

Appendix 5-7: Annual Permit Compliance Monitoring Report for Mercury in the STAs

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KEY FINDINGS AND OVERALL ASSESSMENT

This report summarizes data from compliance monitoring of mercury (Hg) storage, release, and biomagnification in Stormwater Treatment Areas (STAs). Fish data in this report are summarized for the 2006 calendar year while surface water data is summarized for Water Year 2007 (WY2007).

Key findings are as follows:

1. **All STAs:** There were no violations of the Florida Class III numerical water quality standard of 12 nanograms (ng) of total mercury per liter (THg/L) during the reporting year at any of the STAs. As such, the project has met the requirements of Section 6.i of the mercury monitoring program of the referenced permits.
2. **STA-1W:** Stormwater Treatment Area 1 West (STA-1W) subsumed the Everglades Nutrient Removal (ENR) Project in April 1999; the ENR Project had served as the prototype STA and had been in operation since 1994. After 10 years of operation, this STA continued to have low concentrations of both total mercury (THg) and methylmercury (MeHg) in surface water, and consistently exhibited a negative percent change in both THg and MeHg (i.e., concentrations in the outflows were consistently lower than in the inflow). Outflow loads of THg and MeHg continue to be considerably lower than inflow. Furthermore, MeHg biomagnification in resident large-bodied fishes (e.g., sunfish and largemouth bass) has remained relatively constant over the monitoring period at levels almost an order of magnitude lower than observed in fishes from the downstream Everglades. Mercury levels in fish at this STA do not appear to pose a threat to fish-eating wildlife based on the U.S. Fish and Wildlife Service (USFWS) and the U.S. Environmental Protection Agency (USEPA) predator protection criteria.
3. **STA-1E:** In STA I East, both the central flow-way (Cells 3, 4N, and 4S) and the westernmost flow-way (Cells 5 through 7) met the startup criteria, as specified in the Everglades Forever Act (EFA) Permit No. 0195030-001-GL, in August 2005. During WY2007, THg remained at relatively low concentrations in the outflow, as compared to the multiple inflows; however, MeHg demonstrated higher levels in the outflow. This STA continues to show some of the highest THg levels in comparison to all STAs and downstream monitoring locations, which may be due to start-up related factors. However, THg and MeHg loading are low compared to all other STAs. Mercury levels in

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mosquitofish from the interior marshes were much higher than other STAs and did not change appreciably from the first to the fourth quarter of 2006. Mosquitofish from the near-field downstream site in Water Conservation Area 1 (WCA-1) contained levels slightly higher than fish collected from the interior and inflow locations of this STA and were much higher than all other STAs. Mercury levels were also elevated in STA-1E sunfish and bass, particularly those fish from the downstream site. Mercury levels in fish from the near-field downstream site (ST1ELX) were similar to levels recently observed at a more southerly downstream site in WCA-1. THg levels in mosquitofish did not exceed USFWS and USEPA predator protection criteria at outflow and interior locations however did for sunfish.

4. **STA-2:** For WY2007, both THg and MeHg remained at a low concentration in the outflow relative to previous years; however, inflow concentrations increased two-fold since WY2006. However, outflow loads of both THg and MeHg are above inflow. Levels of mercury in tissue (tissue-Hg; measured as ng Hg/g) also remained low in mosquitofish, compared to all other STAs (STA-2 was the lowest out of all STAs) and downstream marshes. Although sunfish and bass continued to exhibit significant among-cell differences, each showed declines in mercury levels since 2005. However, resident sunfish and bass in Cell 1 and sunfish in the outflow had mercury levels in excess of the predator protection criteria.
5. **STA-3/4:** Water-column THg concentrations were low during WY2007. Concentrations of MeHg were highly variable among structures and occasionally concentrations in one or more of the outflows exceeded inflow concentrations; however, there were not consistent differences in MeHg outflow concentration among the three flow-ways. In general, MeHg concentrations remained relatively low compared to levels observed during start-up. Outflow loads of MeHg and THg were much lower than inflow. Tissue-Hg levels in mosquitofish from this STA were moderately elevated compared to mosquitofish from other STAs. Similarly, resident sunfish from the interior marshes of STA-3/4 contained slightly elevated mercury levels compared to fish from all other STAs, but were lower in comparison to downstream sites. An age-standardized three-year-old fish from the outflow was estimated to contain 453 ± 26 ng Hg/g, which is elevated compared to fish in other STAs. Based on USFWS and USEPA predator protection criteria, fish-eating wildlife foraging preferentially at outflow and interior locations within STA-3/4 appear to have an overall moderate risk of mercury exposure.
6. **STA-5:** With the exception of a couple of minor spikes in THg in the inflows and outflows during the fourth quarter, water-column concentrations of both THg and MeHg remained low at STA-5 during WY2007. Inflow and outflow loads of both THg and MeHg continue to decrease and outflow loads are lower than inflow. Mosquitofish collected in 2006 contained relatively low mercury levels compared to fish previously collected at this STA; however, these levels were high compared to other STAs, but lower compared to fish collected from downstream marshes. Sunfish from the interior marshes had lower mercury levels than fish from the supply and discharge canal. Analysis of sunfish from these interior marshes indicates that fish-eating wildlife foraging preferentially at STA-5 were at moderate risk of mercury exposure. Effective analysis of largemouth bass could not be performed due to poor age distribution. However, for the data that was available at each location, fish-eating birds appear to be at low risk.
7. **STA-6:** Both Cells 3 and 5 dried down twice during WY2007, yet neither THg nor MeHg spiked. While it is possible that the methylation rate did not spike, past STA performance following the rewetting of the marsh indicates the likelihood that quarterly surface water sampling missed a transient spike. For WY2007, inflow and outflow loads of THg and

MeHg were lowest compared to all other STAs and outflow loads were less than inflow. Mosquitofish continued to contain relatively low mercury levels compared to fish collected previously from this area; it is possible that semi-annually collected mosquitofish also missed any transient spike in MeHg production. Sunfish and bass collected from all locations did show increases in mercury levels over last year; however, it is uncertain whether these fish, which likely reinvaded the marsh from the canal, did not contain higher levels prior to the immigration. Bass showed a larger increase in THg at the inflow compared to 2005. Based on USFWS and USEPA predator protection criteria, fish-eating wildlife foraging preferentially at STA-6 would appear to have a moderate risk for mercury exposure if feeding from outflow sources; however, a low risk if feeding from interior or inflow locations.

INTRODUCTION

This is the annual permit compliance monitoring report for mercury (Hg) in Stormwater Treatment Areas (STAs). This report summarizes the mercury-related reporting requirements of the Florida Department of Environmental Protection Everglades Forever Act permits [Chapter 373.4592, Florida Statutes (F.S.)], including permits for STA-1W, STA-1E, STA-2, STA-3/4, STA-5, and STA-6. This report summarizes the results of monitoring in the 2005 calendar year. The results of mercury monitoring at far-field sites downstream of the STAs in accordance with these permits, as well as non-Everglades Construction Project discharge structures (Permit No. 06.502590709) is reported separately, in Appendices 3A-4 and 3B-1 of this volume.

This report consists of key findings and overall assessment, an introduction and background, a summary of the Mercury Monitoring and Reporting Program, and monitoring results. The background section briefly summarizes previously identified and published concerns regarding possible impact of STA operation on South Florida's mercury problem. The following section summarizes sampling and reporting requirements of the Mercury Monitoring Program within the STAs. Monitoring results are summarized and discussed in two subsections: results from pre-operational monitoring, and results from STA operational monitoring during the reporting year (i.e., bulk of new discussion).

BACKGROUND

The Stormwater Treatment Areas (STAs) are constructed wetlands designed to remove phosphorus from stormwater runoff originating from upstream agricultural areas and Lake Okeechobee releases. The STAs are being built as part of the Everglades Construction Project (ECP) authorized under the EFA [Chapter 373.4592, Florida Statutes (F.S.)]. When completed, the ECP will include six large treatment marshes totaling about 47,000 acres.

Even prior to passage of the Everglades Forever Act (EFA), concerns were being raised that, in attempting to reduce downstream eutrophication, the restoration effort could inadvertently worsen the mercury problem known to be present in the Everglades (Ware et al., 1990; Mercury Technical Committee, 1991). These concerns stemmed from studies in other areas that showed flooded soils in new impoundments to be a source of inorganic mercury (Cox et al., 1979). Of greater concern, studies had shown wetlands to be an important site of mercury methylation; methylmercury (MeHg) is more bioaccumulative and toxic than the inorganic or elemental form of mercury (St. Louis et al., 1994; Rudd, 1995). Decomposition of flooded terrestrial vegetation and soil carbon in new reservoirs had been reported to stimulate the sulfate-reducing bacteria that methylate inorganic mercury (Kelly et al., 1997; Paterson et al., 1998). Environments that favor methylation also drive bioaccumulation. For example, Paterson et al. (1998) found that annual fluxes of MeHg increased 10 to 100 times through a zooplankton community after impoundment. Newly created reservoirs have also been found to contain fish with elevated mercury burdens (Abernathy and Cumbie, 1977; Bodaly et al., 1984; Bodaly and Fudge, 1999). This so-called "reservoir effect" can occasionally persist for several decades after initial flooding (Bodaly et al., 1984; Verdon et al., 1991; Fink et al., 1999). For instance, Verdon et al. (1991) reported that mercury levels in northern pike (*Esox lucius*) increased from 0.61 to 2.99 parts per million and continued to increase nine years after the initial flooding. Given these observations, Kelly et al. (1997) recently recommended that in siting a new reservoir, (1) total land area flooded should be minimized, and (2) flooding the wetlands, which contain more organic carbon than the uplands, should be avoided.

However, applying these observations directly to the Everglades is problematic because most of these observations were made in deepwater lakes or reservoirs in temperate regions. In a report to the South Florida Water Management District (SFWMD or District), Watras (1993) stated that “the boreal and temperate watersheds, wetlands and reservoirs studied to date are very different geologically, hydrologically, meteorologically and ecologically from the subtropical systems in the Everglades.” Waters recommended monitoring and integrating mass balance and process-oriented studies to understand how this subtropical system would behave. Such studies were initiated in 1994 with the start-up of the prototype STA, the Everglades Nutrient Removal (ENR) Project. Baseline collections at the ENR Project (funded by the SFWMD and others) found no evidence of MeHg spikes in either surface water (PTI, 1994 attributed to KBN, 1994a; Watras, 1993 and 1994) or resident fishes (mosquitofish and largemouth bass; PTI, 1994 attributed to KBN, 1994b). During the first two years of operation, median concentrations of total mercury (THg) and MeHg in unfiltered surface water were reported to be 0.81 and 0.074 nanograms per liter (ng/L), respectively (Miles and Fink, 1998). These low levels persisted in later years; from January 1998 through April 1999, median water-column concentrations in the interior marsh (i.e., excluding inflows and outflows) were 0.81 ng THg/L and 0.04 ng MeHg/L (Rumbold and Fink, 2002b). Resident fishes also continued to have only low mercury levels: 8 to 75 nanograms per gram (ng/g) in mosquitofish, and 100 to 172 ng/g in three-year-old bass (Miles and Fink, 1998; SFWMD, 1999a; Lange et al., 1999). Finally, a mass balance assessment found the ENR Project to be a net sink for both THg and MeHg, removing approximately 70 percent of the inflow mass (Miles and Fink, 1998). Nonetheless, to provide continuing assurance that the ECP does not exacerbate the mercury problem, the Florida Department of Environmental Protection-issued (FDEP) construction and operating permits for the STAs require the SFWMD to monitor levels of THg and MeHg in various abiotic (e.g., water and sediment) and biotic (e.g., fish and bird tissues) media, both within STAs and the downstream receiving waters.

Results from monitoring programs at STAs constructed and operated since 1999 (after the ENR Project) have revealed transitory spikes in MeHg production (see previous reports published by the SFWMD, including Rumbold and Fink, 2002b). These monitoring results combined with the results of a 1999 field study on the effect that drought and muck fires had on mercury cycling in the Everglades (Krabbenhof and Fink, 2001) have demonstrated that spikes can sometimes occur following drydowns and rewetting. Accumulating evidence suggests that oxidation of sulfide pools in the sediments (e.g., organic sulfide, disulfides, and acid volatile sulfides) during the drydown can lead to increased methylation upon rewetting of the marsh either by providing free sulfate, which stimulates the sulfate-reducing bacteria or, in highly sulfidic areas, by reducing porewater sulfide, which can inhibit methylation (Benoit et al., 1999a and b).

SUMMARY OF THE MERCURY MONITORING AND REPORTING PROGRAM

The monitoring and reporting program summarized below is described in detail in the Mercury Monitoring and Reporting Plan for the Everglades Construction Project, the Central and Southern Florida Project, and the Everglades Protection Area. The SFWMD submitted this plan to the FDEP, the U.S. Environmental Protection Agency (USEPA), and the U.S. Army Corps of Engineers (USACE) in compliance with the requirements of the aforementioned permits (SFWMD, 1999b). Details on the procedures for ensuring the quality of and accountability for data generated in this monitoring program are set forth in the SFWMD's Quality Assurance Project Plan (QAPP) for the Mercury Monitoring and Reporting Program, which was approved on issuance of the permit by the FDEP. QAPP revisions were approved by the FDEP on June 7, 1999 (SFWMD, 1999c).

EVERGLADES MERCURY BASELINE MONITORING AND REPORTING REQUIREMENTS

Levels of total mercury (THg) and methylmercury (MeHg) in the pre-operational soils of each of the STAs and various abiotic and biotic media of the downstream receiving waters define the baseline condition from which to evaluate mercury-related changes, if any, brought about by the operation of the STAs. An Everglades Mercury Background Report, prepared prior to the operation of the first STA, defines pre-Everglades Construction Project (ECP) mercury baseline conditions (FTN Associates, 1999).

PRE-OPERATIONAL MONITORING AND REPORTING REQUIREMENTS

Prior to completion of construction and flooding of the soils of each STA, the District is required to collect 10-centimeter (cm) core samples of soil at six representative interior sites for THg and MeHg analyses. Prior to initiation of discharge, the District is also required to collect biweekly samples of supply canal and interior unfiltered water for THg and MeHg analyses. If concentrations at the interior sites are not significantly greater than that of the supply canal, this information is reported to the permit-issuing authority, and the biweekly sampling can be discontinued. Discharge begins after all the start-up criteria are met.

OPERATIONAL MONITORING

Following approval for initiation of routine operation of an STA and thereafter, the permits require that the following samples be collected at the specified frequencies and analyzed for specified analytes:

Water

On a quarterly basis, 500-milliliter unfiltered grab samples of water are collected in pre-cleaned bottles using the ultraclean technique at the supply canals and outflows of each STA. They are analyzed for MeHg and THg (this includes the sum of all mercury species in sample, e.g., Hg^0 , Hg^{I} , and Hg^{II} , as well as organic mercury). THg results are analyzed for compliance with the Florida Class III water quality standard of 12 ng/L. Outflow concentrations of both THg and MeHg are compared to concentrations at the supply canal.

Sediment

Triennially, sediment cores are collected at depth from zero to 10 cm at six representative interior sites. Each depth-homogenized core is then analyzed for THg and MeHg.

Prey Fish

Semiannually, grab samples of between 100 and 250 mosquitofish (*Gambusia* sp.) are collected using a dip net at the supply canal sites, interior sites, and outflow sites of each STA. Individual fish are composited from each size, the homogenate is subsampled in quintuplicate, and each subsample is then analyzed for THg. On March 5, 2002, the FDEP approved a reduction in the number of replicate analyses of the homogenate from five to three (correspondence from F. Nearhoof, FDEP).

Top Predator Fish

Annually, 20 largemouth bass (*Micropterus salmoides*) are collected primarily through electroshocking methods at representative supply and discharge canal sites and representative interior sites in each STA. Fish muscle (fillet) samples are analyzed for THg as an indicator of potential human exposure to mercury.

In 2000, the District began routine collection of sunfish (*Lepomis* spp.) at the same frequency, intensity (i.e., $n = 20$), and locations as for largemouth bass collection. This permit revision fulfilled a USFWS recommendation (USFWS recommendation 9b in USACE Permit No. 199404532; correspondence to Bob Barron, USACE, July 13, 2000). Sunfish, analyzed as whole fish, also serve as a surrogate for attempts to monitor mercury in wading birds that do not nest in the STAs. (For details on the monitoring program tracking mercury in wading birds in downstream areas, see Appendix 3B-1 of this volume.) The addition of sunfish to the compliance monitoring program was approved by the FDEP on March 5, 2002 (correspondence from F. Nearhoof, FDEP).

Tissue concentrations in each of the three monitored fishes will reflect ambient MeHg levels, i.e., their exposure is a function of a combination of factors including body size, age, rate of population turnover, and trophic position. Mosquitofish should respond rapidly to changing ambient MeHg concentrations due to their small size, lower trophic status, short life span, and rapid population turnover. Mosquitofish become sexually mature in approximately three weeks and have an average lifespan of only four to five months; the lifespan of males is shorter than females (Haake and Dean, 1983; Haynes and Cashner, 1995; Cabral and Marques, 1999). Conversely, sunfish (thought to have an average lifespan of four to seven years in the wild) and bass should take a longer to respond, in terms of tissue concentrations, to changes in ambient MeHg availability. Most importantly, sunfish and bass represent exposure at higher trophic levels (TL) with a requisite time lag for trophic exchange. While this focus on a three-year old bass is appropriate to evaluate exposure to fishermen, it complicates the data results by only interpreting tissue concentration over a three-year period. The key is to use these species-related differences to better assess MeHg availability within the system overall.

It is important to also recognize that virtually all (more than 85 percent) of the Mercury in fish muscle tissues is in the methylated form (Grieb et al., 1990; Bloom, 1992). Therefore, the analysis of fish tissue for THg, which is a more straightforward and less costly procedure than for MeHg, can be interpreted as being equivalent to the analysis of MeHg. Further details regarding rationales for sampling scheme, procedures, and data reporting requirements are set forth in the Everglades Mercury Monitoring Plan revised in March 1999 (Appendix 1 of QAPP, June 7, 1999).

QUALITY ASSURANCE MEASURES

For a quality assurance/quality control (QA/QC) assessment of the District's Mercury Monitoring Program during 2006, see Appendix 3B-1 of this volume.

STATISTICAL METHODS

The proper interpretation of residue levels in tissues can sometimes prove problematic due to the confounding influences of age or species of collected animals. For comparison, special procedures are used to normalize the data (Wren and MacCrimmon, 1986; Hakanson, 1980). To be consistent with the reporting protocol used by the Florida Fish and Wildlife Conservation Commission (Lange et al., 1998 and 1999), mercury concentrations in largemouth bass were standardized to an expected mean concentration in three-year-old fish at a given site by regressing mercury against age (hereafter symbolized as EHg3). Sunfish were not aged. Instead, arithmetic means were reported. However, efforts were made to estimate a least square mean mercury concentration based on the weight of the fish. Additionally, the distribution of the different species of *Lepomis* (warmouth, *L. gulosus*; spotted sunfish, *L. punctatus*; bluegill, *L. macrochirus*; and redear sunfish, *L. microlophus*) that were collected during electroshocking was also qualitatively considered as a potential confounding influence on mercury concentrations prior to each comparison.

Where appropriate, analysis of covariance (ANCOVA) using the SAS General Linear Model procedure, was used to evaluate spatial and temporal differences in mercury concentrations, with age (largemouth bass) or weight (sunfish) as a covariate. However, use of ANCOVA is predicated on several critical assumptions (Zar, 1996). These assumptions are that (1) regressions are simple linear functions; (2) regressions are statistically significant (i.e., nonzero slopes); (3) covariate is a random, fixed variable; (4) both the dependent variable and residuals are independent and normally distributed; and (5) slopes of regressions are homogeneous (parallel, i.e., no interactions). Regressions also require that collected samples exhibit a relatively wide range of covariate, that is, that fish from a given site are not all the same age or weight. Where these assumptions were not met, ANCOVA was inappropriate. Instead, standard analysis of variance (ANOVA) or Student's t-tests were used. Possible covariates were considered separately and often qualitatively. The assumptions of normality and equal variance were tested by the Kolmogorov-Smirnov and Levene Median tests, respectively. Datasets that either lacked homogeneity of variance or departed from normal distribution were natural-log transformed and reanalyzed. If transformed data met the assumptions, then they were used in ANOVA. If multi-group null hypotheses were rejected under ANOVA then the group were compared using either Tukey HSD (Honestly Significant Difference; for equal sized data sets) test or the Tukey-Kramer (for unequal sized data sets). If they did not meet the assumptions, then raw datasets were evaluated using nonparametric tests such as the Kruskal-Wallis ANOVA on ranks or the Mann-Whitney Rank sum test. If the multi-group null hypothesis was rejected, then groups were compared using either Nemenyi test (for equal sized data sets) or Dunn's Method (for unequal sized data sets). Pearson Product moment (or the non-parametric equivalent Spearman Rank Order) was used to evaluate the relationship between two parameters. Linear regression was used develop a line of best fit (linear model) between parameters.

SITE DESCRIPTIONS

Site descriptions and operational plans for STAs 1W, 2, 3/4, 5, and 6 are published elsewhere (SFWMD, 1997; 1998a; 1998b; 1999d; 2004); similar information on STA-1E was not available as of the date of this report. For maps of monitoring locations, see **Figures 1** through **6**.

STA1W MERCURY SAMPLING LOCATIONS

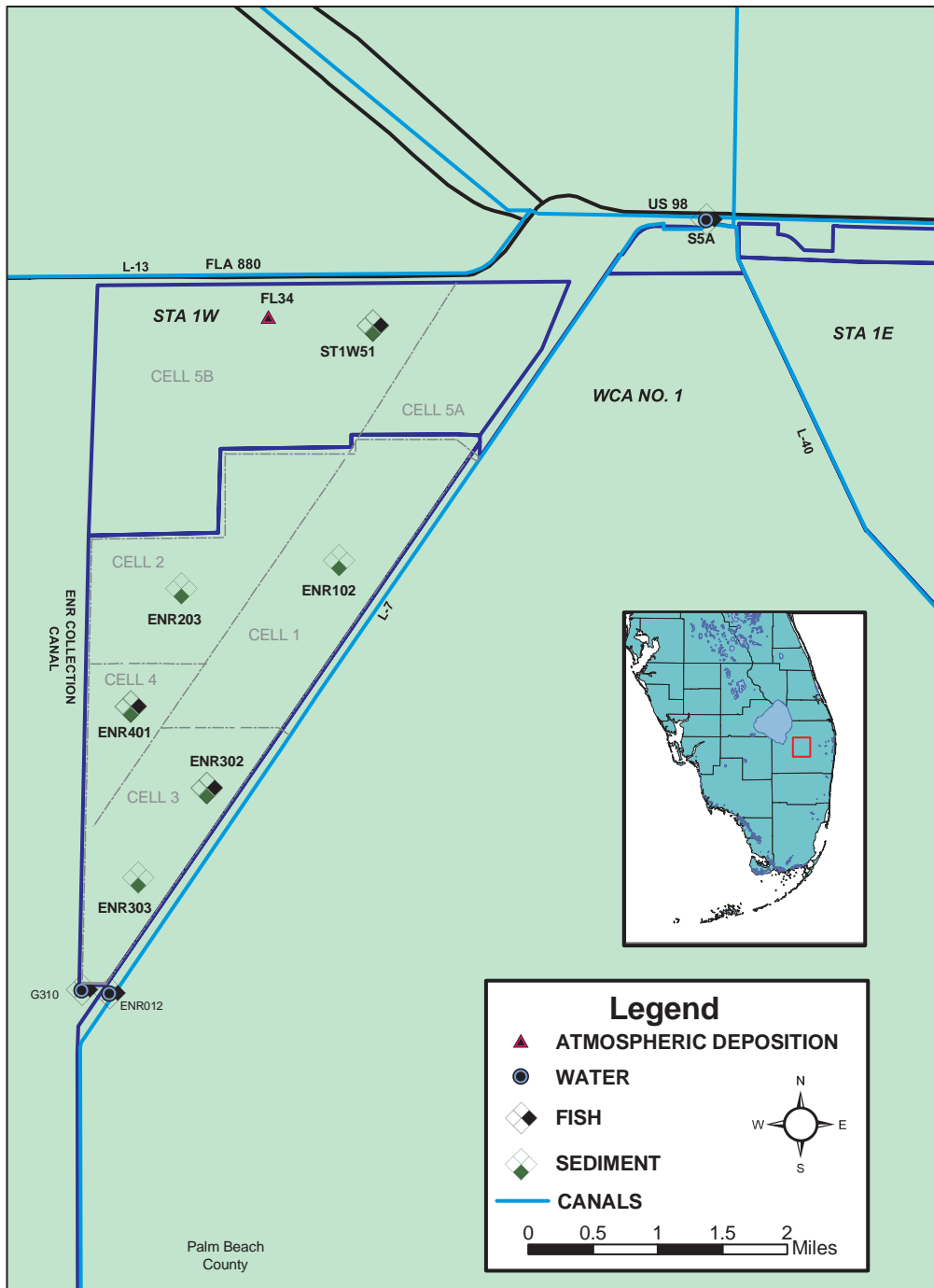


Figure 1. Stormwater Treatment Area 1 West (STA-1W) showing mercury monitoring sites.

STA1E MERCURY SAMPLING LOCATIONS

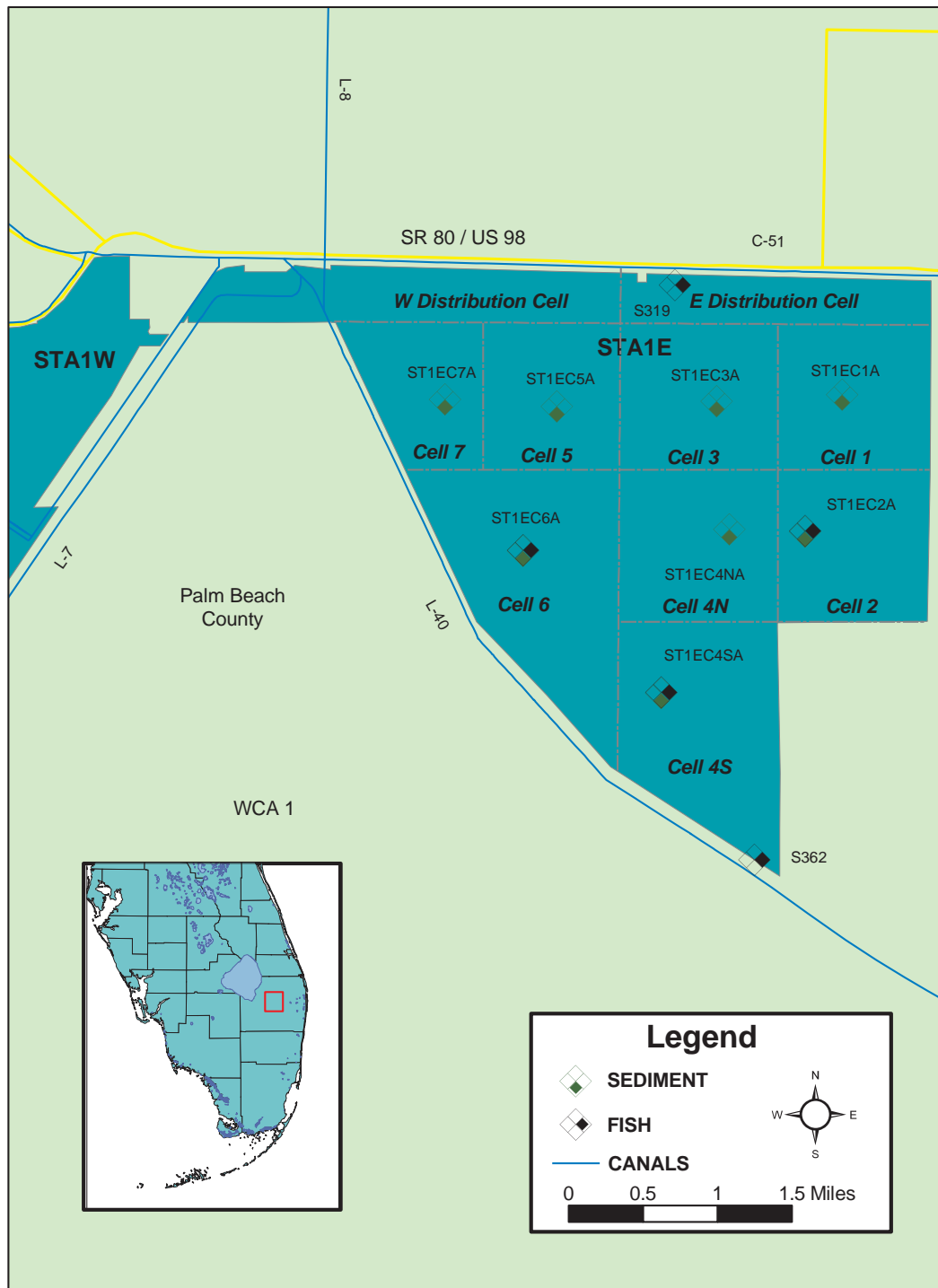


Figure 2. Map of Stormwater Treatment Area 1 East (STA-1E) showing sediment collection sites and future fish collection sites.

STA2 MERCURY SAMPLING LOCATIONS

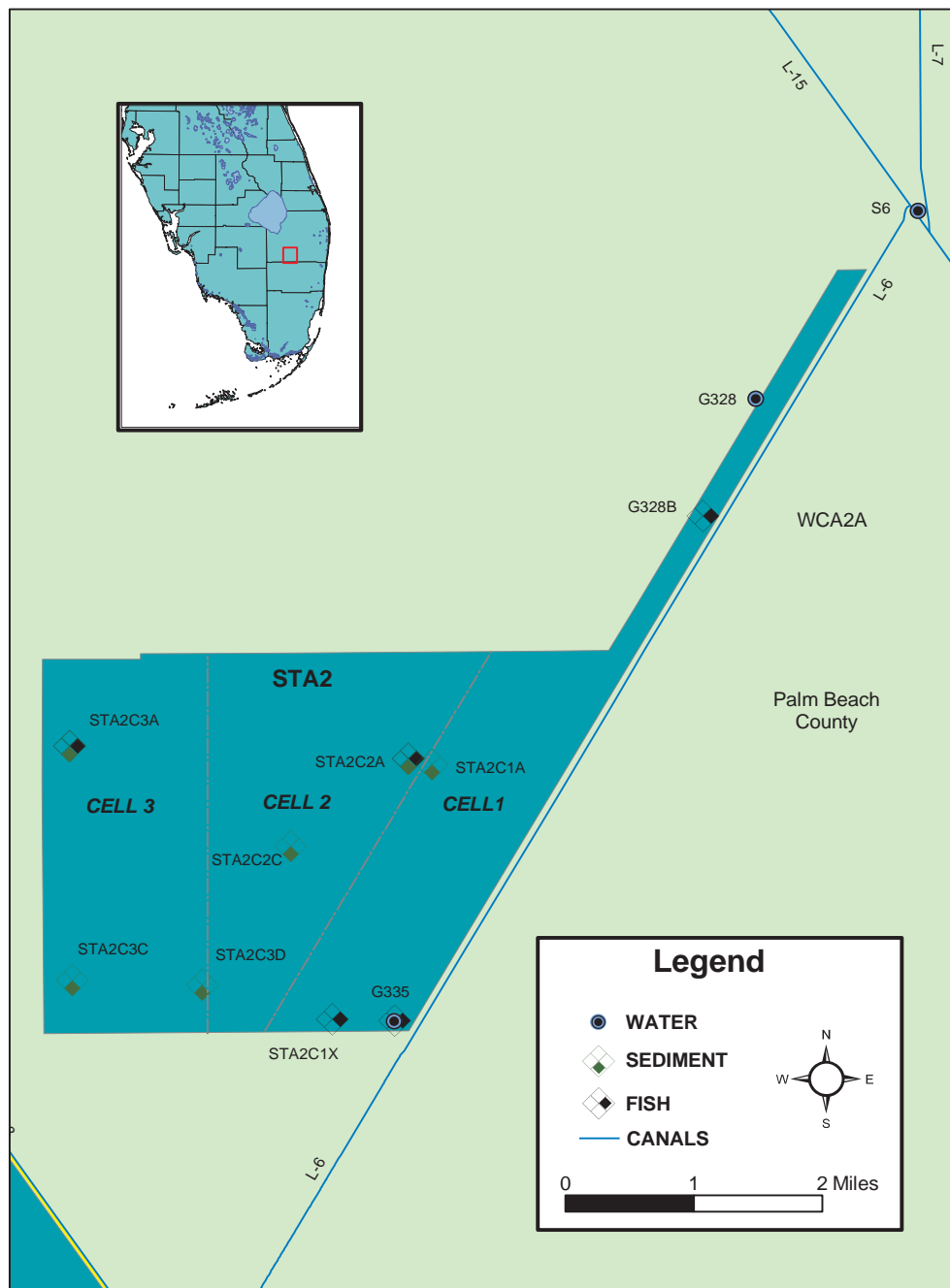


Figure 3. Map of STA-2 showing mercury monitoring sites.

STA 3/4 MERCURY SAMPLING LOCATIONS

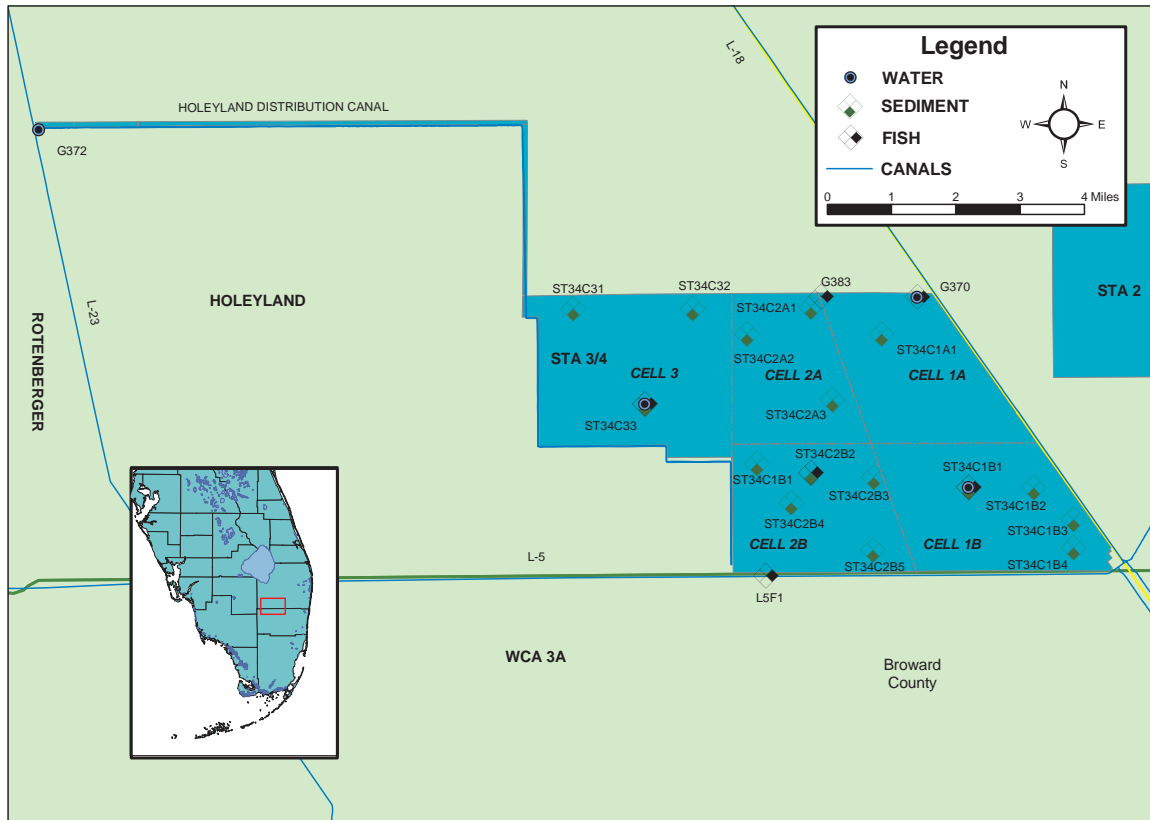


Figure 4. Map of STA-3/4 showing mercury monitoring sites.

STA5 MERCURY SAMPLING LOCATIONS

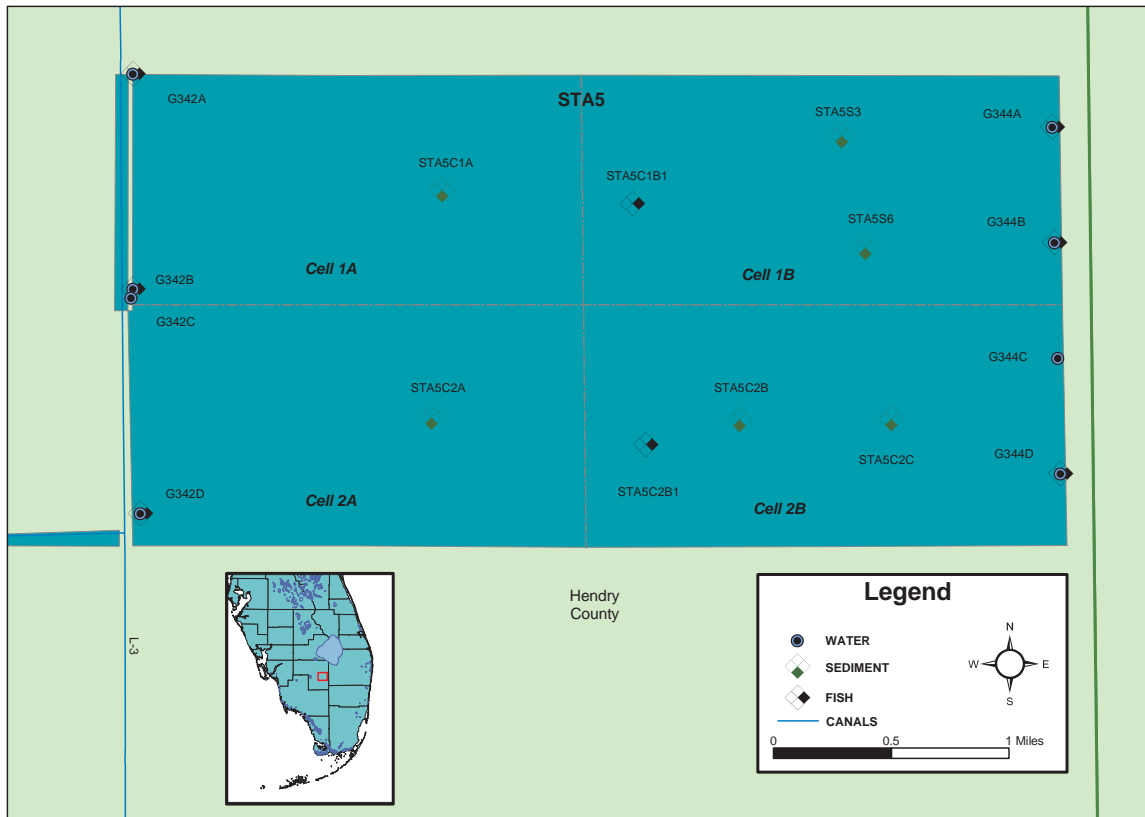


Figure 5. Map of STA-5 showing mercury monitoring sites.

STA6 MERCURY SAMPLING LOCATIONS

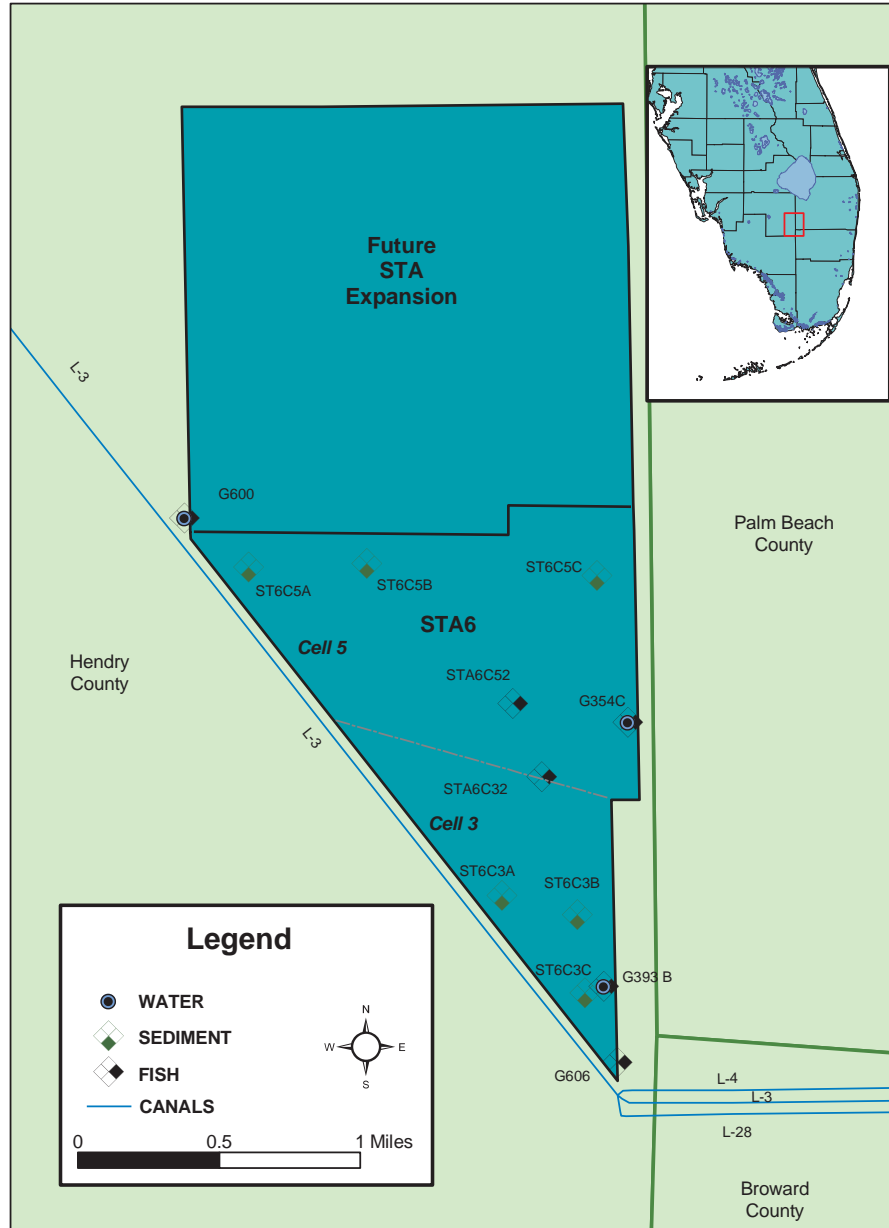


Figure 6. Map of STA-6 mercury monitoring sites.

MONITORING RESULTS

PRE-OPERATIONAL MONITORING

Results from pre-operational monitoring of STAs 1W, 1E, 2, 3/4, 5, and 6 have been reported previously (SFWMD, 1998c, 1999d; Rumbold and Rawlik, 2000; Rumbold and Fink, 2002a, 2003a; Rumbold 2004, 2005a; Rumbold et al., 2001, 2006; **Figure 7** summarizes the results of pre-operational sediment collection).

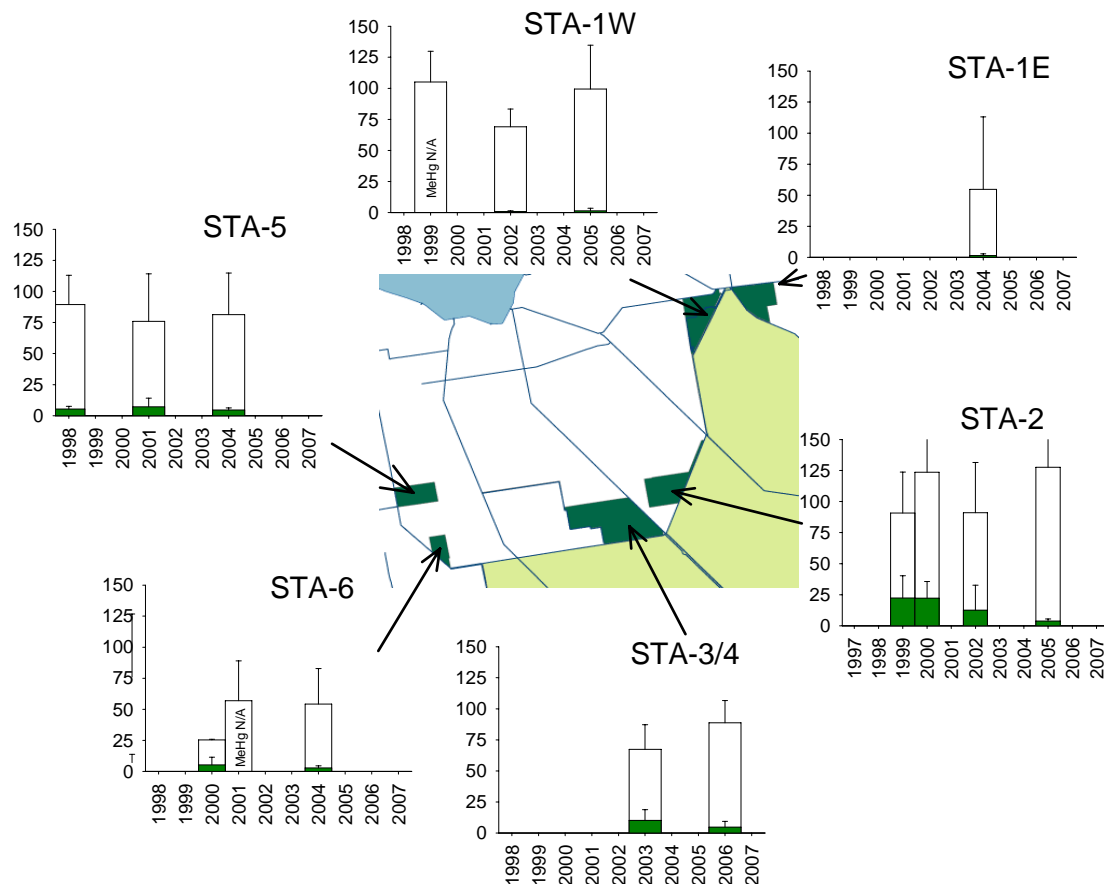


Figure 7. Mean concentration (+1 Standard Deviation [SD]; dry weight basis) of THg (ng/g) and MeHg (10x ng/g) in sediment cores (n = 6; 0–10 cm) collected from each STA prior to start-up and once every three years thereafter.

OPERATIONAL MONITORING

STA-1W

In 2000, STA-1W subsumed the ENR Project (Cells 1 through 4, **Figure 1**), which had been in operation since 1994. STA-1W surface water passed start-up criteria during the week of January 17, 2000; flow-through operations began in early February 2000. Formal monitoring of

mercury levels in STA-1W surface water began on February 16, 2000 (for discussion of results observed prior to 2005, see Rumbold and Rawlik, 2000; Rumbold et al., 2001, 2006; Rumbold and Fink, 2002a, 2003a; Rumbold, 2004, 2005a).

As shown in **Figure 8**, concentrations of both THg and MeHg in surface water at the outflows of STA-1W in WY2007 remained low compared to inflow and outflows of other STAs. As discussed in Appendix 5-5 of the *2007 South Florida Environmental Report, Volume I*, after a period of inundation dating back to 1997 (Rumbold and Fink, 2002b), several of the cells were taken off-line during the calendar year and were allowed to draw down for construction activities (**Figure 9**). The drawdowns appeared to have no marked effect on water-column concentrations at the outflows during this calendar year (**Figure 8**). For WY2007 the drawdown periods that occurred, particularly in Cells 4 and 5 also appeared to have no marked impact on MeHg and Hg levels (**Figures 8, 10 and 11**). Concurrently, outflow loads of MeHg and THg are considerably lower than inflow (**Figures 12 and 13**).

Concentrations of THg in mosquitofish are summarized in **Table 1** and graphically presented in **Figure 14**. Mosquitofish from STA-1W continue to have very low mercury levels particularly from the interior and outflow sampling sites, similar to levels when the area was operated as the ENR project (Rumbold and Fink, 2002b). Furthermore, mercury levels in STA-1W mosquitofish continue to be lower than levels currently observed in fish from other areas of the Everglades (Appendix 3B-1 of this volume). As noted with water-column concentrations, mercury levels in mosquitofish from STA-1W did not increase markedly following the drawdowns and re-flooding during the year; mosquitofish consistently exhibited a negative percent change in tissue-Hg levels across STA-1W (**Table 1**). This pattern was also observed in sunfish and largemouth bass.

As shown in **Table 2** and **Figure 14**, STA-1W sunfish continued to have mercury levels much lower than those observed in sunfish at the other STAs and locations within the Everglades (Appendix 3B-1 of this volume). Sunfish Hg levels can, however, vary depending upon several factors, namely, species type, size and age. After standardizing all sunfish for 2007 by type (bluegill) and by length (124-178; one SD), no fish were available for STA-1W, therefore, this evaluation could not be made. However, in last year's report, following standardization, levels in sunfish were lower than all other STAs.

As with sunfish, largemouth bass from interior sites of STA-1W contained lower mercury levels than bass from most other STAs (**Table 3** and **Figure 14**). Moreover, STA-1W bass contained much lower mercury than fish from downstream sites in the WCAs (Appendix 3B-1 of this volume). As with mosquitofish and sunfish, bass exhibited a negative percent change in mercury levels across the STA (**Table 3**). **Figure 14** shows that bass from the supply canal (upstream of S5A) contained substantially greater mercury levels than fish both from interior marshes and from the discharge canals.

Consistent with previous assessments, mercury–age regressions were not statistically significant for fish from the outflow sites; however, for a different reason than in 2005. In 2006, only two bass were captured from outflow site ENR012 therefore mercury–age regressions could not be developed. In previous years, mercury levels did not increase significantly with age for this STA. In 2006, the two areas where mercury–age regressions could be performed (inflow and interior sites) positive relationships existed between mercury level and fish age.

Mercury levels in fish tissue can also be evaluated for risk to fish-eating wildlife. Contrary to other areas of the Everglades, fish-eating wildlife foraging preferentially at STA-1W do not appear to be at risk from mercury exposure. STA-1W mosquitofish, sunfish, and largemouth bass continue to have some of the lowest tissue-Hg levels in South Florida — well below both the USEPA and USFWS guidance level for predator protection. (Eisler, 1987; USEPA, 1997).

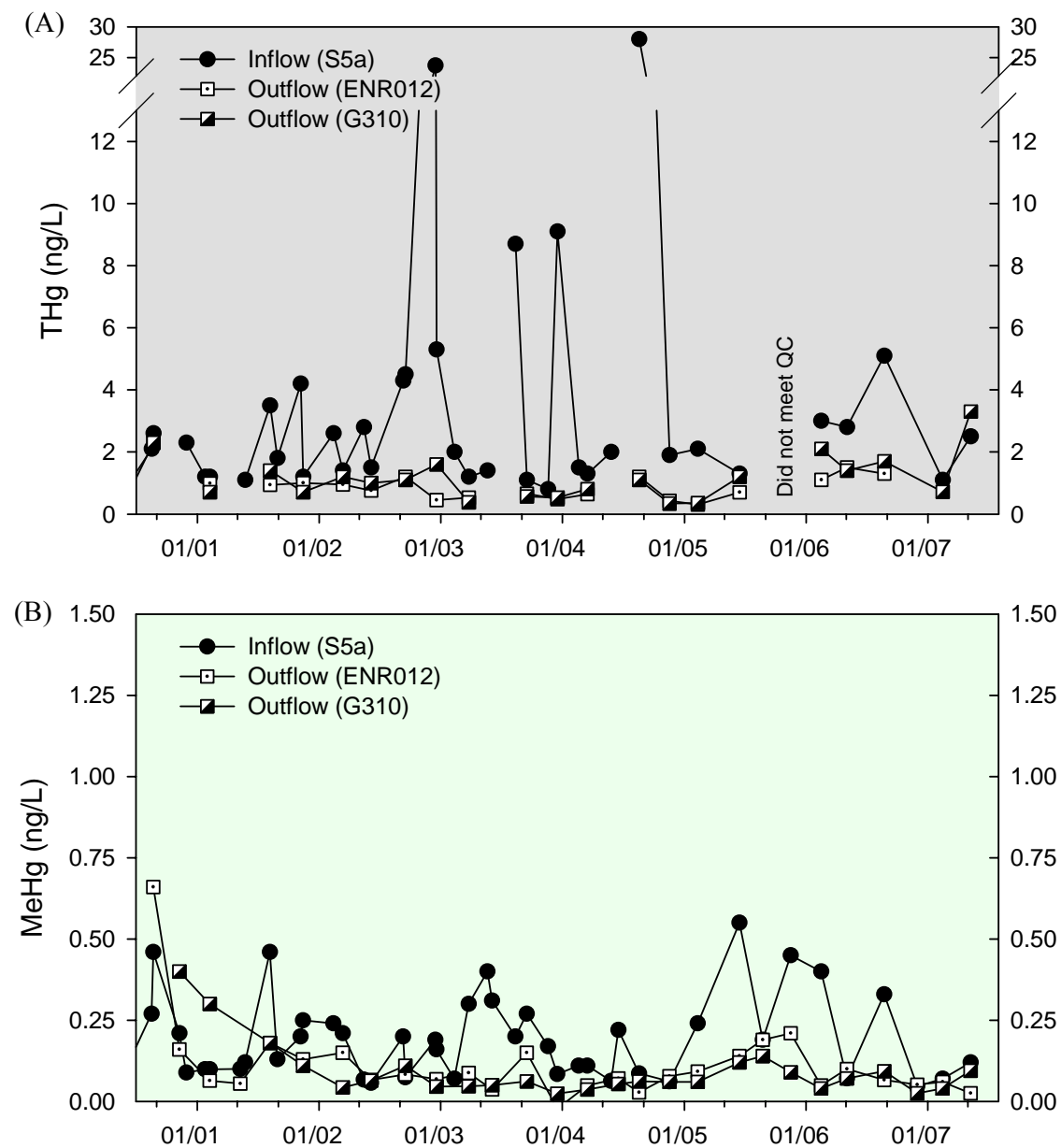


Figure 8. Concentrations of (A) THg and (B) MeHg (ng/L) in unfiltered surface water collected at STA-1W.

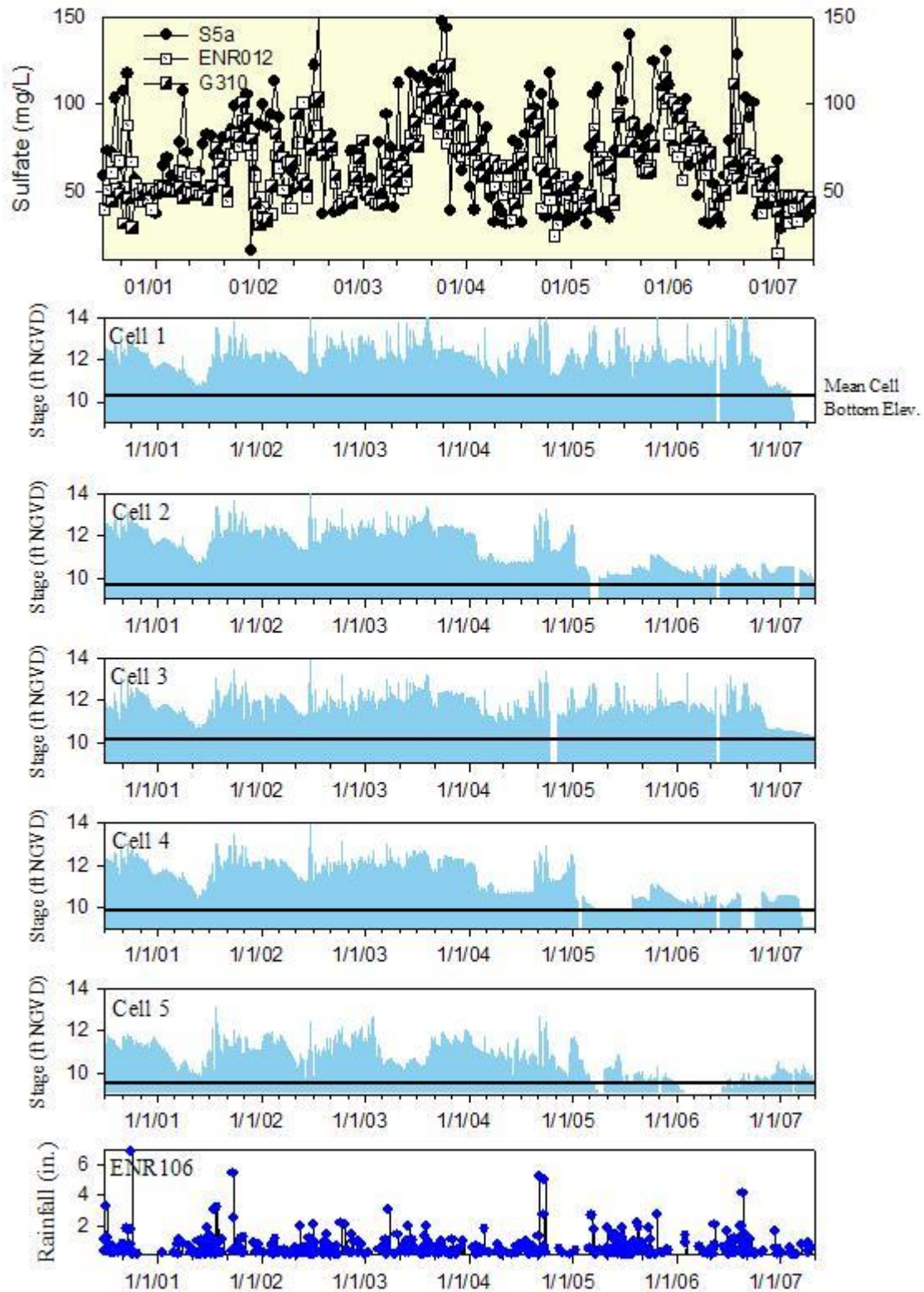


Figure 9. Water column sulfate, stage (recorded immediately upstream of outflow culvert of cell) and rainfall at STA-1W.

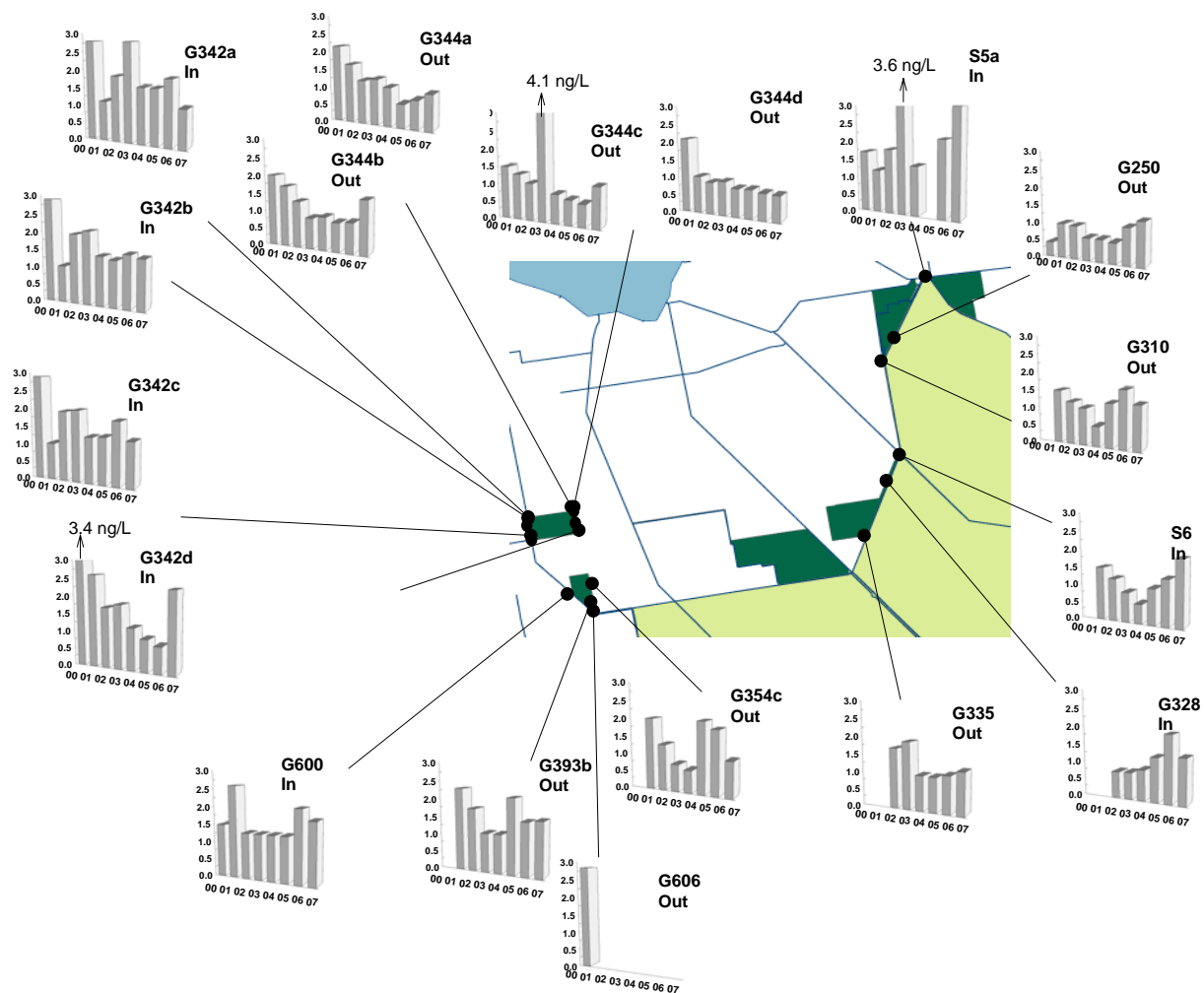


Figure 10. Annual median THg concentrations (ng/L) for period of record (POR) at inflows and outflows of STAs

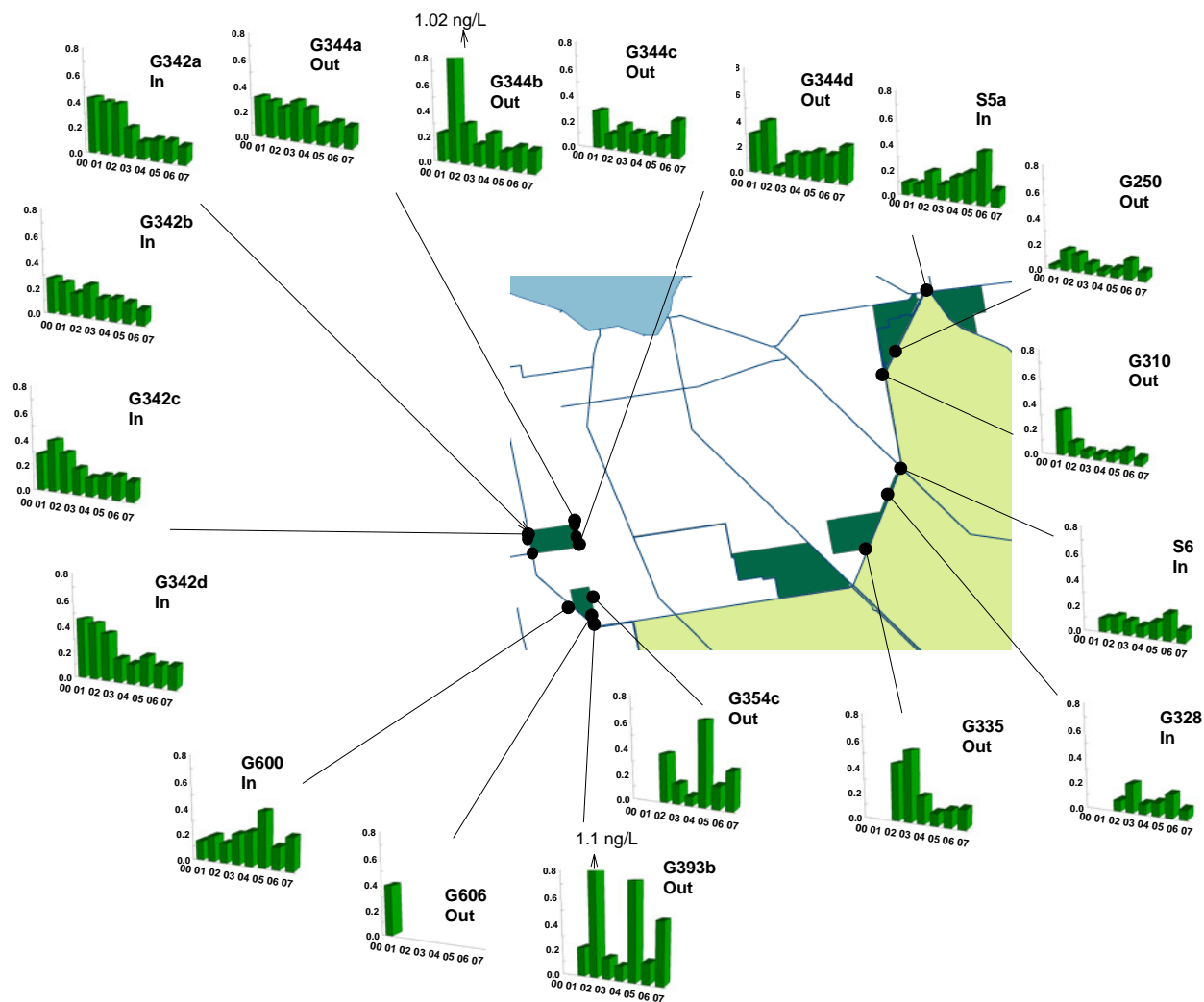


Figure 11. Annual median MeHg concentrations (ng/L) for POR at inflows and outflows of STAs.

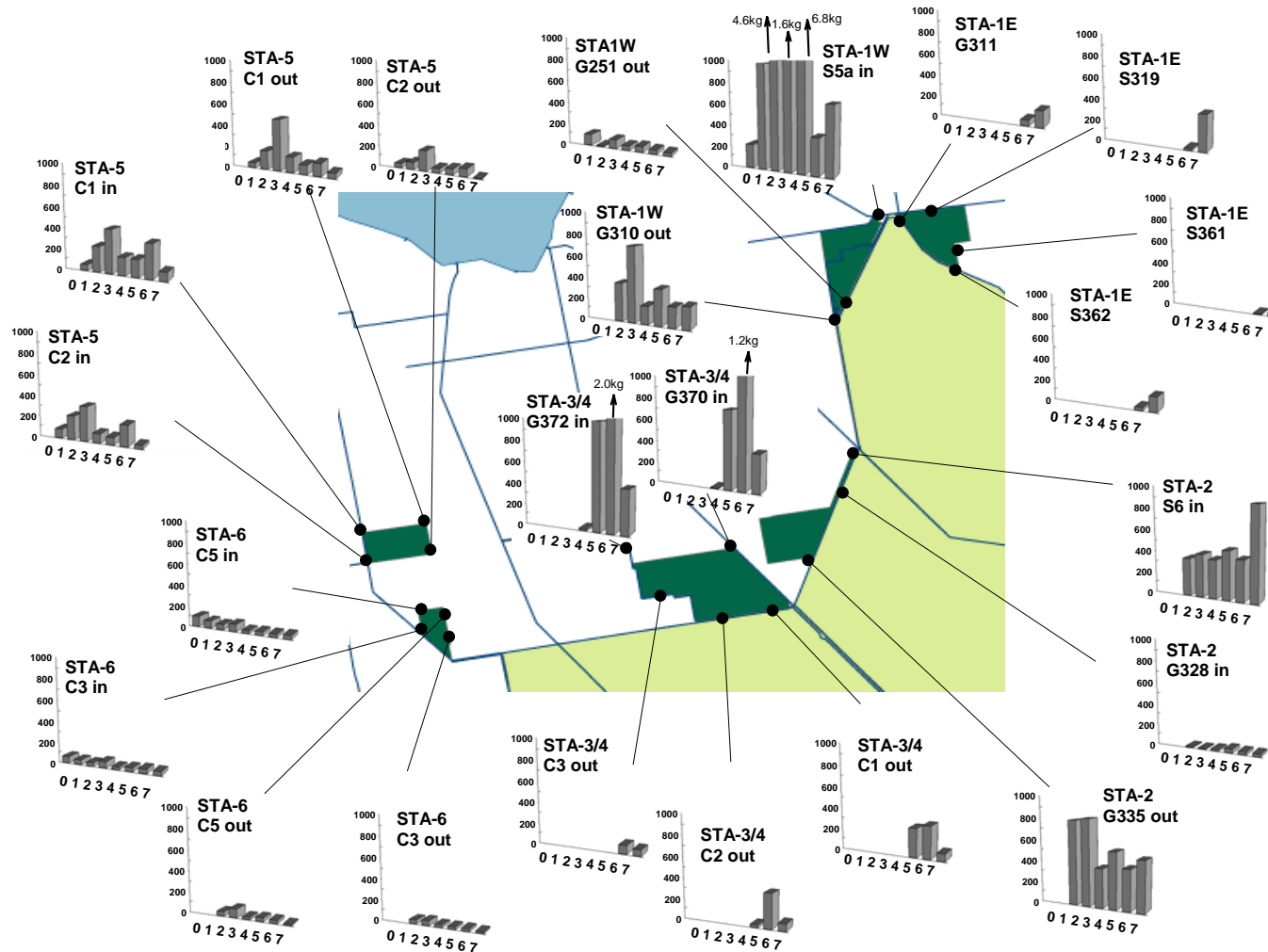


Figure 12. Estimated annual THg loads (scale = 1000 grams) at inflows and outflows of STAs for period of record (2000 to 2007).

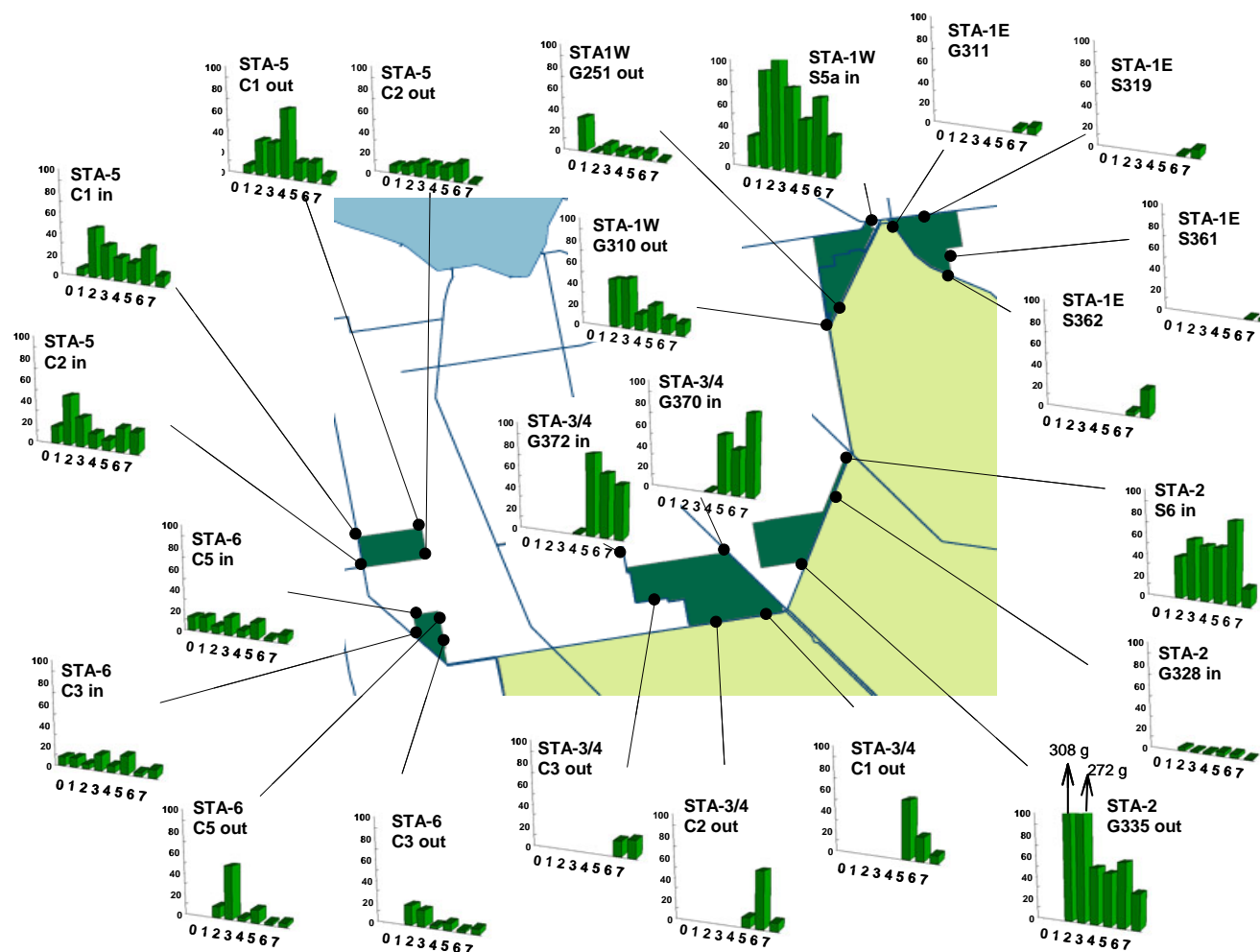


Figure 13. Estimated annual THg loads (scale = 1000 grams) at inflows and outflows of STAs for period of record 2000 to 2007.

Table 1. Concentration of THg in mosquitofish* composites collected semiannually from STAs (units ng/g wet weight).

STA	Half-year/ Quarterly	Inflow Fish	Interior Fish	Outflow Fish	Percent Change(%) ^a
STA-1W	2006-1	14.6	4.3	3.5	-76
	2006-2	15.0	3.9	4.8	-68
	Annual mean	14.8	4.1	4.1	-72
	Cumulative mean	29	21	13	-55
STA-1E ^b	2006-1	Not Applicable	29	41	Not Applicable
	2006-2	Not Applicable	53	67	Not Applicable
	2006-3	Not Applicable	16	69	Not Applicable
	2006-4	Not Applicable	21	53	Not Applicable
	Annual mean	Not Applicable	29	56	Not Applicable
	Cumulative mean	Not Applicable	28	68	Not Applicable
STA-2	2006-1	5.7	8.7	8.8	54
	2006-2	16	10	15	-6.0
	Annual mean	10	9.3	11	10
	Cumulative mean	14	73	82	485
STA-3/4	2006-1	No fish*	No fish*	No fish*	
	2006-2	13	21	30	131
	Annual mean	13			
	Cumulative mean	13			
STA-5	2006-1	18	10	6	-67
	2006-2	19	20	17	-11
	Annual mean	18	15	11	-39
	Cumulative mean	29	26	31	6.8
STA-6	2006-1	7.5	No fish*	13	73
	2006-2	29	5.4	27	-7
	Annual mean	18	5.4	20	11
	Cumulative mean	26	13	23	-0.11

* Mosquitofish are collected semiannually at inflow, interior, and outflow sites.

a Percent change = outflow-inflow/inflow.

b STA-1E differs from other STAs in that mosquitofish are collected on a quarterly basis, are not collected from inflows, and outflow collection has been relocated to downstream marsh.

No fish* Archives submitted, currently waiting for results.

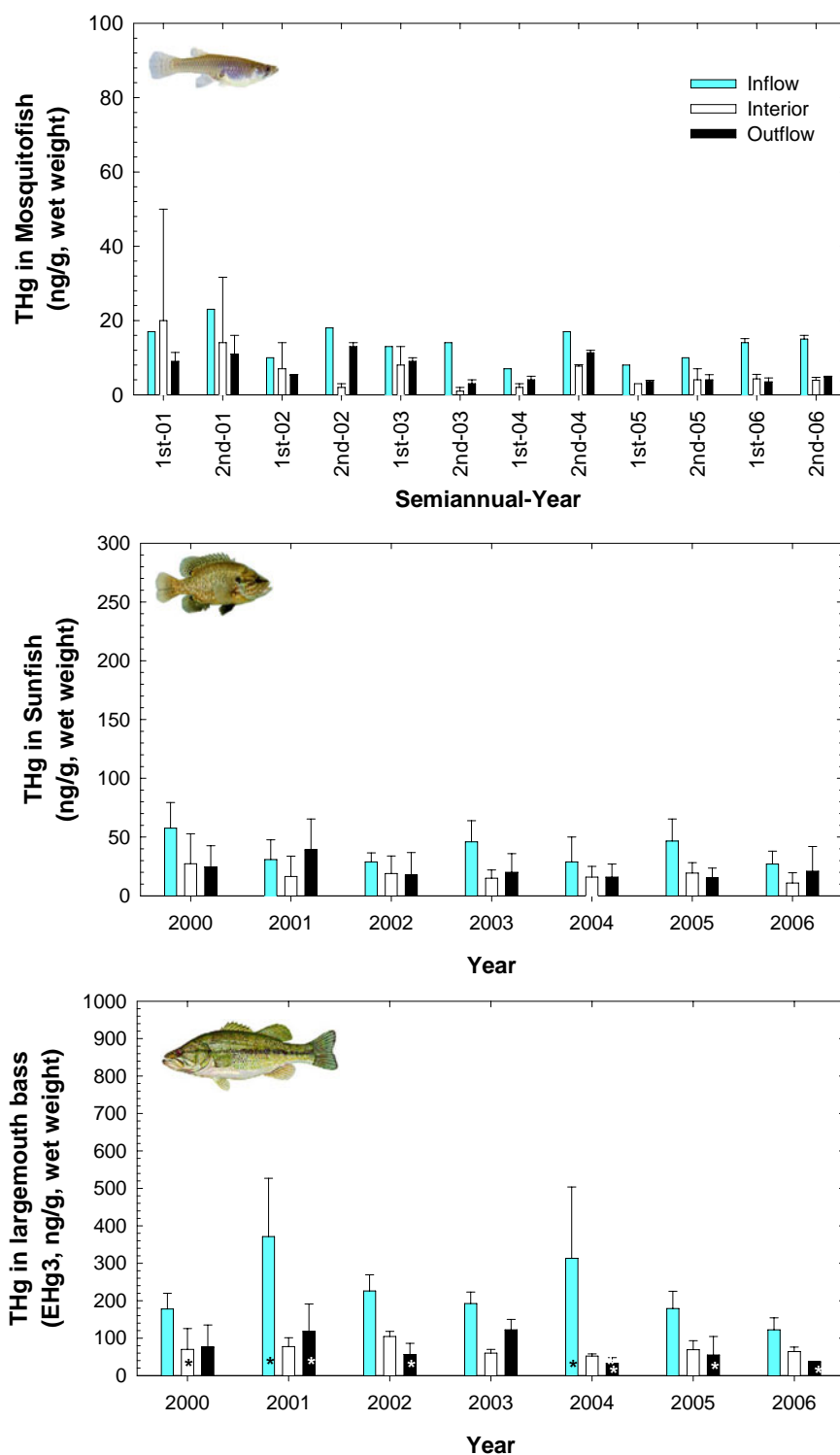


Figure 14. Mercury concentrations (ng/g, wet weight) in (*top*) mosquitofish composites (+range), (*middle*) whole sunfish (\pm SD), and (*bottom*) fillets of largemouth bass (\pm 95 percent Confidence Interval [C.I.] or, if arithmetic, SD) collected at STA-1W. Arithmetic means are noted by an asterisk.

Table 2. Concentration of THg (ng/g, wet weight) in sunfish (*Lepomis* spp.) collected from STAs in 2006 (sample size in parentheses).

STA	Inflow Fish	Interior Fish	Outflow Fish	Percent Change ^a
STA-1W	27 ±11 (8)	11 ± 8(44 ^b)	21±21 (22 ^b)	-22%
Cumulative mean ^c	40	17	22	-45%
STA-1E ^d	Not applicable	93±48 (10)	105±60 (3)	--
Cumulative mean		106	125	--
STA-2	28 ±17(20)	32 ±25 (68 ^b)	48±33(20)	71%
Cumulative mean	58	99	101	74%
STA-3/4	26 ±14 (40 ^b)	55 ±33 (46 ^b)	56 ±37 (32 ^b)	115%
Cumulative mean	40	81	70	75%
STA-5	57 ±25 (17)	41 ±23 (28 ^b)	71 ±25 (21)	24%
Cumulative mean	65	105	92	41%
STA-6	57 ±18 (20)	47 ±17 (11)	105 ±34(20)	84%
Cumulative mean	53	52	92	73%

a Percent change = outflow-inflow/inflow.

b Where n > 20; multiple sites were sampled and pooled, i.e., multiple interior or outflows.

c Grand mean of annual means; sunfish collected in 1999, prior to permit revision or STA operation (in the case of STA-5 and STA-1W), were included in the cumulative average.

d STA-1E differs from other STAs in that sunfish are not collected from inflows and outflow collection has been relocated to downstream marsh.

Table 3. Standardized, EHg3 \pm 95%, and arithmetic mean concentration (mean \pm 1 SD, n; in parentheses) of THg (ng/g, wet weight) in fillets from largemouth bass collected at STAs in 2006.

STA	Inflow Fish	Interior Fish	Outflow Fish	Percent Change ^a
STA-1W	122 \pm 32 (180 \pm 77, 9)	64 \pm 12 (35 \pm 45, 40 ^b)	NC (1,2) (37,2)	--
Cumulative mean ^c	255	61	64	-75%
STA-1E ^d	Not applicable	NC (2) (230 \pm 103, 10)	Not available Not available	--
Cumulative mean ^c		259	510	96%
STA-2	111 \pm 24 (123 \pm 113, 20)	84 \pm 8 (86 \pm 38, 59 ^b)	109 \pm 35 (156 \pm 102, 20)	-2%
Cumulative mean	237	249	552	132%
STA-3/4	198 \pm 29 (192 \pm 113, 26 ^b)	395 \pm 38 (287 \pm 110, 41 ^b)	453 \pm 26 (427 \pm 123, 20)	128%
Cumulative mean	205	359	454	121%
STA-5	305 \pm 42 (197 \pm 99, 18)	NC(2) (93 \pm 20, 8)	NC(2) (114 \pm 113, 20)	--
Cumulative mean ^d	181	355	370	104%
STA-6	287 \pm 46 (343 \pm 172, 40)	230 \pm 50 ^e (266 \pm 63, 5)	447 \pm 20 476 \pm 96	55%
Cumulative mean	256	203	470	83%

- a Percent change = outflow-inflow/inflow based on EHg3 where available.
- b Where n > 20; multiple sites were sampled and pooled, i.e., multiple interior or outflows.
- c Arithmetic grandmean of annual means; bass collected in 1999 prior to operation of STA-5 and STA-1W were included.
- d STA-1E differs from other STAs in that sunfish are not collected from inflows, sample size is 5, and outflow collection has been relocated to downstream marsh.
- e Cell 5 bass only; i.e., excludes single bass from Cell 3.
- NC Not calculated, where: (1) regression slope was not significantly different from 0, or (2) poor age distribution of collected fish.
- NA Not available; no bass in sample area.

STA-1E

Monitoring of water-column concentrations of THg and MeHg began in January 2005 at STA-1E. Both the central flow-way (Cells 3, 4N, and 4S) and the westernmost flow-way (Cells 5 through 7) met the start-up criteria, as specified in EFA Permit No. 0195030-001-GL, in August 2005 (correspondence from R. Bearzotti, SFWMD, dated September 9, 2005). As of the date of this report, the U.S. Army Corps of Engineers (USACE) is constructing and shall operate a Periphyton-Based Stormwater Treatment Area (PSTA) Demonstration Project in the easternmost flow-way (Cells 1 and 2) of STA-1E.

As shown in **Figure 11**, in WY2007 MeHg remained at relatively low concentrations in the outflow following the operation of the central and western flow-ways; however, outflow concentrations were typically higher than inflow. STA-1E displays some of the highest THg concentrations in comparison to all other STAs, including downstream monitoring locations. A concentration of 7.3 ng/L (sampled on 8/23/2007), was the highest recorded level since sampling began in 2005. THg levels from this STA, however, are below the WQS of 12 ng/L. The high THg levels may be related to several factors including (1) construction issues during start-up operations, (2) high pre-existing soil mercury concentrations, (3) high mercury levels within source water discharging into this STA, and (4) “first-flush” effects. The elevated Hg levels are not related to impacts from dry-out and rewetting as each cell has been inundated since early 2006 (**Figure 16**). Despite relatively high THg concentrations, this STA appears to be functioning well with respect to THg and MeHg loading: outflow loading is less than inflow (**Figures 12 and 13**).

Before assessing the results from monitoring tissue concentrations in resident fish from STA-1E, several points should be emphasized. It should be noted that sampling locations, frequency of mosquitofish collections and numbers of sunfish and bass sampled at this STA differ from the older STAs (i.e., no inflow site and outflow site has been relocated to become a near-field downstream site within WCA-1 marsh, semi-annual collection to quarterly, $n = 5$ each). It was felt that these changes in the monitoring plan would better capture and alert us to environmental impacts; it is the intent of the District to make similar changes to monitoring plans for the other STAs. It should also be noted that the first samples of mosquitofish were collected within a month of flooding. Although this may have been sufficient time for body burdens in mosquitofish to change in response to altered mercury cycling, results from the sunfish and bass collected in October 2005 should be considered baseline.

Quarterly collection of mosquitofish from STA-1E sites at interior marshes and the single downstream site (ST1ELX), began during the third quarter of 2005 (**Table 1, Figure 17**). As shown in **Figure 17**, mercury levels in mosquitofish from the interior marshes and discharges were higher than all other STAs in 2006; however, levels decreased significantly (by 65 percent) in the interior sites starting the third quarter of 2006. Mosquitofish from the near-field downstream site in WCA-1 contained levels comparable to levels in this STA (**Table 1**). The high levels in mosquitofish may be attributed to high THg in surface water (**Figure 15**).

Annual collection of bluegill sunfish and largemouth bass occurred in September 2006. At the downstream site, no largemouth bass were found and only three sunfish were collected. As evident from **Tables 2 and 3**, mercury levels were elevated in STA-1E fish compared to the other STAs. Levels in fish from the near-field downstream site (ST1ELX) were also elevated compared to levels recently observed at one of the far-field downstream sites, LOX4 (Appendix 3B-1). The standardized concentration in bluegill from ST1ELX was 0.29 ng/g/mm, whereas bluegill from nearby LOX4 averaged 0.9 ng/g/mm (**Figure 17**; cf. Figure 13 in Appendix 3B-1). At this point, the factor(s) responsible for this geographical difference in mercury levels between ST1EX and LOX4 are unknown.

Regarding risks to fish-eating wildlife, average THg concentration for resident sunfish within STA-1E were just below the USFWS criterion of 100 ng/g; however, concentrations were above the USEPA predator protection criterion of 77 ng/g for trophic level 3 (TL 3) fish. Most of the exceedance for sunfish was due to the elevated concentrations from downstream locations (105 ± 60 ng/g). Mosquitofish (falling under TL 2 or 3) did not exceed the 77 ng/g criterion.

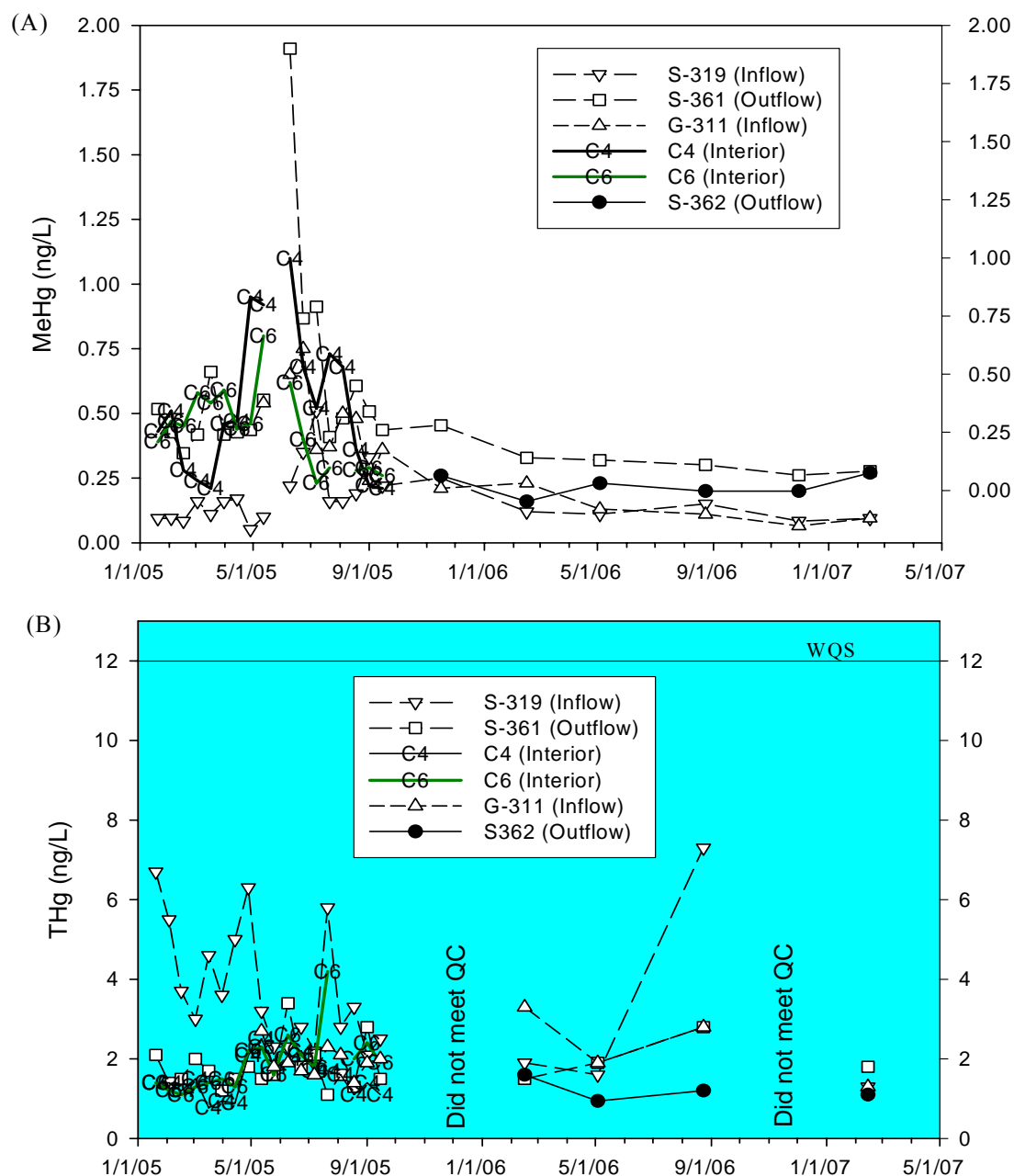


Figure 15. Concentrations of (A) MeHg and (B) THg (ng/L) in unfiltered surface water collected at STA-1E.

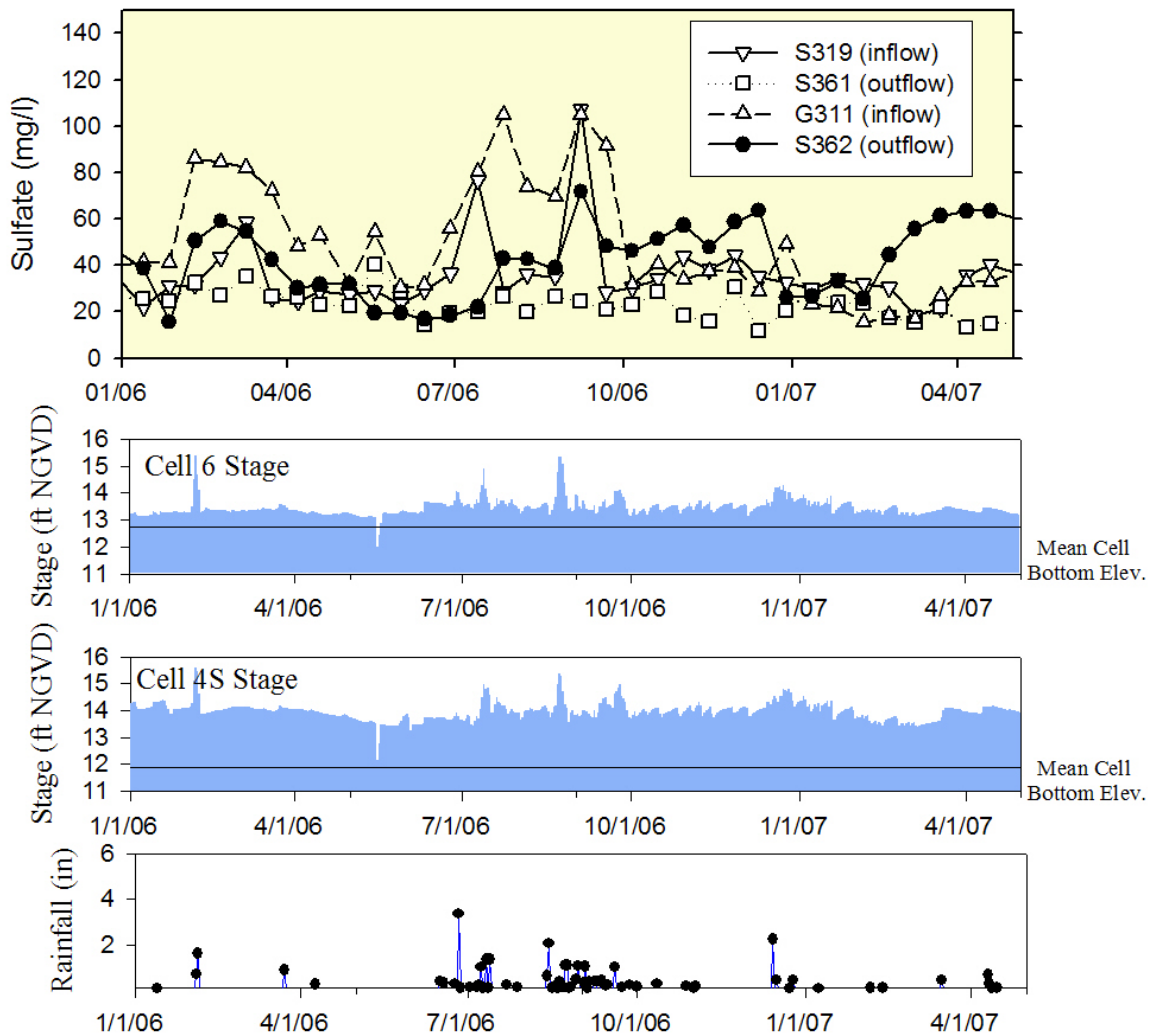


Figure 16. Water-column sulfate, stage (recorded immediately upstream of outflow culvert of cell), and rainfall at STA-1E.

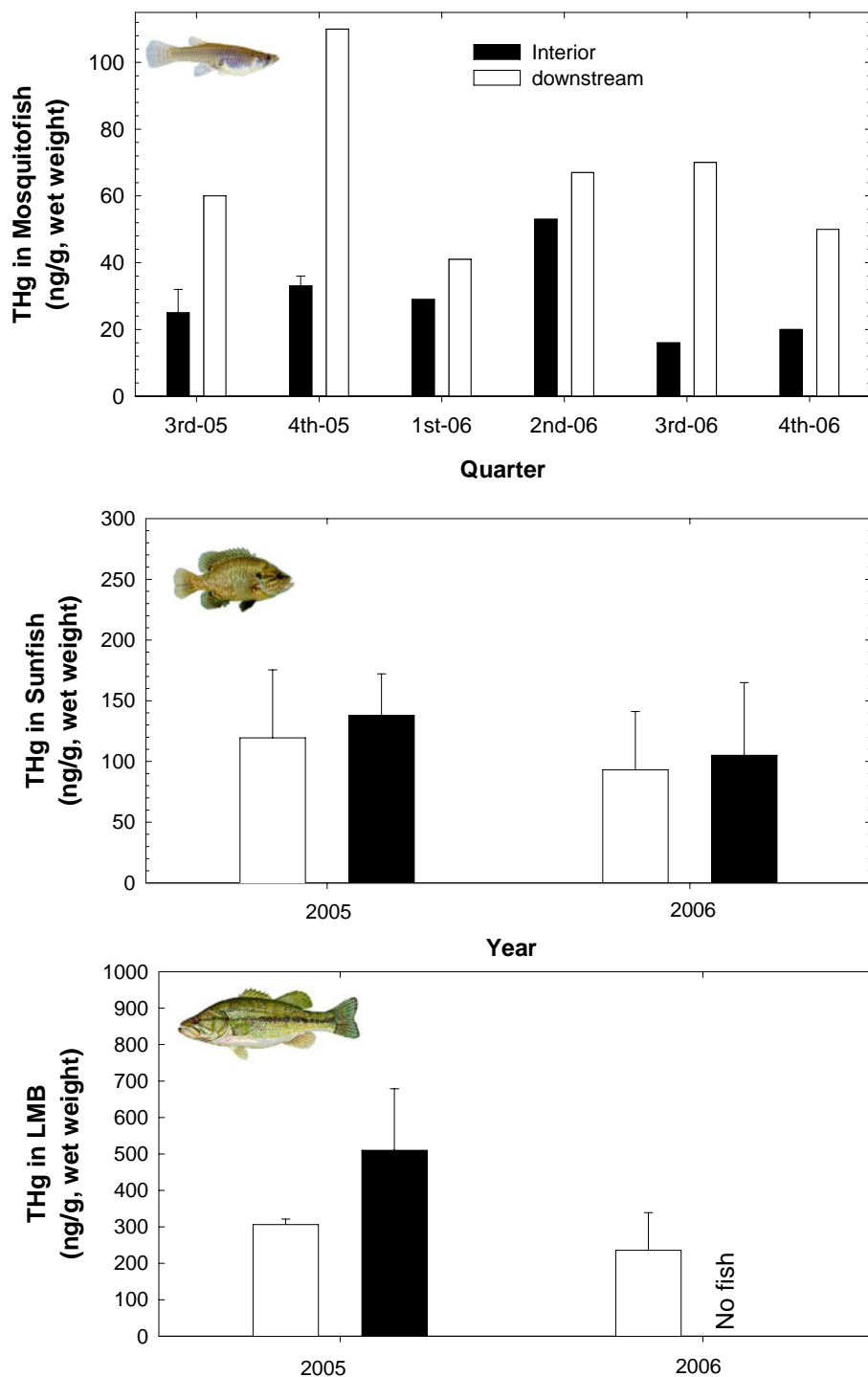


Figure 17. Mercury concentrations (ng/g, wet weight) in (*top*) mosquitofish composites (+range), (*middle*) whole sunfish (\pm SD), and (*bottom*) fillets of largemouth bass (\pm 95 percent C.I. or, if arithmetic, SD) collected at STA-1E. Arithmetic means are noted by an asterisk.

STA-2

STA-2 Cells 2 and 3 met mercury start-up criteria in September 2000 and November 2000, respectively. In August 2001, flow-through operation of Cell 1 was approved under a permit modification. Cell 1 met start-up criteria in November 26, 2002. Operational monitoring of mercury at STA-2 began during the third quarter of 2001 after completion of the S6 connection (for discussion of results observed prior to 2005, see Rumbold and Fink, 2002b, 2003b; Rumbold 2004, 2005a; Rumbold et al., 2006).

Results from monitoring mercury concentrations in surface water at STA-2 (**Figure 18**) show THg concentration in outflow did not exceed the Class III numerical water quality standard (WQS) of 12 ng/L during WY2007. More importantly, both MeHg, which has no numerical WQS, and THg remained at low concentrations in outflow as compared to previous monitoring results. However, outflow loads of both THg and MeHg are above inflow (Figures 12 and 13). Notably, although stage has fallen several times, Cell 1 has remained inundated since late 2002 (**Figure 19**), when the weir boxes in front of the outflow culverts were reconfigured, in part to prevent recurrence of steep gradients in stage that were thought to have influenced methylation rates.

Both **Table 1** and **Figure 20** summarize results from operational monitoring of mercury concentrations in STA-2 mosquitofish for 2006. **Figure 20** graphs results from different interior sites separately for this STA because of the degree of spatial variability previously observed here. The figure indicates that mercury levels in mosquitofish from Cell 1 and the discharge canal have declined dramatically since 2001 and 2002 (in some cases, by an order of magnitude). Moreover, among-cell differences in mercury levels in mosquitofish decreased greatly in the second quarter of 2005; however, concentrations rose slightly in Cell 1 in 2006.

Sunfish from STA-2 showed relatively uniform levels in all cells for 2006 (**Table 2** and **Figure 20**) and with consistent decline since 2003. Standardizing by species (bluegill) and length reveals the same general trend in concentration distribution as when considering all sunfish types and lengths. Following standardization, average concentration at the supply locations was 0.19 ng/g/mm, 0.14 ng/g/mm for all interior locations, and 0.34 ng/g/mm for all discharge locations.

Concentrations of THg in fillets of resident largemouth bass from STA-2 (**Table 3** and **Figure 20**) reflect an overall average EHg3 of 110 ± 35 ng/g collected across the three cells, which is relatively low compared to previous estimates and downstream fish (Appendix 3B-1 of this volume). Regarding risk to fish-eating wildlife, resident fish at STA-2 generally contained mercury levels lower than both the USFWS (100 ng/g) and USEPA predator protection criteria (77 ng/g and 346 ng/g for TL 3 and 4 fish, respectively); sunfish and bass from Cell 1 and sunfish from the outflow were the only notable exceptions.

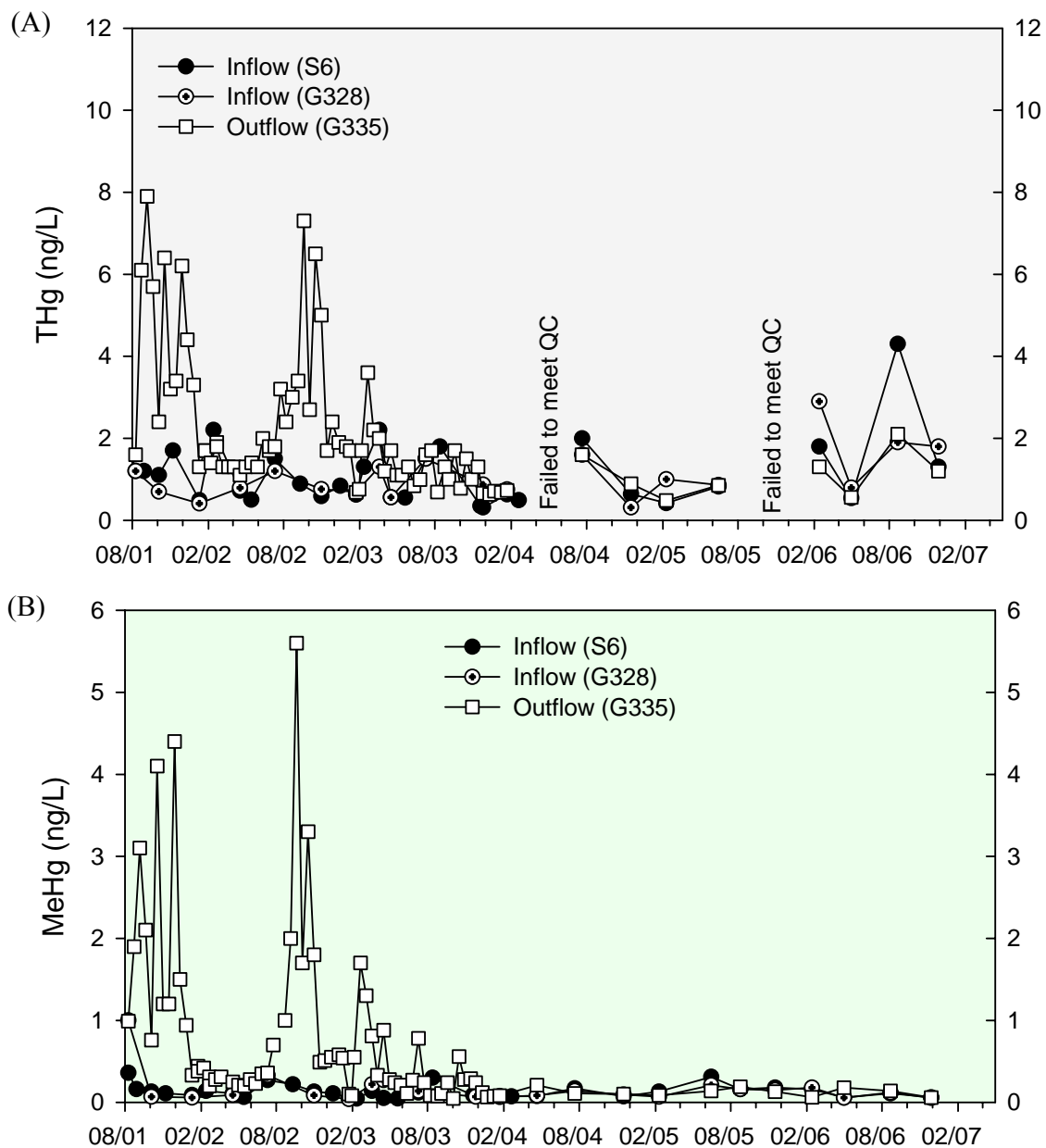


Figure 18. Concentrations of (A) THg and (B) MeHg (ng/L) in unfiltered surface water collected at STA-2, including routine and expanded sampling.

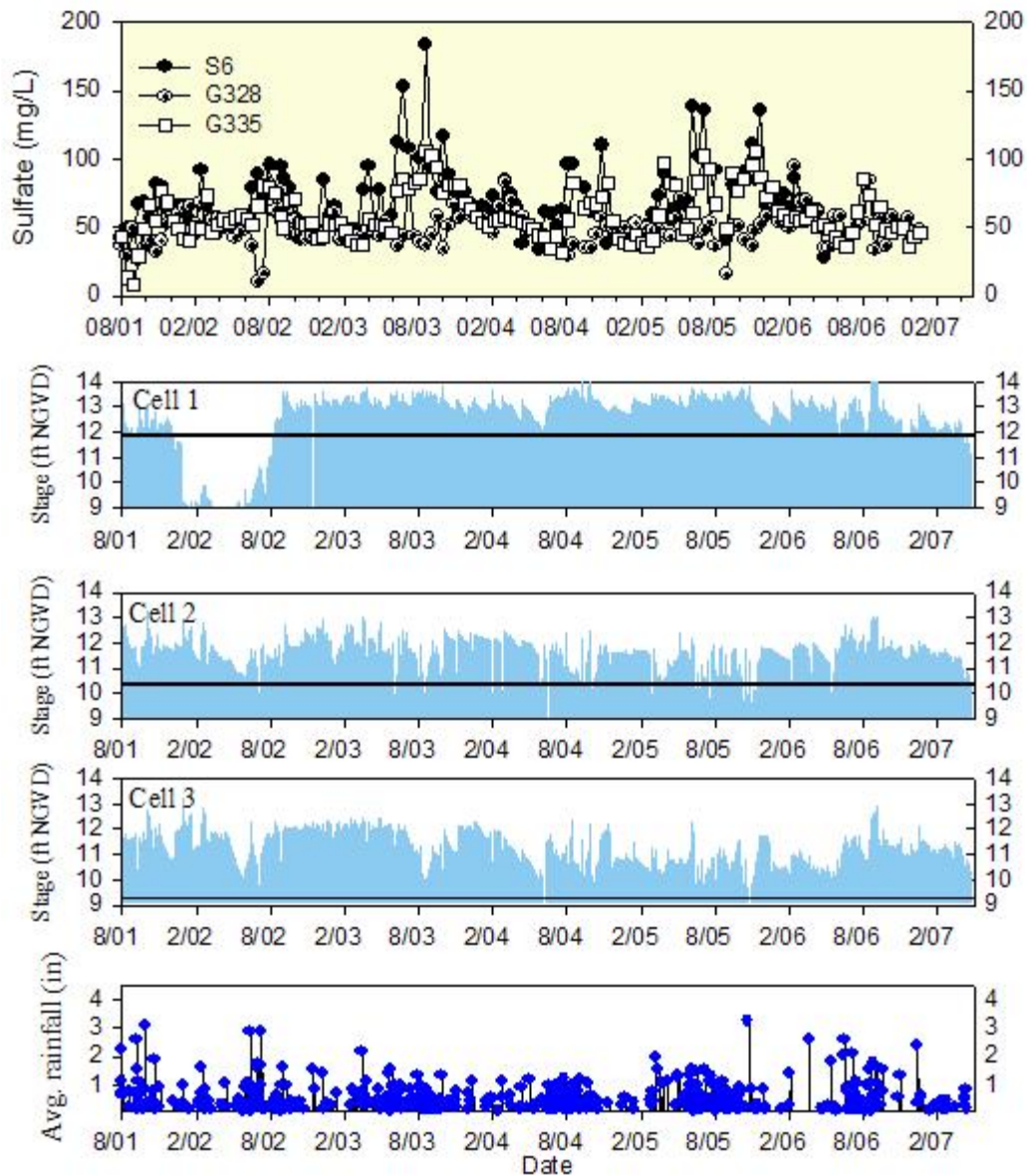


Figure 19. Water-column sulfate, stage (recorded immediately upstream of outflow culvert of cell), and rainfall totals at STA-2.

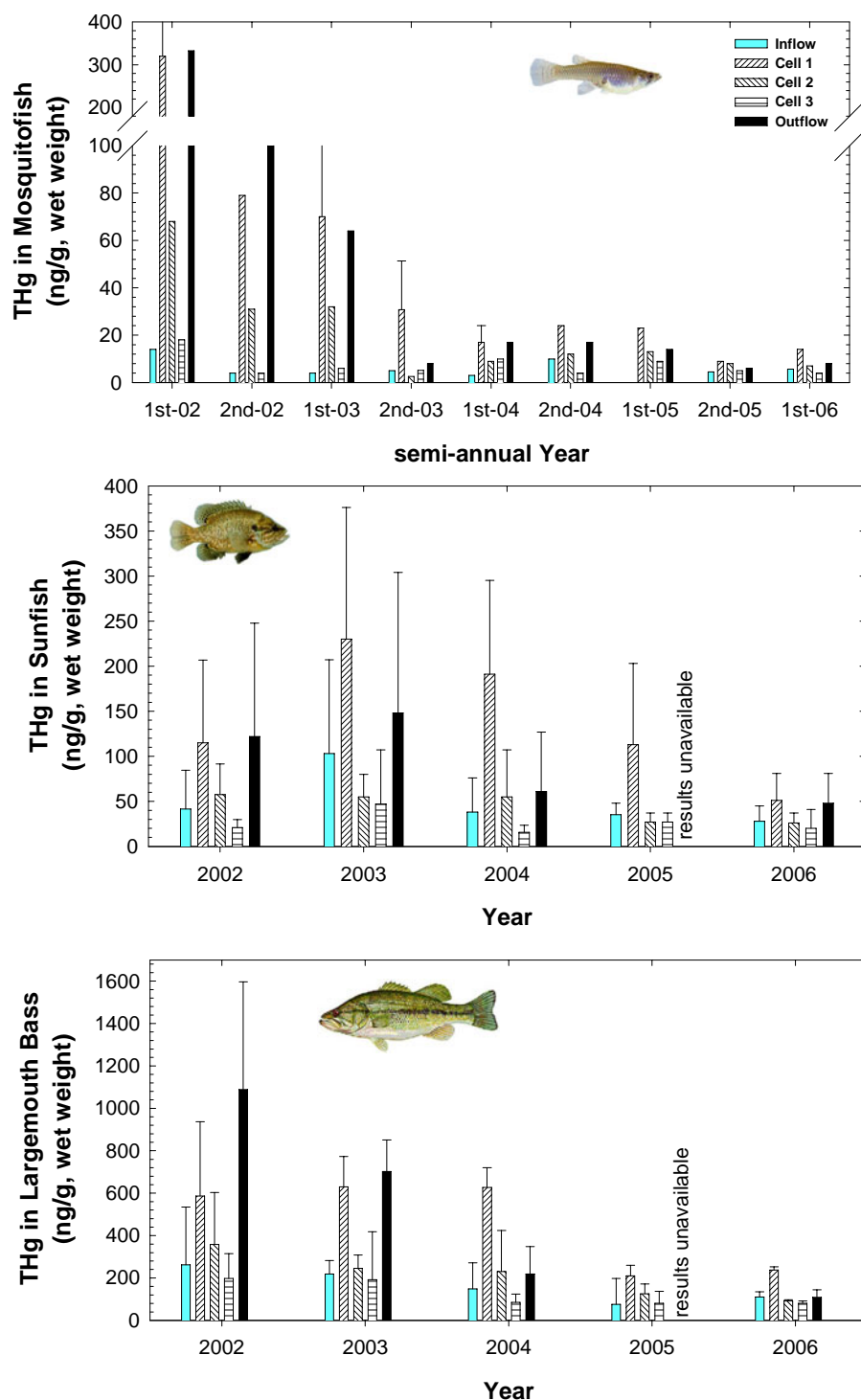


Figure 20. Mercury concentrations (ng/g, wet weight) in (*top*) mosquitofish composites (+range), (*middle*) whole sunfish (\pm SD), and (*bottom*) fillets of largemouth bass (\pm 95 percent C.I. or, if arithmetic, SD) collected at STA-2. Arithmetic means are noted by an asterisk.

STA-3/4

STA-3/4 Cell 1 satisfied start-up criteria for mercury in January 2004; the first discharges of treated water from this STA were in February 2004. Accordingly, routine operational monitoring of this flow-way began during the first quarter of 2004. STA-3/4 Cell 3 satisfied start-up criteria for mercury in June 2004; Cell 2 in August 2004, with consensus from FDEP in September 2004, at which time discharges began (for discussion of results observed prior to 2005, see Rumbold et al., 2006).

Results from monitoring mercury concentrations in surface water at STA-3/4 (**Figure 21**) show THg concentrations were fairly low and uniform during WY2007. At no time during 2006 did THg concentration at any of the individual outflows of STA-3/4 exceed the Class III WQS of 12 ng/L. In addition, outflow loads of THg and MeHg were much lower than inflow (Figures 12 and 13). Concentrations of MeHg were more highly variable among structures and occasionally concentrations in one or more of the outflows exceeded inflow concentrations. Inspection of **Figure 21** reveals consistent differences in MeHg outflow concentration among the three flow-ways during the third quarter of 2006. In general, MeHg concentrations remained relatively low compared to levels observed during start-up. Sulfate concentrations in the inflows were uniform through WY2007 (**Figure 22**).

Results from operational monitoring of mercury concentrations in resident fish from STA-3/4 are summarized in **Tables 1, 2, and 3**, and in **Figure 23**. Levels were elevated compared to other STAs (**Table 1**). Mosquitofish from the discharge canal generally contained higher mercury levels than fish from the interior marshes and the supply canal (**Figure 23**). Currently, mosquitofish are collected at two outflow culverts from each flow-way.

Although mercury levels occasionally differed in mosquitofish collected at culverts from the same flow-way, one mosquitofish collection site could suffice for each flow-way, given the similarities. For example, in 2006, the percent difference in mosquitofish THg for the culverts discharging flow-way 1 (G376 B, E) was 37 percent, 29 percent for flow-way 2 (G379 D, B), and 45 percent for flow-way 3 (G381 B, E). The percent difference between Quality Control (QC) duplicate samples of mosquitofish (i.e., two composites of 100 fish each collected sequentially at the same site) ranged from 0 percent to 63 percent (For Quality Assurance (QA) review of mercury monitoring, see Appendix 3B-1 of this volume.), therefore demonstrating that further attempts to identify differences in mosquitofish levels between differing flow-way sites may be worth the effort since the percent difference between flow-way is within the analytical precision range.

Similar to mosquitofish, resident sunfish from the interior marshes of STA-3/4 contained mercury levels similar to or lower than fish at downstream sites (Appendix 3B-1 of this volume) but slightly elevated compared to fish from other STAs (**Table 2**). Average tissue concentration in sunfish for all flow-ways was 55 ± 33 ng/g (**Table 2**). However, among-cell differences were evident in bluegill. When normalized based on length (only between 178 and 24), bluegill from Cell 3 had an average concentration of 0.84 ng/g/mm, compared to 0.21 ng/g/mm in Cell 2.

An age-standardized three-year-old bass from STA-3/4 were in the middle range compared to all other STAs in 2006 (**Table 3**). Bass THg levels at outflow sites were higher than inflow and interior sites (**Table 3** and **Figure 23**). In 2005, age-standardized bass from interior sites ranged 485 ± 94 ng/g and 292 ± 28 ng/g for inflow (no age-standardized bass were calculated for the outflow because regression slopes were insignificant) which amounted to a 22 percent reduction from 2005 to 2006 for the interior and a 47 percent reduction for the inflow.

Regarding risk to fish-eating wildlife, mosquitofish from STA-3/4 contained mercury at concentrations lower than the USFWS (100 ng/g) and USEPA criterion (77 ng/g). While sunfish

from inflow marshes of STA-3/4 contained levels below the USFWS criteria, sunfish from the discharge canal and interior exceeded these criterion. After adjusting the arithmetic mean mercury concentrations in fillets to whole-body concentrations (whole-body THg concentration = $0.69 \times$ fillet THg; Lange et al., 1998) mercury levels in largemouth bass from inflow and interior marshes (means equal to 192 and 287 ng/g) were less than the USEPA predator protection criteria based on TL 4 fish (346 ng/g); however, were above this criterion for range concentrations within the outflow marshes (453 ± 23 ng/g). Therefore, fish-eating wildlife foraging preferentially at STA-3/4 would appear to have an overall moderate risk to mercury exposure.

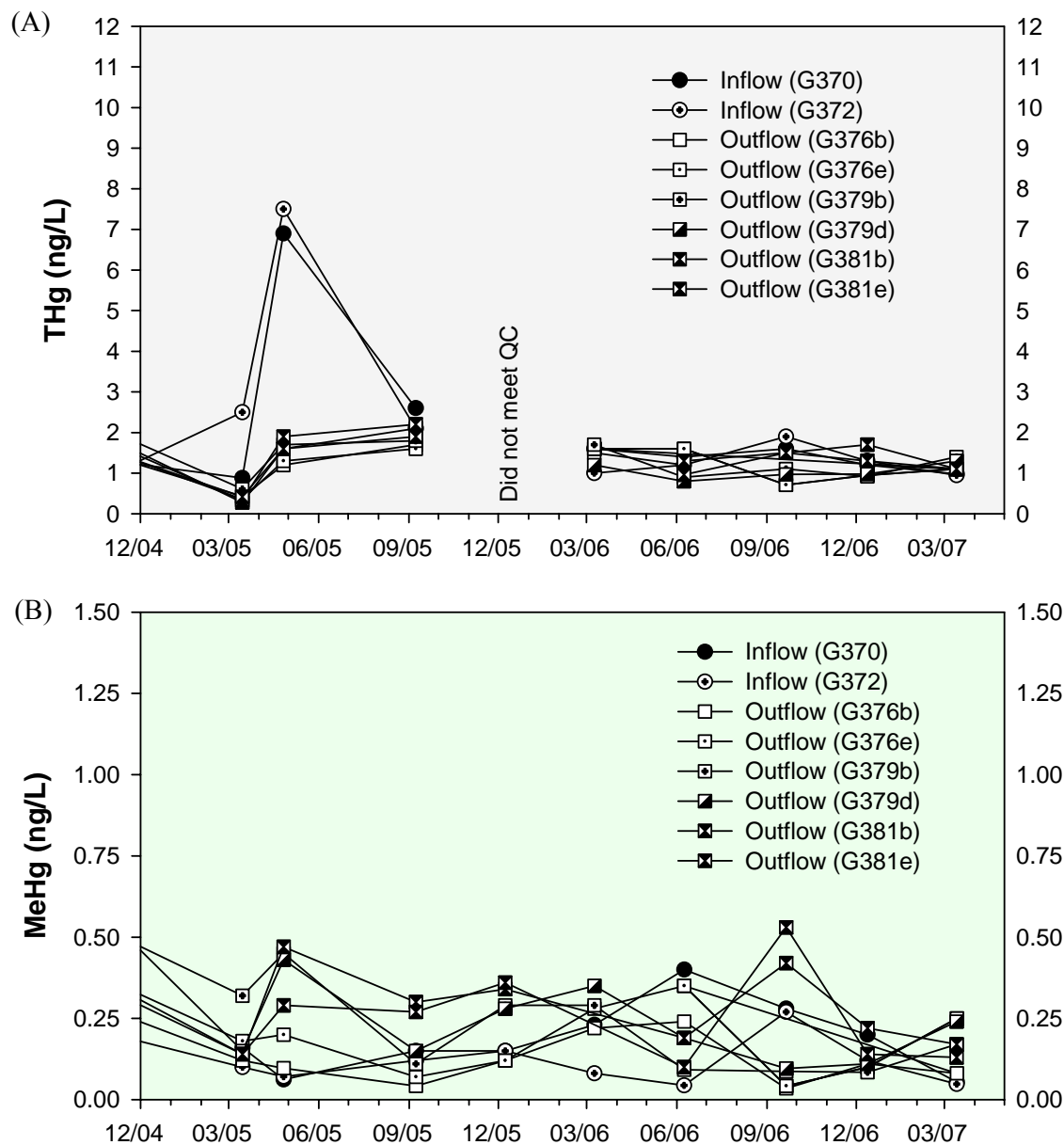


Figure 21. Concentrations of (A) THg and (B) MeHg (ng/L) in unfiltered surface water collected at STA-3/4, including results of start-up monitoring at inflows (i.e., prior to flow-through operation of all cells).

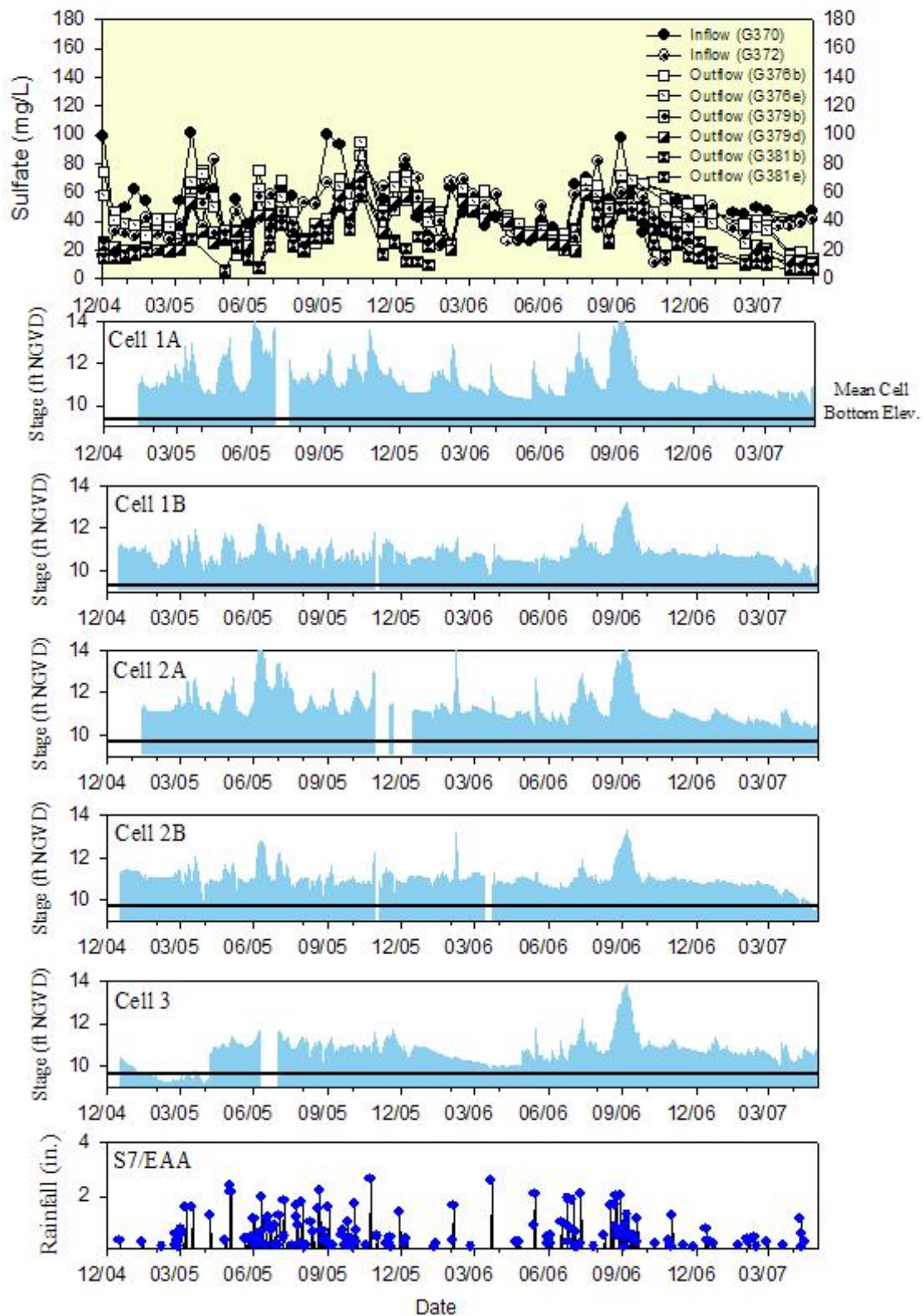


Figure 22. Water-column sulfate, stage (recorded immediately upstream of outflow culvert of cell), and rainfall at STA-3/4.

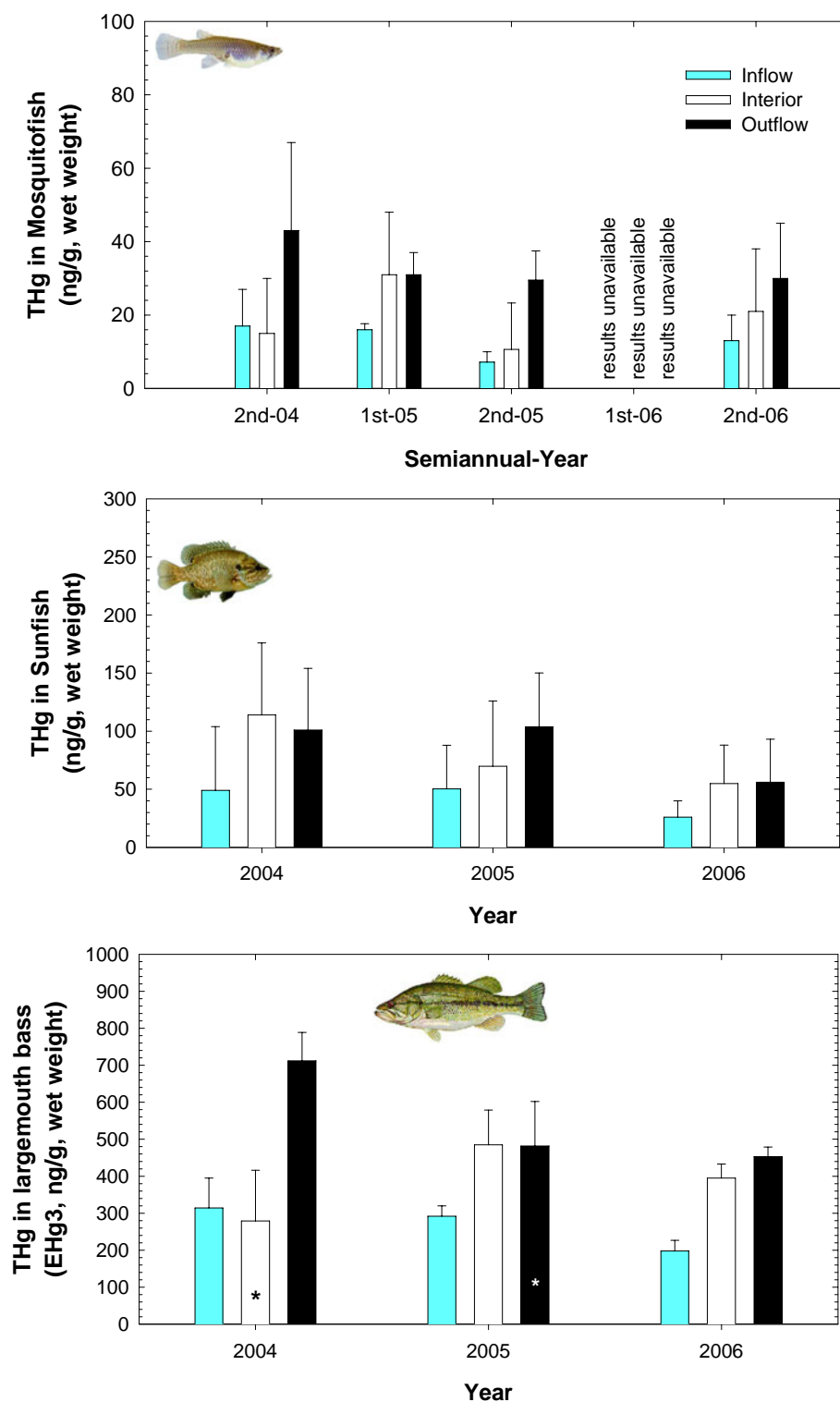


Figure 23. Mercury concentrations (ng/g, wet weight) in (*top*) mosquitofish composites (\pm SD), (*middle*) whole sunfish (\pm SD), and (*bottom*) fillets of largemouth bass (\pm 95 percent C.I. or, if arithmetic, SD) collected at STA-3/4. Arithmetic means are noted by an asterisk.

STA-5

STA-5 met start-up criteria for mercury in September 1999; however, because of drought conditions and the detection of high phosphorus concentrations at the outflows, STA-5 did not begin flow-through operation until July 2000 (for discussion of results observed prior to 2005, see Rumbold and Rawlik, 2000; Rumbold et al., 2001, 2006; Rumbold and Fink, 2002a, 2003a; Rumbold, 2004 and 2005a).

As shown in **Figure 24**, water-column concentrations of both THg and MeHg in WY2007 remained low at STA-5, with the exception of a few spikes in THg at the inflows during the fourth quarter of 2007. At no time during the reporting year did THg concentrations exceed the Class III WQS of 12 ng/L and outflow loads of THg and MeHg were lower than inflow. Overall, THg and MeHg loads have decreased appreciably since high levels were observed in 2001 and 2003; however, in the past two water years, THg levels have begun to rise at all inflows.

Mosquitofish collected from STA-5 in 2006 contained high mercury levels (**Figure 29**), compared to fish collected at other STAs (**Table 1**); however, were lower than fish collected from downstream marshes (Appendix 3B-1 of this volume). Mosquitofish from outflow were lower than fish from both the interior marshes and the supply canal which contrasts 2005

As in previous years, the Florida Fish and Wildlife Conservation Commission (FWC), under contract to the District to electroshock and collect large-bodied fishes for mercury monitoring, encountered difficulty in filling sample quotas for STA-5. For 2006, only eight sunfish were collected from interior marsh Cell 1B (**Tables 2 and 3**). Sunfish from the interior marshes contained mercury levels similar to or lower than concentrations observed in the past depending on the cell (**Figure 29**). As observed in many of the STAs, sunfish from the interior marshes in 2006 had lower mercury levels than fish from the supply and discharge canals, possibly due to greater predation by fish-eaters of fish in canals. From 2005 to 2006, there appears to be an evenly distributed decrease in THg at supply, interior marsh, and discharge locations. However, these differences may result from collected sunfish species varying from year to year. For example, in 2005, the predominant sunfish from STA-5's supply locations was bluegill, while in 2006, there was an even split between bluegill, redear, and spotted sunfishes. In previous consolidated reports, it has been demonstrated that sunfish species can play a part in THg accumulation, therefore these results should be viewed with caution. (See the 2007 *South Florida Environmental Report – Volume I*). Detailed evaluation of LMB from STA5 is difficult due to (1) lack of fish collected through the years and (2) lack of age-standardization. However, despite these drawbacks there does appear to be a decline since sample collection began in 1999.

Regarding the risk to fish-eating wildlife, resident sunfish and bass at STA-5 contained levels that were near, and in some cases above, the USFWS (100 ng/g) and USEPA criterion (77 ng/g for TL 3 and 346 ng/g for TL 4) for protection of predatory wildlife. These higher concentrations were observed particularly from supply and discharge locations. Therefore, fish-eating wildlife foraging preferentially from supply and discharge locations of STA-5 appear to be at moderate risk from mercury exposure; and at low risk if feeding from interior marsh sites.

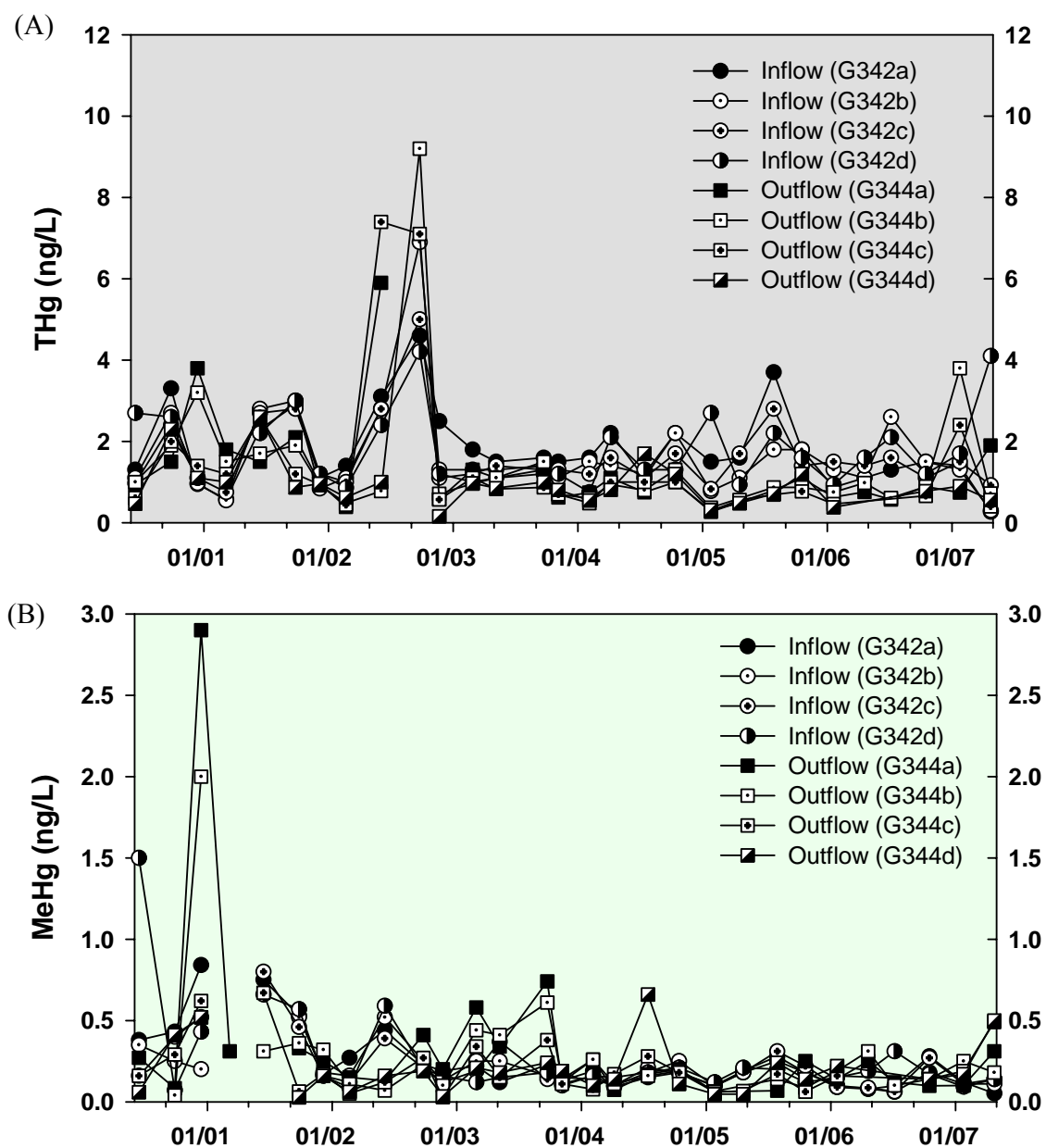


Figure 24. Concentrations of (A) THg and (B) MeHg (ng/L) in unfiltered surface water collected at STA-5.

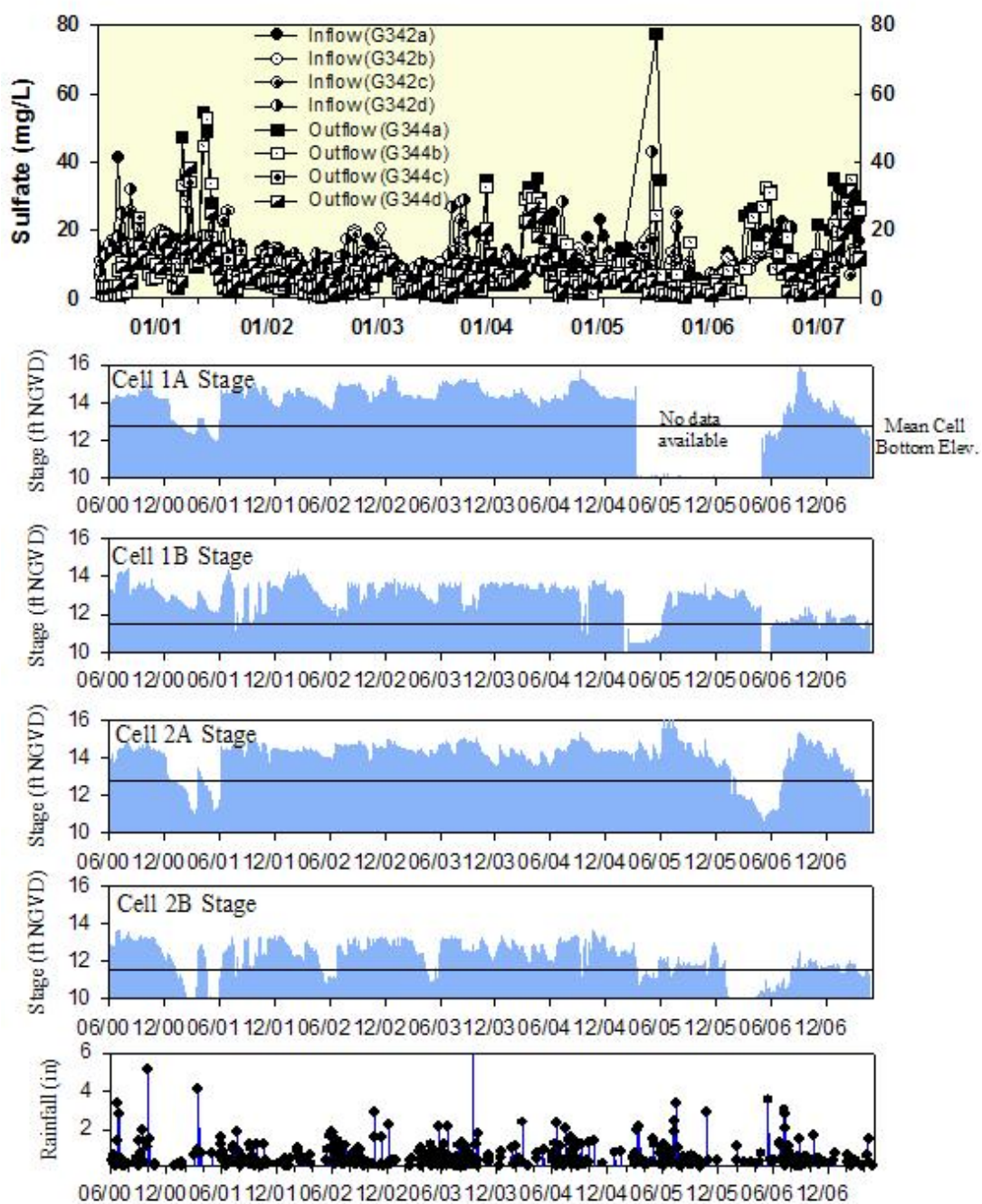


Figure 25. Water-column sulfate, stage, and rainfall at STA-5. In 2005, several structures were replaced, with a long delay in instrumentation installation.

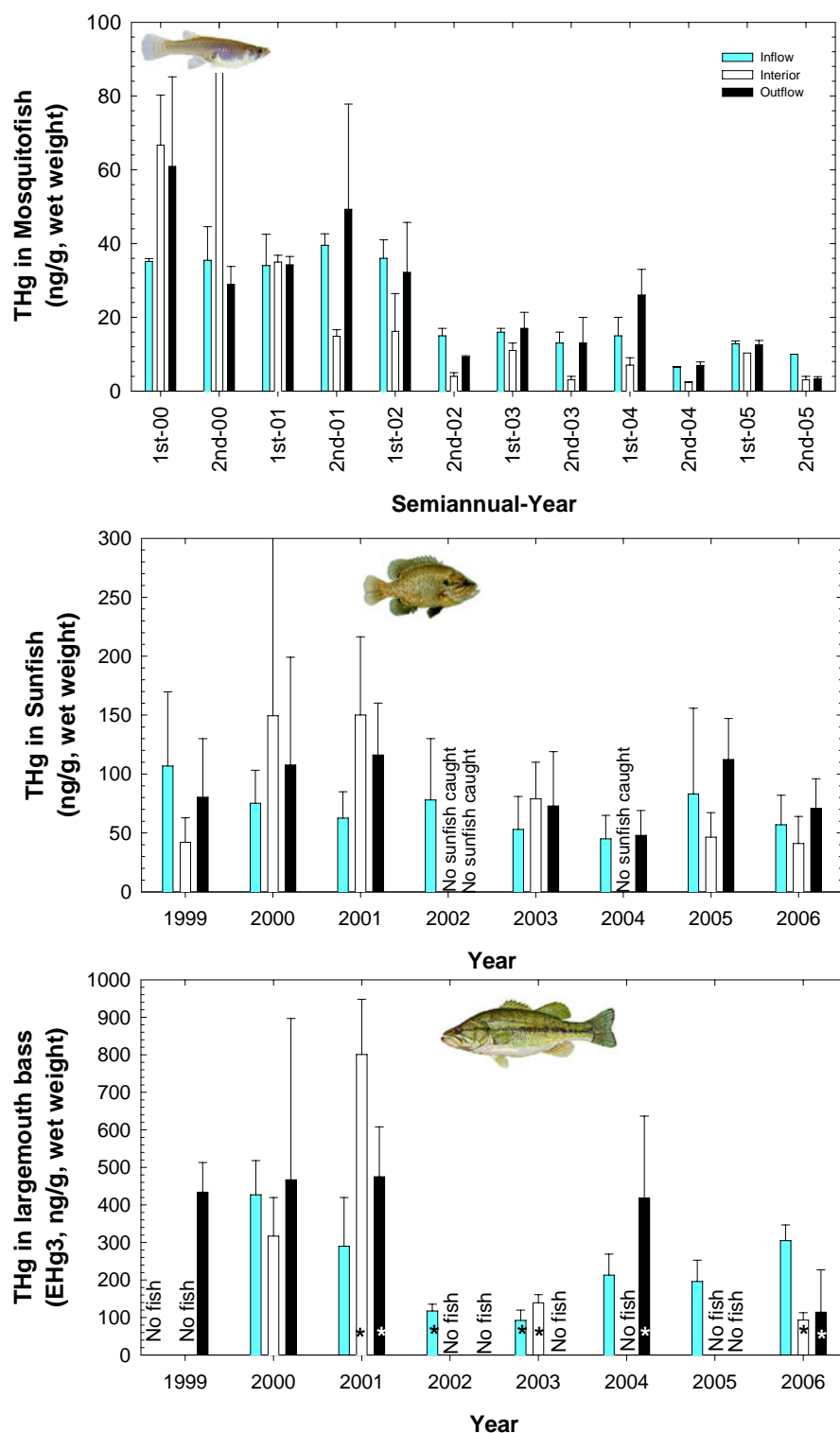


Figure 26. Mercury concentrations (ng/g, wet weight) in (*top*) mosquitofish composites (\pm range), (*middle*) whole sunfish (\pm SD), and (*bottom*) fillets of largemouth bass (\pm 95 percent C.I. or, if arithmetic, SD) collected at STA-5. Arithmetic means are noted by an asterisk.

STA-6

STA-6, Section 1 (Cells 3 and 5) met start-up criteria for mercury in November 1997, and began operation in December 1997. Routine monitoring of mercury at STA-6 was initiated in the first calendar quarter of 1998. Monitoring results prior to May 2004 have been reported (SFWMD, 1998c and 1999d; Rumbold and Rawlik, 2000; Rumbold et al., 2001; Rumbold and Fink, 2002a; Rumbold and Fink, 2003a; Rumbold, 2004 and 2005a; Rumbold et al., 2006).

As shown in **Figure 27**, THg concentrations at the inflows and outflows were nearly the same throughout WY2007, and remained relatively low compared to previous spikes. MeHg remained at very low concentration throughout the year as well. Outflow loads of THg and MeHg were also lower than inflow. Yet, as shown in **Figure 28**, both cells dried down during WY2007 for two periods lasting approximately 3 months each. Hence, the relatively low concentrations of both THg and MeHg in the outflows appear incongruous with hypotheses previously offered regarding dry-out and rewetting effects on sediment oxidation, sulfur biogeochemistry and stimulation of methylation by sulfate-reducing bacteria (Rumbold et al., 2006). Nonetheless, if a spike in MeHg production did occur (as in the past) following drydown and rewetting, and if it was environmentally significant, it would likely be evident in the levels of MeHg bioaccumulated in downstream fish and newly immigrated fish.

Concentrations of THg in mosquitofish are summarized in **Table 1** and are graphically presented in **Figure 29**. Levels of mercury in mosquitofish from STA-6 continue to be relatively low compared to fish collected previously from other STAs; levels spiked in fish from both the discharge and supply canals in October 2006. The spike in outflow and inflow fish may be related to the first dryout period from April to July (**Figure 28**). Because the semiannual (March and October) mosquitofish collection has the potential to miss transient spikes related to dryout, moving to quarterly collection of mosquitofish is recommended (see also the STA-1E section in this appendix).

As **Table 2** and **Figure 29** indicate, STA-6 sunfish for 2006 have mercury levels greater than those observed in sunfish at all other STAs, with the exception of locations within the Everglades and EPA downstream monitoring locations (Appendix 3B-1 of this volume). Visual inspection of **Figure 29** reveals a slight increase from 2006, particularly for discharge locations. However, closer examination of mercury levels in bass and bluegill normalized to age and fish length hints at the possibility that mercury concentrations were actually similar to last year, particularly for inflow sites and interior marshes. Young bass (i.e., ≤ 1.8 yrs old) in the inflow (only one that could be compared) contained 0.72 ng/g/mm in 2005 and 0.68 ng/g/mm in 2006. Bluegill in the interior (Cell 5) contained 0.49 ng/g/mm in 2005 and 0.81 ng/g/mm in 2006 (**Figure 17**) and 0.41 ng/g/mm in 2005 and 0.31 ng/g/mm in 2006. Mercury levels in bluegill in the discharge canal were nearly the same: 0.3 ng/g/mm in 2005 to 0.37 ng/g/mm in 2006. As previously discussed, during WY2007 there were two dry periods that lasted from April to July and one from January to May 2007 (**Figure 28**). In WY2006 there was one dry period during the month of March that lasted only half as long as the dry periods in WY2007. In 2006 the interior marsh sunfish had nearly double the Hg in sunfish from the previous water year, which may have resulted from the biogeochemical processes associated with the dryout and rewetting. However this cannot be confirmed since the sampling periods (October) were distant from the inception and ending of the dry periods. In addition canal fish are typically impacted by factors beyond interior marshes i.e. invasion from outer areas (Appendix 3B-1 of last year). Consequently, it is not clear whether the dry out played a role in altering mercury levels in the large fish in the discharge canal. Nonetheless, it is reasonable to assume that the dryout and rewetting in 2006 produced a spike in MeHg production similar to what has been observed in past. It is also reasonable to assume that annual pulses of MeHg maintain higher tissue-Hg levels in these fish.

Regarding risk to fish-eating wildlife, mercury levels in mosquitofish, sunfish, and largemouth bass (whole-body concentration estimated from fillet concentration) from STA-6 were at or below the USFWS (100 ng/g) and USEPA (77 ng/g, 346 ng/g for TL 4 fish) predator protection criteria depending upon the location. Sunfish and largemouth bass within discharge locations exceeded both criteria. Therefore, the risk of mercury exposure to fish-eating wildlife foraging preferentially at discharge locations within STA-6 appear to have a moderate risk of mercury exposure.

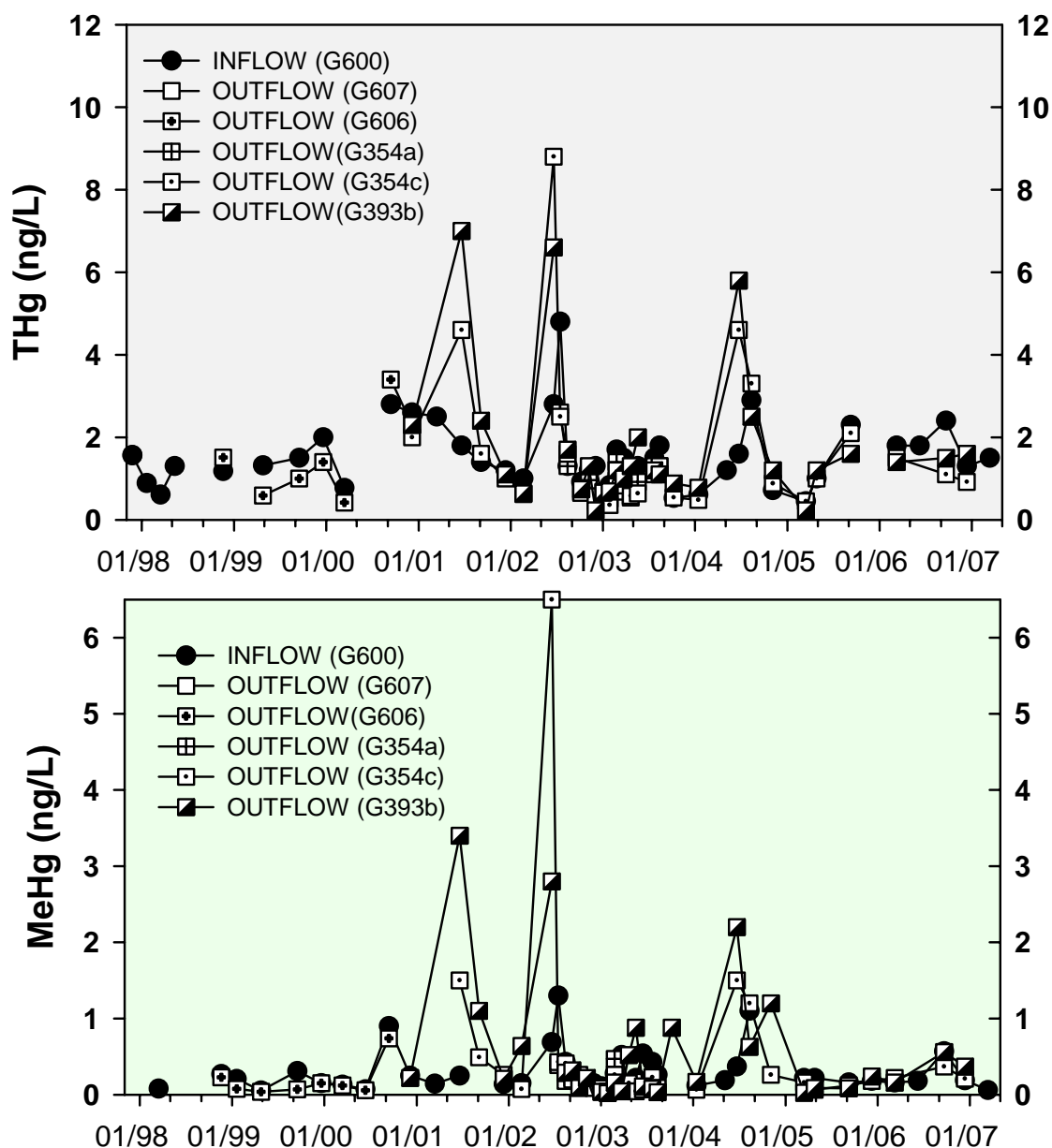


Figure 27. Concentrations of (A) THg and (B) MeHg (ng/L) in unfiltered surface water collected at STA-6, including results from routine and expanded sampling.

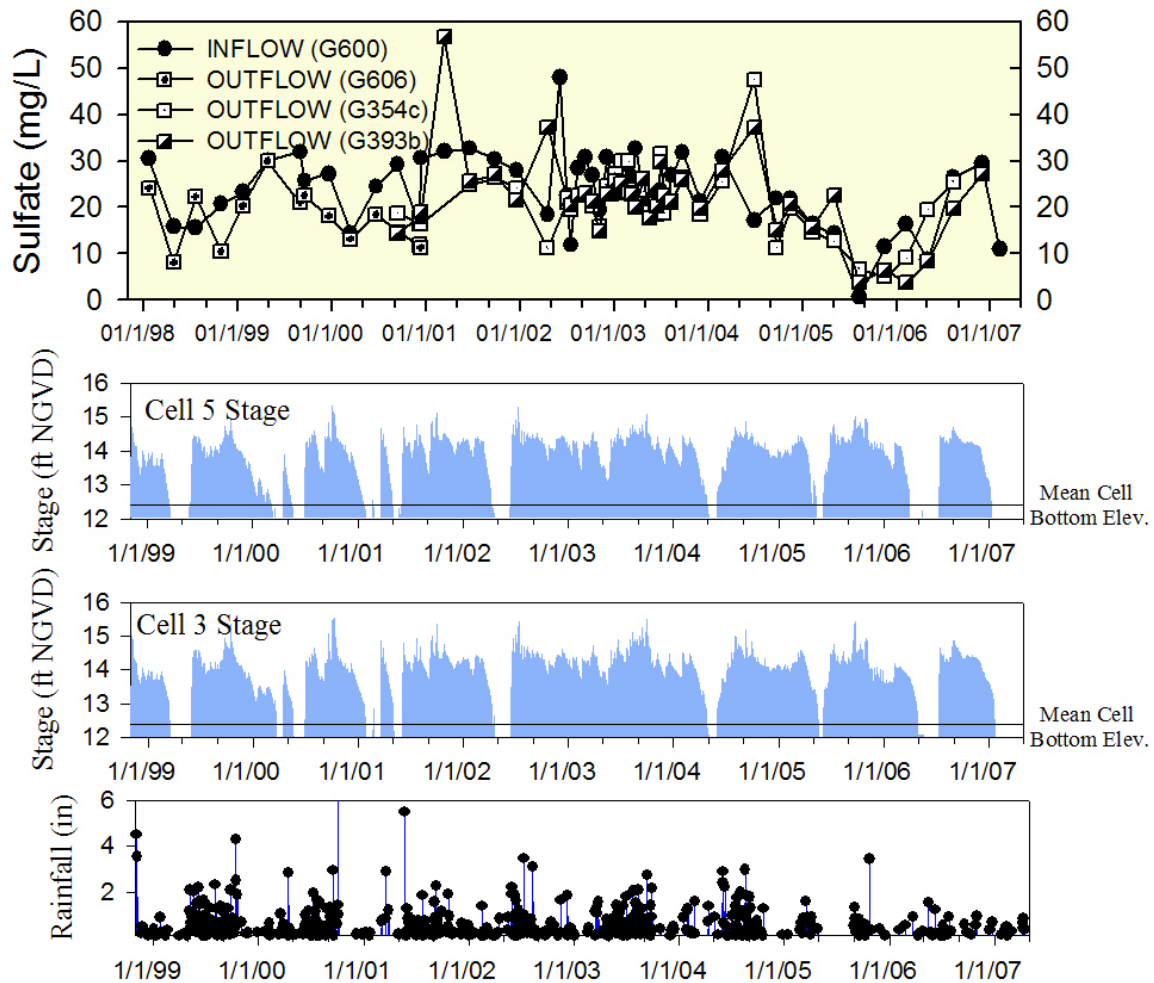


Figure 28. Concentrations of sulfate (*top*), stage in the two cells (recorded immediately upstream of outflow culvert of cell), and rainfall at STA-6.

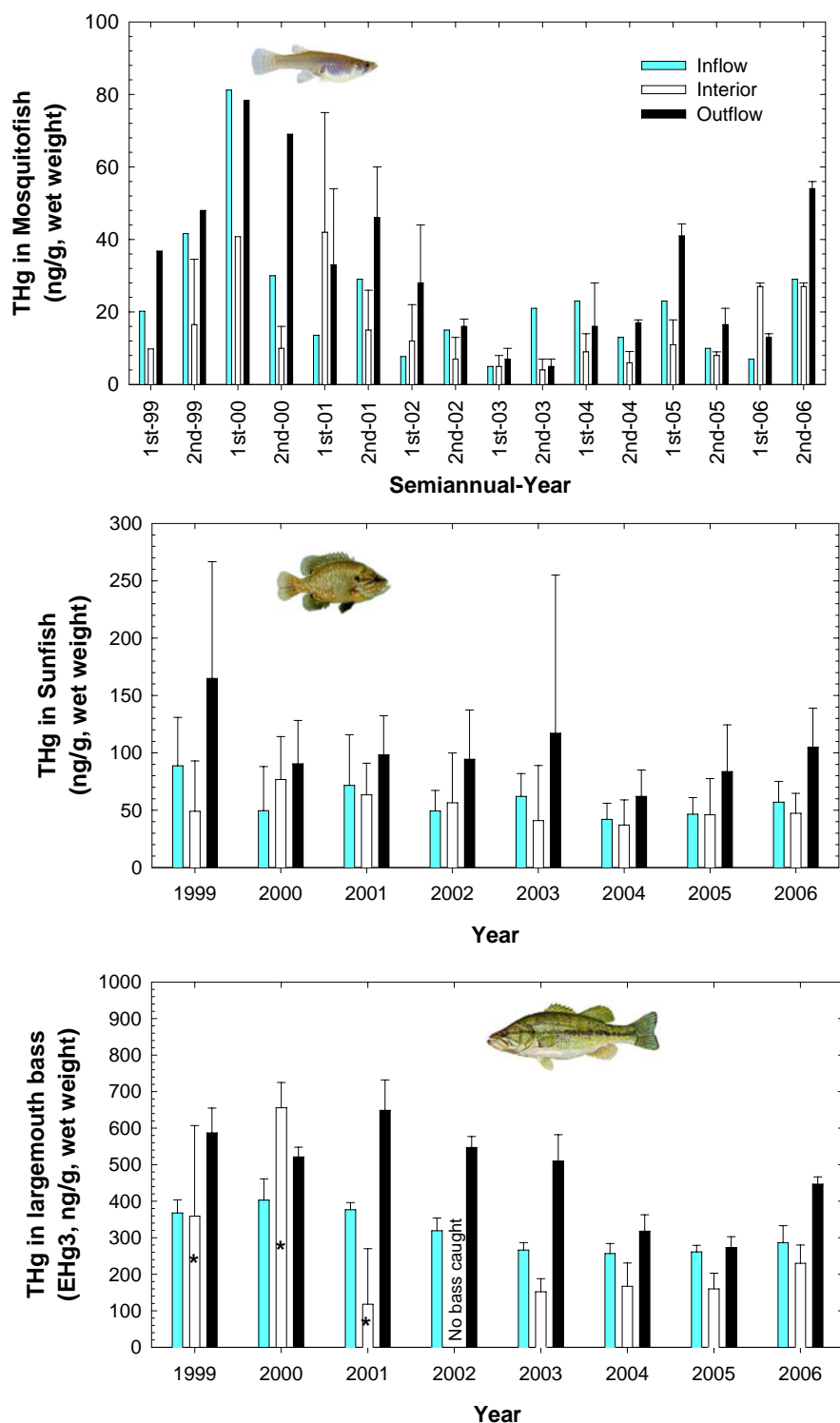


Figure 29. Mercury concentrations (ng/g, wet weight) in (*top*) mosquitofish composites (+range), (*middle*) whole sunfish (\pm SD), and (*bottom*) fillets of largemouth bass (\pm 95 percent C.I. or, if arithmetic, SD) collected at STA-6. Arithmetic means are noted by an asterisk

OPPORTUNITIES FOR OPTIMIZING THE MONITORING NETWORK

A key component of any monitoring program is regular reevaluation of objectives and methods to more sharply focus available finite resources. The monitoring plan should be revisited regularly to see if improvements, such as use of a different data collection method or a revised sampling regime can be implemented without compromising the quality of the data stream while continuing to meet the program's objectives. In early 2005, a Strategic Plan was drafted to optimize the District's Mercury Monitoring Plan (Rumbold, 2005b). The recommendations below follow from that strategic plan and are based on guidance contained in "A Protocol for Monitoring Mercury and Other Toxicants" (adapted from Rumbold and Pfeuffer, 2005; signed by both the FDEP and the District in February 2006; hereafter referred to as the Protocol).

STA-1W

Data summarized above and elsewhere (in justification document written by D. Rumbold, SFWMD, and submitted to the FDEP for support of Revised Monitoring Plan, dated January 24, 2006) for STA-1W demonstrate that it has met criteria contained in the Protocol that allow monitoring of certain media to ramp down.

The Protocol states:

If after the first three years of monitoring neither downstream loading nor residue levels in fishes has exceeded action levels in the preceding two years, then (1) surface water sampling would be discontinued, (2) frequency of mosquitofish collection would be reduced to semiannually, and (3) frequency of large-bodied fish collection would be reduced to one collection event every three years. If not met within the first three years, criteria would be re-evaluated annually based on preceding two-year period.

For detail on the actions levels referenced above, refer to the Protocol document (Rumbold and Pfeuffer, 2005).

STA-1E

Because STA-1E was only recently completed and because its monitoring plan was already consistent with guidance contained in the Protocol, only minor clarifications were recommended during the early permit renewal process (see the plan dated April 27, 2006). On September 25, 2007 the newly constructed Eastern Flow-way passed start-up criteria for mercury.

STA-2

The District is constructing a new western flow-way, Cell 4, in STA-2. Based on the current status of the new western flow-way, initial performance of the other three flow-ways (summarized here) and the guidance contained in the Protocol, the District submitted a revised plan in May 2006, that continues to monitor inflows and outflows. This plan revises the start-up protocols for the new cell and frequency of fish collections to be consistent with the Protocol. On July 19, 2007, Cell 4 passed start-up criteria for mercury.

STA-3/4

Operation of STA-3/4 has been monitored for four years and thus has met the time requirement contained in the Protocol. Thus, current data will be evaluated to determine if monitoring can be moved into Phase 3, as described in the Protocol.

STA-5 AND STA-6

The District has constructed new flow-ways in both STA-5 and STA-6. On September 11, 2007 Cell 2 of STA-6 passed start-up criteria for mercury. During the permit renewal process, efforts will be made to revise each mercury monitoring plan consistent with guidance contained in the Protocol, especially as it relates to frequency of mosquitofish collection, numbers of large-bodied fish and re-location of current sampling site within the discharge canal to a near-field, downstream site.

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