Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

25th Annual Progress Report
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Chapter 12: Calculating Clifton Court Forebay Inflow

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12 Calculating Clifton Court Forebay Inflow

12.1 Introduction

Located in the southern portion of the Sacramento-San Joaquin Delta and about 20 miles southwest of the city of Stockton, Clifton Court Forebay is a regulated reservoir at the head of the State Water Project's (SWP) California Aqueduct. Flow into the forebay is controlled by five radial gates. Flow through the individual gates is not directly measured. DWR's Delta Field Division (DFD) indirectly measures inflow by calculating the difference in expected storage from the actual measured storage in the forebay.

Another method of calculating inflow is to use stage data measured both inside and outside of the forebay gates and gate heights. In 1988 a series of regressions were developed to determine the flow through the gates using the gate heights instead. This chapter describes the methodology used to develop these equations and then compares these equations with the DFD storage based estimates.

12.2 Field Tidal Gate Operations

The intake structure to Clifton Court is comprised of five 20' x 20' radial gates along Old River. Figure 12.1 shows the location and configuration of the gates in the field. These gates are generally operated during the tidal cycle to reduce approach velocities, prevent scour in adjacent channels, and minimize water level fluctuation in the south Delta. When a large head differential exists between the outside and the inside of the gates, instantaneous flows into the forebay could theoretically reach 15,000 cfs. However, existing operating procedures identify a maximum design rate of 12,000 cfs, which prevent water velocities in surrounding Delta channels from exceeding three feet per second (ft/s) to control erosion and prevent damage to the facility.

Generally, all five gates are operated to open and close in tandem. However, during maintenance and/or gate repairs, individual gate(s) may be independently operated. The daily opening and closing of gates depends on the scheduled SWP exports, timing and amplitude of the local tides, and storage availability in the forebay.

Gate operations are constrained by a scouring limit (i..e. 12,000 cfs) at the gates and water level concerns in the south Delta for local agricultural irrigators. An interim agreement between DWR and South Delta Water Agency, outlined in the Draft Agreement "Regarding Implementation of CALFED Bay Delta Program Activities in the Delta", specifies a series of priorities that dictate gate restrictions. The least restrictive operation is commonly referred to as Priority 3.

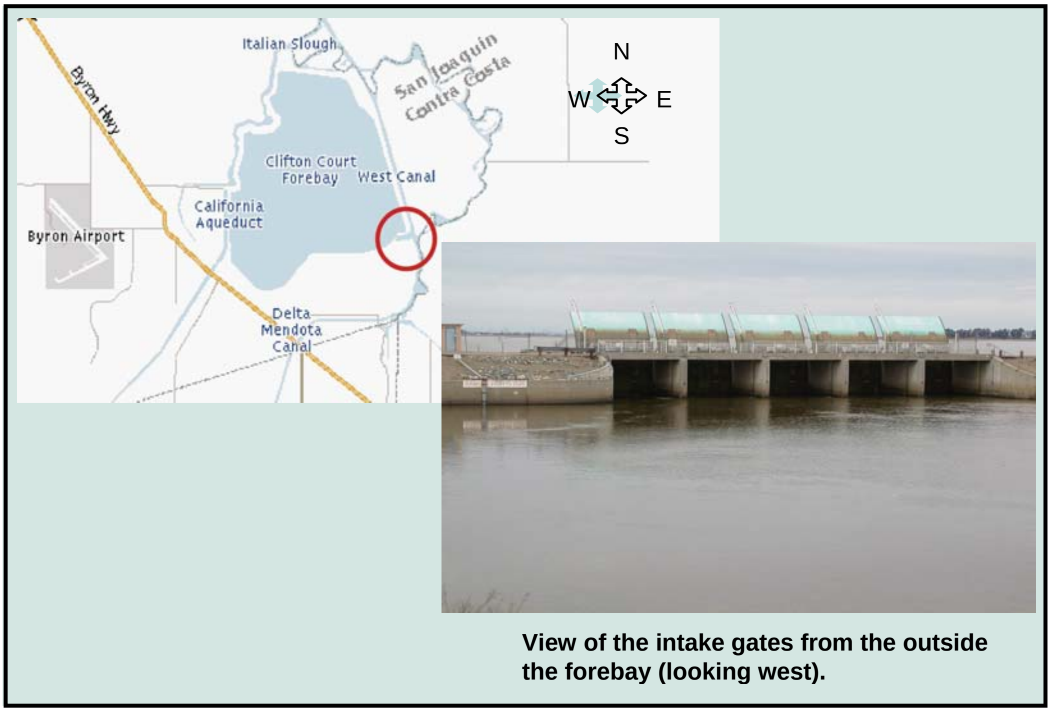


Figure 12.1: Location of Clifton Court Forebay Intake Gates.

DFD receives daily allocation information from the Project Operations Center, and knows when the gates can be opened based on forecast tides in the south Delta and at the forebay gates. If the water level inside the forebay is lower than outside, then DFD opens the gates for the time period allowed under the acceptable priority level at the time. When the water level inside is higher than outside or the gates cannot be opened under the current priority system, then the gates remain closed.

Once the allocation has been reached for the day, the gates are closed. If the allocation was not achieved for the day, then Joint Operations Center staff will adjust the schedule the same day to make up the remaining allocation the next day. The schedule for pumping at Banks must frequently be adjusted to accommodate the tide-based restrictions and still obtain the targeted allotment. The same is also the case when maintenance or debris limits the function of the Skinner Fish Facility or Banks Pumping Plant.

In general, DFD operates to Priority 3. However, due to low water levels or other constraints, Priority 2 or Priority 1 operation might be necessary to meet water allocation schedule for the day. An example of all three priorities is shown in Figure 12.2. The rules used to determine when the gates can be opened depend on whether the lower low tide is followed by the lower high or higher high tide.

The first situation is when the lower low tide is followed by the lower high tide. During this condition, Priority 3 allows the gates to open 1 hour after the lower low tide, close 2 hours after the higher low tide, open again 1 hour before the higher high tide, and close 2 hours before the next lower low tide. Under Priority 2, the gates are allowed to open 1 hour after the lower low tide until 1 hour before higher low tide, and open again 1 hour before the higher high tide until 2 hours before the next lower low tide. Under Priority 1, the gates may be opened 1 hour after the lower high tide until 1 hour before the higher low tide and 1 hour after the higher high tide until 2 hours before the next lower low tide.

The second situation is after the tides have reversed, i.e. when the lower low tide is followed by the higher high tide. During this condition, Priority 3 allows the gates to open 1 hour before the higher high tide and remain open until 2 hours before the next lower low tide. Under Priority 2, the gates are allowed to open 1 hour before the higher high tide until 1 hour before the higher low tide and can reopen again 1 hour after the higher low tide until 2 hours before the next lower low tide. Under Priority 1, the gates may be opened 1 hour after the higher high tide until 1 hour before the higher low tide and 1 hour after the lower high tide until 2 hours before the next lower low tide. Essentially the Priority 1 operation is the same after the tides have reversed.

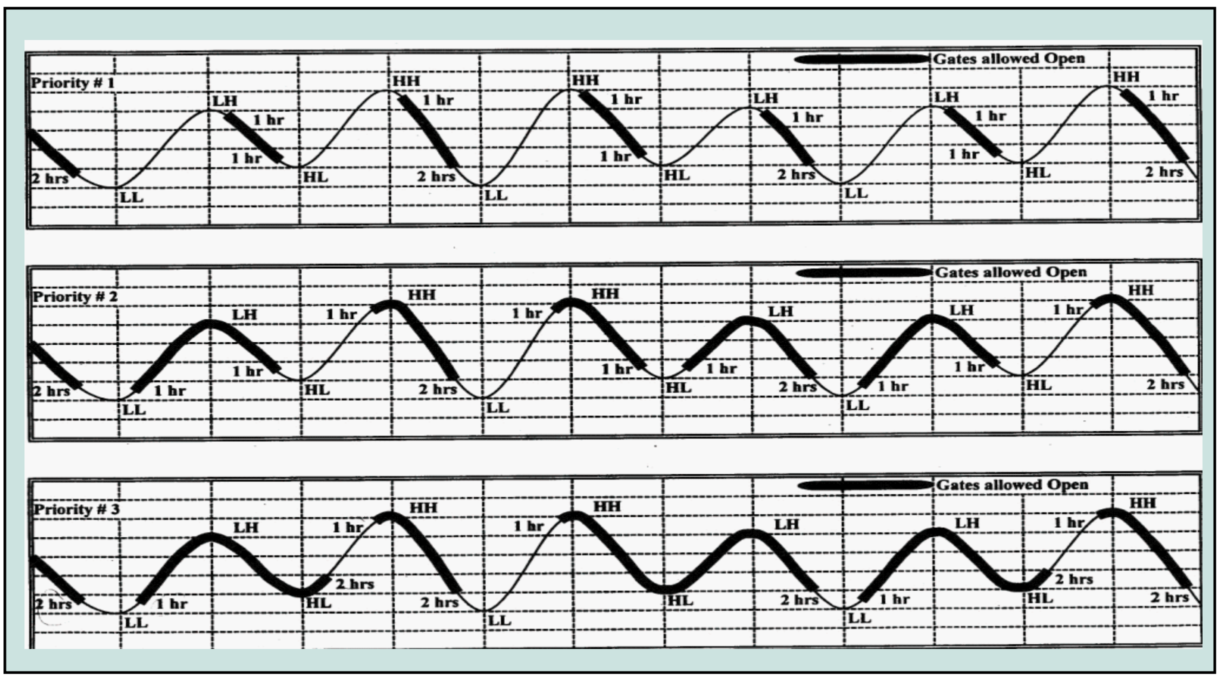
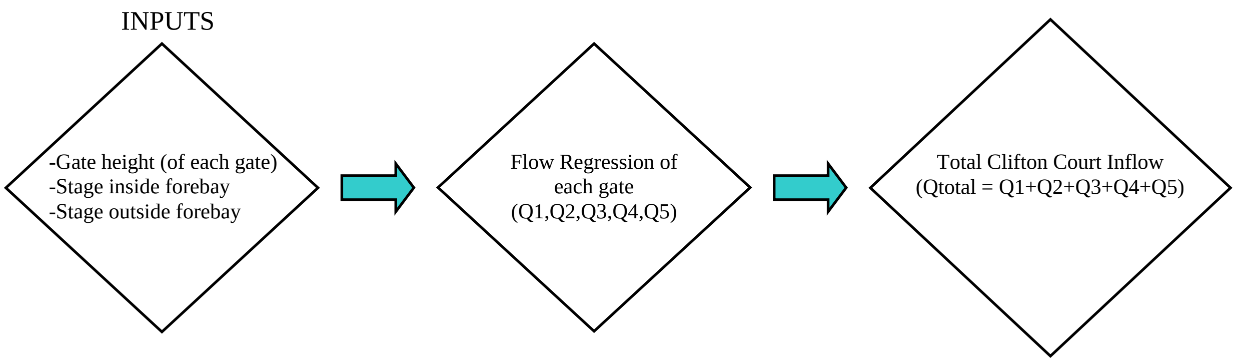


Figure 12.2: Clifton Court Forebay Gate Priority Operation Rules.

12.3 New Clifton Court Gate Equations

Hills (1988) developed a new set of gate position - elevation difference regressions to estimate the flow passing through the Clifton Court Forebay Gates. A flow chart illustrating Hills's methodology is shown below:



Hills used data on the gate height (position), the difference in stage inside and outside of the forebay, and measured flow through each of the gates, *i*, to develop the following equations:

$$Q_1 = H_1\left\{0.44 + 215.224\left(Elev_{outside} - Elev_{inside}\right)^{1/2}\right\} \quad \text{[Eqn. 12.1]}$$

$$Q_2 = H_2\left\{4.46 + 181.804\left(Elev_{outside} - Elev_{inside}\right)^{1/2}\right\} \quad \text{[Eqn. 12.2]}$$

$$Q_3 = H_3\left\{4.76 + 173.378\left(Elev_{outside} - Elev_{inside}\right)^{1/2}\right\} \quad \text{[Eqn. 12.3]}$$

$$Q_4 = H_4\left\{3.380 + 173.378\left(Elev_{outside} - Elev_{inside}\right)^{1/2}\right\} \quad \text{[Eqn. 12.4]}$$

$$Q_5 = H_5\left\{2.38 + 168.790\left(Elev_{outside} - Elev_{inside}\right)^{1/2}\right\} \quad \text{[Eqn. 12.5]}$$

$$Q_{total} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 \quad \text{[Eqn. 12.6]}$$

where,

Q_i = flow through gate *i* (cfs),
H_i = gate height / position of gate *i* (ft),
$Elev_{outside}$ = stage outside Clifton Court Forebay (ft),
$Elev_{inside}$ = stage inside Clifton Court Forebay (ft), and
Q_{total} = Total Clifton Court gates inflow (cfs).

In 1997, DWR, SWP, Joint Operations Control staff used MS Excel to quickly and easily create estimates of Clifton Court inflows based on the gate heights and difference in stage inside and outside of the forebay.

12.4 Validation of the Equations

The DFD indirectly measures the net flow through the Clifton Court Forebay Gates by measuring the water levels in the forebay and estimating the anticipated change in storage due to pumping. These indirect measurements are then stored every 10 minutes on a DFD Information and Storage Retrieval (ISR) system which can be accessed only by the Department. Hills's equations were validated for August 2003 through September 2003 by comparing the total flow calculated using Equation 12.6 with the ISR measurements.

Both the DFD measured flow through the gates and the flow calculated using Hill's equations for August and September 2003 are shown in Figures 12.3 and 12.4. The difference between the DFD measured and calculated flows are compared with the Banks export levels for August and September 2003 in Figures 12.5 and 12.6. The plotted difference in flows includes times when all five gates were closed. Banks pumping was included in order to determine if any differences in the calculated and measured inflows could be attributed to different pumping conditions (i.e. low versus high pumping). The difference in flows is also compared with the stage outside and inside the Clifton Court Forebay for August and September 2003 in Figures 12.7 and 12.8.

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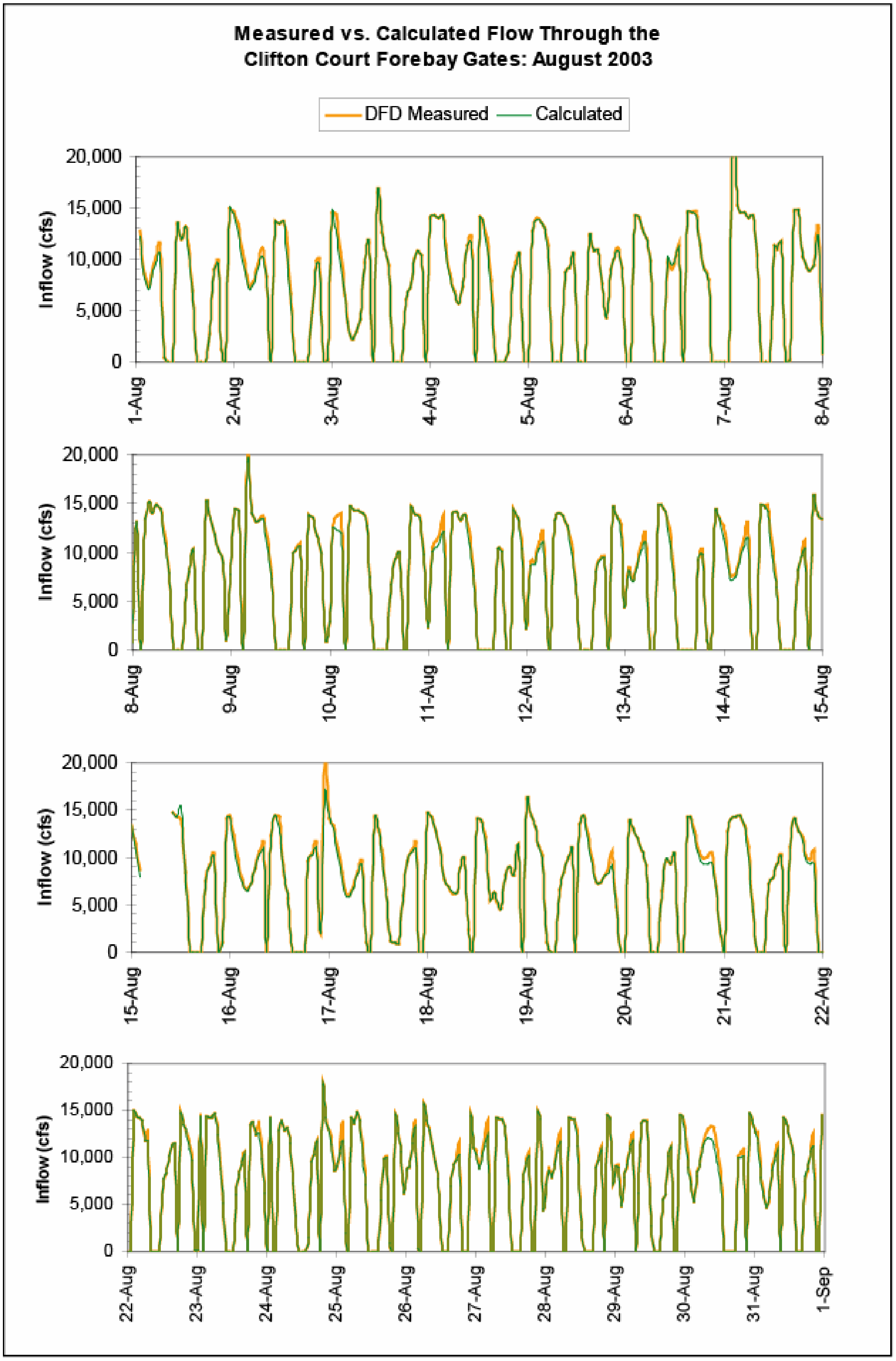

Figure 12.3: Measured vs. Calculated Flow Through the Clifton Court Forebay: August 2003.

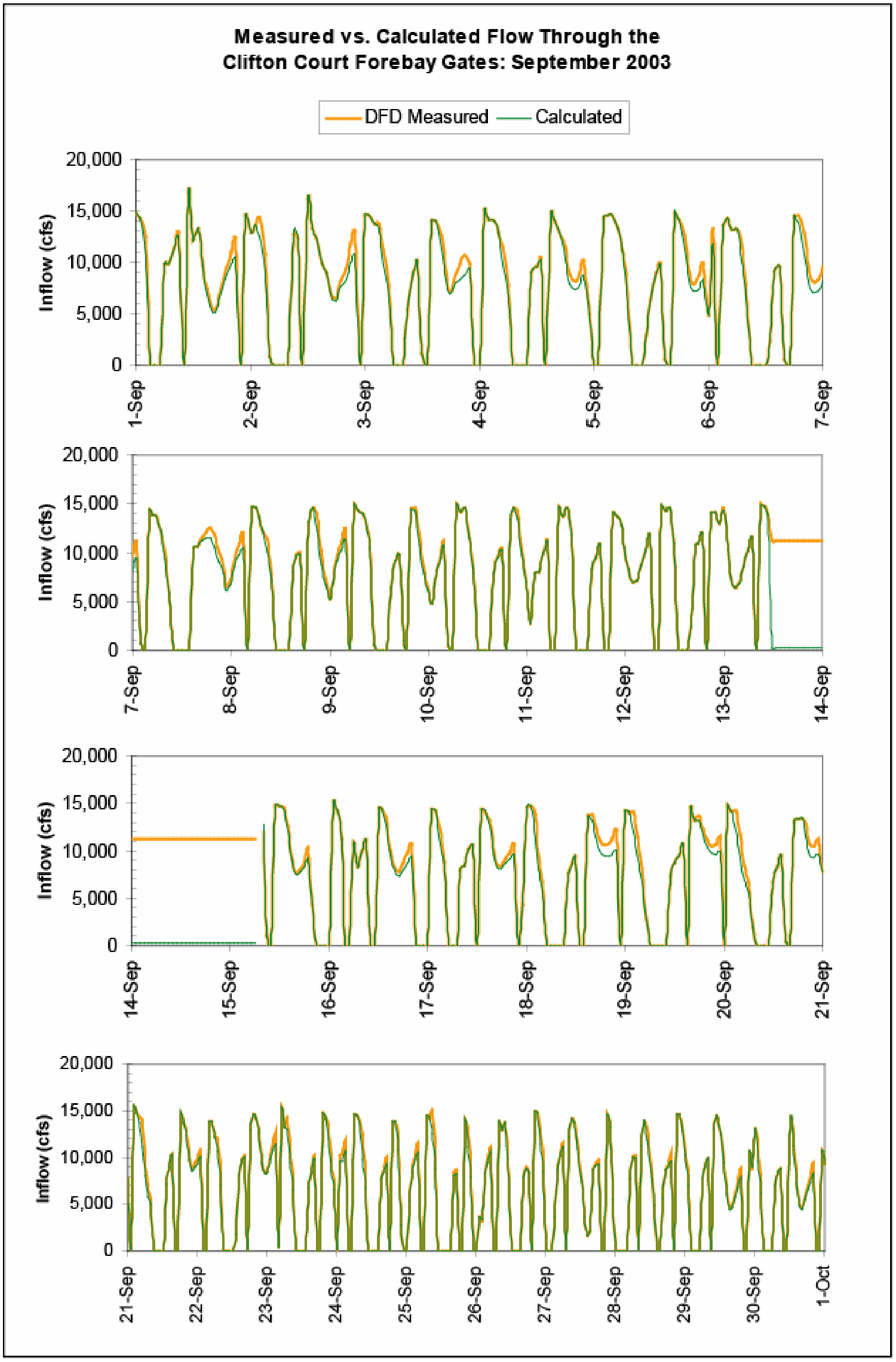

Figure 12.4: Measured vs. Calculated Flow Through the Clifton Court Forebay: September 2003.

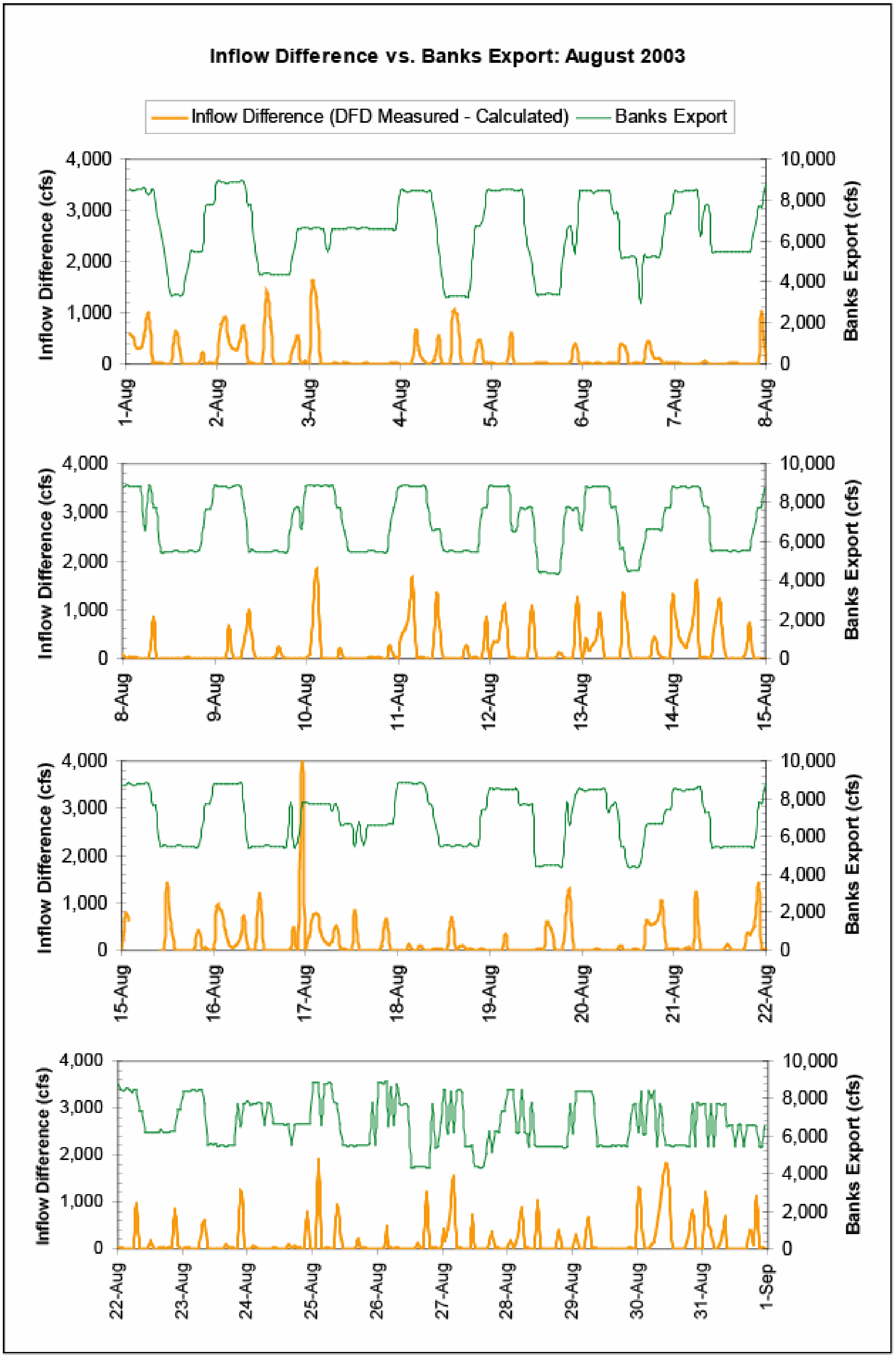

Figure 12.5: Inflow Difference vs. Banks Export: August 2003.

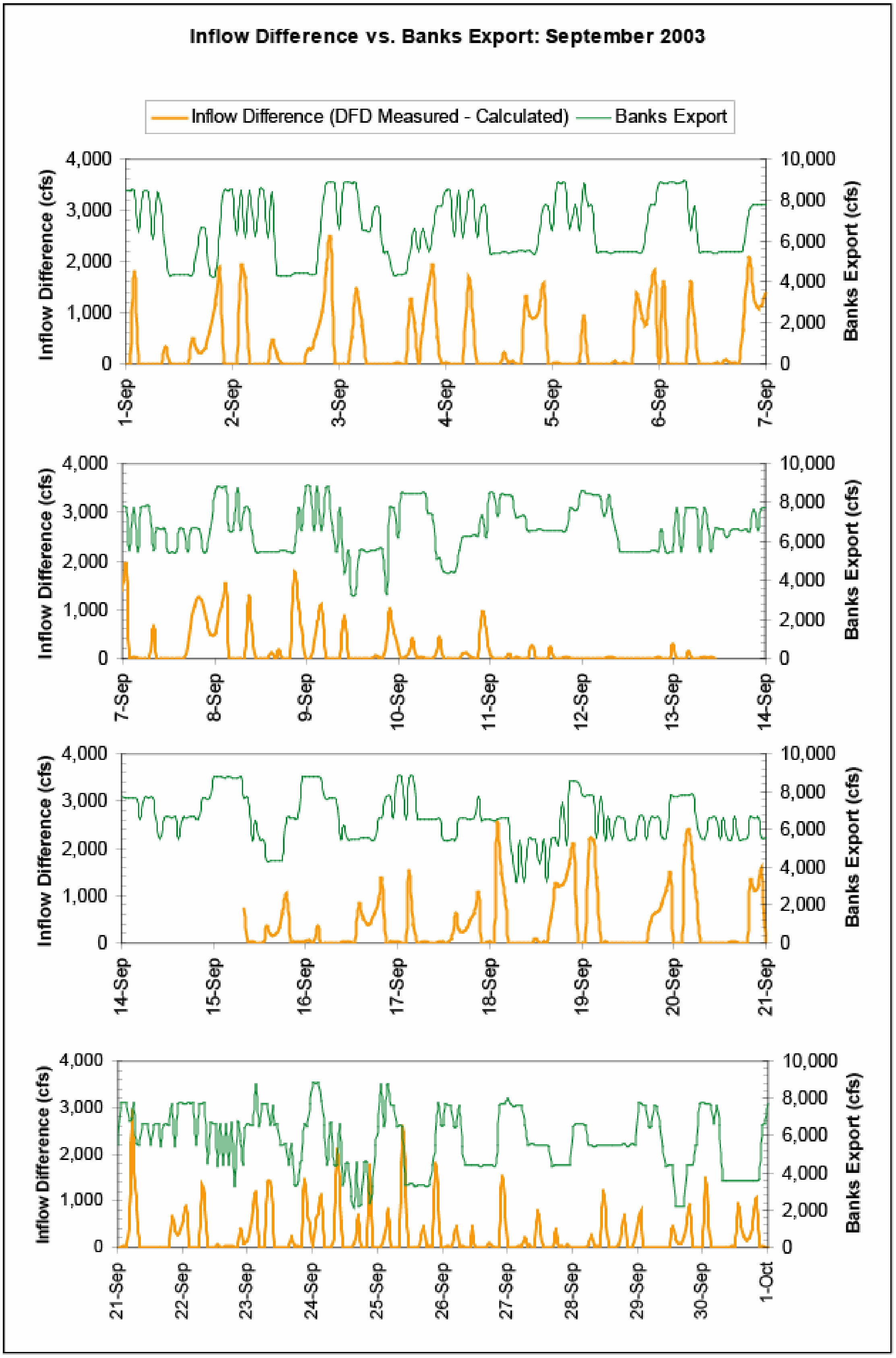

Figure 12.6: Inflow Difference vs. Banks Export: September 2003.

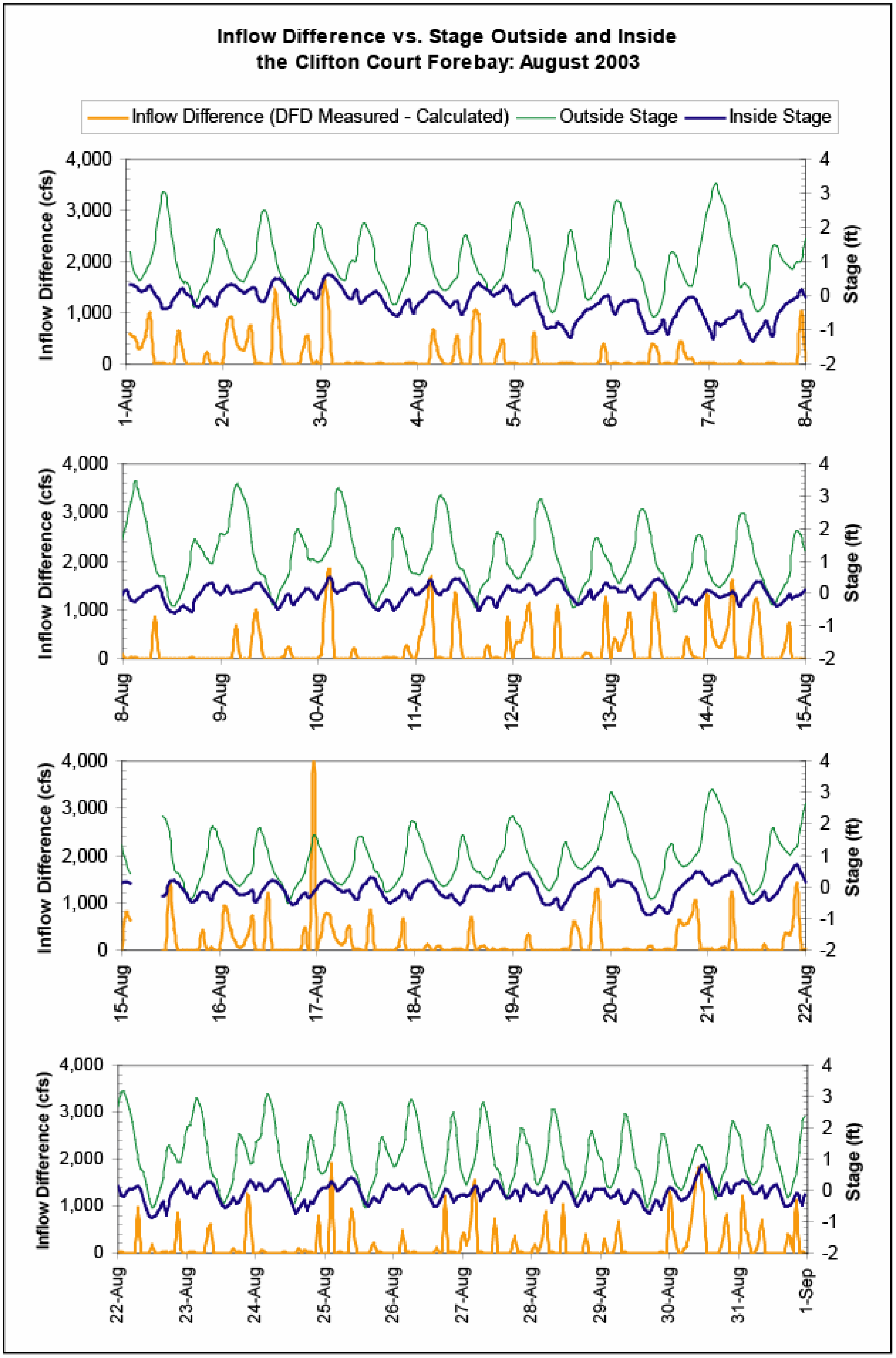

Figure 12.7: Inflow Difference vs. Stage Outside and Inside the Clifton Court Forebay: August 2003.

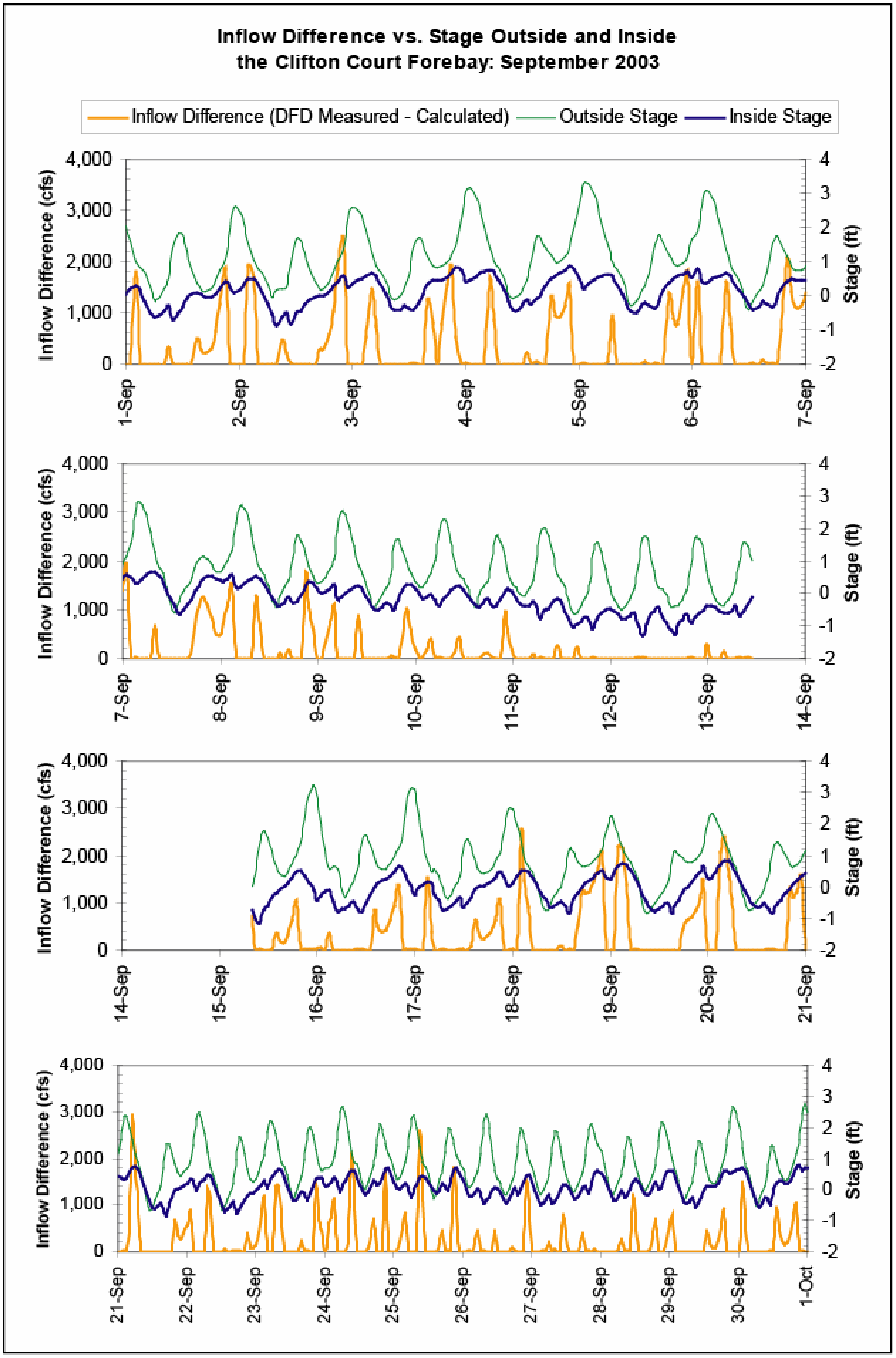

Figure 12.8: Inflow Difference vs. Stage Outside and Inside the Clifton Court Forebay: September 2003.

The following observations were noted of the plotted results:

- The maximum instantaneous flow difference between calculated and measured in August 2003 was 4,292 cfs, but on average the flow difference is 173 cfs as shown in Figure 12.3. It is important to note that the average flow difference includes times when the forebay gates were closed.

- The maximum instantaneous flow difference between calculated and measured in September 2003 was 2,919 cfs, but on average the flow difference is 297 cfs as shown in Figure 12.4.

- Figures 12.5 and 12.6 indicate no direct correlation between Banks pumping rates with the difference between calculated and measured flow.

- Figures 12.7 and 12.8 indicate a relationship between flow difference and stage outside of the intake gates. Most of the flow differences occurred half-way coming into and/or half-way off a high tide.

Monthly averaged data for the period of April through September 2002 were examined. Banks pumping was included to verify if the measured DFD and calculated flow through the forebay gates were valid. The results are shown in Table 12.1. The absolute monthly difference is the difference of the measured from the calculated flows.

Table 12.1: Monthly Averaged Flow Through the Clifton Court Forebay Gates.

Year 2002	*Monthly Avg. Banks Pumping*	*Monthly Avg. Q(calculated)*	*Monthly Avg. Q(measured)*	*Absolute Monthly Difference*	*% Difference*
April	2104	2217	2120	96	4
May	625	855	678	177	21
June	2146	2584	2266	318	12
July	6222	6161	6241	80	1
August	n/a	n/a	n/a	n/a	n/a
September	4131	4452	4199	252	6

* Does not include August due to missing data.

12.5 Conclusions

The Clifton Court individual gate equations are the result of Hill's efforts to find a better method to estimate at the gates. DWR's Joint Operations Center added these equations into MS Excel and uses them to estimate the flows into the forebay based on the difference in water levels inside and outside of the forebay. Validations made by Hills (1988) indicate that the tool, offers a quick and consistent method for estimating inflows to the intake gates. The observations of inflow results are as follow:

- A noticeable pattern was noted that most of the differences between the estimated and field inflows occurred half-way into and half-way out of a high tide.

- Between August and September of 2003, the largest averaged instantaneous flow difference was 3,605 cfs, but on average the flow difference was 235 cfs.

Though the DSM2-DB (see Chapter 7) will allow accurate modeling of the Clifton Court Forebay Gates, Hills's equations will be useful in recreating the flow through the Clifton Court Forebay Gates.

12.6 Reference

Hills. (1988). *New Flow Equations for Clifton Court Gates*. Technical Memorandum. California Department of Water Resources, State Water Project Division of Operations and Maintenance. Sacramento, CA.

12.7 Website

An example of the MS Excel Spreadsheet used by the Department is available in the Reports section at:

http://iep/dsm2pwt/dsm2pwt.html

Download the *Clifton Court Inflow Spreadsheet*.