundwater seepage and precipitation. The concentration of the CCS water is also very much the same at the outlet as the intake, despite having some mass of salt retained from evaporation. This is because salt buildup is ameliorated by loss of some hypersaline water through seepage, gain of freshwater from precipitation, and gain of saline water from groundwater seepage. The temperature of the CCS water, however, has decreased by 4°C to 88°C from outlet to intake.

4.2 Summary of Water Budget Results (1st nine months)

Appendix L of the August 2011 Annual Report (FPL 2011b) presented a water budget for the first nine months of data collection. This water budget is consistent with the conceptual model presented above. Appendix L described, in detail, the methodology for computing components of the water budget. Less description was devoted to providing an explanation of the results of the water budget. This section provides a summary of the water budget results and addresses what we believe are misconceptions regarding the water budget.

The results of the water budget are summarized for the nine-month period in Table L.2.1 and presented on a month-by-month basis in Tables L.4.1, L.4.3, L.4.5, L.4.7, L.4.9, L.4.11, L.4.13, L.4.15, and L.4.17 in the Annual Report. The month-by-month values are summarized in the stacked bar graph presented as Figure 4.2-1, which shows the individual components of inflow and outflow. Note that inflow does not necessarily equal outflow. This imbalance is reflected by a change in storage (Figure 4.2-2). When inflow exceeds outflow, water goes into storage and water levels in the CCS rise. Conversely, when outflow exceeds inflow, water is coming out of storage and water levels decline. Note that, although inflow and outflow quantities have similar magnitudes, the water that inflows is generally not the same water that outflows and the water that outflows is not the same water that inflows.

Note that the control volume is such that the fate or eventual destination of “lost water” is not considered further. In this sense, the water budget quantifies, for example, the amount of water lost through the bottom of the CCS, but does not compute where it goes after it has left the CCS. Such an analysis of solute transport is beyond the scope of the water budget.

Although the quantities in the water budget that are lost from or gained by the CCS appear large—some on the order of tens of millions of gallons per day—these values are a relatively small component of the overall flow in the CCS, which is estimated to be approximately 1,700 mgd. For example, the average loss from the CCS is on the order of 4.5% of the flow in the CCS.

Losses from and gains by the CCS vary from month to month. These differences result from changes in regional and CCS water elevations, evaporation, precipitation, plant operations, etc. Within the discharge side of the CCS, the largest gains occur in spring and summer and the largest losses occur in fall and winter.

Over the nine-month period, 15,000 million gallons were lost to evaporation and 6,200 million gallons were lost to groundwater seepage. This water was made up by the addition of 8,200 million gallons of precipitation and 12,000 million gallons of groundwater seepage. Note that during the nine-month period, more water outflows from CCS than inflows; this is consistent with a loss of water in the CCS evidenced by a small drop in water levels during this period of time.

A salt budget is summarized for the nine-month period in Table L.2.2 in Appendix L of the August 2011 Annual Report (FPL 2011b). The salt budget is presented for specific months in the even-numbered tables starting with L.4.2 and ending with L.4.10. The quantities in the salt budget will likely change when the modeled bathymetry of the CCS is revised; therefore, these quantities are not discussed further.

4.3 Ongoing and Future Work

At the time that the Annual Report was submitted, the Agency had not given approval of the methodology. Since that time, the water budget has continued to be refined for the September 2010 to May 2011 period. Some of the changes and advances that have been made to the water budget since the prior submittal include the following:

- Inclusion of the bathymetry of the cooling canal system. The preliminary water budget assumed the canal side walls were vertical such that the change in the volume of the system due to additions or subtractions of water was reflected by a proportional change in water level. The new bathymetry accounts for sloping side walls, differential depths in each segment of the system, and provides a more accurate estimate of the surface area of the canal system at any given time. Inclusion of the bathymetry should provide better estimates of gains and losses of water due to evaporation and precipitation, a more accurate depiction of the relationship between water level changes and these gains and losses, as well as a better salt budget due to a better estimate of the volume of water that a given amount of salt is diluted in.

- Inclusion of additional precipitation stations. The preliminary water budget used a single station (TPM-1) for precipitation data. Based on agency input, data from other stations, where available, are being included into the revised water budget.

- Consideration of adjusting water levels for density differences. The preliminary water budget assumed that calculations based on water level differences would not need to have water levels adjusted for density differences because the concentrations were not significantly different in well pairs used for these calculations. However, based on Agency input, there may be some instances where adjustment for density could be important. Details of this adjustment are being resolved.

- Evaluation of the effect of underflow between the northern and southern flow meters. It was noted that the apparent water loss between the northern and southern ends of the discharge side of the cooling canal system as determined from the flow meters was substantially larger than the water loss predicted by the preliminary water budget. It is believed that this discrepancy is related to the different ways that each method defines a water loss. Water that seeps from the discharge canals to the return canals as underflow appears in the difference between flow meter measurements as a loss of water. However, the water budget does not treat this as a loss because it is an inter-CCS transfer of water and does not leave the control volume as a true water loss. Efforts are underway to demonstrate, via temperature measurements, that the underflow phenomenon is occurring. Although it may be possible to demonstrate that underflow is occurring, it is not possible to measure it. Hence, it is likely that the flow meters will only have limited use in the water budget.

Meetings will be held with the Agencies to provide interim results and further discuss findings. The 2012 Annual Report will include the items described above and will include results from September 2010 through May 2012. In addition, data from the period September 2010 to September 2011 will be used to calibrate the model; data for the period after September 2011 will be used to validate the calibrated model. As a result of the changes described above, the salt budget will be more comprehensive and accurate than the preliminary salt budget presented in the August 2011 Annual Report.

FIGURES

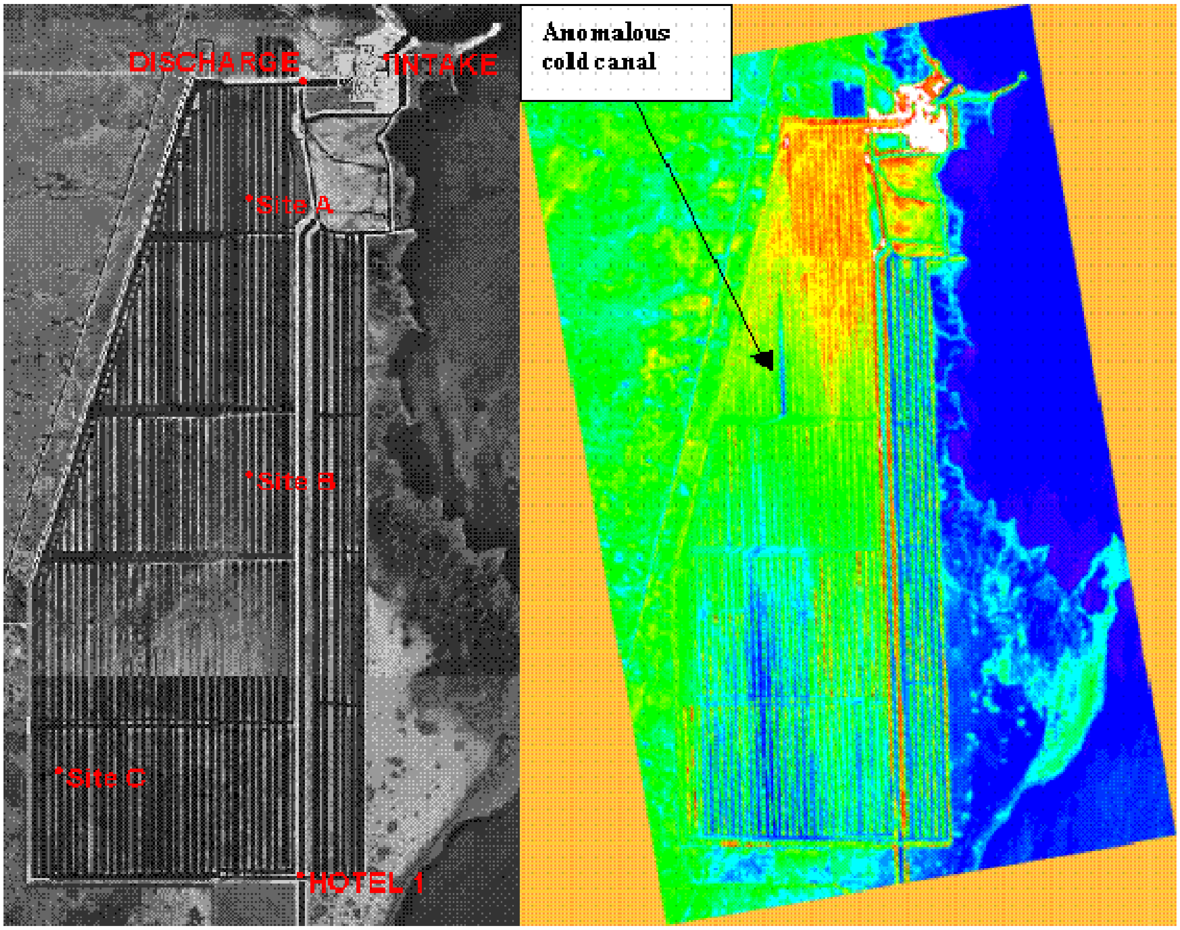

Figure 5: Aerial photograph of Turkey Point power plant cooling canals, with ground truth sensor locations.

Figure 6: MTI image of Turkey Point power plant cooling canals taken on 11/28/00.

Figure 4.1-1. Thermal Image of CCS.

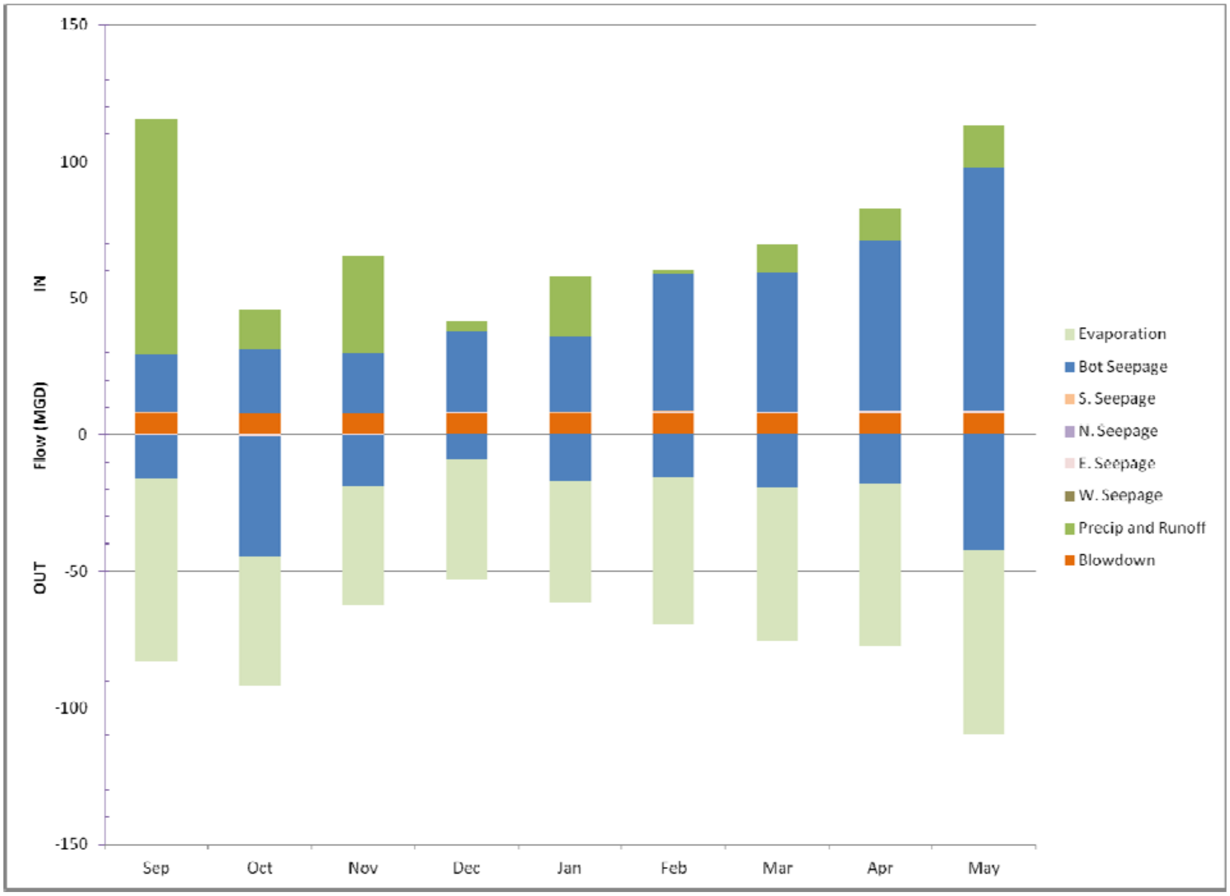

Figure 4.2-1. Summary of Components of Water Budget.

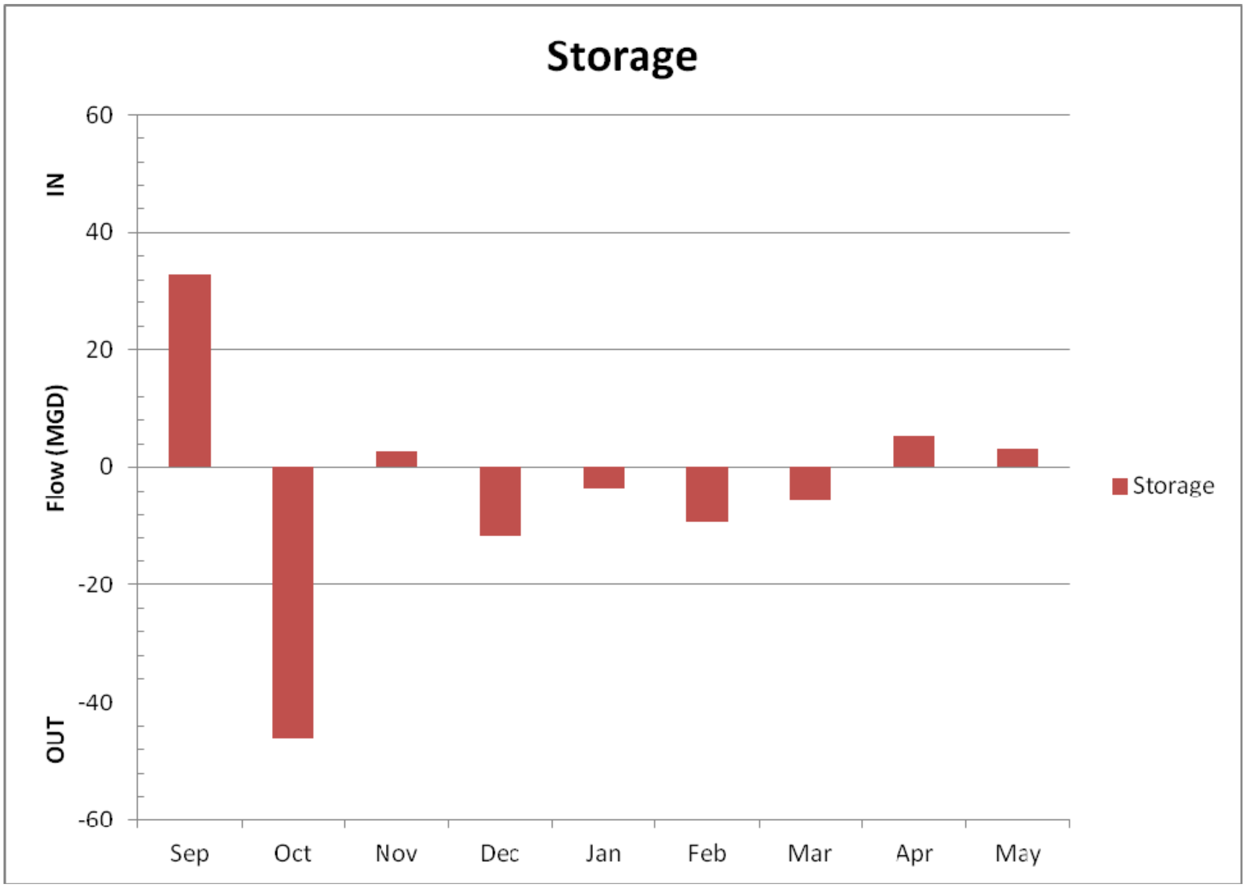

Figure 4.2-2. Storage Component in Water Budget.