NAPA-SONOMA MARSH RESTORATION
NAPA SIPHON FIELD DATA COLLECTION

Prepared for

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San Francisco District

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1. INTRODUCTION

The Napa-Sonoma Salt Marsh consists of tidal slough channels with salt ponds that are connected by a network of canals, siphons, pumps, gates and valves. Historically, Cargill Inc., the previous owners of the salt ponds, used this network to move water through the ponds for the purpose of industrial salt production. The site is presently owned by the California State Department of Fish and Game (CDFG) who use the network to circulate lower salinity water from the sloughs, the Napa River and San Pablo Bay adjacent to the salt ponds, for management of water levels and salinity in the ponds. The marsh complex is presently undergoing investigative studies to assess the viability for restoration of the salt ponds back to tidal marsh, under a contract between the U.S. Army Corps of Engineers (USACE), San Francisco District and Philip Williams & Associates, Ltd. (PWA).

PWA was contracted by the USACE in May 2000, to undertake fieldwork at the Napa-Sonoma Salt Marsh complex, Napa County, California. The purpose of the fieldwork was to collect flow data through a sample of the siphons at the site. PWA also measured salinity and water surface elevation data in the salt ponds adjacent to the siphons. This data was collected to enable actual stage-discharge relationships to be developed that would supplement theoretical stage-discharge relationships for the flow through the siphons connecting the salt ponds. The siphons were constructed in the mid 1950s and it is likely that the physical conditions of the siphons are corroded and filled with sediment in addition to subsidence that may have occurred over time. Therefore it is unlikely that theoretically derived stage-discharge relationships will be valid. The original approach devised in collaboration between PWA and the USACE was designed to provide data that would characterize flow through the siphons sufficiently for incorporation into the numerical modeling effort undertaken jointly by PWA and the Danish Hydraulic Institute Water & Environment (DHI).

This report describes the results of the fieldwork undertaken between June and November 2000.

2. SUMMARY

The primary purpose of this study was to address concerns regarding the ability of the model to accurately simulate the transfer of water between ponds. Specifically, the goal was to generate accurate differential head (or difference in water surface elevation at either end of the siphons), salinity and discharge data. The results of this study were unanticipated, but reinforced the critical nature of the hydraulic characteristics of the siphons. In fact, under some density conditions during some seasons it may be impossible to get any flow through the siphons without major pumping to increase the differential head. Failure to recognize this phenomenon could have resulted in serious management problems during the implementation phase of the project. A relationship has been defined to predict the hydraulic and salinity conditions that will result in no flow in the siphons, even if there is a significant difference in water surface elevations. This relationship can also be used to calculate the head difference required for flow through the siphons and therefore could provide a useful management tool. Stage-discharge relations for the monitored siphons that did experience some flows during the study period have been developed. Table 1 shows a summary of the findings of the study.

Table 1. Summary

Siphon / Location	Type / Parameter	Condition / Findings
Siphon 6	Canal to canal siphon	▪ Controlled by pump rate at inlet. Stage-discharge not important provided current pump system is used. ▪ Siphon is probably leaking. ▪ Salinity level approximately same either side of siphon. ▪ Differential stage-discharge relation established at start up of pump.
Siphon 5	Canal to pond (donut) siphon	▪ Controlled by pump rate at inlet of Siphon 6. Stage-discharge not important provided current pump system is used. ▪ Siphon is probably leaking. ▪ Differential stage-discharge relation established at start up of pump.
Siphon 3	Pond to pond siphon	▪ No flow in Fall due to exceptionally high density gradient. Flow was observed in Spring prior to monitoring study when salinity gradient was much lower. ▪ Demonstrates that timing of circulation between ponds is critical in the early stages of the rehabilitation of the ponds.
Pond 6A	Salinity	▪ Salinity reduction success due to pumping through Siphons 6 and 5 is marginal. ▪ Risk of increasing salinities exists – pumping saline solution into a closed system.
Pond 6A	Wind and seiche observation	▪ Diurnal pattern to water surface elevation assisting in circulation in pond. ▪ Diurnal pattern is seasonal
Pond 3 and 4	Salinity	▪ Salinity reduction technique ineffective due to seasonal blockage of siphon. ▪ Risk of increasing salinities exists – pumping saline solution into a closed system.
Pond 3 and 4	Wind and seiche observation	▪ Diurnal winds create seiche pattern to water surface elevation assisting in circulation in pond. ▪ Diurnal pattern is seasonal
Pond 2	Wind and velocity observations	▪ Wind induced velocities have a significant effect in internal circulation in relatively shallow pond (5-6 ft in depth).
Pond 2	Stratification	▪ Mixing of flows over the depth is confined to a near-field region within 200 ft of the siphon. ▪ Far-field regions are well mixed.

3. ORIGINAL APPROACH

The original fieldwork schedule agreed under contract with the USACE is listed as follows and is shown diagrammatically by Figure 1.

Task 1: **Siphon 1 – under South Slough connecting Ponds 1 and 2**.

Water level and salinity recorders will be installed immediately upstream and downstream of the siphon in the Ponds 1 and 2 for a two-week period of flow through the siphon. A velocity meter will be installed in the siphon if accessible or as close to the entrance to the siphon if not accessible, for the same time period. Two water level and salinity recorders will be installed over the same time period at locations in Ponds 1 and 2 removed a significant distance from the siphon outlet. Manual measurements of salinity at various locations throughout Pond 1 and 2, as well as manual velocity measurements in the siphon, will be made at times of instrument installation and removal, and at one week after instrument installation.

Task 2: Siphon 4 – from canal to Pond 5 under Devils Slough.

Manual measurements of salinity at various locations throughout Pond 5, including manual velocity and water level measurements in the siphon, will be made over a total of two days of site visits.

Task 3: Siphon 5 – from canal to Pond 6A under Napa Slough.

Similar procedure to Task 1, Siphon 1.

Task 4: Siphon 6 – from canal to canal under Mud Slough.

Similar procedure to Task 1, Siphon 1, except that because the siphon operates from canal to canal, no recorders will be placed a significant distance from the siphon outlet.

The approach described above included one siphon passing from pond to pond (1), two siphons passing from canal to pond (4 and 5) and one siphon passing from canal to canal (6) thus encompassing all of the configurations of siphon at the site.

Figure 1. Napa Siphon Data Collection – Siphon Measurement Schedule

4. REVISED APPROACH

4.1 PHASE 1

The initial Phase 1 of the fieldwork commenced with measurement of Siphons 5 and 6 after consultation with Tom Huffman of CDFG regarding water management issues. Mr. Huffman is the field manager for the marsh complex with whom PWA worked closely during the contract. Phase 1 followed Tasks 3 and 4 outlined above and was conducted between June and July 2000.

4.2 PHASE 2

Phase 2 consisted of a revision to the originally agreed approach as a result of the experience of the site conditions gained during Phase 1. PWA originally understood that Siphon 1 consisted of a siphon passing directly from Pond 1 to Pond 2. However, upon site inspection and consultation with CDFG it was found that the flow passing through Siphon 1 was generated by a pump adjacent to Pond 1, which transferred pond water from Pond 1 at a flow rate of 1.8 m^3/s (29,000 gallons/minute) into a donut (water conveyance structure - a small, circular holding pond approximately 30 meters in diameter), through Siphon 1 under South Slough, into a canal and finally into Pond 2. This flow path was similar to the flow path for Siphon 5. Therefore, PWA agreed with USACE to change the original approach and to undertake measurements at Siphon 3, which passed pond water directly from Pond 3 into Pond 4 under South Slough. Siphon 3 is the only siphon of this type on the site and it was therefore considered that it was important to collect data at this siphon. In addition, due to unforeseen increased fieldwork costs and water management issues, it was agreed to undertake hand held measurements in Pond 2 only.

Figure 2 shows the revised approach used in the fieldwork schedule.

Figure 2. Napa Siphon Data Collection – Revised Siphon Measurement Schedule

5. PHASE 1 FIELD WORK

Phase 1 fieldwork was conducted during June and July 2000 at Siphons 5 and 6. Instrumentation platforms were installed at the locations listed by Table 2 and shown by Figure 3. Figures 4, 5, 6 and 7 show photographs of some of the instrument installations.

Table 2. Instrumentation Platform Locations Phase 1

Platform Notation	Location	Instrumentation
S6 P1 US	Upstream of Siphon 6 in canal	▪ Pressure transducer (water surface elevation) ▪ Velocity meter ▪ Salinity probe
S6 P1 DS	Downstream of Siphon 6 in canal	▪ Pressure transducer (water surface elevation) ▪ Salinity probe
S5 P2 US	Upstream of Siphon 5 in canal	▪ Pressure transducer (water surface elevation) ▪ Salinity probe
S5 P1 US	Immediately upstream of Siphon 5	▪ Pressure transducer (water surface elevation) ▪ Velocity meter ▪ Salinity probe
S5 P1 DS	Immediately downstream of Siphon 5	▪ Pressure transducer (water surface elevation) ▪ Salinity probe
S5 P2 DS	Downstream of Siphon 5 in Pond 6A approximately 10m from S5 P1 DS	▪ Acoustic water level sensor (water surface elevation) ▪ Salinity sampling unit
S5 P3 DS	Downstream of Siphon 5 in west section of Pond 6A	▪ Acoustic water level sensor (water surface elevation) ▪ Salinity sampling unit

Figure 3. Napa Siphon Data Collection – Phase 1 Platform Positions
Figure 4. Isco Salinity Sampler

Figure 5. Platform Installation at the inlet to Siphon 3 in Pond 3.
Figure 6. Access platfom to upstream canal side of Siphon 5.

Figure 7. Access shaft to Siphon 5.

Where possible (due to high salinity restrictions) pressure transducers were used in preference to acoustic water level sensors. Velocity measurements were taken using an acoustic velocity sensor mounted in the invert of each siphon intake. Whenever possible, verification was obtained using a hand held Marsh-McBirney velocity meter. Commercially available salinity meters were used to measure salinities in the range 0 to 75 ppt. To record higher salinities, samples were diluted with pure water to the measurement range and the true salinity derived using correction equations. Similarly, verification of salinity measurements was undertaken using a hand held salinity (YSI) refractometer during each visit to the site.

5.1 RESULTS

Figures 8 and 9 show summarizing graphs for water surface elevation and flow with date and time in Siphons 5 and 6. General comments that can be made are as follows:

- Driving head is plotted against flow rate (Figures 10 and 19) and both driving head and flow rate (Figures 11 to 16 and 20 to 23) are plotted against time for Siphon 6 and Siphon 5 respectively. The head and flow rate vs. time plots have been split into several detail plots focusing on specific periods of operation. Trend lines have been added to the plots for the periods of steady state operation, and plots were created to focus on periods of flux around pump shutdowns. In addition Figures 17 and 23 show stage discharge curves for Siphon 6 and Siphon 5 respectively during periods of shut down of the pump.
- Flow through Siphon 6 and Siphon 5 is essentially driven by the Cargill pump which transfers water from the Napa River into Siphon 6. When the pump is shut down, flow ceases through the siphons a short period after.
- There appears to be significant amounts of “noise” particularly in the flow measurements. The noise could be attributed to turbulence and could be removed using a moving average filter with a duration of the turbulence pulses.
- Cyclic fluctuations were observed throughout the water surface elevation measurements suggesting that tidal influences were present.
- The harsh environment and difficult access to some locations resulted in equipment difficulties including battery failure, electronic problems and instrument “drift” particularly of the salinity instrumentation.
- The salinity data were the most suspect of all the measurements. The site conditions are very extreme in terms of salinity and the conductivity sensors suffered due to prolific algal growth at the site frequently fouling the sensors. The algal growth causes the sensors to drift yielding higher conductivities in fresh water and lower conductivities in more saline water. To combat this problem, pre-deployment and post-deployment calibration curves were computed using results in known “standard” solutions and YSI handheld results collected at the site. The slope and intercept of the resulting pre- and post-deployment

Figure 8. Napa Siphon - Flow Rate Data

Figure 9. Napa Siphon - Water Surface Elevation Data

Figure 10. Napa Siphon 6 - Head and Flow Rate Data

Figure 11. Napa Siphon 6 - Head and Flow Rate Data

Figure 12. Napa Siphon 6 - Head and Flow Rate Data

Figure 13. Napa Siphon 6 - Head and Flow Rate Data

Figure 14. Napa Siphon 6 - Head and Flow Rate Data

Figure 15. Napa Siphon 6 - Head and Flow Rate Data

Figure 16. Napa Siphon 6 - Head and Flow Rate Data

Figure 17. Napa Siphon - Flow Rate Data

Figure 18. Napa Siphon 6 - Head and Flow Rate Data

Figure 19. Napa Siphon 5 – Head and Flow Rate Data

Figure 20. Napa Siphon 5 – Head and Flow Rate Data

Figure 21. Napa Siphon 5 – Head and Flow Rate Data

Figure 22. Napa Siphon 5 – Head and Flow Rate Data

Figure 23. Napa Siphon 5 – Head and Flow Rate Data

curves were utilized to develop a time weighted calibration curve that provided data that more closely matched the hand held readings collected at the site.

- To minimize the anticipated difficulties in this harsh environment, more than one type of salinity meter was deployed to evaluate the best performance for future monitoring. Problems were experienced with the daisy wheel salinity samplers, which proved unreliable over extended periods of time. There is a gap in the data for Siphon 5 Downstream Platform 1 between June 19 and June 26. There also is a gap in the data for Siphon 5 Downstream Platform 2 between June 17 and June 20.
- Instrumentation platforms consisted of one pressure transducer and one salinity probe per platform. In the high salinity Pond 6A, a daisywheel salinity sampler was used in preference to salinity probe.

5.1.1 Siphon 6

Figures 10 to 18 show the results obtained for Siphon 6. The results and interpretation for Siphon 6 can be summarized as follows:

- Generally speaking, while the pump near Siphon 6 was in operation (a pump operated by Cargill which pumps water from the Napa River into a canal running along the side of Pond 8), the head and discharge relationship remained approximately constant. Allowing for tidal variations (in nearly every case the results indicated tidal fluctuations due possibly to head changes at the pump near Siphon 6 or levee permeability and siphon leakages), the head difference from the upstream to the downstream side of Siphon 6 increased from approximately 0.16 ft to 0.21 ft. The increase in head difference resulted in a corresponding increase in flow from 14.5 cfs to 16.0 cfs an increase of 1.5 cfs. This would suggest that the Cargill pump has a discharge capacity in excess of the conveyance capacity of Siphon 6 since the head difference increased across Siphon 6 over the duration of the measurements. A period of record was missing due to malfunctioning of equipment between June 20 to June 24. Figure 17 shows an overlay of the tidal signal at Edgerly Island for the same period of record. This figure clearly shows the effect of tidal variation on the operation of the pump.
- The velocity data for Siphon 6 matched the Marsh McBirney manually measured data reasonably well. There is a gap in the Siphon 6 flow rate data set between June 19 and June 23. Marsh McBirney readings collected on June 21 indicate that there was an exceptionally high flow rate at that time with a measured velocity of ~3.4 ft/s.
- The Cargill pump adjacent to the Napa River appears to have been shut down on June 12 for approximately 24 hours, on June 28 for approximately 12 hours, and finally on June 30 at the end of the data collection period.

- It was not possible to produce a stage discharge curve for the period of pump shutdown on June 12 due to insufficient flow data. However, it is interesting to note that flow was still measured through the siphon from upstream to downstream despite a negative head difference. This could not be explained by a salinity gradient since generally the salinity was lower upstream of the siphon than downstream of the siphon. It could, however, be explained by seepage into the system.
- A stage discharge curve can be plotted however for the shutdown period when the pump was stopped on June 30 (Figure 18). During the shutdown period negative head differences were again measured yet flow still remained in an upstream to downstream direction although at a considerably reduced rate. Possible explanations for this could be momentum effects, seepage into the system or density gradients. Equipment drift could also be an explanation due to high salinity water or proximity to the steel structure of the siphon.
- After the pump shutdown on June 30, the head difference remained approximately constant at about –0.11 ft with a corresponding flow rate of approximately 1.5 cfs. However the water surface elevations either side of the siphon reduced steadily, at a reasonably constant rate, as flows passed into Pond 6A (with possibly some evaporation effects).

5.1.2 Siphon 5

Figures 19 through 25 show the results obtained for Siphon 5. The results and interpretation for Siphon 5 can be summarized as follows:

- The velocity and flow rate data for Siphon 5 was slightly higher compared to the manual Marsh McBirney readings. The data were adjusted to reflect the measured pipe diameter (3.65 ft vs. 4 ft), but that failed to bring the numbers inline with the Marsh McBirney readings. This could be due to location of the sampling position. Due to the parabolic velocity profile in pipe flow, higher velocities are measured in the center of the pipe than near the pipe wall. The flow rate also went negative (indicating flow direction reversed) in early July.
- The head difference between S5 P1 US and S5 P2 US remained reasonably constant (allowing for tidal fluctuation) at a mean head difference of 0.1 ft during periods when the Cargill pump was operating continuously. Therefore after a period of approximately two weeks, the platform at S5 P2 US was removed. This platform was installed to identify any changes in elevation and salinity along the canal leading to Siphon 5.
- The head difference between S5 P1 DS and S5 P2 DS, found to be less than 0.05 ft and S5 P2 DS, was removed after a period of approximately two weeks. S5 P1 DS and S5 P2 DS were installed approximately 10m apart to investigate any draw down or turbulent mixing effects on either the water surface elevation or the salinity in Pond 6A.
- Between June 23 and June 30, just before the Cargill pump shutdown, the general trend allowing for tidal influence gave a constant flow of 14.5 cfs at a constant head difference

Figure 24. Napa Siphon 5 – Stage Discharge Relationship for Pump Shutdown

Figure 25. Napa Siphon 5 – Flow Rate Data

- between the upstream and downstream sides of Siphon 5 of 0.33 ft. The Cargill pump, operating from the Napa River, pumps approximately 13.4 cfs (6,000 gallons/minute). The difference between this pump flow and the increased flow through Siphon 5 is probably attributed to infiltration through leaking siphons or levees.
- The flow rate and head difference remain reasonably constant during the Cargill pump operation. However, after the shutdown of the pump at Siphon 6 on June 30, the water surface elevation either side of Siphon 5 appeared to converge towards equilibrium.
- Spot water surface elevations, taken in the donut water distribution pond structure at the downstream end of Siphon 5, seem to correlate reasonably well with the water surface elevation measured by the gauge at S5 P1 DS.
- It was not possible to produce a stage discharge relationship after the pump shutdown on June 30 as equilibrium is reached since the fluctuations in flows are too great (probably caused by tidal influence). However, it was possible to produce a stage discharge curve during the pump shutdown on June 30 as shown by Figure 24.
- It was not possible to produce a stage discharge relationship during the one-day pump shutdown of June 12 since no flow measurements were taken at Siphon 5 during this time.
- The water surface elevations on either side of Siphon 5 seem to be influenced significantly by the tidal signal in the Napa Slough channel adjacent to Siphon 5, as shown by Figure 20. Therefore, either the levee is permeable or as is more probable, the siphon is leaking. The tidal signal appears to have more influence when the Siphon is running at a constant rate (i.e., when the Cargill pump near Siphon 6 is in operation). Clearly, there is a tidal influence because, after the pump shut down on June 30, tidal fluctuations can be seen both in the water levels either side of the siphon and on residual flows passing through the siphon.
- Figure 25 clearly shows the effect of the head at the intake to the pump on flows through the siphon. At higher tides the energy required to force water through the siphons is greater and hence the flow is lower than at the lower tides.

5.1.3 Water Surface Elevations in Pond 6A

Figures 27 and 28 show the results obtained for water surface elevation measurements in Pond 6A. The results and interpretation of these analyses can be summarized as follows:

- Clearly wind speed and direction have an effect on the water surface elevation in Pond 6A.
- Water surface elevations are greater at S5 P3 DS than at S5 P1 DS and S5 P2 DS by almost 0.4 ft on average. It was assumed that this could be attributed to datum errors although upon re-inspection and re-survey, no errors were found.
- The water surface elevations seem to be cyclic, to a greater extent at S5 P1 DS and S5 P2 DS (due probably to the added influence of tidal effects).

Figure 26. Wind directions and water setup.

Figure 27. Napa Siphon – Water Surface Elevation and Wind Speed Data

Figure 28. Napa Siphon – Water Surface Elevation and Wind Speed Data

- Water surface elevations at S5 P3 DS seem to be less dependent upon wind speed but more dependent on wind speed at S5 P1 DS. However, at certain instances the wind fetch and set up effects cause the elevation to reduce at S5 P3 DS and increase at S5 P1 DS with an increase in wind speed.
- The wind direction appears to be predominantly in a north south direction in the early morning hours of the day, moving to a west east direction by the afternoon. Figure 26 clarifies this phenomenon. The strong diurnal pattern may not be observed during different seasons but the significant water surface gradients that result are likely to have pronounced effects on the process of internal circulation in the ponds.
- Further clarification of the wind effects on water surface elevation can be explained with direct correlation to actual wind speeds and directions at the site. The USGS operate a website which gives archival information of wind speeds and directions based upon a numerical model of San Francisco Bay that is calibrated using measured data at various locations around the Bay. This site gives the most accurate archival information available for wind data for the site and can be found at: http://sfports.wr.usgs.gov/cgi-bin/wind/.

5.1.4 Salinity Measurements

Figures 29 and 30 show the results of the salinity measurements taken. The interpretation of these results can be summarized as follows:

- Generally the salinity upstream of Siphon 6 increased steadily from approximately 11 ppt to approximately 14 ppt. This was probably because the water passing through Siphon 6 was pumped directly from the Napa River and the salinity of the Napa River water was increasing with reducing summer flows in the River.
- Similarly, the trend downstream of Siphon 6 was a general increase in salinity (ignoring the possible instrument drift and malfunctioning).
- Initially the salinity at S5 P2 US was lower than the salinity at S5 P1 US. This was probably due to P2 positioned in an area of flowing water (canal) whereas P1 was positioned at the entrance to Siphon 5 and the results at this location may be influenced by the higher salinity Ponds 6A or 7, and is indicative of the poor mixing in the canals. However, as pumping progresses the salinity at P1 reduces and the salinity at P2 increases, converging to approximately similar levels.
- At the point of the Cargill pump shutdown on June 30, the salinities at all the measurement positions had approximately equilibrated to around 12 ppt.
- A significant amount of "noise" appeared to be present in the results obtained from Pond 6A. The general trend observed, however, was that the salinity in Pond 6A reduced from approximately 68 ppt to 58 ppt over a measurement period of approximately three weeks.

Figure 29. Napa Siphon – Salinity Data

Figure 30. Napa Siphon – Salinity Data

6. PHASE 2 FIELDWORK

Phase 2 fieldwork was conducted during October, November and December 2000 at Siphon 3. Instrumentation platforms were installed at the locations listed by Table 3 and shown by Figure 31.

Table 3. Instrumentation Platform Locations Phase 2

Platform Notation	Location	Instrumentation
S2 M	Pond 2 manual measurements from canoe	▪ Aquadopp velocity meter ▪ Water column sampler ▪ Refractometer
S3 P1 US	Upstream of Siphon 3 in Pond 3	▪ Pressure transducer (water surface elevation) ▪ Velocity meter ▪ Salinity probe
S3 P1 DS	Downstream of Siphon 3 in Pond 4	▪ Acoustic water level sensor (water surface elevation) ▪ Salinity sampling unit
S3 P2 US	At eastern shore of Pond 3	▪ Pressure transducer (water surface elevation) ▪ Salinity probe

Phase 2 of the fieldwork was revised to take account of siphon conditions on the site and the previously measured siphons as described in the introduction to this report. Phase 2 was delayed until October 2000 due to water management issues at the site. A permanent pump is situated near Siphon 1 which pumps water at 67 cfs (30,000 gallons/minute) from Pond 1 into a donut which then passes water through Siphon 1 into Pond 2. In August 2000 this pump was damaged and was repaired by CDFG during August and September 2000. It was re-commissioned at the end of September 2000. CDFG then proceeded to pump water into Pond 2 from Pond 1, which in turn raised the water surface elevation in Ponds 2 and 3, thus creating a water surface head difference between Pond 3 and 4 of approximately 3 ft by October 2000.

Historically, Siphon 3 has had a tendency to block with, what is thought to be, a wedge of high salinity (and hence greater density) pond water, which prevents flow through the siphon. In May 2000, and on previous attempts, CDFG has successfully removed this saline wedge from Siphon 3 by pumping less saline slough water into Siphon 3. This process usually takes approximately 24 hours to un-block the siphon and thus allow water to flow from Pond 3 to Pond 4.

PWA completed the installation of instrument platforms either side of Siphon 3 and to the east shore of Pond 3 on October 9, 2000. CDFG started to pump less saline water into Siphon 3 in the week commencing October 9, 2000. PWA returned to the site on October 18, 2000, to check and download

Figure 31. Napa Siphon Data Collection – Revised Siphon Measurement Schedule Phase 2

the instrumentation. It was discovered at this point that Siphon 3 had not become unblocked by pumping but that it appeared from the measurements taken that the blockage had reduced in size. In addition the pumps used by CDFG to try to unblock the siphon malfunctioned and required repairs between October 17 and November 1, 2000. CDFG tried repeatedly to unblock the siphon during November 2000 but with no success. Eventually, at the end of November, agreement was reached between PWA, CDFG and the USACE to abandon this phase of the measurement exercise since PWA had expended over six weeks, in excess of the two weeks agreed to in the scope, of equipment hire. PWA and the USACE agreed to re-visit the task of measuring Siphon 3 as and when the siphon is unblocked. At the time of this report the siphon had not been unblocked. PWA subsequently analyzed the problem further and produced a rationale behind why flow could not be achieved through the siphon as described in Section 5.2.

PWA also experienced further problems, when it was discovered that the instrumentation platform positioned at S3 P2 US (Figure 31), had been stolen from the eastern shore of the Pond 3. Unfortunately, the theft occurred immediately prior to a scheduled download of data resulting in the loss of 14 days of data. This data would have been valuable to supplement the wind wave set up data collected in Pond 6A during the first phase of the project.

Hand held measurements were undertaken in Pond 2 on November 11, 2000. A two-man crew using a canoe took 2D velocity vector measurements at ten locations across the pond. At these locations salinities were also measured near the bed and near the surface in attempt to identify possible stratification in the pond. All measurements were correlated with wind velocity and direction recorded at the CIMIS wind gauge at Carneros (adjacent to CDFG Napa-Sonoma field office). Data collected by the exercise will be valuable for calibration of the 2D hydrodynamic model of the salt ponds.

Section 6.1 shows the data obtained from the data collection at Siphon 3.

6.1 SIPHON 3 RESULTS

6.1.1 Water Surface Elevation in Pond 3 and Pond 4

Figure 32 shows the water surface elevation data that was collected immediately upstream and downstream of Siphon 3 in Pond 3 and Pond 4 respectively. Data was collected in Pond 3 from October 9 to November 3, 2000 and in Pond 4 from October 9 to December 7, 2000. Since it was unclear how useful the data captured would be, temporary benchmarks were established near the platforms and the data were approximately tied into NAVD88.

Figure 32 shows approximately 2.6 ft of head difference between the Pond 3 (upstream) and Pond 4 (downstream) side of Siphon 3. It appeared that the water surface elevation increased slightly in Pond 3 (upper line) due to water being transferred by CDFG into Pond 3 from Pond 2, in an attempt to increase the water surface elevation in Pond 3. Water surface elevations in Pond 4 remained approximately constant apart from some abnormalities between October 23 – 26. The reason for this can be explained with reference to the wind velocities and directions during this period, shown by Figures 33 and 34.

Figure 32. Siphon 3 – Water Surface Elevation Data

Figure 33. Siphon 3 – Water Surface Elevation Data

Figure 34. Siphon 3 – Water Surface Elevation Data

Figure 34 clearly shows that a prolonged period of increased velocity winds occurred around October 23 followed by a period of lower velocity winds on October 24 and 25. It is likely that this, in conjunction with a corresponding change in wind direction, caused a reverse set-up of the water in Pond 4 to the pattern normally observed. A corresponding fractional lowering of the water surface elevation in Pond 3 is also observed.

However, no stage relationship either side of Siphon 3 is observed since no flow passed through the siphon.

6.1.2 Flows through Siphon 3

Figure 35 shows the results of the flow measurement through Siphon 3 recorded over two periods between October and December 2000. It is clear from these results that apart from some residual flows the only flows measured were due to the pumping operations CDFG used as an attempt to try to move the saline wedge in the siphon. However, the measurements can also be used to detect if the siphon was leaking. The tidal signal was plotted with this data as shown by Figure 36. Clearly there is no tidal influence on the flow measurements taken in the siphon which suggests that the siphon was not leaking.

6.1.3 Salinities in Ponds 3 and 4

Figure 37 shows the results of the salinity measurements that were collected in Ponds 3 and 4 immediately upstream and downstream of Siphon 3. Salinity measurements in Pond 3 were recorded using a conductivity probe and in Pond 4 using a salinity sampling unit due to the hyper-saline conditions. It appears that over the period of records from October 12 to November 15 in Pond 4, that the salinity reduced slightly from 380 ppt to 360 ppt. This could perhaps be attributed to precipitation or possibly seepage into the pond (although the tide would have to get reasonably high to work against the salinity gradient). However, the salinity of Pond 3 remains approximately constant at 50 ppt.

6.2 HAND-HELD MEASUREMENTS IN POND 2

In addition to the hand-held measurements taken at all stages of the data collection project for calibration of the equipment and verification of the readings, PWA also took measurements in Pond 2 in order to try to identify the presence of stratification in the pond and to measure velocities induced by wind action and siphon discharge. PWA took these measurements on November 8, 2000. Table 4 gives the coordinates of the measurement points and Figure 38 gives a location diagram of the points.

Figure 35. Siphon 3 – Flow Rate Data

Figure 36. Siphon 3 – Flow Rate Data

Figure 37. Siphon 3 – Salinity Data

Figure 38. Location Map for Velocity Measurements

(photo)

Table 4. Hand-held Measurement Locations

Point	Eastings (m UTM Zone 10)	Northings (m UTM Zone 10)
1	557067.11	4223125.53
2	557071.26	4223158.85
3	557142.59	4223190.79
4	557360.76	4223314.38
5	557617.89	4223502.98
6	557885.31	4223680.57
7	557607.74	4223286.54
8	557141.13	4223190.78
9	557081.53	4223151.52
10	557034.79	4223153.04
11	557067.21	4223110.74

6.2.1 Salinity Measurements

Salinity samples were taken at each location near the bed and near the surface of Pond 2, using a specially designed water-sampling device. The salinity of the samples was analyzed using a refractometer. Table 5 shows the results of the analyses of these samples. The salinity of the water flowing through the siphon was 27 ppt.

Table 5. Pond 2 Salinity Results

Point	Salinity near Bed (ppt)	Salinity near Surface (ppt)	Time (24 hr)
1	N/A	31	11:02
2	N/A	30.5	11:09
3	36	33	11:19
4	36	35	11:51
5	36	35	12:05
6	N/A	35	12:37
7	N/A	35	13:04
8	34	31	13:56
9	33	29	14:13
10	30	29	14:30
11	29	29	14:44

The following observations can be made from the results shown by Table 4:

- The pump situated adjacent to Pond 1 was started at approximately 10:30 on the day of measurement. Thus water started to flow through Siphon 1 into Pond 2 shortly after this time.

- The salinity in the pond reduced over the recorded time from 11:02 to 14:44 by approximately 2 ppt in the vicinity of the siphon outlet. Notice points 1 and 11 and 3 and 8, which were taken at approximately the same location near the start and near the beginning of the measurement period.
- There was generally a low degree of stratification observed. A maximum difference in salinity of 9% was measured between the bed and the surface of the pond.
- Salinity readings taken further into Pond 2, away from the siphon outlet, were generally higher than near the siphon outlet. Water passed through the siphon from Pond 1, which has a lower salinity than Pond 2 and over the period of the measurements full mixing in this section of the pond did not occur.
- The degree of stratification generally reduced away from siphon outlet. PWA observed marginal differences in salinity between the bed and the surface depths: the differences were greater closer to the siphon and decreased further from the siphon.
- These results suggest that stratification is negligible for the section of pond sampled and can be ignored for the purposes of 2-dimensional, depth averaged modeling.

6.2.2 Velocity Measurements

Table 6 shows the results obtained from the analysis of the velocity measurements that were taken in Pond 2. Figure 39 also shows the resulting velocity vectors plotted on an aerial image of Pond 2. In general the velocity was taken at mid-depth.

6.2.3 Velocity Measurements

Table 6 shows the results obtained from the analysis of the velocity measurements that were taken in Pond 2. Figure 39 also shows the resulting velocity vectors plotted on an aerial image of Pond 2. In general the velocity was taken at mid-depth.

Figure 39. Velocity Measurements in Pond 2 (in ft/s)

Table 6. Velocity Measurements in Pond 2

Point	Time	Water Velocity (ft/s)	Water Velocity Direction (Degrees from North)	Wind Speed (ft/s)	Wind Direction (Degrees from North)	Depth of Water (ft)
1	11:02	0.66	337	18.6	48	5.8
2	11:09	0.36	348	18.6	48	5.3
3	11:19	0.07	13	18.6	71	5.7
4	11:51	0.36	37	18.6	85	5.4
5	12:05	0.18	16	18.6	85	5.2
6	12:37	0.28	42	22.0	84	5.1
7	13:04	0.07	56	22.0	84	5.2
8	13:56	0.29	49	22.0	82	5.7
9	14:13	0.42	29	22.0	N/A	5.5
10	14:30	0.21	278	22.0	N/A	5.8
11	14:44	0.71	11	22.0	N/A	4.9

The following observations can be made from the results shown by Table 4 and Figure 39:

- Wind directions are not given at points 1, 2, 9, 10 and 11 since the velocities here are more likely to be driven by outflow from the siphon than to be wind induced.
- The wind speed increased from 8.1 ft/s at 11:02 to 12.7 ft/s at 14:44, but the direction remained approximately constant at east-north-east.
- Similarly the wind induced water velocities appeared in some instances to increase with increases in wind velocity. Notic e that Points 3 and 8 in Table 6 are at the same location, where, at 11:19, the water velocity was 0.07 ft/s compared to 0.29 ft/s at 13:56. The corresponding wind speeds at these times were 8.1 ft/s and 11.1 ft/s respectively.
- Velocities were largest at the outfall of the siphon as expected.
- The direction of the water velocity is generally similar to the wind direction. Note that the wind speed and direction is measured approximately two miles away from this site at Carneros. Therefore, local conditions will prevail and some discrepancy is expected.

7. CONCLUSIONS

The preceding pages have described the data collection procedure and results that were collected between June and December 2000 for the siphons and ponds at the Napa-Sonoma Salt Marsh complex. The study provided important insight to the complexity of the flow conditions in the siphons. To summarize these can be listed as follows:

- The means by which flow passes through siphons connected by canals or donuts was identified. Essentially the siphons operating under these scenarios act as flow conduits which pass water only when driven by a pump such as Siphons 6 and 5 in the north of the site.
- Siphons 6 and 5 almost certainly have leaks. It was not possible to identify the quantity of the leakage without further measurements. It is likely that other siphons on the site also leak due to the age of the structures.
- Measurements taken indicate that Siphon 3 is not leaking.
- Changes in salinity in the ponds were measured over time with flow passing from less saline to more saline environments.
- Significant seasonal changes in salinity were observed. This could mean that gravitationally driven flows from low to high density water may only be achieved without massive pumping operations at certain times of the year.
- The magnitude of wind induced water elevation set up was measured and characterized.
- The volume of flow passing between ponds was identified for Siphons 1, 5 and 6.
- The nature of stratification was identified for Pond 2. It is likely that this is similar to other ponds on the site.
- Wind induced velocity measurements were successfully taken in Pond 2.
- Mixing was qualitatively characterized in Pond 2 using salinity and velocity measurements.

8. LIST OF PREPARERS

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