Streamgauging Planning at Stormwater Treatment Area-1 West

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Introduction

- The main purpose of STAs in South Florida is to remove pollutants such as phosphorus and nitrogen from agricultural water before discharging them into the everglades.
- Accurate flow measurements (QMEAS) in and out of these STAs, is one of the most important tasks performed by the District.
- While it will seem to be a relatively simple task to "go streamgauging" at the STA structures whenever the opportunity presents itself, the actual need for streamgauging at STA structure, is dependent upon the operation of the STA.
- Performing streamgauging without taking into consideration the operational needs of the STA may lead to unnecessary repetitious measurements and an inadequacy of the flow predictions in terms of the range of operational requirements for the water control structures.
- Having a framework and a methodology for (1) capturing the streamgauging needs either from the operational plan or from historical operations and using these to (2) develop an analytical framework for identifying appropriate streamgauging opportunities is necessary for effectively monitoring flow through STAs.

Figure 1: Arial View of STA-1West

Location

STA-1 West, together with its associated canals and the STA-1 Inflow Basin, is a primary component of the Everglades Construction Project mandated by the 1994 Everglades Forever Act (Section 373.4592, Florida Statutes). STA-1W is located within Sections 1, 2, 3, 6, 7, 10, 11, 12, 13, 14, 15, 22, 23, 26, 27, 34, Township 44 South, Range 39 East within Palm Beach County and is positioned immediately west of the Arthur R. Marshall Loxahatchee National Wildlife Refuge, also known as Water Conservation Area 1 (WCA-1). (Operation Plan 2004).

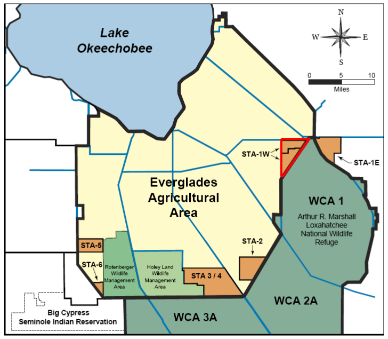


Figure 2: Location of STA-1W in South Florida

Objective

This South Florida Water Management District instigated project focuses on providing the framework for identifying appropriate streamgauging opportunities at inflow and outflow structures in STA-1 West and introduces new flow rating techniques applied to weir-box culverts at the STA. The result of such an exercise will provide for STA-1 West: (1) An established region or range of need of flow measurements based on the operation of the STA; (2) Recommendations on future streamgauging measurements based on the rating developed and used for the flow type(s) in question; and (3) Recommendations on future streamgauging based on the historical data and operational needs of the structure.

Operation & Main Structures

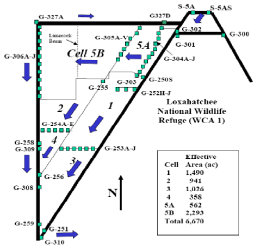


Figure 3: Schematic of STA-1 West Flows

During the design flow condition of 3,250 cfs, approximately 930 cfs (29%) will flow through the eastern flow-way, 850 cfs (26%) will flow through the western flow-way, and 1470 cfs (45%) will flow through the northern flow-way. Inflow is distributed to the eastern and western flow-ways through structure G-303, and into the northern flow-way through structures G-304A-J. Flows passing through G-303 are distributed either south into the eastern flow-way or west through structure G-255 into the western flow-way.

Table 1: Inflow and Outflow Structures with QMEAS Data

Station	Structure Type	Possible Flow Types	
G300_S	Spillway	CF; CS; UF; US	
G301_S	Spillway	CS; US	
G302_S	Spillway	CF; CS; UF; US	
G303_S	Spillway	CF; CS; UF; US	
Compound Structures		Weir	Culvert
G304A-J	Weir-culvert combinations	Free; Submerged; Transition	III; IV; V
G306A-J	weir-culvert combinations	Submerged	IV

The structures at G300, G301, G302 and G303 are gated spillways which control flow in and out of STA 1West. G302 discharges the most flow into the STA.

Table 2: Design Operations at Main Structures

Spillway	Design Flow Rate (cfs)	Headwater	Tailwater
G-300 & G-301	3,080 cfs	18.5	14.0
G-302	3,250 cfs	18.0	15.8
G-303	1,780 cfs	15.7	14.46

Figure 4: Upstream View of G303

G304 and G306 are weir-box culverts which control flow distribution in the STA. These structures have weir type inlets that require a flow computation procedure different from those employed for simple structures. The inflow into the culverts is affected by the presence of the weir box at the inlet.

Table 3: Design Operations at Main Structures

Compound Structures	Design Flow Rate (cfs)	Headwater	Tailwater
G-304A-J	1,470 cfs	15.7	12.7
G-306A-J	1,470 cfs	11.5	9.0

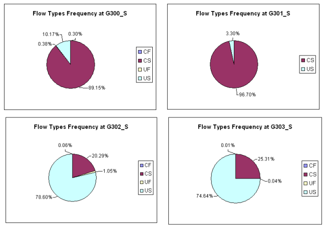
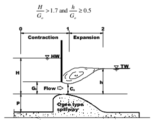


Figure 5: Patterns at STA-1 West Spillways Based on FLOW Program

CF: Controlled Free; CS: Controlled Submerged; UF: Uncontrolled Free; US: Uncontrolled Submerged.

Figure 6: Upstream View of G304A

Flow Rating



$$Q = C_s L G_s \sqrt{2g(H-h)}$$

Figure 9a: Controlled Submerged

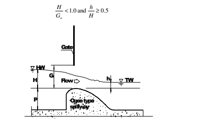


Figure 9b: Uncontrolled Submerged

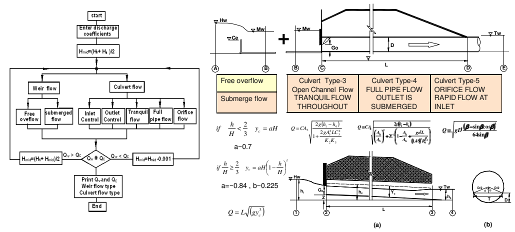


Figure 10: Flow Chart and Equations of Structural Element Method for Weir-Box Culverts

The iteration process starts with guessing the water stage average between tailwater and headwater elevation inside the weir box. The traditional weir and culvert flow ratings equations are used for each structure component. Based on the difference of flow discharges between these structures, the intermediate water stage is systematically adjusted in each of the iteration step. When the discharge convergence criteria is finally satisfied, the flow rate for the weir-box culverts can be obtained.

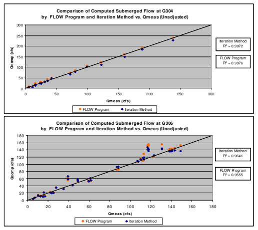


Figure 11: Comparison between Fitting Qcalc and Qcomp with respect to Qmeas at STA-1West Weir-Box Culverts

QA of Flow Measurements

The data validation process for the 162 measurements collected at STA-1 West involved a variety of processes, including a verification of stage(s) and gate opening(s) in DCVP as well as measurement specific conditions in QMEAS. The historic data in DCVP provides a reference for checking the measurements' stages and gate-openings, while other measurement characteristics were found in the QMEAS database.

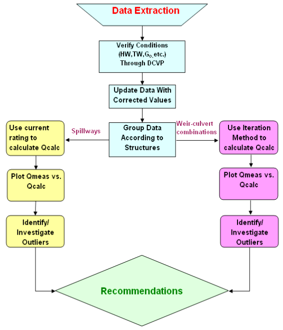
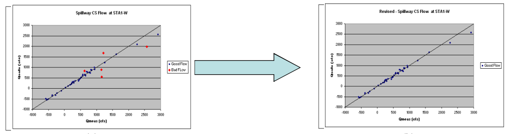


Figure 7: Flow Chart Describing Data Validation Methodology



(a) (b)

Figure 8: Qmeas vs. Qcalc Graph showing Outliers (a), Revised Qmeas vs. Qcalc Graph (b)

Table 4: Spillways CSF Identified Outliers and Recommendations

#	Station	HW	TW	Qmeas	Qcomp	% ERROR	Type	# of Operations	G	Comment	Recommendations
182	G301_S	17.64	17.08	1211.34	1677.55	38.49%	CSF	3	4.96	There is not enough evidence to verify the accuracy of the measurements. Unlike most measurements, Qmeas of #182 does not compare well with respect to Qcomp using the suggested rating.	Further investigation is needed.
183	G301_S	17.99	17.09	626.35	830.17	32.54%	CSF	3	1.99	The measurement is questionable and needs more investigation.	Retaking flow measurements under similar conditions is suggested.

Structures at which the rating equation presented larger deviations with respect to the measurements ($R^2<0.95$), were further investigated by recalibrating rating currently used in the flow program or introducing a new algorithm to suit the particular structure site. Outliers to such a recalibration were again investigated and recommendations made, in comparison to similar measurements at the same culvert site.

Conclusion and Recommendations

Out of 162 measurements in STA-1 West, 147 were considered good. This is 90.74% efficiency. 3.09% of the measurements were considered unsatisfactory based on the data validation process while 6.17% of the measurements were considered questionable. Improvements are recommended for both the FLOW program and the iteration method to provide better results when computing the flow at weir-box culverts G304 and G306.

Table 5: Number of Measurements Needed per Range of Operation per Structure

	Recommendations					
Name	Flow Type	Flow Range (cfs)	HWE	TWE	Go	# of Measurements
G301 G302	USF	1000-2000	$17.4 \le Hwe \le 18.0$	$15.4 \le Twe \le 15.7$	Go>3.2	5
G304A-J	Free	25-65 100-120	$12.0 \le Hwe \le 13.00$ $13.0 \le Hwe \le 13.85$	$Twe > 11.0$ $Twe < 11.0$	2.4<Go<6 3.5<Go<6	5 5
G304A-J	Submerged	50-230	$12.0 \le Hwe \le 15.0$	-	1<Go<2.3	4
G306A-J	Submerged	60-105	$10.5 \le Hwe \le 11.2$	$Twe > 9.2$	1<Go<4	5

References

1. Ansar M. and S. Nair. 2003. Flow computations at STA-1 west gated spillways. SFWMD technical publication.
2. Damisse and Fru, 2006, Improved Flow Computation at District Culverts, Technical Report.
3. 2004, Operation Plan, Stormwater Treatment Area 1 West, South Florida Water Management District, West Palm Beach, FL.
4. Zeng, Jie, 2007, Report of Implementation of Iteration Algorithm for Weir-Box Culverts.