HYDROLOGY OF A FORESTED WETLAND COMPLEX IN AN URBANIZING AREA OF THE TEXAS GULF COAST AND CLEAN WATER ACT IMPLICATIONS

A Thesis

by

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ABSTRACT

Swales in wetland complexes can provide evidence of hydrologic connectivity for wetlands on the Texas Gulf Coast, supporting the idea that many coastal wetlands in Texas are vitally connected to navigable waters covered by the Clean Water Act. In this study, runoff that accounted for more than 18% of rainfall was observed from a representative "isolated" wetland complex—wetland depressions and upland areas interconnected by shallow erosional features—southeast of Houston, Texas between March 2005 and April 2010. Annual runoff ranged from 0% in 2005 to 27% in 2007. This result was surprising, given the presumably isolated nature of the wetlands.

The wetland complex was predominantly forested, with emergent vegetation dominating some of the depressions. Measured hydrologic fluxes included: (1) rainfall, using a tipping-bucket rain gauge supplemented with official weather station data; (2) surface runoff, using a v-notch weir to measure discharge from a wetland swale; (3) transpiration of *Quercus nigra* (18.0 cm diameter) and *Quercus pagodafolia* (15.9 cm diameter) using the heat-dissipation sap flux method; (4) groundwater level changes, using piezometers, and (5) soil moisture changes, using soil moisture probes. Watershed-scale evapotranspiration was estimated using the Hargreaves model. Surface runoff, although intermittent, occurred during 25 of 57 months. Monthly runoff ranged from 0% of rainfall to 57% of rainfall. Soil moisture loss trended with increased transpiration rates, where the *Q. nigra* specimen transpired 11.6 to 35.8 L d^{-1} and *Q. pagodafolia* specimen transpired 2.43 to 13.8 L d^{-1}. Moisture was depleted rapidly in the upper soil layer, emphasizing the importance of considering local weather patterns when identifying wetlands and making jurisdictional decisions.

The results of this study call into question regulatory presumptions about coastal plains wetlands (at least 400,000 ha in Texas alone), of which roughly 50% are considered geographically isolated. One way to improve implementation of federal rules for wetlands similar to those in this study, which are reasonably close to both navigable and non-navigable streams, is for regulatory agencies to determine whether the wetlands are adjacent to a navigable water before making other decisions that would lead to a presumption that significant nexus does not exist.

DEDICATION

This work is dedicated to the citizens of the State of Texas and to all who will benefit from the research presented here.

ACKNOWLEDGEMENTS

To my wife, Kendra, and to our family—thank you for all that you are and for your encouragement in bringing this research to where it is today.

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CHAPTER I

INTRODUCTION, LITERATURE REVIEW, AND GOALS*

This thesis addresses whether existing regulatory policies for implementing the Clean Water Act match the current scientific knowledge of wetland hydrology. Specifically, small swales and similar erosional features in a wetland complex provide prima facie evidence of the hydrologic connectivity necessary to justify Clean Water Act jurisdiction for wetlands on the Texas Gulf Coast. This thesis also addresses improvements needed to ensure that regulatory agencies are implementing the Clean Water Act in a way that is true to the law's purpose and the public interest. Specifically, a sequential decision-making process—beginning with the decision that would most readily identify nexus and ending with the decision that would least readily identify nexus— will eliminate heuristics (rules of thumb and other mental shortcuts) that produce variability in decision-making, leading to more accurate and consistent jurisdictional determinations.

This study was motivated by uncertainty about how the Clean Water Act should be implemented. The Clean Water Act amendments passed in 1972 rewrote the United States policy toward the quality of U.S. waters, with the specific objective of restoring and maintaining the physical, chemical, and biological integrity of the nation's waterways (33 U.S.C. 1251 §101, 2002). Congress set aggressive goals that exhibited a high level of commitment to meeting the Clean Water Act's objective. Specifically,

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* Portions of this chapter are reprinted or adapted from *Wetlands*, vol. 31, 2011, pp. 451-458, Evidence of surface connectivity for Texas Gulf Coast depressional wetlands, Bradford P. Wilcox, Dex D. Dean, John S. Jacob, and Andrew Sipocz, with consent of the authors and with kind permission from Springer Science and Business Media.

Congress expected the nation's waterways to be fishable and swimmable by 1983 and discharges of pollutants into navigable waters to be eliminated by 1985 (33 U.S.C. 1251 §101, 2002).

A major Clean Water Act issue in Texas today is the rate of wetland losses on the Texas Gulf Coast. For example, approximately 13% of wetlands that existed in Harris County in 1992 were no longer present in 2002 (Jacob and Lopez 2005). This staggering rate of loss is a Clean Water Act issue because wetlands have well-documented functions, such as pollutant trapping, that play a critical role in maintaining the water quality of streams and other waters (Mitsch and Gosselink 2000).

In Texas, a huge portion of the public interest in wetland functions related to water quality rests solely in the hands of two federal agencies. This means that the public ultimately bears more risk if the federal agencies fail to safeguard and support the public's interests. In many other states, wetland conservation policies for public lands help to preserve the water quality functions that wetlands provide. However, wetland conservation policies for public lands do not make much of an impact in Texas, where approximately 97% of the land is privately owned. Additionally, several other states have laws that compel freshwater wetland conservation on private property—for example, Maryland's Non-Tidal Wetlands Act requires permitting of all activities in or near non-tidal wetlands, unless specifically exempted by the state (McNeer 1992), and Wisconsin's Act 6 requires state water quality certification of all non-federal wetlands (Environmental Law Institute 2008). Texas does not have specific wetland conservation laws for wetlands on private property, instead relying on Clean Water Act § 401 water quality certifications of federal permit applications and on state-level outreach programs like the Galveston Bay Estuary Program.

For Texans and their public interests, all of this amounts to a crucial need for an effective Clean Water Act § 404 permitting program that produces consistent and reliable decisions based on the best available knowledge. Clean Water Act § 404 permits regulate the discharge of pollutants, more specifically dredged or fill material, into waters of the United States. A Clean Water Act § 404 permit must be obtained before a wetland can be filled if the wetland is considered a water of the United States. Clean Water Act § 404 permitting does not guarantee wetland preservation, but it does require a permit applicant to consider all feasible alternatives and to mitigate impacts when wetland destruction is unavoidable.

However, uncertainty about which wetlands are within jurisdiction of the Clean Water Act is a hurdle to effective Clean Water Act § 404 permitting. Some of the uncertainty can be traced back to 2001, when the United States Supreme Court considered whether the Clean Water Act applied to isolated wetlands in the case *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers* (*SWANCC*) (Downing et al. 2003). The main upshot of the Supreme Court's opinion was that the Clean Water Act is about the integrity of the nation's waterways (Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers 2001) — *not* migratory birds or interstate commerce. The court's opinion also caused the United States Army Corps of Engineers and the Environmental Protection Agency to question whether 33 Code of Federal Regulations (CFR) § 328.3(a) could still be used to assert Clean Water Act jurisdiction (United States Government Accountability Office 2005). In 33 CFR § 328.3(a), the Corps of Engineers defined "waters of the United States" to include almost any water, including wetlands, that could be used in or have an effect on interstate or foreign commerce, presumably based on language Congress used in the text of the Clean Water Act (see Clean Water Act § 404(g)(1)). Despite additional case law, two proposed rulemakings, and joint guidance from the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers, the question of the Clean Water Act's reach remains unsettled today.

The main problem presented by this legal uncertainty is that isolated wetlands—wetlands that are presumed not to affect the physical, chemical, or biological integrity of the nation's waterways in any substantial way—can be drained or filled at will without a permit application. In other words, there is no review that considers the public interest and no opportunity to voice concerns about public impacts.

A recent inventory of isolated wetlands in the United States estimated that about 50% of wetlands on the Texas Coastal Plain were geographically isolated (Tiner 2002, 2003). But what if these presumably isolated wetlands are not really isolated? What if, in fact, many of these so-called "isolated" wetlands actually affect public waters, where people fish and swim? In that case, should the public have a say about the acceptable level of impacts? Determining whether "isolated" wetlands are actually connected to downstream waters hits at the heart of the issue that federal regulatory agencies and the courts have been struggling with: specifically, how to define the scope of the Clean Water Act for non-navigable streams and adjacent wetlands.

Literature Review

Post-SWANNC wetland science

In an effort to build knowledge for sound policy development, the September 2003 issue of the journal *Wetlands* became the foundational scientific conversation about isolated wetlands and the Clean Water Act. Wetland scientists from the U.S. Environmental Protection Agency identified specific research needs in the issue's closing article (Leibowitz and Nadeau 2003), including:

1. fundamental wetland process studies, particularly hydrology;
2. rapid land assessment method development;
3. nation-wide geographic extent studies;
4. impact estimates for wetland loss; and
5. studies that compare isolated wetlands to other wetland and non-wetland ecosystems.

Substantial and important progress has been made in response to the September 2003 *Wetlands* issue on land assessment methods (e.g. Smith et al. 1995, Johnson 2005, Reif et al. 2009, Lane and D'Amico 2010), nation-wide wetland extent (*see* the National Wetlands Inventory, U.S. Fish and Wildlife Service, available at http://www.fws.gov/wetlands), and impacts of wetland loss (e.g. Tiner 2005, Zedler and Kercher 2005, Ringeval et al. 2010, McCauley et al. 2013). Hydrologic studies have also been conducted across North America (e.g. Hayashi et al. 2004, Lu et al. 2006, Harder et al. 2007, Wu and A Johnston 2008). However, relatively few wetland hydrology studies have focused on urban or urbanizing environments, and even fewer have enjoyed the widespread attention given to the research on wetlands loss, ecosystem services, and rapid assessment methods. A study by Stander and Ehrenfeld (2009) underscored the importance of basic hydrology research by concluding that the popular hydrogeomorphic rapid assessment method (see Smith et al. 1995) does not effectively predict basic wetland functions or useful wetland reference sites in an urban setting and suggested that year-long hydrologic characterizations are indispensable for understanding wetland processes in both urban and non-urban settings. In response to the research needs identified by the U.S. Environmental Protection Agency's scientists in 2003, the study reported in this thesis examines the fundamental hydrology of a forested freshwater wetland complex on the Upper Texas Gulf Coast using the kind of year-long hydrologic characterization that Stander and Ehernfeld promote. For additional context, the hydrology of the study wetlands was compared to that of a nearby urbanized watershed, to Texas streams in general, and to major global water balances.

Texas coastal wetlands

A few scientists have made significant contributions that are specifically related to wetlands on the Texas Gulf Coast. Moulton et al. (1997) reported on the status and distribution of coastal wetlands in Texas. They also quantified and categorized wetland

land use changes between 1955 and 1992. Jacob and Lopez (2005) employed a rapid assessment method to provide a better understanding of recent wetland trends in the Lower Galveston Bay watershed.

In a 2008 article, researchers from Texas A&M University provided insight from a landscape and urban planning perspective, specifically contributing to the understanding of patterns for Clean Water Act § 404 permits issued in Texas (Brody et al.). They examined the record of issued permits by permit type, wetland type, year, and location between 1991 and 2003. The most typical permits issued during their study period were nationwide permits for development projects, located outside of the 100-year floodplain, and near an urbanized area. The researchers involved in the study also correlated permit issuance to flooding (Brody et al. 2007) but noted study limitations that substantially restricted confidence in causation.

In one of the most comprehensive reports to date on the functions of wetlands on the Texas Gulf Coast, researchers from Baylor university linked rapid GIS assessment methods with wetland functional assessment models, hydrologic models, and water quality models (Forbes et al. 2009, Forbes et al. 2010, Enwright et al. 2011, Forbes et al. 2012). This series of studies determined that freshwater wetlands on the Upper Texas Gulf Coast are highly effective at removing inorganic nitrogen, inorganic phosphorus, and other oxygen-demanding organic materials. The studies also determined that these wetlands are moderately effective at removing organic nitrogen, phosphorus, and heavy metals.

Though their cumulative work was a significant step forward for understanding coastal wetlands in Texas, the research from Baylor University did not clearly settle the issue of connectivity versus isolation between coastal wetlands in Texas and downstream waters, which became increasingly important after the U.S. Supreme Court issued its opinion for the *Rapanos et ux., et al. v. United States* case in 2006. During the time after the *Rapanos* case went before the Supreme Court, the idea of "significant nexus" emerged as perhaps the most important legal concept for wetlands jurisdiction (Murphy 2007). A critical question in terms of wetland jurisdiction and regulation under the Clean Water Act is the nature of the connection to receiving water bodies: is the connection significant enough to affect "the chemical, physical, and biological integrity of the nation's waters"—the maintenance of which is the purpose of the Clean Water Act (33 U.S.C. §§ 1251–1387) (Wilcox et al. 2011)? In fact, the Environmental Protection Agency's scientists suggested that relationships between precipitation and runoff could be used to predict which watersheds have significant nexus to waters of the United States (see Leibowitz et al. 2008). As a result, the study reported in this thesis directly addresses the question of nexus by examining hydrologic connectivity of the study wetlands to downstream waters using rainfall and runoff relationships.

Study Goals and Expectations

The presence of surface or shallow subsurface connections is an essential requirement for significant nexus to exist in Clean Water Act evaluations (Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers 2001). The other essential requirement is an effect on the physical, chemical, or biological characteristics of a waterway, which Forbes and her colleagues already documented for Texas coastal wetlands. Because surface or shallow subsurface connections are an essential component of nexus, the primary scientific goals of this study were to:

1. determine whether forested wetlands on the Upper Texas Gulf Coast form surface connections to navigable waterways; and
2. determine whether forested wetlands on the Upper Texas Gulf Coast form direct shallow subsurface connections to navigable waterways.

Wetlands in the area are considered closed systems from a regulatory perspective. The federal agencies that oversee implementation of the Clean Water Act identified surface and shallow subsurface connections as the pathways for hydrologic nexus (USEPA and USACE 2008). For surface nexus to exist, rainfall from the wetlands and swales must flow out of the watershed as surface runoff.

Hypothesis 1:	Surface runoff from the wetlands and swales occurs in amounts that are quantifiable using a reasonably available water measurement technology.
Null Hypothesis 1:	Surface runoff from the wetlands and swales does not occur in amounts that are quantifiable using a reasonably available water measurement technology.

To demonstrate that subsurface nexus to exists, water that infiltrates in the watershed must flow into a waterway that is covered by the Clean Water Act. For the purposes of this thesis, groundwater nexus will be confirmed if the predominant direction of groundwater flow is within ± 45 degrees of the shortest path to Armand Bayou.

Hypothesis 2: Groundwater flows predominantly within ± 45 degrees from the shortest path to Armand Bayou (~243 ± 45 degrees).

Null Hypothesis 2: Groundwater does not flow predominantly within ± 45 degrees from the shortest flow path to Armand Bayou (~243 ± 45 degrees).

If nexus exists, then more detailed information about the near-surface hydrology could prove useful for predicting nexus in other landscapes. Therefore, secondary scientific goals of this study were related to collecting observational information on hydrologic processes including:

1. precipitation;
2. surface runoff;
3. evapotranspiration;
4. groundwater movement and storage; and
5. near-surface soil moisture.

Original expectations, based on allegory and initial observation of the study area, were that both surface and near-surface groundwater connections were likely to occur. The allegorical evidence indicated that the wetlands in the study area were seasonally wet, especially after prolonged rainfall, but not always during the same season of the year. The wetlands were usually, though not always, dry during the spring and summer. Physical evidence in the watershed indicated that surface runoff probably occurred with some regularity. The watershed contained a complex of wetland depressions, separated by uplands, with small swales connecting the wetland depressions and an intermittent stream channel downslope. Though swales do not have the bed and banks that are characteristic of streams, the location of the swales has remained fairly constant throughout recent memory, providing evidence that flow concentrates in the same places year after year. Near-surface groundwater was expected to flow in a reasonably direct path from the wetlands to the navigable bayou.

Because this research is linked to policy development, additional goals of this research are to:

1. bring important knowledge of the Clean Water Act, federal rules, and guidance on wetland regulation back into the scientific and popular dialog;
2. explain how heuristics made inconsistent Clean Water Act implementation possible; and

3. propose a process that will improve consistency of Clean Water Act implementation by eliminating opportunities for the use of heuristics.

Study Area

Landscape context

The landscape context of the study watershed is representative of many wetlands on the Texas Gulf Coast, making it an ideal test case to determine if surface or near surface connectivity is likely to exist for other wetlands along the Texas Gulf Coast. The study watershed exhibits the flat terrain and shallow wetlands depressions that typically occur on the Texas Coastal Plain, which can make it especially difficult to identify wetlands and their connections to waters of the United States in the field during drier periods of the year. The Texas Coastal Plain is a 30,000-km^2 depositional plain located along the Gulf of Mexico. The area is characterized by very poorly drained and seasonally waterlogged soils and a lack of incised channels (Sipocz 2005). Freshwater palustrine wetlands at one time covered more than one-third of the landscape. A recent inventory of isolated wetlands in the United States estimated that about 50% of wetlands on the Texas Coastal Plain were geographically isolated (Tiner 2002, 2003). Others, however, have argued on the basis of aerial imagery analysis that these wetlands are in fact connected to major waterways through intermittent and generally unmapped channel networks (Jacob and Lopez 2005; Sipocz 2005).

This study took place in a watershed located on the Beaumont geologic formation, a Pleistocene-age fluvial-deltaic deposit common on the Texas Coastal Plain (Blum and

Aslan 2006). Most of the wetlands on this formation took shape in meander scars or other fluvial features of the ancestral rivers that laid down the formation. Many of the soils in the vicinity of the study site are characteristic of meander scars and shifting river berms, according the soil series descriptions in the Natural Resources Conservation Service web soil survey. The undisturbed surface of the Beaumont geologic formation does not typically show strong visible evidence of a naturally integrated drainage system. At first glance, and especially during dry periods, it can be difficult to identify outlets from the wetland depressions. However, closer inspection reveals numerous shallow swales between depressions (FIG. 1) that often coalesce before flowing to a watercourse. The overall pattern is a complex mosaic of depressions, surrounding wetlands, and small non-wetland hillocks (known locally as a pothole–pimple-mound complex) which occurs in both forested and prairie landscapes (Moulton and Jacob 2000; Sipocz 2005).

Location

The coastal flatwoods wetland used in this study, like many forested wetlands in the United States, is situated on the margins of a growing metropolitan area. The study watershed is located southeast of Houston, Texas at the Armand Bayou Nature Center. Located along the banks of Mud Lake and Taylor Lake in Harris County, the Armand Bayou Nature Center is surrounded by a host of distinctive land uses, with the Clear Lake Oilfield to the north, chemical refineries and the Bayport Ship Channel to the north and to the east, residential and commercial development to the south and to the east, the Lyndon B. Johnson Space Center to the southwest, the University of Houston Clear Lake

Campus to the west, and mixed-density residential development in the City of Houston to the north and to west (USGS 1998a, b, c, d).

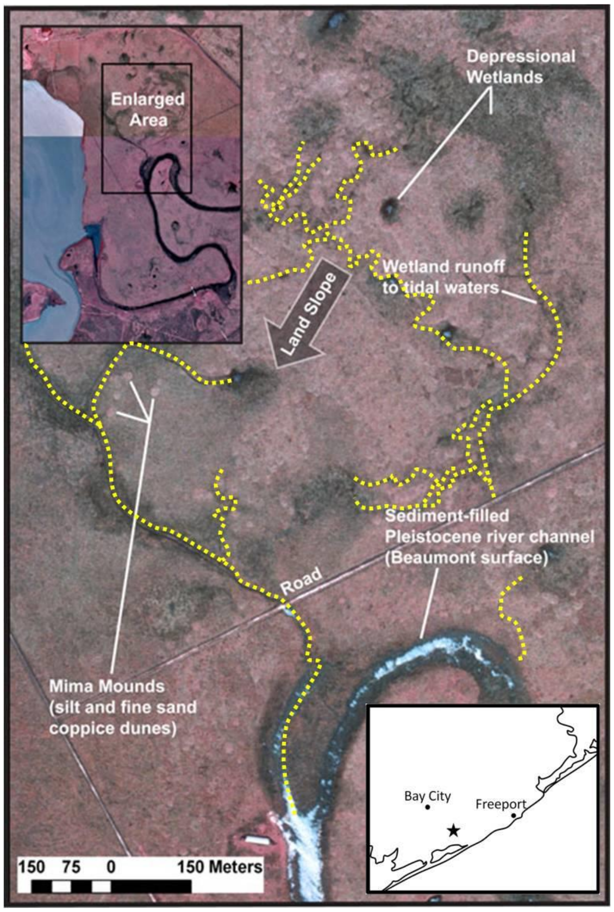

Fig. 1. Color infrared aerial photo highlighting typical features of depressional wetlands on the Texas Gulf Coast. *Adapted from Wilcox et al. (2011)*. This image is of the Lake Austin estuary adjacent to the Matagorda Bay. The area is underlain by the same Beaumont Coastal Terrace geologic formation as the Armand Bayou study site; however, it is located on an unforested prairie where wetland and runoff patterns are readily visible from the air. Lighter shaded areas correspond to growing vegetation on drier lands and darker areas correspond to senesced vegetation in wetlands. Open water is blue or white. Three paleo-river tributaries are visible as drainages, with the most recent being well-defined and tidal in its lower reach (discernible natural drainages are highlighted using dotted lines). Wind-deflated wetland basins similar to the study site, which overflow into the drainage swales, are carved from the lighter textured channel and levee soils.

The study watershed (FIG. 2) is part of a pothole–pimple mound complex in a riparian forest adjacent to a large prairie. The watershed is slightly larger than 8 ha (20 ac) and lies just outside the 100-year floodplain of the bayou. About 25% of the watershed consists of wetland depressions having emergent herbaceous vegetation; these depressions are interspersed with transitional flats and forested upland mounds.

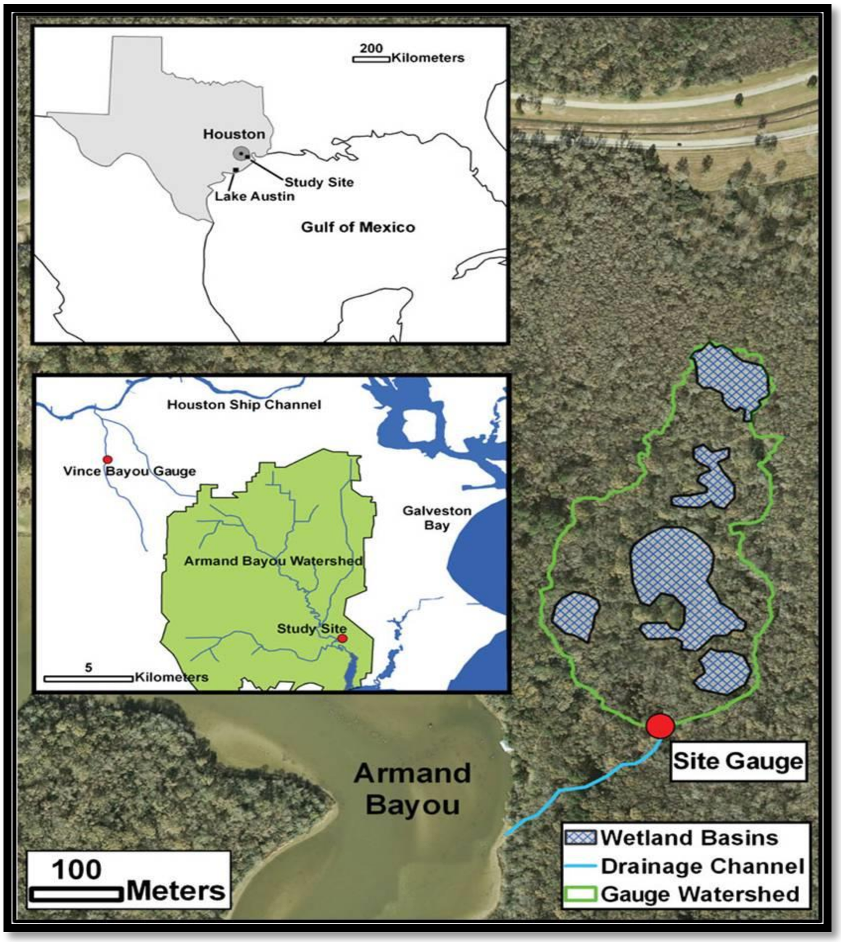

Fig. 2. Study watershed location and boundaries. ***From Wilcox et al. (2011).*** **The study watershed outlet is represented by the large dot at the intersection of the watershed boundary and the drainage channel. Hatched shapes represent wetland basins (depressions). Insets show the study site's general location (top) and its location within the Armand Bayou watershed (bottom).**

The study watershed is mapped as Verland silty clay loam (fine, smectitic, hyperthermic Chromic Vertic Epiaqualfs, see http://soils.usda.gov/survey/online_surveys/texas/). Our observations suggest most of the soil in the watershed is significantly wetter than what is described for the Verland series. Depressions were not mapped separately from the surrounding soils, but they likely correspond to the Leton series (fine-silty, siliceous, superactive, hyperthermic Typic Glossaqualfs), which is commonly mapped in similar depressions in the area. The typical profile for a Verland soil is 18 cm of silty clay loam over clay to about 2 m. It is listed on the Web Soil Survey with a moderately low saturated hydraulic conductivity (K_{sat}) class (0.2877 µm s^{-1} for the entire profile). The Leton typical profile is 30 cm of loam over clay loam to about 150 cm, with a listed K_{sat} of 2.6 µm s^{-1} for the entire profile. The depressional Leton soil, at least in this area, has a substantially lower K_{sat} than a typical Verland soil.

Saturation appears to occur from the top down, as indicated by the "Epi" formative element in the taxonomic classification of the Verland soil series. Dry soil at less than 25 cm depth under a ponded surface was observed while boring wells during the study. These saturated surface soil conditions, with relatively shallow unsaturated soils below, can last for several months. Drainage features are quite subtle. The watershed's outlet swale—which becomes evident about 60 m from the center of the largest, farthest-downslope depression—is only about 2 m wide and 10 cm deep at its most distinctive point. Towards the base of the study watershed, a small incised channel has developed that drains into the nearby tidal Armand Bayou (for additional context, see FIG. 23 on page 77).

Climate

Average annual rainfall is 1,330 mm (Wheeler 1976). Snowfall is negligible and soil temperatures at a depth of 20 cm never drop below 4° C. The average temperature during the study period was 20º C (NOAA, Houston NWSO, 29°28′N/95°05′W, records available November 1990–present).

Vegetation

Willow oak (*Quercus phellos*), swamp red oak (*Quercus pagodafolia*), and water oak (*Quercus nigra*) are prominent tree species in the watershed. Common understory species include Chinese tallow (*Triadica sebufera* or *Sapium sebiferum*) and yaupon (*Ilex vomitoria*). Emergent species observed in the depressions include swamp smartweed (*Polygonum hydropiperoides*), finger dogshade (*Cynosciadium digitatum*), giant plume grass (*Saccharum giganteum*), sedges (*Carex spp*.), and palmetto (*Sabal minor*). For a more extensive list of species that are known to occur in the Armand Bayou watershed, see *Armand Bayou Watershed Plan*, Appendix J (Coastal Coordination Council et al. 2006).

CHAPTER II

WETLAND HYDROLOGY[*]

This study investigated the hydrology of a forested freshwater wetland complex on the Texas Gulf Coast from the spring of 2005 to the spring of 2010. Research from 2005 through 2009 focused on: (1) determining whether swales in the watershed form hydrologic connections between the wetland depressions and the jurisdictional waters downslope and (2) characterizing the relationship between precipitation and surface runoff. Further research during the spring of 2010 focused on: (1) determining whether groundwater flowed directly toward the adjacent bayou and (2) collecting observational information on hydrologic processes, including evapotranspiration, groundwater storage, and soil moisture storage.

Theory and Methods

Watershed delineation

Andrew Sipocz of the Texas Parks and Wildlife Department delineated the watershed boundary on February 15, 2007, using flags and a handheld GPS unit, while the watershed was saturated and runoff was occurring. According to his notes, most of the boundary was easily discernible, but in some instances flow direction was used to identify the watershed boundary.

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Survey

The site was surveyed using a total station (Leica Geosystems) to develop a common reference elevation for groundwater levels. Survey components included the weir, the groundwater monitoring well sites, and the bayou reference well. The survey also included the profile and cross sections of the main swale in the watershed and a partial survey of a tributary swale.

Hydrologic fluxes

Documentation of hydrologic fluxes in this study focused on the components of a simplified water balance, derived from the generalized water balance presented by Hornberger (1998), which is given by

$$P - R - ET - \Delta G - \Delta S = 0$$

where P = precipitation, R = surface runoff, ET = evapotranspiration, ΔG = the change in groundwater storage, and ΔS = the change in soil moisture (modified from Shen 2007). Many hydrology studies assume that all fluxes are uniform across a given area, such that a flux can be expressed as a depth of water. The uniform depth representation of water fluxes is used in this thesis unless other units are provided. This study also directly compares measured runoff and precipitation using a runoff ratio, where

$$Runoff\ Ratio = \frac{R}{P}.$$

Precipitation

Rainfall was measured with a tipping bucket rain gauge (Infinities USA) located in the largest wetland depression. Readings from the gauge were collected at 10 minute sampling intervals from March 31, 2005 until January 19, 2008, and at 20 minute intervals after January 19, 2008. Missing on-site measurements were supplemented with daily rainfall data from the weather station at the Houston National Weather Service Office whenever more than 20 percent of the on-site data was missing for a given day. The weather station at the Houston National Weather Service Office, located about 18 km south of the study area (Houston NWSO, 29°28′N/95°05′W, records available November 1990–present) is the nearest official National Climatic Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html) weather station that encompassed the full duration of the study.

Although the Houston NWSO weather station was the nearest official weather station that covered the study entire study period, the weather station at the nearby William P. Hobby Airport had a much longer period of record and was therefore used to estimate long-term average rainfall (29º39’N/95º17’W, records available November 1941 – present).

Runoff

Surface runoff (i.e. runoff, ground surface runoff) was measured at the watershed outlet to determine whether surface nexus exists. Runoff flowing through the outlet was measured using a 90º V-notch weir equipped with a sonar water-level recorder (Infinities

USA). The weir was located to measure surface runoff that flowed through the main swale in the wetland complex. Any water that flowed over the weir passed through a culvert and into an intermittent stream channel immediately downslope of the outlet (an intermittent channel is one that holds water during wet periods of the year but is periodically dry—Svec et al. 2005). The intermittent stream channel runs from the watershed outlet into Armand Bayou. All surface water appeared to flow into the wetland depressions or into the system of swales that interconnects the wetland depressions before discharging into the intermittent stream channel.

The water level at the weir was converted to runoff using the Kindsvater-Shen equation (USBR 1997), given by

$$Q = 2.47\, H^{5/2}$$

where Q = the discharge in cubic feet per second and H = the head on the weir in feet. Dividing the total volume of water per unit of time by the watershed area gives a depth of water per unit time. Readings from the water-level recorder were collected at 10 minute sampling intervals until January 19, 2008, at 20 minute intervals from January 19, 2008 until April 9, 2009, and at 30 minute intervals thereafter. There were occasional data gaps due to equipment problems. These data gaps were not filled. Most of the gaps were inconsequential because they occurred during the extremely dry conditions of 2005 and during other periods without substantial rainfall. However, 403 mm of rainfall coincided with a large data gap that spanned from February 18, 2009, through May 11,

2009. Moreover, ample antecedent moisture was present because 56 mm of rainfall fell during the week before the largest rainfall event in the missing data period. Therefore, runoff presented for 2009 is certainly a considerable underestimate.

Evapotranspiration

Two evapotranspiration methods were used in this study. The heat dissipation sap flux method (Granier 1985, Granier 1987) was used for individual tree specimens, and the Hargreaves method was used for watershed-scale evapotranspiration estimates. The theoretical basis for each method is discussed below.

Hargreaves method

The Penman-Monteith model is a widely-used and well-documented evapotranspiration model (Droogers and Allen 2002), but data availability prevented its application in this study. When critical Penman-Monteith data is not available, the United Nations Food and Agriculture Organization recommends the Hargreaves model (Kingston et al. 2009). The 1985 Hargreaves model was calibrated in the United States using precision lysimeters. The 1985 Hargreaves model demonstrated greater accuracy and flexibility, compared to other evapotranspiration methods that were available at the time (Hargreaves and Samani 1985). Hargreaves and Samani based their conclusions on precision lysimeter tests that were conducted on several different continents. Droogers and Allen (2002) compared evapotranspiration estimates using the Penman-Monteith and the Hargreaves methods worldwide, and their analysis did not show appreciable differences between the two methods in Texas.

The generalized Hargreaves equation is

$$ET = K_{ET} \times R_a \times TD^{0.5}(TC + 17.8)$$

where K_{ET} is an empirically derived coefficient taken to be 0.0023 in the 1985 Hargreaves equation, R_a = location-dependent average solar radiation at the top of the atmosphere for the time step in millimeters per day, TD = monthly mean maximum temperature minus monthly mean minimum temperature in degrees Celsius, and TC = the average temperature for the time step in degrees Celsius (Hargreaves and Samani 1985, Hargreaves and Allen 2003).

Hourly solar radiation data was obtained from the National Solar Radiation Database (Station 722436, Ellington Air Force Base, Houston, Texas). Daily temperature data was obtained from the nearest official National Climatic Data Center weather station (Houston NWSO, 29°28′N/95°05′W). Radiation data in watts per square meter was multiplied by a factor of 0.035 to convert to millimeters of equivalent evapotranspiration (Allen et al. 1998) for use with the Hargreaves model.

Sap flux method

This study measured transpiration from individual trees using the heat dissipation sap flux method (Granier 1987). The heat dissipation method allows empirical estimation of sap flux density. The empirical relationship for sap flux density was correlated using a variety of species (Granier 1985). Granier gives a thorough explanation of the theory in his works. The basic concept is that the rate of convective heat transfer to sap flowing in a tree is related to the actual flow rate of sap. This concept allowed Granier to relate the flow rate of sap to the temperature difference between a heated sensor and an unheated reference sensor. The reference sensor is located below the heated sensor to minimize interference with the reference temperature of the xylem. The mathematical basis for this method (Granier 1987) involves an empirically derived, dimensionless value K which is related to the temperature difference between the heated and reference sensors such that

$$K = \frac{\Delta T_M - \Delta T}{\Delta T}$$

where ΔT_M = the temperature difference between the sensors when there is no xylem flow, and ΔT = the temperature difference between the sensors when there is positive xylem flow. In his 1985 article, Granier demonstrated that trends in the value of K reasonably approximate trends in Penman potential evapotranspiration over the course of a day. Using the value K, xylem flow is calculated from the relationship

$$u = 119 \times 10^{-6} K^{1.231}$$

where u = xylem flow in meters per second. Total sap flow through the tree in cubic meters per second is calculated by multiplying the xylem flow by the total sap wood area. Sap flow values presented in this thesis were converted to liters per hour.

A selection of trees in the watershed was instrumented with sap flux sensors (see Granier 1985 for a sensor diagram). Data was collected at a 30 minute sampling interval to allow sub-daily analysis for a *Quercus pagodafolia* specimen (15.9 cm diameter, 0.017 m^2 sap wood area) and a *Quercus nigra* specimen (18.0 cm diameter, 0.024 m^2 sap wood area). The usable data extended from March 31, 2010 through April 14, 2010. The trees in this study were selected because (1) they were near the weir site and the largest wetland depression, (2) they represented common species in the watershed, and (3) they received good exposure to sunlight. Sensors (10 mm length) were installed in the xylem layer between the bark and the less active tissue of the inner trunk (see Granier 1987 for an installation diagram).The sensor zone on each tree was wrapped with reflective material to minimize thermal interference. Sensors were installed on the east and west sides of the selected trees to further minimize thermal differences between sensors.

Groundwater

Groundwater monitoring wells were installed so that the direction of groundwater flow in the watershed could be determined. Conclusively determining the direction of groundwater flow requires at least four wells—three for calculation, and one additional well to confirm whether the other wells are located in the same groundwater lens (Mathewson 2009). According to Mathewson, wells are located in the same groundwater lens only if the calculated groundwater flow direction is reasonably consistent between all three-well combinations within the same set. Three groundwater monitoring well sites and a bayou level reference well (FIG. 3 on page 27) were added to the watershed in January 2010. A fourth well site was added in June 2010. The wells were made from PVC well casing, with a 127 mm section of slotted screen installed at the bottom of each casing.

Each well site consisted of two wells. The shallow wells were installed to monitor perched water tables, which are top-saturated soil zones separated from the apparent water table by unsaturated soil. Deeper wells were installed to measure the true groundwater table elevation (FIG. 4 on page 28). Installing a deep and shallow well at each site also made it possible to observe whether the apparent groundwater table would interact with perched water tables in the watershed.

All holes for groundwater monitoring wells were bored using hand-powered soil augers. Auger heads used in this study included mud and sand heads with 63.5 millimeter diameters. The small gap between the bore hole and the well casing at each well was filled with the original material, which was layered to match the original profile and gently tamped. Sodium bentonite pellets were used to seal the borings to a depth of 0.31 meters from the surface. Each well casing was covered to prevent rainfall and debris from entering the well.

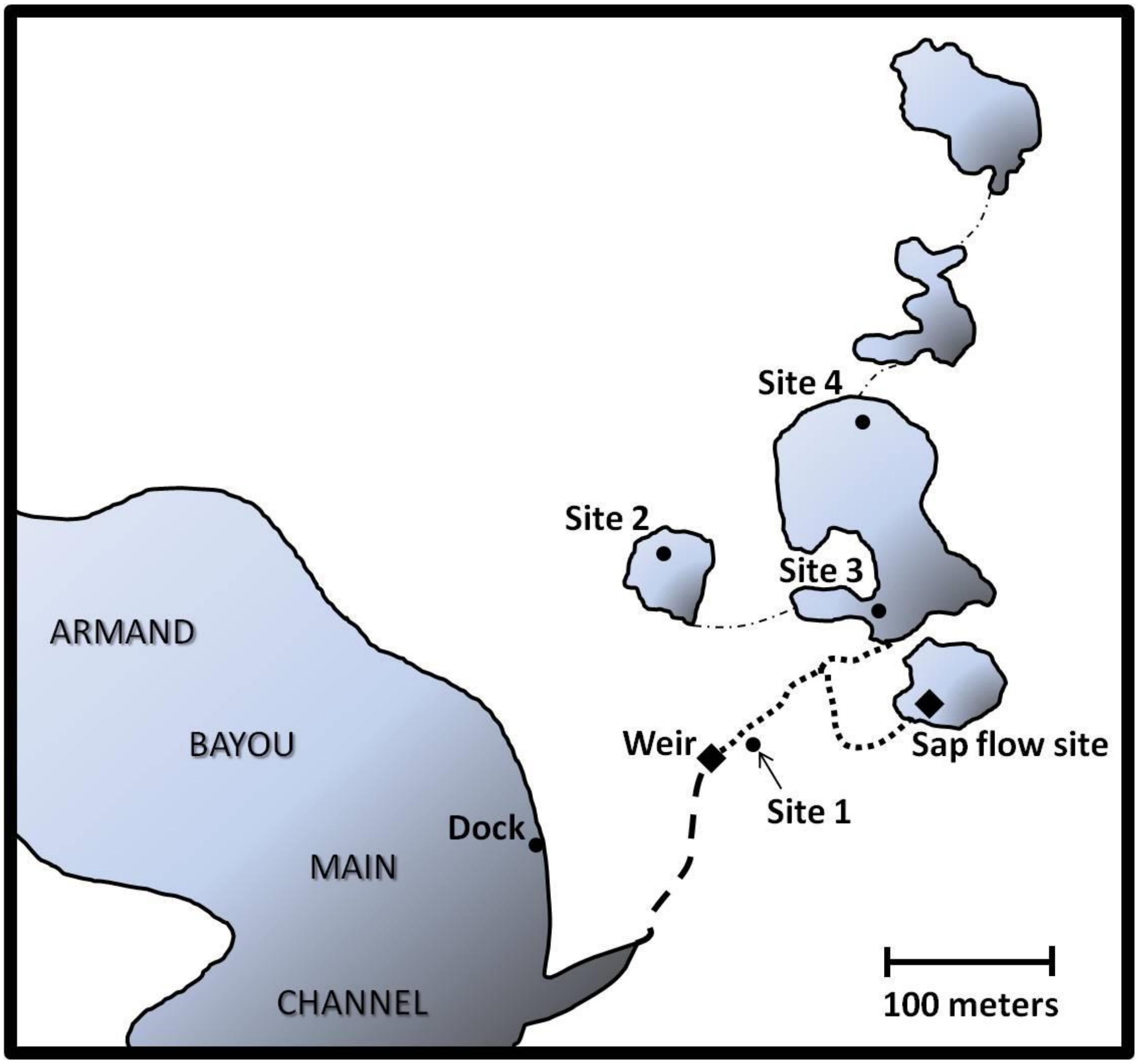


Fig. 3. Site locations of groundwater monitoring wells (Dock, Site 1, Site 2, Site 3, and Site 4). The relative positions of other important features, such as the weir and the sap flow site, are provided for reference.

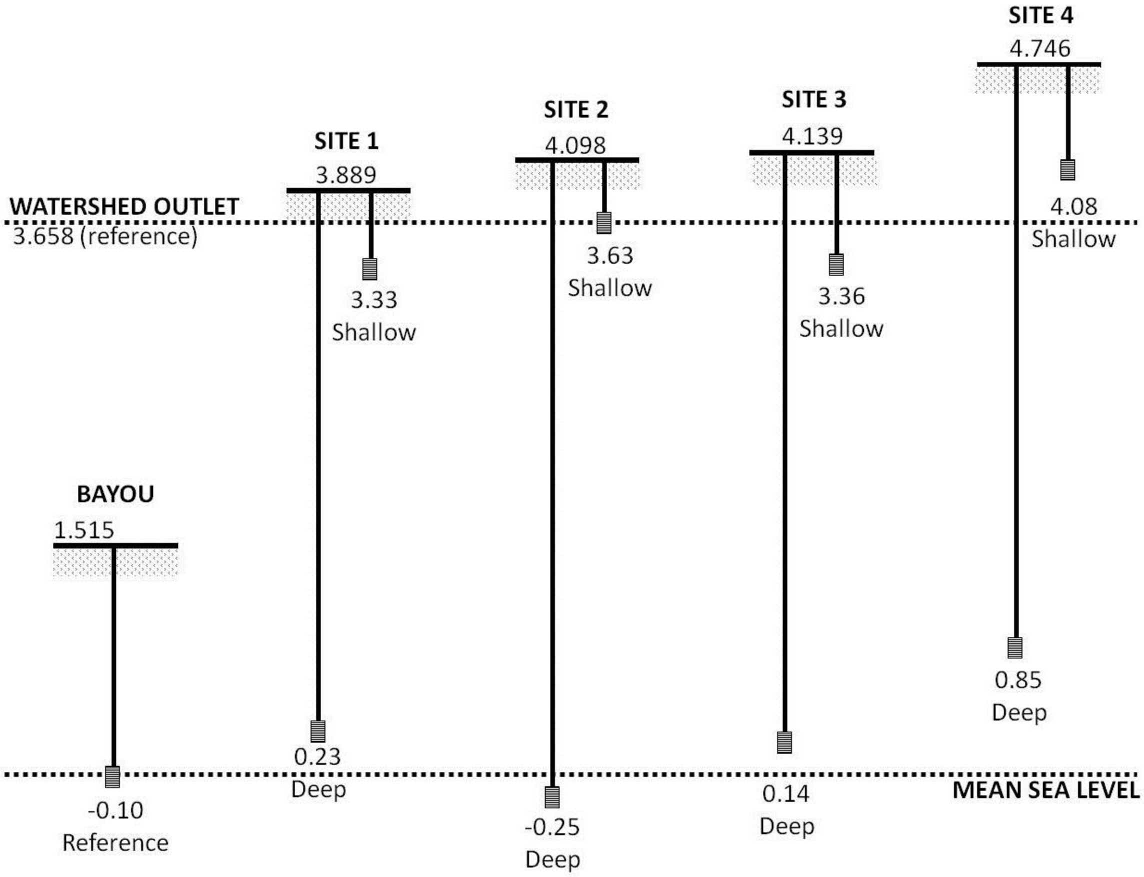


Fig. 4. Groundwater monitoring well profiles. The numbers represent elevation in meters relative to mean sea level. PVC well casing is displayed as vertical lines, and the gray boxes at the base of vertical lines represent PVC slotted well screen. The shallow wells were installed to monitor perched water tables. Deeper wells were installed to measure the true groundwater table elevation

Soil storage

A total of six soil moisture probes (Hydra Probe II, Stevens Water Monitoring) were installed in the middle of the sap flux plot to measure near-surface soil moisture. Probes were installed at the surface, at 100 mm deep, and at 150 mm deep. One set of probes was installed in a loam surface soil and the other set was installed in a clay surface soil. Data was collected at 30 minute sampling intervals from late-December 2009 through late-April 2010. Missing data was filled linearly. Linear fill was reasonable in this case because: (1) the changes in soil moisture between the nearest data points were small for all sensors, and (2) surface observations made during groundwater level monitoring indicated that the surface remained saturated in the proximity of the soil moisture sensors throughout the missing data periods.

Results

Rainfall and runoff

This study included years with significantly below-average rainfall (2005), near-average rainfall (2006, 2008, 2009), and significantly above-average rainfall (2007). The long-term annual average rainfall was approximately 1310 mm per year, with a standard deviation of approximately 350 mm, based on the entire record from November 1941 to April 2014 using the William P. Hobby Airport weather station.

No runoff was observed during 2005, which was among the driest years on record for the region. Runoff was observed during each other year of the study, with runoff ranging between approximately 13% and 27% of watershed precipitation on an annual basis

(FIG. 5). Over the study period as a whole, including 2005, surface runoff from the watershed accounted for approximately 18% of precipitation.

Over the course of the study, wetland runoff was observed during every season of the year (FIG. 6). Wetland runoff occurred during 25 of the 57 months of the study, most often when monthly precipitation approached or exceeded the long-term monthly average. Occasionally, runoff occurred in months of below-average rainfall, but in most of these cases rainfall had been above average in the preceding months. During normal years runoff occurred during every month where rainfall exceeded 130 mm. Runoff was observed during 37 days in 2006, 180 days in 2007, 80 days in 2008, and 40 days in 2009.

In general, runoff was highly episodic and strongly associated with individual rainfall events (FIG. 6), but there were occasional periods of extended flow that lasted well beyond the rainfall event, the longest being 68 days. Periods of continuous runoff ranged from 4 days to 68 days. For some individual events, runoff accounted for as much as 60% of watershed rainfall.

Null hypothesis 1 can be rejected based on these findings, meaning that surface nexus exists between the wetlands and waters covered by the Clean Water Act.

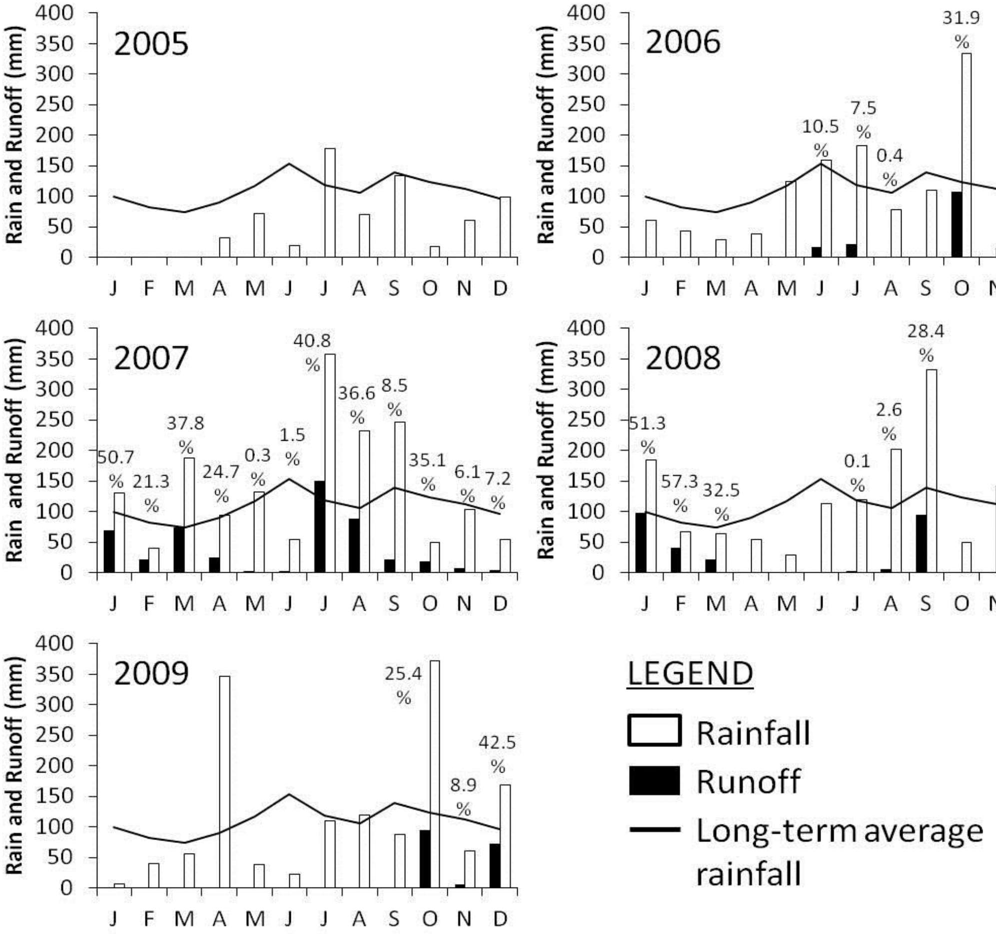


Fig. 5. Monthly precipitation and runoff for 2005–2009. The annual runoff ratio was 0.0% in 2005, 12.9% in 2006, 27.4% in 2007, 18.2% in 2008, and 12.0% in 2009. The percentage of rainfall discharged as runoff is shown for each month.

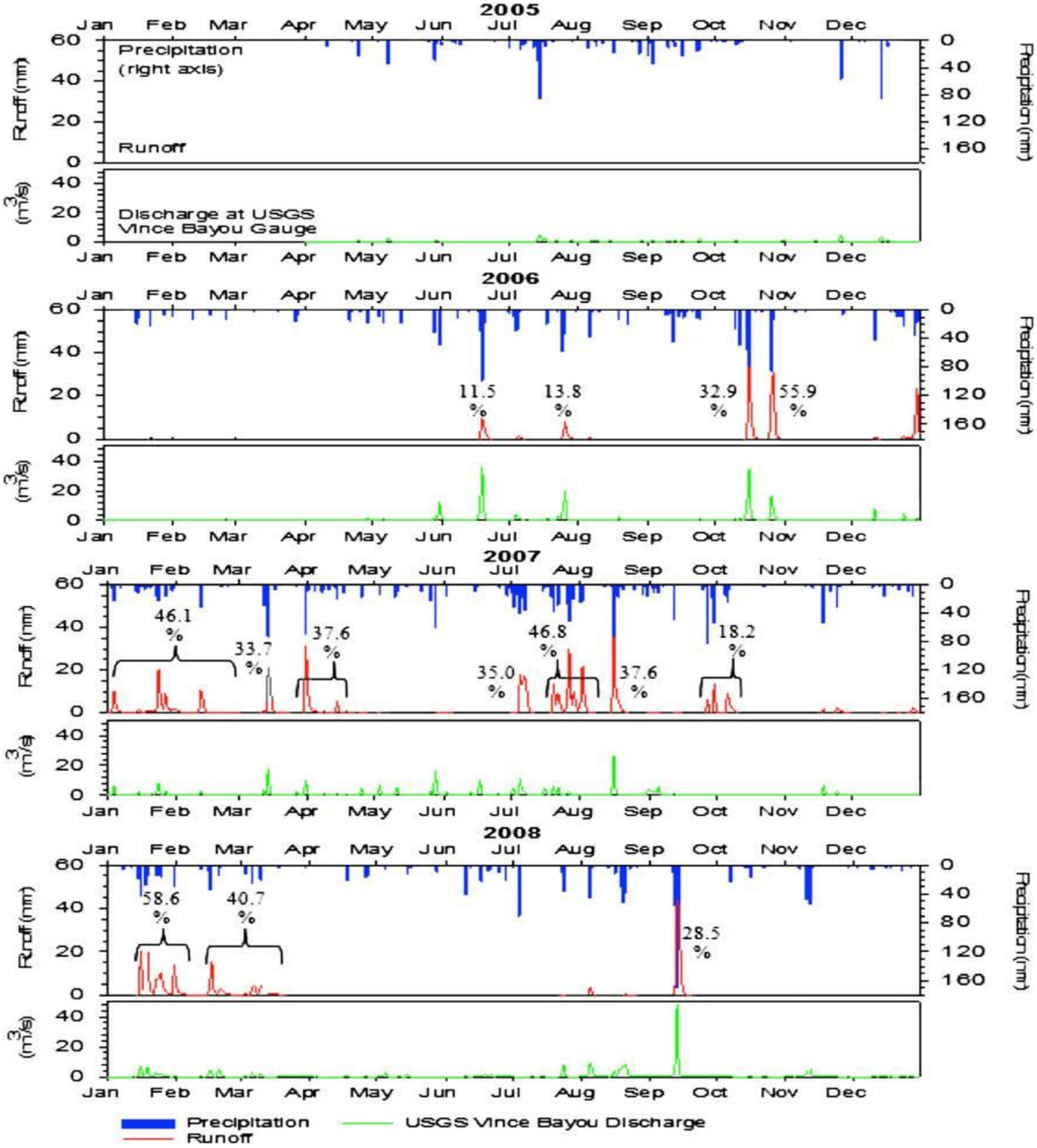


Fig. 6. Annual hydrographs (2005–2008) of daily precipitation and runoff data (axes plotted at different scales for clarity). Runoff percentages are given for major events, and the rate of runoff at the USGS gauge on Vince Bayou is shown for each year. Gaps in the red line indicate no runoff or no data.

Groundwater

Saturated soil conditions and ponding were observed at each groundwater monitoring well site during the 2010 growing season. Perched water tables were also present at all of the monitoring well sites between February 6, 2010 and August 13, 2010. The perched water tables observed in the study watershed consisted of saturated zones that were positioned above the actual groundwater table and were separated from the actual groundwater table by a zone of unsaturated soil. As discussed in the study area description, soils in the watershed are episaturated (from the top down), meaning that rainfall is a primary driver of the moisture state for surface soils.

Groundwater level observations in the deep wells indicated that the general direction of groundwater flow is southeasterly, approximately parallel to Armand Bayou. This means that groundwater does not take the shortest path to Armand Bayou. Instead, groundwater may connect with Armand Bayou farther downstream, or may enter a more regional groundwater system that connects to Clear Lake, Galveston Bay, or the Gulf Coast Aquifer. The groundwater flow direction was calculated for all available sampling dates between January 23, 2010 and August 19, 2011 using the deep wells at Sites 1, 2, and 3. The calculations showed that groundwater flowed at an average heading of approximately 158 degrees (FIG. 7 on page 35). Groundwater flow calculated from these three wells varied within a 62 degree range. The following observations have been excluded from the average because they do not represent the groundwater flow direction of the entire watershed: (1) March 30, 2010, because of possible groundwater recharge behavior at Site 3; (2) April 23, 2010, because of possible groundwater recharge behavior at Site 3; and (3) May 11, 2010, because of lag from the possible groundwater recharge behavior at Site 3.

Site 4 was installed later, and observations began on July 9, 2010. The southeasterly direction of groundwater flow was the same in each set of calculations, meaning that the four wells are located in the same groundwater lens. The deep groundwater flow direction calculated using Sites 1, 2, and 4 had an average heading of approximately 149 degrees, with a range of approximately 40 degrees. The deep groundwater flow direction calculated using Sites 1, 3, and 4 had an average heading of approximately 143 degrees, with a range of approximately 20 degrees. Finally, the deep groundwater flow direction calculated using Sites 2, 3, and 4 had an average heading of approximately 147 degrees, with a range of approximately 17 degrees.

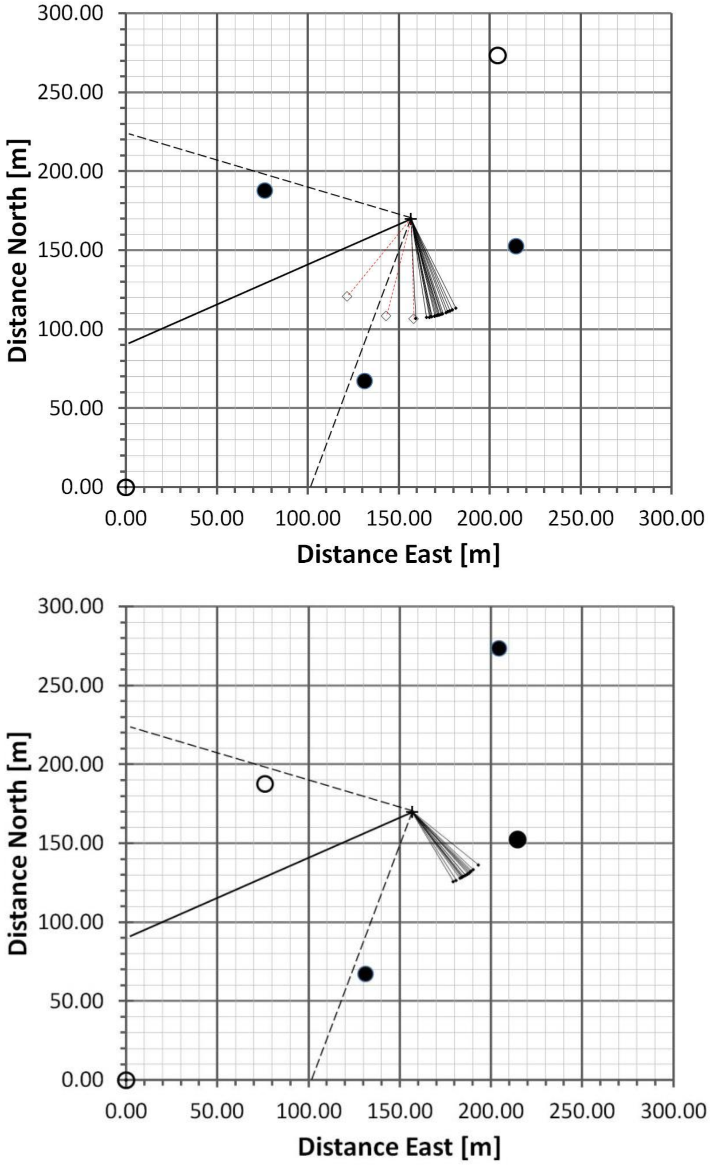


Fig. 7. Graphical summary of groundwater flow direction calculated using deep wells. Wells used in the calculations are represented by dark circles. The point (0, 0) is located at the bayou level reference well. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou (243 degrees) ± 45 degrees. Three dates resulted in questionable groundwater flow directions, for the reasons noted in the main discussion, and the endpoints of these flow direction lines are open diamonds. Note the similar direction of flow.

The level of groundwater in each of the deep groundwater wells followed similar trends over the course of the study (FIG. 8 and FIG. 9), supporting the idea that the deep wells were interconnected in a common groundwater lens. However, the variation in groundwater levels at the deep groundwater wells did not appear to correlate with variation in the level of Armand Bayou. It is difficult to establish clear effect because the portion of Armand Bayou adjacent to the study area is tidal, and there are no tide gauges within the Armand Bayou watershed (Texas Commission on Environemental Quality 2014).

No well combination produced flow directions that were predominantly within the range of 243 ± 45 degrees; therefore Null Hypothesis 2 cannot be rejected based on the deep well observations of this study. In other words, this study was unable to conclusively demonstrate a subsurface connection to Armand Bayou using the deep wells. However, it is also important to note that groundwater observed in the deep wells ultimately flows somewhere outside of the study watershed boundary, whether that be into Armand Bayou south of the study watershed, into Clear Lake or another nearby water, or into the Gulf Coast Aquifer.

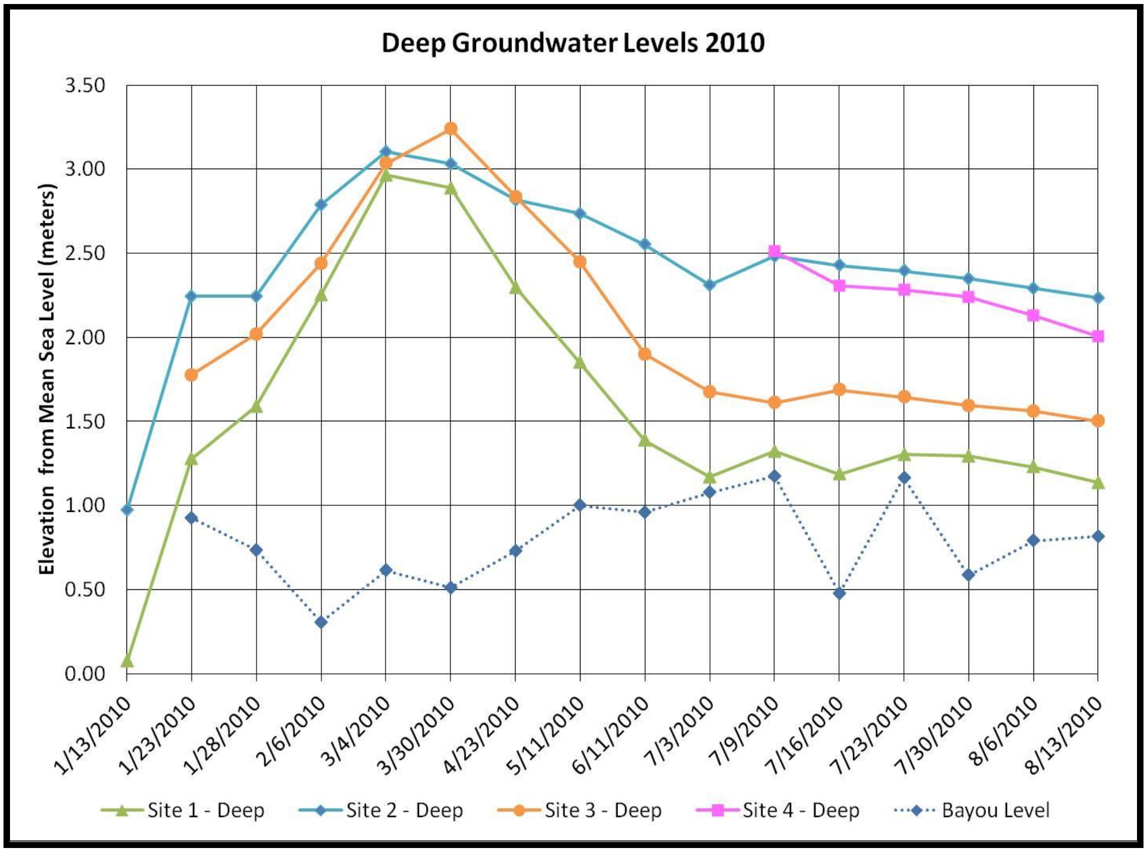


Fig. 8. Groundwater levels in deep monitoring wells (2010). All groundwater levels are given relative to mean seal level. The relative level of Armand Bayou is given for comparison.

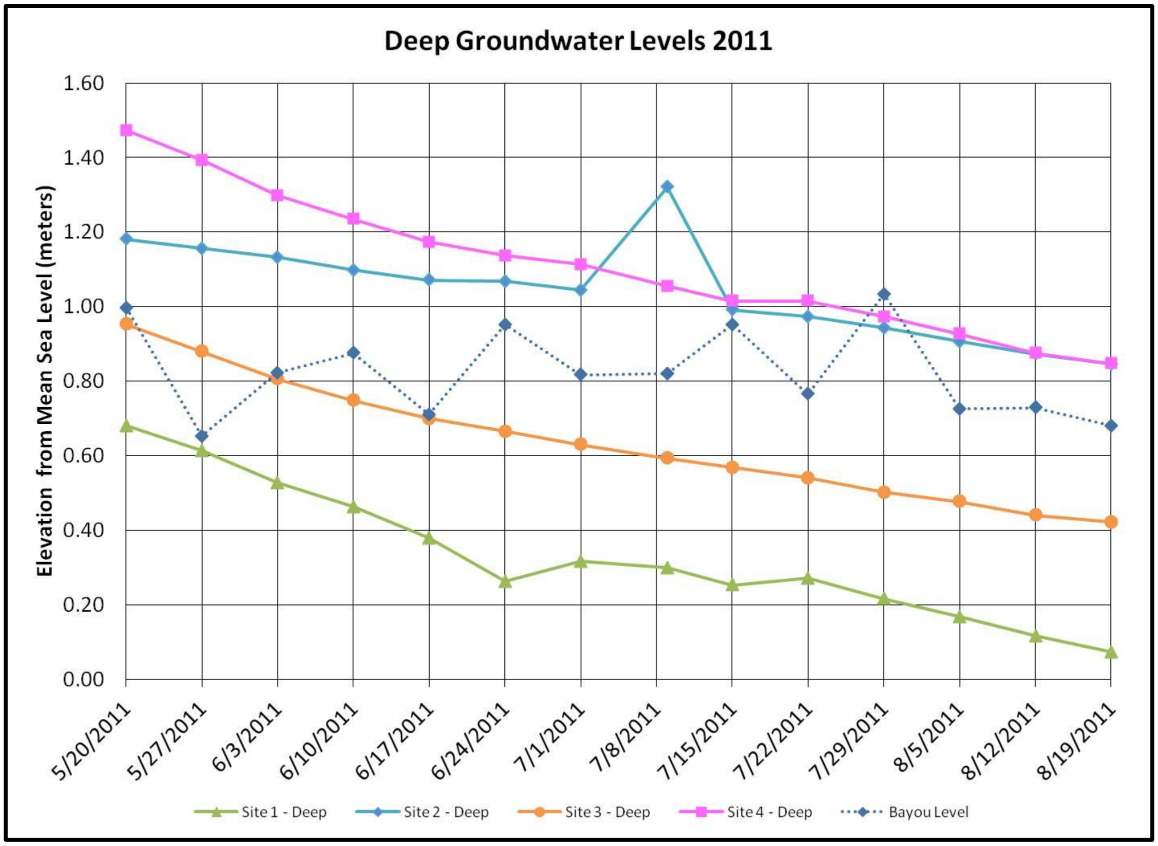
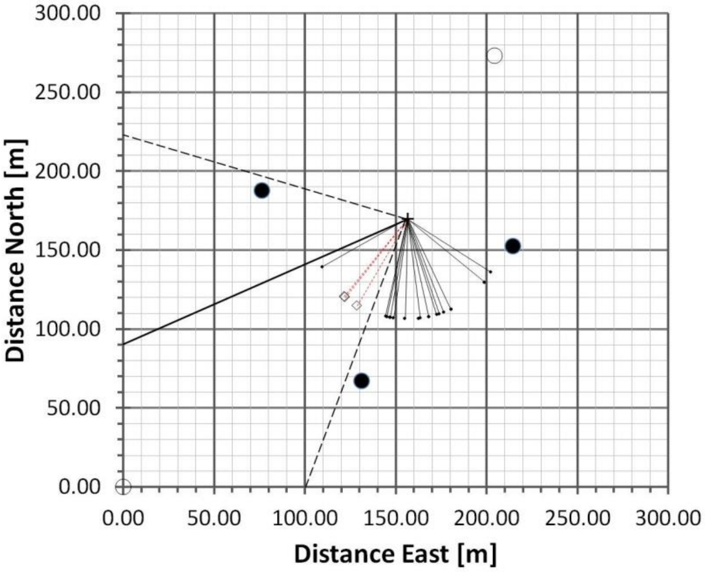


Fig. 9. Groundwater levels in deep monitoring wells (2011). All groundwater levels are given relative to mean seal level. The relative level of Armand Bayou is given for comparison.

In contrast to the deep groundwater wells, which trended together and were located in a common groundwater lens, the shallow groundwater levels indicated that the shallow wells were located in separate perched water tables. The calculated direction of groundwater flow using the shallow wells was more variable than the direction calculated from the deep groundwater wells. Additionally, the calculated direction of groundwater flow for the shallow wells was not reasonably consistent among all of the well combinations, demonstrating that not all of the wells were located in a common groundwater lens (FIG. 10).This result was not unexpected, because perched water tables are known to occur in the area (Griffin 1991) and the soils are associated with meandering streams, which can cause soil heterogeneity by creating different lenses of surface soil. Excluding the period between January 1, 2010 and February 8, 2010, when less than three wells were active, there was only one case (July 3 through July 16) during the 2010 observation period where the direction of the groundwater trend matched between all of the shallow wells for more than a single observation (FIG. 11). Additionally, the groundwater level trend did not match consistently between any two of the shallow wells for the 2010 observation season.

The shallow groundwater flow direction calculated using Sites 1, 2, and 3 had an average heading of approximately 170 degrees, with a range of approximately 136 degrees. The shallow groundwater flow direction calculated using Sites 1, 2, and 4 had an average heading of approximately 190 degrees, with a range of approximately 95 degrees. The shallow groundwater flow direction calculated using Sites 1, 3, and 4 had an average heading of approximately 142 degrees, with a range of approximately 129 degrees. Finally, the shallow groundwater flow direction calculated using Sites 2, 3, and 4 had an average heading of approximately 168 degrees, with a range of approximately 32 degrees.



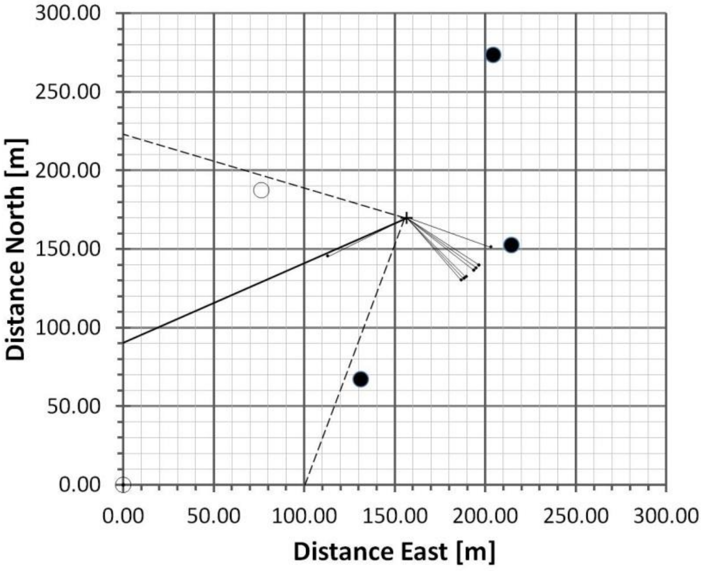


Fig. 10. Graphical summary of groundwater flow direction calculated using shallow wells. The calculated direction of groundwater flow was not reasonably consistent between different wells, meaning that the shallow wells were not all located in a common groundwater lens. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou and ± 45 degrees, respectively. Note the differences in direction of flow.

No shallow well combination produced flow directions that were predominantly within the range of 243 ± 45 degrees; therefore Null Hypothesis 2 cannot be rejected based on the shallow well observations of this study. In other words, this study was unable to conclusively demonstrate a subsurface connection to Armand Bayou using the shallow groundwater wells.

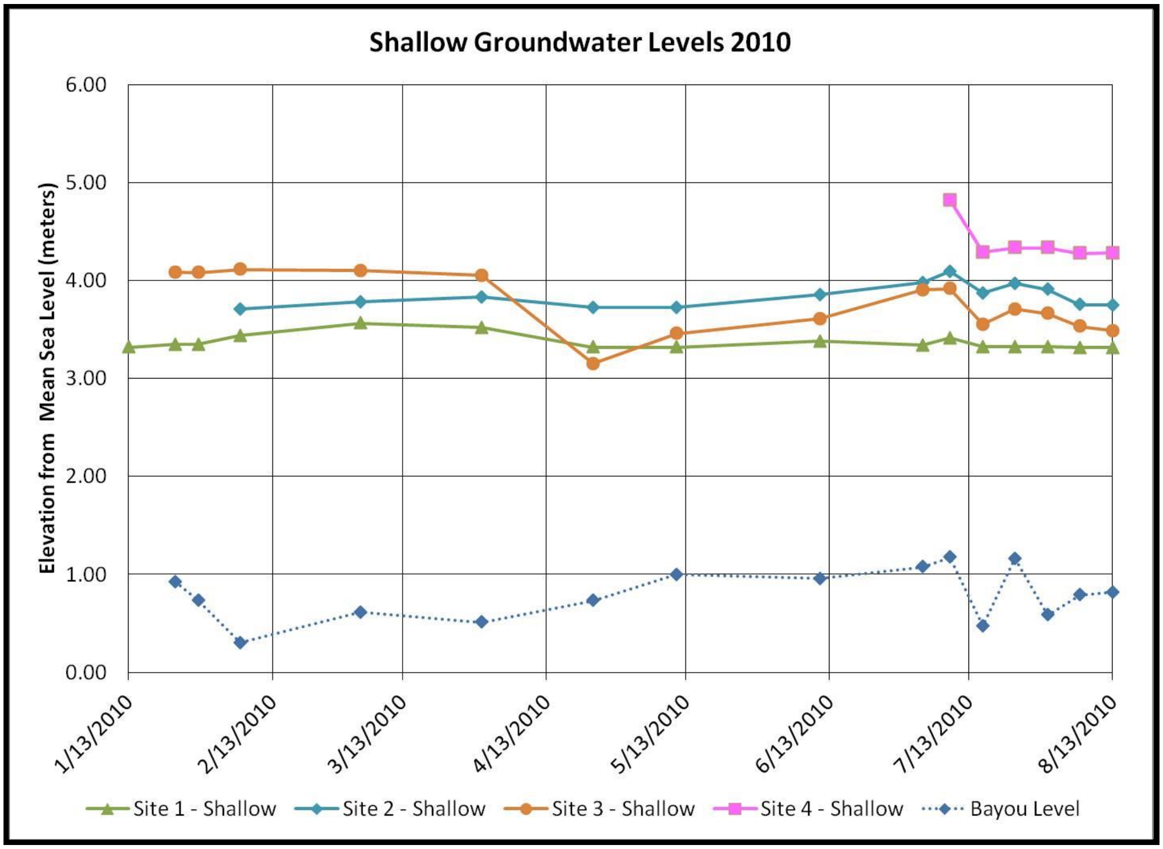


Fig. 11. Groundwater levels in shallow monitoring wells (2010). All groundwater levels are given relative to mean sea level. The relative level of Armand Bayou is given for comparison.

One interesting result is that the shallow groundwater level trends (FIG. 11 and FIG. 12) reflected the trend of the water level at Armand Bayou more closely than did the deep groundwater level trends (FIG. 7 and FIG. 8). This may mean that water levels in the shallow wells and in the bayou were both driven by precipitation because (1) episaturation occurs in the area, (2) perched water tables were observed at the shallow wells, and (3) the shallow wells are not all located in a common groundwater lens.

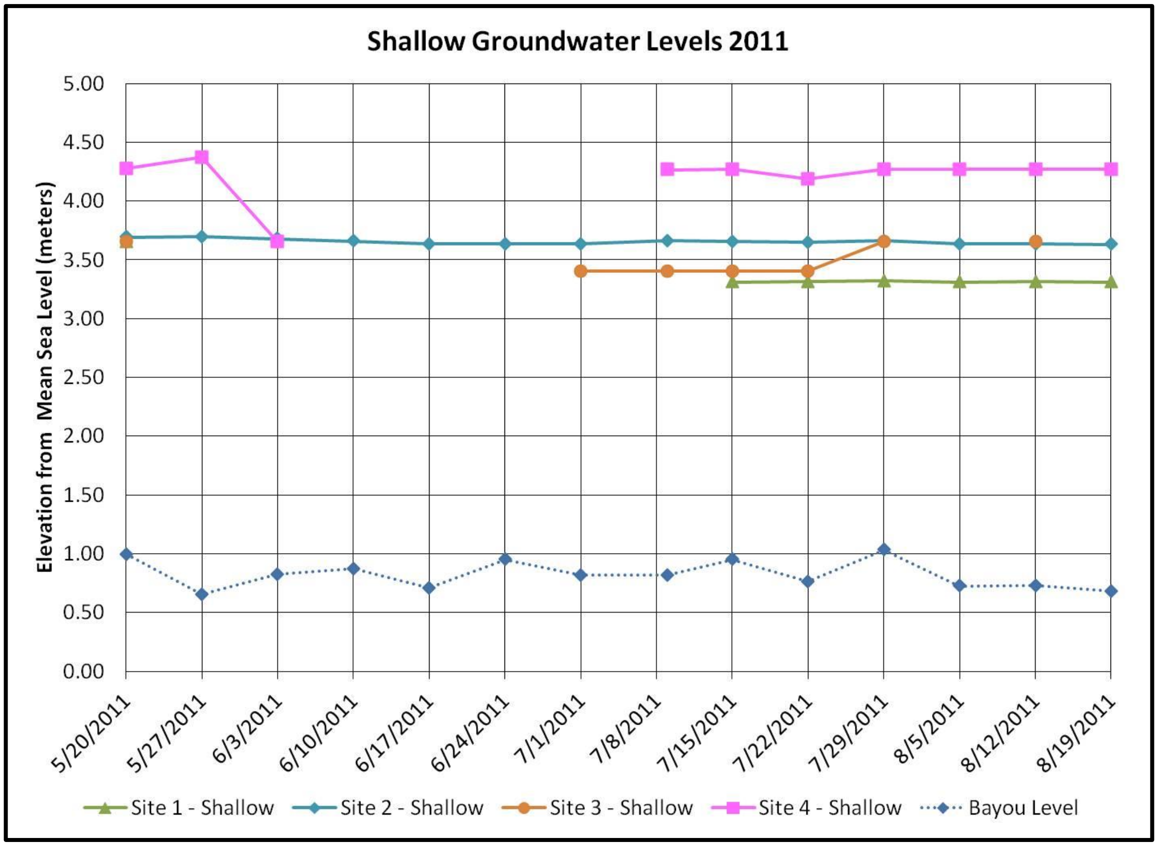


Fig. 12. Groundwater levels in shallow monitoring wells (2011). All groundwater levels are given relative to mean sea level. The relative level of Armand Bayou is given for comparison. Gaps in a data line means that the well was dry.

Unusual groundwater behavior was observed at Site 3, beginning around March 30, 2010. During that time, deep groundwater was observed within the shallow groundwater zone (approximately 0 m to 1 m deep). The level in the shallow well decreased dramatically between March 30, 2010, and April 23, 2010 (FIG. 13), especially when compared with the other shallow wells. Though no definitive cause was identified in this study, one possibility is that groundwater recharge may have occurred at Site 3.

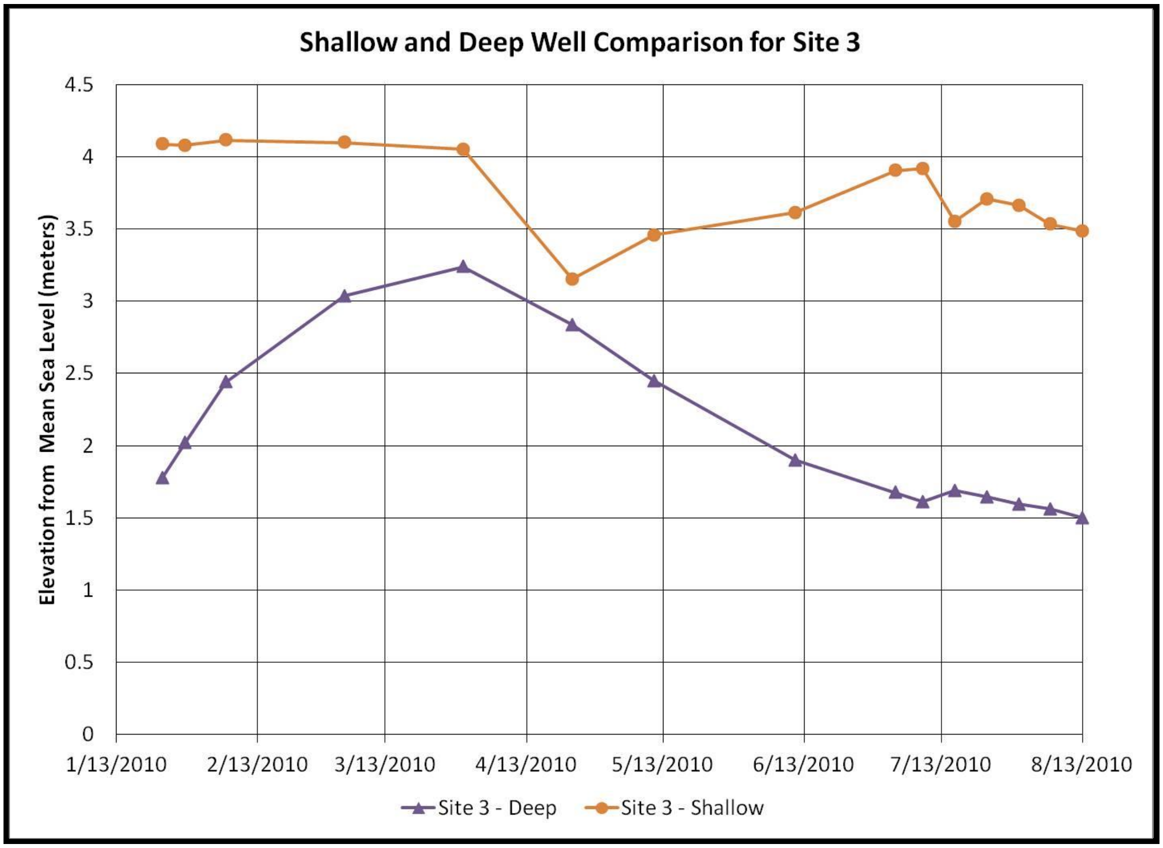


Fig. 13. Unusual behavior at the Site 3 groundwater wells. One possible explanation is that the deep groundwater intruded into the shallow water zone around March 30, 2010, after which the shallow water table fell dramatically.

Unlike the other well sites, no limiting clay layer was observed in the soil profile at Site 3 (FIG. 14). Without a clay layer to limit water and air movement, if the unsaturated zone between the shallow and deep water tables became saturated, the difference between the unsaturated and saturated hydraulic conductivity might provide a pathway for relatively rapid movement of groundwater out of the shallow layer as the deeper groundwater receded.

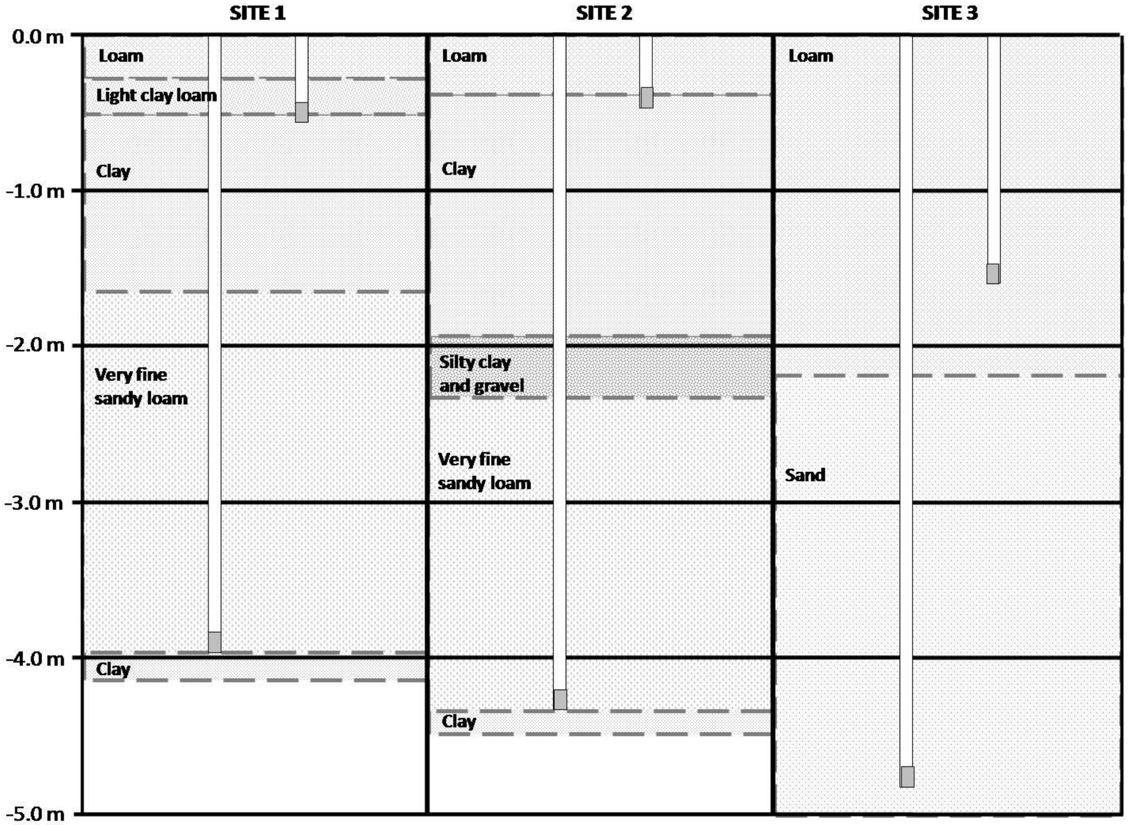


Fig. 14. Soil strata of groundwater monitoring well sites in service prior to March 30, 2010. The soil profile at Site 3 was substantially different from the soil profiles at the other sites because no limiting clay layer was present. This difference may have contributed to the unusual behavior observed at Site 3.

Evapotranspiration and soil storage

Evapotranspiration and soil moisture measurements were evaluated from late-December 2009 through late-April 2010. Losses to evapotranspiration and soil storage increased through the period of record. On average, the surface soil layer remained at or near saturation throughout January and February (FIG. 15). Five-day average evaporative demand actually decreased by approximately 0.8 mm d^{-1} during January. Evaporative demand increased significantly during February. However, the evaporative demand was more than offset by rainfall during January and February (FIG. 16). Dynamic soil moisture behavior began around March 12, 2010, corresponding to increased losses by evapotranspiration. Deciduous trees in the watershed came out of dormancy sometime between March 4 and March 30—a timeframe that corresponds to the sudden change in soil moisture behavior. The amount of evapotranspiration was nearly double the amount of rainfall during March, and was more than seven times greater than rainfall during April. The differences between evapotranspiration values during March and April can be partially explained by the lack of data beyond April 23. However, even if the evapotranspiration trend were to continue to the end of the month, there would still be approximately 20 mm less evapotranspiration in April than during March.

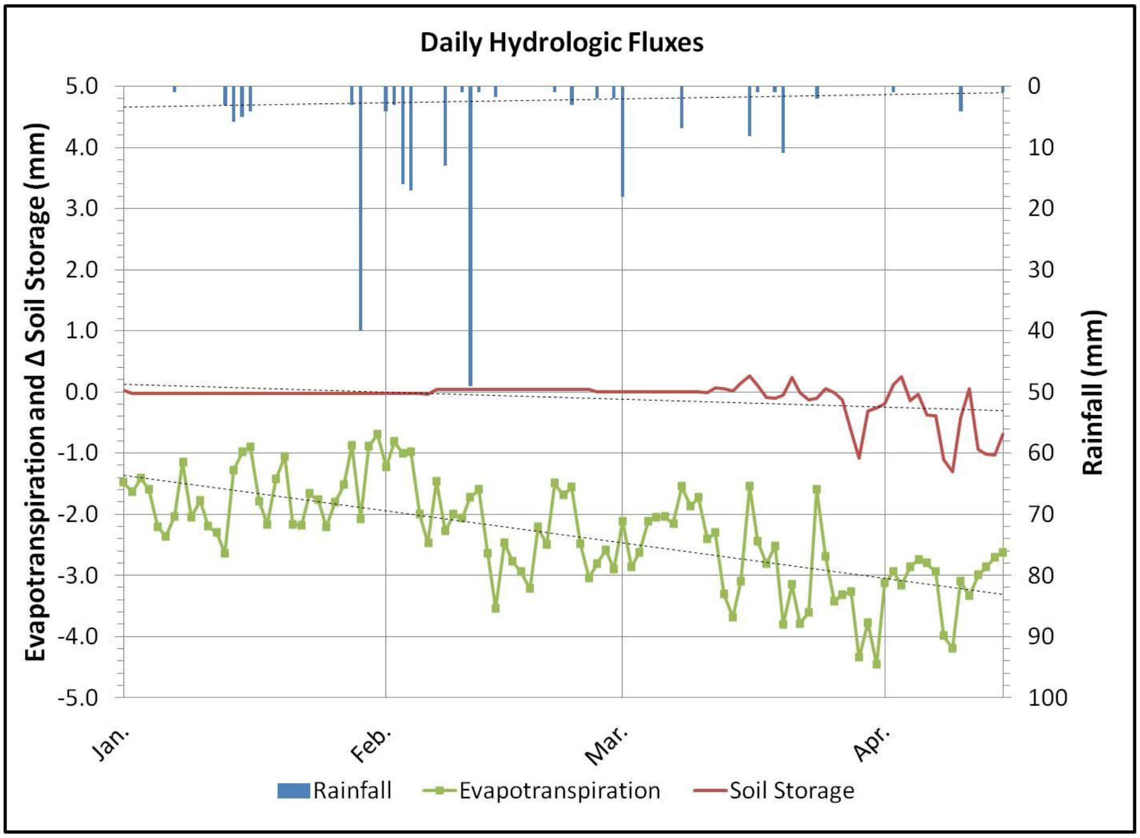


Fig. 15. Daily hydrologic fluxes, January 1 through April 23, 2010. Evapotranspiration (line with markers) and the change in soil storage (solid line) are represented on the left axis. Rainfall (bars from top) is represented on the right axis. A dashed trend line is provided for each flux.

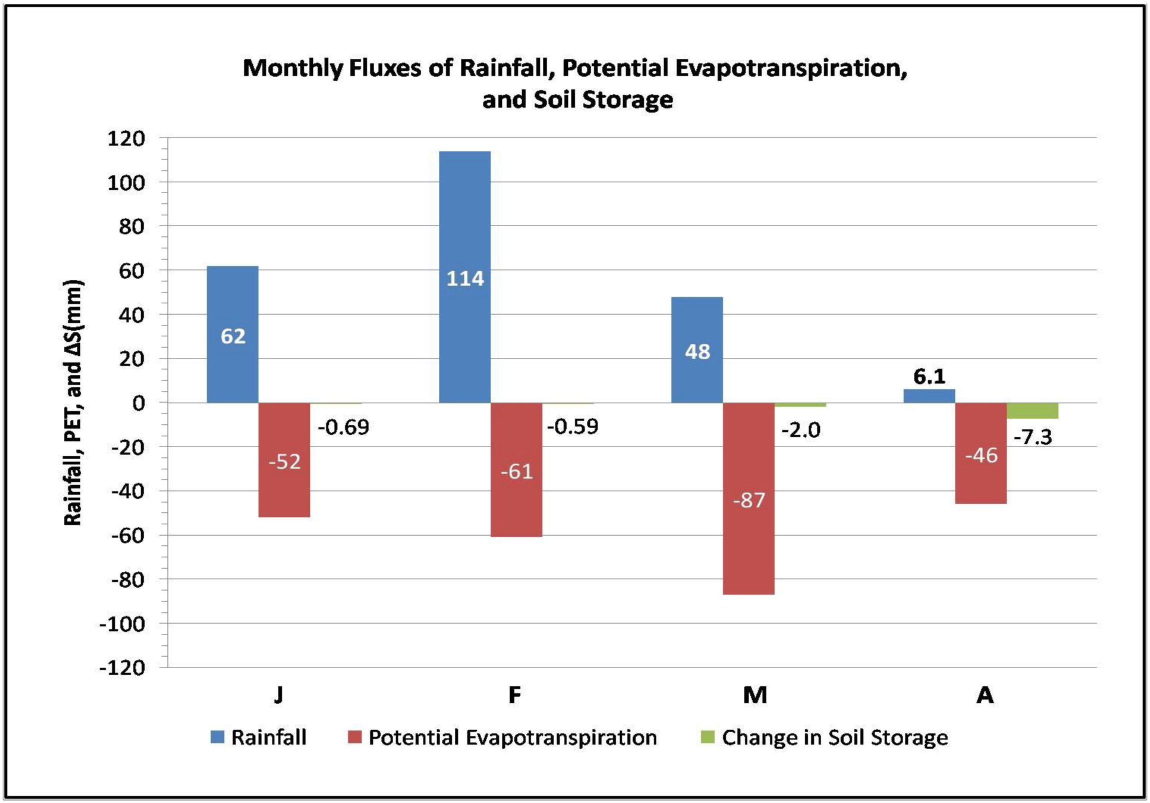


Fig. 16. Monthly fluxes of rainfall, potential evaporation, and soil water for January to April of 2010. April is a partial month (15 days).

A closer look at hydrologic fluxes during March and April (FIG. 17) gives additional insight that could help explain the remaining difference in evapotranspiration between the two months. Evapotranspiration was most dynamic during March—the same month in which soil moisture began to fluctuate. Although evapotranspiration exceeded 3.0 mm d^{-1} only three times before March 12, evapotranspiration suddenly increased to exceed 3.0 mm d^{-1} for 13 of the 19 days remaining in March. Approximately half of those days had evapotranspiration rates between 3.5 mm d^{-1} and 4.5 mm d^{-1}.

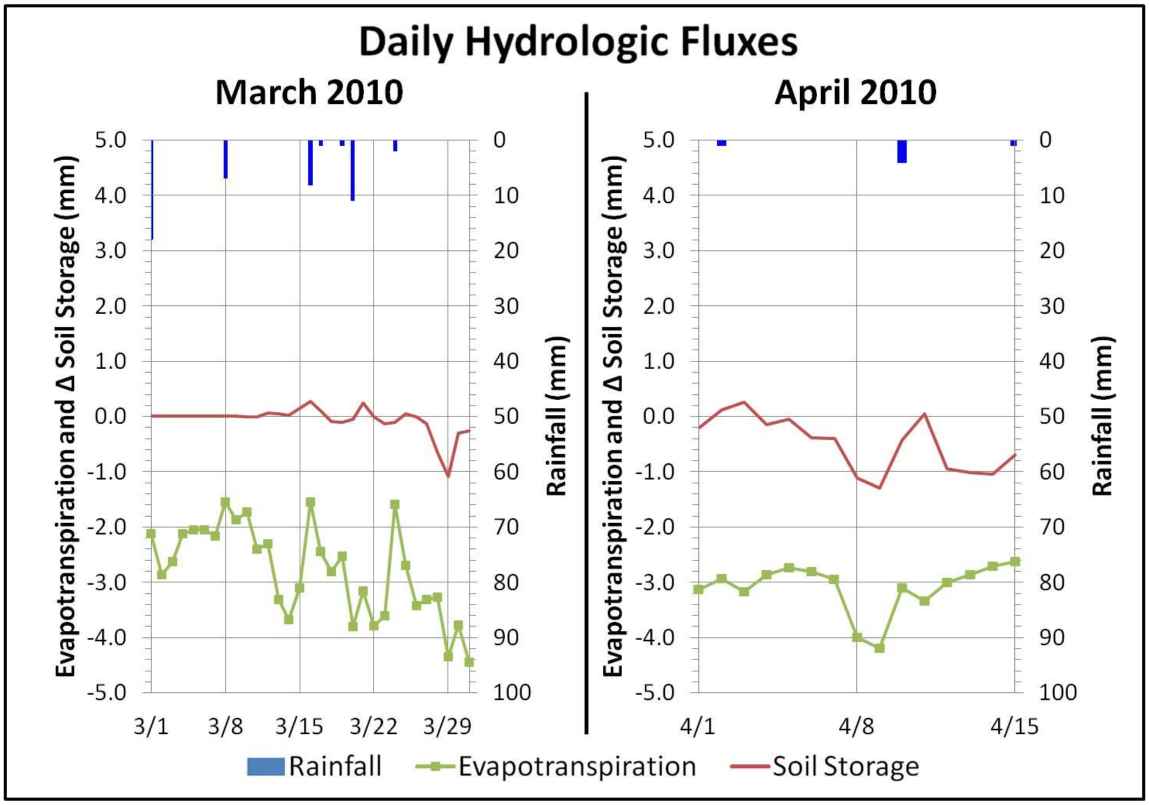


Fig. 17. Daily hydrologic fluxes, March-April 2010. Evapotranspiration (line with markers) and the change in soil storage (solid line) are represented on the left axis. Rainfall (bars from top) is represented on the right axis.

For most of April, evapotranspiration hovered around 3.0 mm d^{-1}. Evapotranspiration began to trend more tightly with soil moisture in April than it did in March. At the same time, saturated surface conditions were no longer observed at the groundwater monitoring sites, and did not return for the rest of the season. Deeper groundwater levels also began to decline during this time. Based on these facts, it appears that the surface soil layer had actually become water limited in less than one month. This phenomenon might help explain why wetland hydrology can be difficult to identify from aerial images and surface observations on the Texas Gulf Coast.

Sap flux measurements

Whole-tree transpiration was compared with solar radiation at the top of the atmosphere (FIG. 18) to confirm that Hargreaves estimates could reasonably represent the watershed. Solar radiation at the top of the atmosphere is the primary energy component in Hargreaves equation. The tree species observed included *Quercus nigra,* an overstory species, and *Quercus pagodafolia*, an understory species. Although the initial transpiration response from both species lagged behind solar radiation by a few hours, *Quercus nigra* transpiration tracked the solar radiation trend closely. *Quercus pagodafolia* exhibited a strong initial response to solar radiation, but could not maintain the response throughout the day. Although the information collected in this study does not provide direct evidence that can explain the difference in response between the two tree specimens, it is possible that the *Quercus pagodafolia* specimen, as a facultative upland species (USACE 2014), may not have been as well-suited for growth in an inundated environment as the *Quercus nigra* specimen, which is a facultative species (USACE 2014). The time lag between the incidence of radiation at the atmosphere and at the surface of the earth could have contributed to the lag in response from both species.

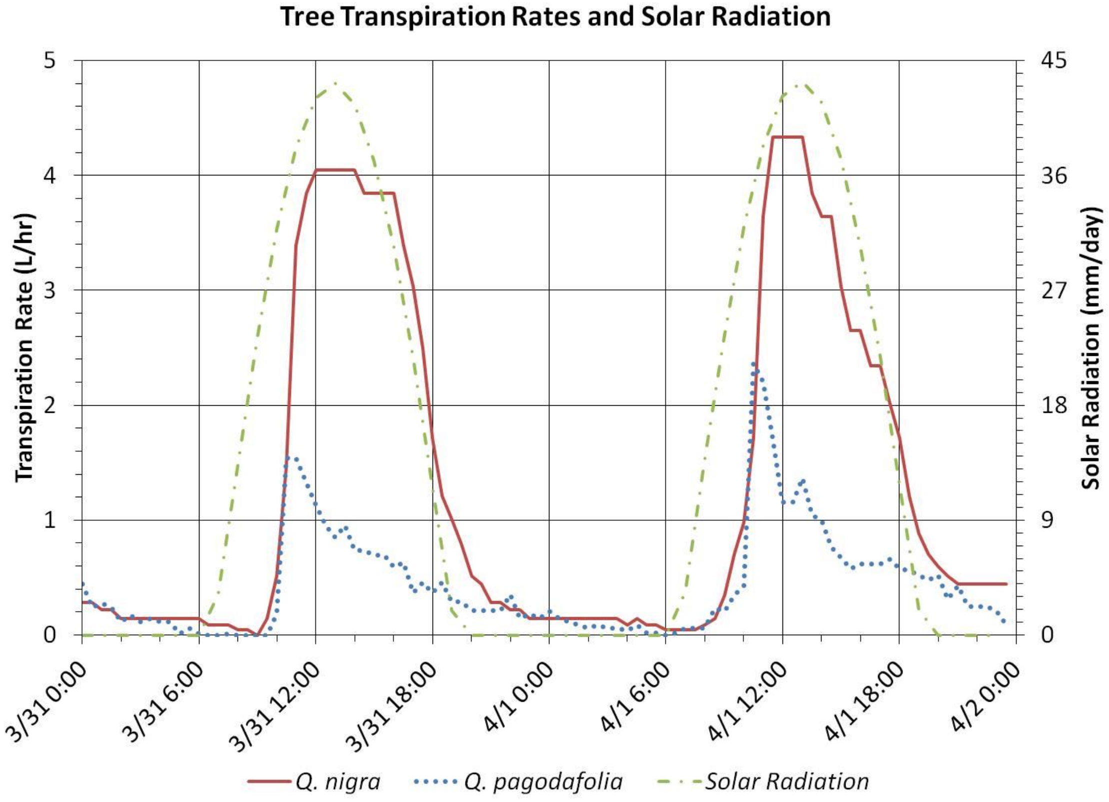


Fig. 18. Comparison of whole-tree transpiration rates for *Q. nigra* and *Q. pagodafolia* trees with incident solar radiation.

Over the course of a day, the transpiration rate of *Quercus nigra* ranged between zero and 4.83 L hr^{-1}, with peak transpiration typically occurring between 12:00 noon and 3:00 pm (FIG. 19). The peak transpiration rate was typically greater than three liters per hour. The transpiration of *Quercus pagodafolia* ranged between zero and 3.61 L hr^{-1}, with peak transpiration most often occurring between 10:30 am and 11:30 am. Peak transpiration was typically less than two L hr^{-1}.

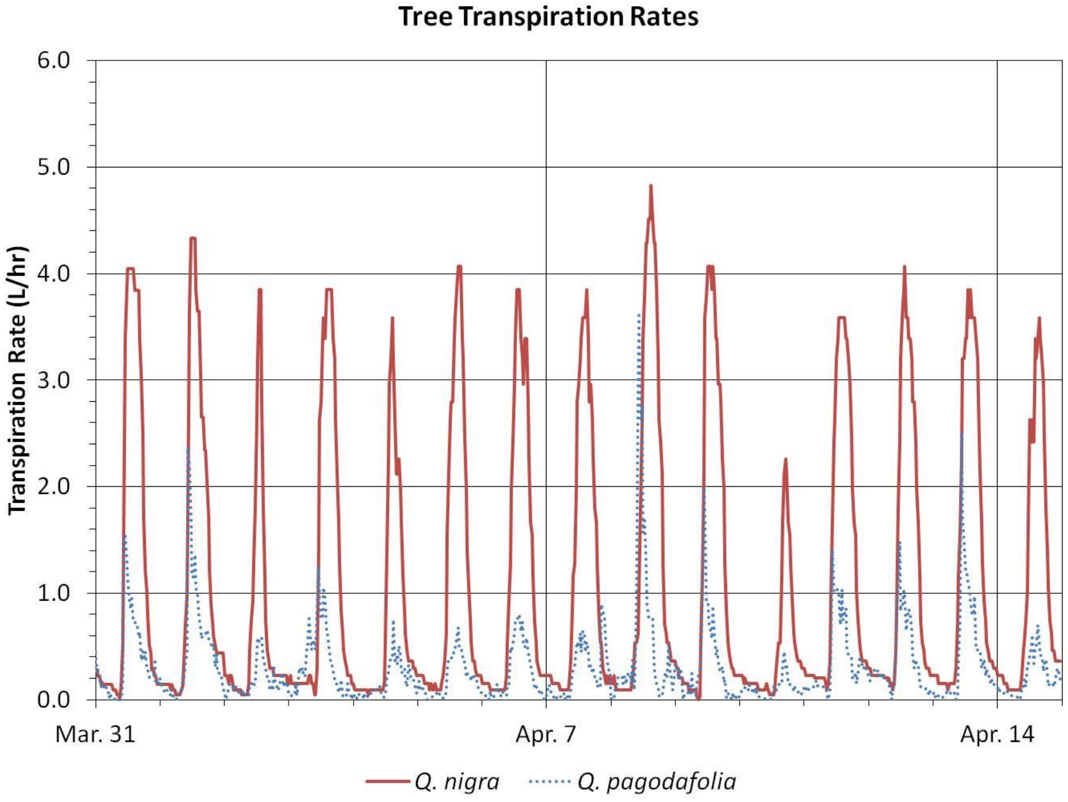


Fig. 19. Whole-tree transpiration rates for *Q. nigra* and *Q. pagodafolia* trees. The transpiration rate ranged between zero and 4.83 L hr^{-1} for *Q. nigra*, and between zero and 3.61 L hr^{-1} for *Q. pagodafolia.*

When the 30-minute interval data were summed to give total daily transpiration, *Quercus nigra* transpired between 11.6 L d^{-1} to 35.8 L d^{-1}, with an average of 24.6 L d^{-1} based on all usable observation days (FIG. 20). *Quercus pagodafolia* transpired between 2.43 L d^{-1} and 13.8 L d^{-1}, with an average of 7.66 L d^{-1} based on all usable observation days. Similar trends in daily transpiration were observed for *Quercus nigra* and *Quercus pagodafolia*. There were only four days where a decrease in transpiration from *Quercus nigra* was not met with a corresponding decrease in transpiration from *Quercus* *pagodafolia*. All increases in daily transpiration from *Quercus nigra* were met by an increase in transpiration from *Quercus pagodafolia*.

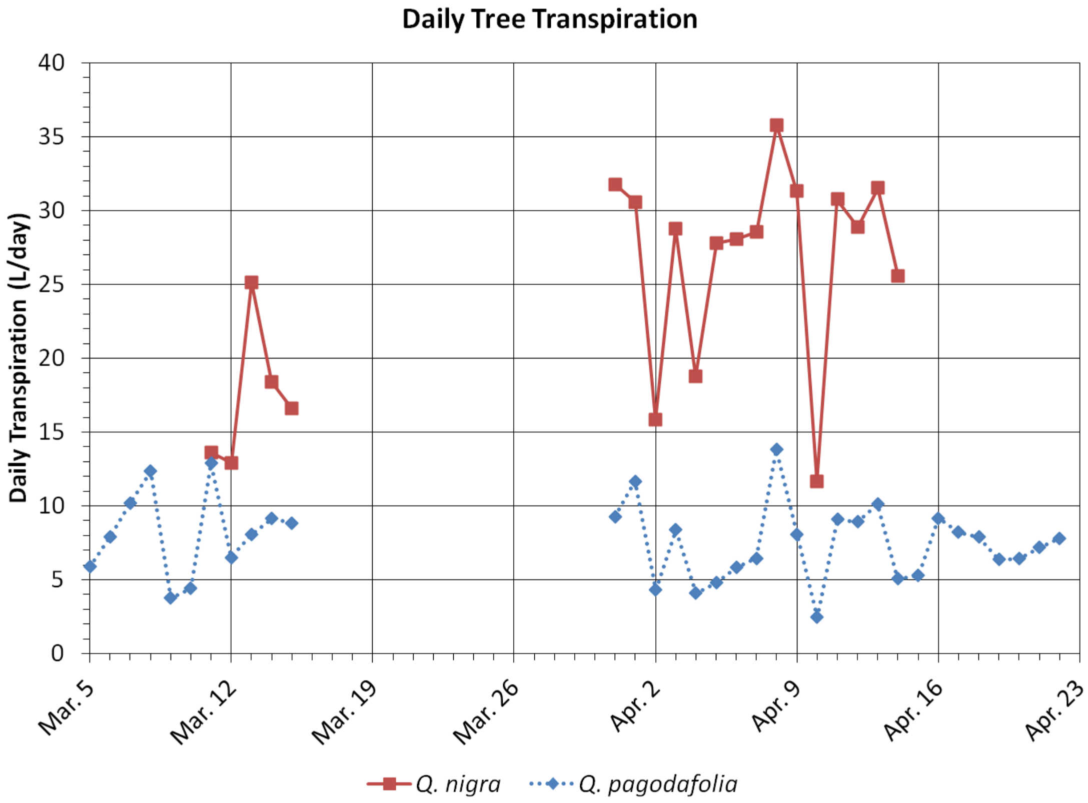


Fig. 20. Daily transpiration from Q. nigra and Q. pagodafolia trees. The average transpiration rate was 24.6 L d^{-1}for *Q. nigra*, and 7.66 L d^{-1} for *Q. pagodafolia.*

Discussion

Runoff from the wetlands was expected going into this study because of the small swales running through the watershed, but it was difficult to make an initial prediction about how much runoff to expect. So far, scientists and the regulatory agencies that oversee the Clean Water Act have not been able to reach any consensus on a runoff threshold that would demonstrate significant nexus. Wetlands are also known to serve flood storage functions, so one would expect that the percentage of runoff from a wetland watershed would be substantially lower than the runoff percentages from a large-scale water balance.

No one expected to see runoff average 18% over the course of the study. The relevance of the runoff produced from the complex of wetland depressions and small swales in this study cannot be easily overstated. From a regulatory perspective, these wetlands have historically been considered closed or virtually-closed systems, with essentially no runoff that reaches waters covered by the Clean Water Act. More striking is the fact that runoff averaged 18%, even though the wetlands produced no runoff and received more than half of the rainfall expected in 2005. Certainly no one anticipated that runoff would reach 27% of the total incoming rainfall during 2007. These kinds of runoff percentages meant that the amount of runoff generated per unit area of the wetland complex was within range of the runoff generated per unit area in larger upland watersheds. Legates and Mather (1992), for example, used latitudinally-corrected precipitation and evapotranspiration to predict that runoff accounts for approximately 28% of the average annual water budget of North America. Further confirmation of surface hydrological connectivity on the Texas Gulf Coast was provided by Forbes et al. (2009), who monitored outflow for one year at six wetland locations on the Texas Gulf Coast. Enwright et al. (2011) observed that wetlands and their catchments occupy 40% of the land area around Galveston Bay. If the 18% runoff observed in this study is universally applied to the land area covered by wetlands and their catchments (40% of the land area) and if 28% runoff is universally applied to the non-wetland catchment areas (60% of the land area, then approximately 30% of the runoff received by streams in the area would flow out of wetlands.

Runoff comparison with Vince Bayou

In a publication from earlier work on this study (Wilcox et al. 2011), the flow data from 2005 through 2008 were compared with data from the 23-km^2 watershed of the USGS-gauged Vince Bayou (USGS-8075500) (http://waterdata.usgs.gov/tx/nwis/current/?type=flow), a site near Armand Bayou that is largely urbanized (FIG. 2 on page 1514).

Interestingly, runoff from the study site was synchronous with that measured from the nearby Vince Bayou USGS location (FIG. 6 on page 32). Event-based runoff percentages were calculated from the first precipitation event following a 24-hour dry period to the beginning of the first 24-hour period with no runoff. Baseflow in Vince Bayou is minuscule, with median flow rates ranging from 0.05 to 0.08 m^3 s^{-1} (0.2–0.3 mm d^{-1}); however, during major events the rate of flow through the bayou was as high as 48.14 m^3 s^{-1} (180 mm d^{-1}). Runoff from Vince Bayou is largely episodic, exhibiting strong similarities with the hydrographs of runoff from the study watershed near Armand

Bayou. The urbanized Vince Bayou watershed was slightly more responsive to rainfall than the study watershed, probably because of its limited water-storage capacity. Once the storage capacity of the study watershed was satisfied, its runoff response was very similar to that of Vince Bayou. The episodic nature of the runoff is explained in part by the fact that precipitation from smaller events can be completely stored within the wetland depressions and shallow soil horizons, and in part by the fact that a significant portion of annual precipitation comes by way of large storms. From 2006 to 2008, storms that produced major runoff events accounted for 37% to 62% of annual rainfall.

In essence, the runoff characteristics observed in this study are not that dissimilar from the runoff characteristics expected from other watersheds in the vicinity. The amount of runoff observed from the wetland complex in this study, per unit area, was not unlike the amount of runoff that would be expected based on large-scale water balances for river systems. Likewise, the timing of flow from the wetland complex in this study was similar to the timing of flow from a nearby urbanized watershed.

CHAPTER III

IMPROVING THE CURRENT LEGAL FRAMEWORK

With several years of experience and scientific discovery since the *SWANCC* and *Rapanos* Supreme court cases, the agencies that oversee the Clean Water Act are currently in the rulemaking process. Therefore, it is more important for the scientific community to understand and inform wetland policy now than ever before. The Scientific Advisory Review Board released a draft report for public comment (see USEPA 2013). The finalized report will be the scientific basis for the rulemaking.

The purposes of this chapter are to: (1) bring important knowledge of the Clean Water Act, federal rules, and guidance on wetland regulation back into the scientific and popular dialog; (2) explain how heuristics made inconsistent Clean Water Act implementation possible; and (3) propose a process that will improve consistency of Clean Water Act implementation.

Important Law, Rules and Guidance for Wetlands

If scientists intend to inform policy in a useful way, then an understanding of the current law and the rules designed to implement the law is absolutely critical. The text of the law and rules is vitally important because the public has rights to representation and participation in the development of laws and rules that govern them—rights that do not exist in the development of regulatory guidance documents and court opinions. The purpose of this section is to shed light on important elements of the existing law, rules, and guidance as they relate to wetlands.

The Clean Water Act

The objective of the Clean Water Act is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Federal Water Pollution Control Act 1972 as amended, codified in 33 U.S.C. § 1251 et seq.). The Clean Water Act's stated goals for achieving this objective focus on eliminating discharges of pollutants, developing research programs, developing pollution control programs, and funding treatment works. The important message is that Congress intended to restore and maintain the nation's waters by keeping pollutants out. The Clean Water Act's definition of pollutants is broad enough to explicitly include dredged spoil, rocks, sand, cellar dirt, and heat as pollutants (Clean Water Act § 502(6)).

The Clean Water Act applies to waters of the United States, but the term "waters of the United States" is not expressly defined in the Clean Water Act. Therefore, the chief source of uncertainty in pollution control is not how to identify pollution, but rather how to identify where the law applies in a physical sense. The Environmental Protection Agency's CWA Definition of Waters of the United States web page emphasizes this uncertainty by pointing out the Environmental Protection Agency's inability to pursue enforcement in egregious pollution cases, such as the Edwards Creek crude oil discharge case in Titus County, Texas (FIG. 21 on page , see additional photos and captions on the Environmental Protection Agency's Clean Water Act Definition of Waters of the United

States web page, accessed September 17, 2013, available at http://water.epa.gov/lawsregs/guidance/wetlands/Clean Water Actwaters.cfm#). The Environmental Protection Agency had to walk away from enforcement proceedings, despite possible drinking water impacts and a clear violation of the Clean Water Act's goals and objectives. It was too difficult for the Environmental Protection Agency to demonstrate that the Clean Water Act applied to the physical location, because the crude oil was discharged into a relatively small, non-permanent waterway.

Fig. 21. Oil in Edwards Creek (*from the Environmental Protection Agency's Clean Water Act Definition of Waters of the United States web page*).

The Clean Water Act does not directly address whether wetlands are waters of the United States subject to pollution control requirements. However, the Clean Water Act gives clear signals about Congress's intent. Congress addressed wetland protection and restoration in the Chesapeake Bay region (Clean Water Act § 117) and in Long Island Sound (Clean Water Act § 119). Congress expressly identified wetlands as part of the Lake Champlain Drainage Basin for the purpose of developing a comprehensive pollution prevention, control, and restoration plan (Clean Water Act § 120). Congress specifically directed the Environmental Protection Agency to assure continued coordination with other agencies on the National Wetlands Inventory, and authorized a $6.0 million appropriation for the National Wetlands Inventory's timely completion (Clean Water Act § 208). The most telling clue to Congress's intent is in Clean Water Act §404, where Congress allowed the States to administer permit programs, but reserved federal control over permit programs for waters that can reasonably be used for interstate or foreign commerce *and their adjacent wetlands*. Taken together, these examples show Congress clearly intended that the Clean Water Act would apply to wetlands. The U.S. Supreme Court supported this interpretation of the Clean Water Act's applicability to wetlands in several cases, including *United States v. Riverside Bayview Homes, Inc., et al.* (1985), *Solid Waste Agency Of Northern Cook County v. United States Army Corps of Engineers et al.* (2001), and *Rapanos et ux., et al. v. United States* (2006).

Corp of Engineers rules in Title 33, Code of Federal Regulations

The Environmental Protection Agency was given primary responsibility for carrying out the Clean Water Act. However, the Clean Water Act authorized the Secretary of the Army, acting through the Chief of Engineers, to issue permits for the discharge of dredged or fill material. This permitting program, administered through the United States Army Corps of Engineers, is the primary vehicle for permitting construction in existing wetlands.

The Navigation and Navigable Waters title of the federal regulations (33 CFR) includes the most important set of rules for Clean Water Act § 404 permitting. According to these rules, the U.S. Army Corps of Engineers District Engineer, U.S. Army Corps of Engineers Division Engineer, and Environmental Protection Agency have authority to determine jurisdiction over Clean Water Act § 404 permits (33 CFR § 325.90). Though both agencies have this authority, the Environmental Protection Agency has final authority as the administrator of the Clean Water Act (33 CFR § 328.3(a)(8)). Title 33 also defines certain terms used in the Clean Water Act and establishes the limits of the Clean Water Act with respect to wetlands (*see* 33 CFR §§ 328.1-328.5).

The term "waters of the United States" refers to all waters that have been or could be used for interstate or foreign commerce, all interstate waters, and all other waters that could affect interstate or foreign commerce if used, degraded, or destroyed. Wetlands adjacent to any covered water are also waters of the United States (33 CFR § 328.3(a)). Waters of the United States can include waters which are not typically considered navigable, such as mudflats, sandflats, prairie potholes, wet meadows, and playa lakes (33 CFR § 328.3).

The term “adjacent” means bordering, contiguous, or neighboring. Wetlands separated from other waters of the United States by man-made dikes or barriers, natural river berms, beach dunes, and the like are still adjacent wetlands (33 CFR § 328.3(c)). When adjacent wetlands are present, Clean Water Act jurisdiction extends beyond the ordinary high water mark to the limit (far boundary) of the adjacent wetlands (33 CFR § 328.49(c)(2)).

An individual permit is required to discharge dredged or fill material, unless the discharge is covered by a nationwide permit or is specifically exempt from permit requirements (33 CFR § 323.3(a)). Individual permits are subject to closer review and sometimes allow for public review and comment. Discharges from normal farming, silviculture, or ranching activities at an ongoing operation are exempt from regulation (33 CFR § 323.4). Generally speaking, the discharge from farming, silviculture, or ranching must not be intended to convert land to a different use, and the landowner must use best management practices to minimize effects on waters of the United States.

The U.S. Army Corps of Engineers can issue two kinds of individual permits. A standard individual permit requires public notice and a public interest review (33 CFR § 325.5). A letter of permission does not require public notice, but still requires public interest review and coordination with fish and wildlife agencies (33 CFR § 325.2(e)(1)). The U.S. Army Corps of Engineers can issue a letter of permission for large categories of common minor activities governed by Clean Water Act § 404 permits in consultation with the Environmental Protection Agency, fish and wildlife agencies, the state certifying agency, and the coastal zone management agency (33 § CFR 325.2(e)(1)(ii)).The U.S. Army Corps of Engineers can also issue a letter of permission for Section 10 permits (see Rivers and Harbors Act of 1899, § 10) if the District Engineer feels such permits would be minor, would not have significant environmental impacts, and would be unlikely to encounter appreciable opposition from the public (33 CFR § 325.2(e)(1)(i)).

The U.S. Army Corps of Engineers can issue four kinds of general permits. These include regional permits, national permits, programmatic permits, and Section 9 permits. Regional and national permits apply to a specific region of the United States or to the United States as a whole. Programmatic permits avoid duplication by relying on existing local, state, or federal programs. Section 9 permits authorize bridge construction (33 CFR § 325.5(c)).

Permits for structures do not generally have an expiration date, but permits for maintenance dredging are limited to ten years (33 CFR § 325.6). The District Engineer may reevaluate permits and may suspend, revoke, or modify individual and regional permits for cause (if the District Engineer has a defensible reason). Permit reevaluation can be initiated by the District Engineer, the permittee, a third party, or an inspector (33 CFR § 325.7).

The U.S. Army Corps of Engineers must consider impact on wetlands when evaluating a permit application. The rules identify wetlands that perform functions important to the public interest in 33 CFR § 320.4(b)(2). These include wetlands that:

- serve significant natural biological functions,
- are set aside for study or as a sanctuary or refuge,
- prevent detrimental effects on sedimentation patterns and other natural drainage characteristics,
- shield other areas from wave action or erosion,
- store flood waters,
- allow groundwater recharge or discharge,
- serve significant water purification functions, or
- are unique or scarce in a region.

According to the rules, a wetland site must be evaluated with the recognition that it may be part of a complete and interrelated wetland area (33 CFR § 320.4(b)(3). The rules further state that no permit will be issued for a project in a wetland that is important to the public interest, or in a wetland site that may be part of an interrelated wetland area, unless a public interest review shows that the benefits of alteration outweigh the damage to the wetland resource (33 CFR §320.4(b)(4)).

Regulatory guidance issued in 2008

The 2008 regulatory guidance (USEPA and USACE 2008) was intended to provide clarity to regulatory staff and the regulated community after the United States Supreme Court's decision in the *Rapanos* case (2006). However, guidance does not have the force of law, and does not require public notice during the development process. Therefore, the 2008 guidance has actually brought about uncertainty, doubt, and a lack of significant consensus from those in the regulated community, who often seek to treat the guidance as if it were a rule.

The 2008 regulatory guidance established a decision-making framework based on the navigability and the relative permanence of a waterbody. It also established conditions for the agencies to consider before exercising jurisdiction over a waterbody. The document also identified when the regulatory agencies may presume that significant nexus exists between a wetland and a waterbody, and when a more intensive assessment is required (FIG. 22). According to the 2008 guidance, significant nexus is presumed if a wetland is adjacent to a traditional navigable waterbody. Nexus is also presumed for a wetland adjacent to a relatively permanent non-navigable waterbody if a continuous surface connection exists between the wetland and the waterbody. All other wetlands require more specific information before jurisdiction can be determined.

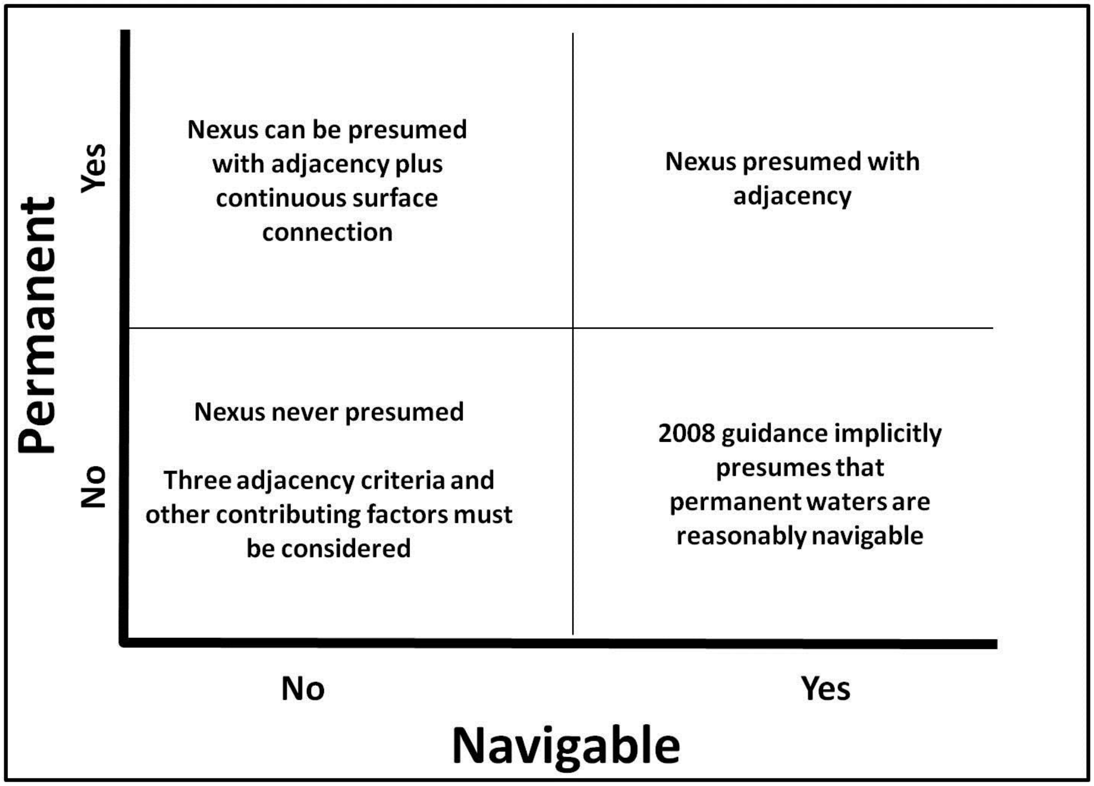


Fig. 22. Nexus presumption matrix. The agencies only presume significant nexus where the main waterbody is relatively permanent. If a relatively permanent waterbody is not navigable, the agencies may still presume nexus if a continuous surface connection exists. If the agencies cannot presume significant nexus, they must conduct a significant nexus finding.

This guidance document uses the term “adjacent” as it is defined in 33 CFR § 328, but also points out three indicators of adjacency that show the agencies’ intent when drafting the original rules. These include (1) unbroken hydrologic connections, (2) physical separation by man-made or natural barriers, and (3) reasonably close proximity. Based on the context, and for the purpose of clear discussion, the second indicator of adjacency may be stated more clearly as, “an otherwise adjacent water should be considered adjacent, even if barriers exist between that water and navigable waters of the U.S.” This essentially leaves two indicators of adjacency, but for consistency this thesis mirrors the language in the guidance document and refers to three indicators of adjacency. The guidance states that *any* of the above conditions can be used to establish adjacency. In other words, a wetland only needs to meet *one* of the criteria to be considered adjacent. The guidance also states that a continuous surface connection is not required. Rather, intermittent surface and near-surface connections can be used to establish adjacency.

The terms “continuous surface connection” and “unbroken hydrologic connection” are used in the guidance to describe hydrologic connections. The term “continuous surface connection”, as used in *Rapanos*, has a temporal element. It qualifies whether a connection lasts for days, months, or years. Justice Scalia also argued that a continuous surface connection is limited, spatially, to wetlands that are directly abutting waters such that there is inseparable intermingling. However, the majority of the justices, including the four dissenting justices and Justice Kennedy, rejected the spatial limitation that Justice Scalia attempted to impose on the term “continuous surface connection.” In contrast to the temporal sense of “continuous surface connection, the 2008 guidance implies that the term “unbroken hydrologic connection”, means the conveyance route must be physically continuous in space. The guidance acknowledges that shallow subsurface connections contribute to unbroken hydrologic connections. Most importantly, the guidance explicitly states that intermittent connections can be used to demonstrate adjacency. It is important to note that the federal agencies’ interpretation of adjacency in the guidance document rests on unbroken hydrologic connections instead of continuous surface connections.

The 2008 guidance states that adjacency will be determined on a case-by-case basis for individual wetlands. In other words, an individual wetland's adjacency does not carry over to other wetlands in the watershed that may be farther from the adjacent waterbody. The guidance also states that a case-specific study of ecological interconnection is usually not needed to demonstrate reasonable proximity. Rather, the ecological interconnection can be inferred from the existing body of science (as of September 2014, a search for "wetlands" in the Environmental Protection Agency's science inventory yielded more than 1,400 results).

In the case of a wetland that is adjacent to a relatively permanent non-navigable waterway, a continuous surface connection must exist for nexus to be presumed. The 2008 guidance emphasizes that a wetland must be in direct physical contact with a non-navigable waterway.

According to the 2008 guidance, nexus would never be presumed for any wetland that is not adjacent to a navigable waterway or directly abutting a relatively permanent non-navigable tributary. Other wetlands would only be considered jurisdictional if significant nexus were established by assessment. In the remainder of the guidance, the agencies expanded on factors to be considered when significant nexus analyses are performed, including: the flow and functions of the tributary; whether any adjacent wetlands are present, and if so, their functions and contributions; and the degree of physical, chemical, and biological effects that the tributary and adjacent wetlands have on navigable waters, with some consideration for ecological functions. The guidance points out that swales, ditches, and similar features are not themselves wetlands, but can function as point sources that transfer water from wetlands to other waterways. The importance of this distinction is that point sources could be subject to other parts of the Clean Water Act, such as § 402 (pertaining to the National Pollutant Discharge Elimination System).

Draft regulatory guidance released in 2011

After a few years, the Environmental Protection Agency and the U.S. Army Corps of Engineers concluded that the December 2008 guidance did not reflect the full extent of authority that the Clean Water Act intended (USEPA and USACE 2011). The resulting 2011 draft guidance is arranged in sections that specifically cover: (1) traditional navigable waters, (2) interstate waters, (3) significant nexus analysis, (4) tributaries, (5) adjacent wetlands, and (6) other waters. The draft guidance also includes an appendix that expands on the legal and scientific basis for the new guidance.

The 2011 draft guidance draws more attention to collective impacts than did the 2008 guidance. Recall that the 2008 guidance directed field staff to evaluate wetlands on an individual, case-by-case basis. In contrast, the draft guidance states:

> *Watershed ecosystems, and their interrelationships, are constructed of component parts that have relevance when considered collectively. Failure to protect the components can undermine the ecosystem in its entirety. Therefore, the agencies have an obligation to evaluate waters in terms of how they interrelate and*

> *function as ecosystems rather than as individual units, especially in the context of complex ecosystems where their integrity may be compromised by environmental harms that individually may not be measurably large but collectively are significant.*

Where significant nexus analysis is required, the draft guidance directs field staff to determine the resource type of the water to be evaluated. The choices are: (1) tributary, (2) adjacent wetland, or (3) other proximate water. After the resource type is identified, the guidance directs field staff to determine the extent of the region. The guidance defines the region as watershed that contributes to a navigable or interstate water through a single point of entry. The result is that all resources of the same type within a single-point-of-entry watershed will be considered together. Finally, the guidance directs field staff to determine whether cumulative effects of similarly situated waters in a region are significant. The draft guidance considers all waters of the same resource type to be similarly situated. The guidance allows staff to rely on scientific information and explains that field staff do not need to identify every similarly situated water in the region if significant nexus can be demonstrated or reasonably presumed from a smaller set.

The draft 2011 guidance maintains that natural and man-made swales are not tributaries. However, in contrast to the 2008 guidance, the draft guidance notes that ditches or swales may include areas that meet the regulatory definition of "wetlands." Under the plurality or Kennedy standard, the 2011 guidance states that wetland ditches and swales will be evaluated as wetlands, not as tributaries. Like the 2008 guidance, the 2011 draft guidance recognizes that a swale or ditch can function as a point source and can contribute to a hydrologic connection between an adjacent wetland and a traditional navigable water or interstate water, even if the ditch or swale is not jurisdictional on its own.

In the 2008 guidance, it was not explicitly clear whether the term “unbroken hydrologic connection” referred to spatial or temporal continuity. The reader had to rely on inference and deduction. The draft 2011 guidance clarifies the meaning of “unbroken hydrologic connection” by explicitly stating:

> *An unbroken surface or shallow sub-surface hydrologic connection to jurisdictional waters may be established by a physical feature or discrete conveyance that supports periodic flow between the wetland and a jurisdictional water. Water does not have to be continuously present in this hydrologic connection and the flow between the wetland and the jurisdictional water may move in either or both directions. The hydrologic connection need not itself be a water of the U.S.*

In the section that specifically addresses adjacent wetlands, the draft guidance maintains the standards set forth in the 2008 guidance. Specifically, a wetland can be considered adjacent if one or more of the following conditions exist: (1) unbroken hydrologic connections, (2) physical separation by man-made or natural barriers, or (3) reasonably close proximity. Again, for clear discussion it is important to note that there are really only two conditions, and that the presence of barriers does not simply invalidate adjacency found by proximity or hydrologic connection. The draft guidance recognizes that these conditions can be extremely variable for different wetlands, and that field staff will need to exercise judgment to determine whether wetlands are adjacent to navigable or interstate waters. The guidance specifically addresses adjacency concerns for wetland mosaics, stating, “All wetlands within a wetland mosaic should ordinarily be considered collectively when determining adjacency. Wetlands present in such systems act generally as a single ecological unit.”

Most importantly, the draft guidance distinguishes between situations where adjacency and significant nexus evaluations are most appropriate. Discussion on this important question is completely absent from the 2008 guidance. To make this distinction, the agencies introduce the concept of a “nearest jurisdictional water.” The idea is that adjacency analysis applies if a navigable or interstate water is the nearest jurisdictional water to the wetland in question. Significant nexus analysis applies in all other cases.

Toward Inconsistent Clean Water Act Implementation

Despite the best efforts of Congress and regulatory agencies, inconsistencies can develop between a law, the rules used to implement the law, and the procedures used to implement the rules. In 2004, the United States General Accounting Office (now named the Government Accountability Office) found that Corps of Engineers district offices differ in how they interpret and apply federal regulations related to Clean Water Act jurisdiction, and in how they document their practices (United States General Accounting Office 2004). Though it was not directly stated in the two reports, the message was clear—inconsistency and lack of public transparency placed the Environmental Protection Agency and the Corps of Engineers at significant risk.

High information costs trigger the use of heuristics

Although the Government Accounting Office report noted that the federal regulations leave room for judgment and interpretation by district offices—a concept that the U.S. Supreme Court also acknowledged—the report specifically drew attention to several rules-of-thumb and decision-making shortcuts (i.e., heuristics) that certain Corps of Engineers district offices had been using to make jurisdictional decisions. Heuristics speed up decision-making, but can also lead to decision-making errors. This section explores the use of heuristics and some of the conditions that promote reliance on heuristics in making jurisdictional determinations. For example, perceived high information costs are known to trigger the use of heuristics (Bröder 2000). The information costs of a jurisdictional decision for a non-navigable water is certainly high compared to a clear-cut navigable waterway, creating conditions where reliance on heuristics is more likely to occur. The Environmental Protection Agency and the Corps of Engineers acknowledge that, especially after the *SWANCC* case, non-navigable waters that appear to be isolated are tough case-by-case decisions (Downing et al. 2003).

Heuristics can lead to errors and inconsistency

The Government Accounting Office specifically identified differing practices used to evaluate jurisdiction related to: (1) hydrologic connections, (2) proximity, (3) man-made and natural barriers, (4) ditches and other man-made surface conveyances, and (5) man-made subsurface conveyances. For example, the Government Accountability Office found that districts varied widely in whether the 100-year floodplain was used as evidence of a hydrologic connection. Some districts would never consider the 100-year floodplain, other districts might consider the 100-year floodplain as one factor of many, and still other districts might consider the 100-year floodplain as prima facie evidence of hydrologic connection.

The main issue raised by the previous example is that there are proxies in play that can cause errors. The use of the 100-year floodplain to determine whether a wetland is adjacent is actually a proxy for *two* entirely different questions, specifically: (1) whether there is an unbroken hydrologic connection, whether or not intermittent, between the wetland and a navigable waterway (USEPA and USACE 2008); and (2) whether the wetland is close enough to a navigable waterway to reasonably support a science-based inference of ecological interconnectedness (USEPA and USACE 2008). Worse yet, the 100-year floodplain is by no means a perfect proxy for either of those decisions. The science in this thesis, for example, demonstrates that the probability of hydrologic connection in any given year for a wetland outside of the 100-year floodplain can be much greater than the probability that flooding will occur at the 100-year floodplain boundary.

Sequential and non-sequential decisions produce different results

Assuming that all of the inconsistencies raised by the Government Accounting Office report were totally eliminated, conditions that promote heuristics still make the Environmental Protection Agency and the Corps of Engineers legally vulnerable. Currently, there is no clear sequence of decisions to determine whether a waterbody falls within Clean Water Act jurisdiction. Research from several different fields—including psychology, marketing, economics, and criminal law— as shown that sequential and simultaneous decision processes produce different results, and that the results obtained by non-sequential processes are more variable (e.g. Lindsay and Wells 1985, Simonson 1990, Read and Loewenstein 1995, Benartzi and Thaler 2001, Steblay et al. 2011).

For example, the 2008 guidance does not clearly identify what Corps of Engineer staff should consider first in the case of a wetland such as the wetland complex used in this study. Should staff first identify whether the wetland is isolated? Or should staff first identify the most proximate water and then determine whether the wetland is adjacent to a navigable waterway or a non-navigable waterway? Or should the adjacency of the wetland to a relatively permanent waterway, an intermittent waterway, or an ephemeral waterway be considered first? Or does adjacency to a navigable waterway take precedence, even where non-navigable waterways are more proximate? Or if water flows from the wetland through a ditch or swale, should staff first consider whether the ditch or swale is jurisdictional?

In the case of the wetland used in this study, the sequence of information considered can have huge impacts on whether nexus might be presumed because of adjacency, or whether a fact-based nexus evaluation would be required, or whether the wetland would be dismissed as isolated without any nexus evaluation. All three of these endpoints are possible, depending on the sequence of the information considered. To expand on this point, the wetland depressions evaluated in this study are almost equally proximate to a relatively permanent navigable waterway, and to an intermittent non-navigable channel with a discernible high water mark (FIG. 23 on page 77). None of the depressions are directly abutting a clearly-defined, bed-and-banks waterway. The distance from the navigable bayou to the closest wetland depression is about 125 m. The length of the shortest flow path from the depressions to the bayou is approximately 260 m, which consists of about 120 m of swale and about 140 m of intermittent channel. The wetland is clearly unidirectional, based on the Environmental Protection Agency's draft scientific basis for the current rulemaking (USEPA 2013). The Environmental Protection Agency's draft report concluded that all tributary streams are physically, chemically, and biologically connected to downstream waters; including perennial, intermittent, and ephemeral streams. The draft report also concluded that headwater streams supply most of the water in rivers. This study demonstrated that mosaics of unidirectional wetlands on the Texas Gulf Coast can and do form these very headwaters by sending water to intermittent streams through small swales. Although the Environmental Protection Agency's report concluded that it was impossible to generalize about the connectivity of unidirectional wetlands, this study clearly shows that swales flowing from unidirectional wetlands are prima facie physical evidence of surface connectivity.

If staff focuses first on the proximity to the navigable bayou and the continuity of the hydrologic features, including the swales, then it is possible that the study wetland might be found adjacent to the navigable bayou based on the unbroken hydrologic connection observed in this study. In stark contrast, if staff focuses first on the facts that portions of the swales are not always easy to identify and are not jurisdictional in their own right, these facts may be viewed as evidence that the wetlands are isolated and no significant nexus analysis would be performed. In between the previous endpoints, if staff first determined that the wetland depressions are adjacent to the non-navigable intermittent stream, then an analysis would be performed to determine if significant nexus exists, but the potential adjacency to the bayou might be overlooked. If the wetlands are in fact adjacent to a navigable waterway, then the final case could cost the Corps of Engineers unnecessary time and resources.

A Proposition for Increasing Consistency

The previous examples show that the decision process itself may be to blame for producing a degree of inconsistency. One easy way to reduce the potential for process-induced inconsistency is to adopt a set of sequential decisions to determine whether a wetland falls within Clean Water Act jurisdiction. A sequence of decisions would remove the variability created by the process, so that any remaining inconsistencies would be primarily related to the facts of the case being considered.

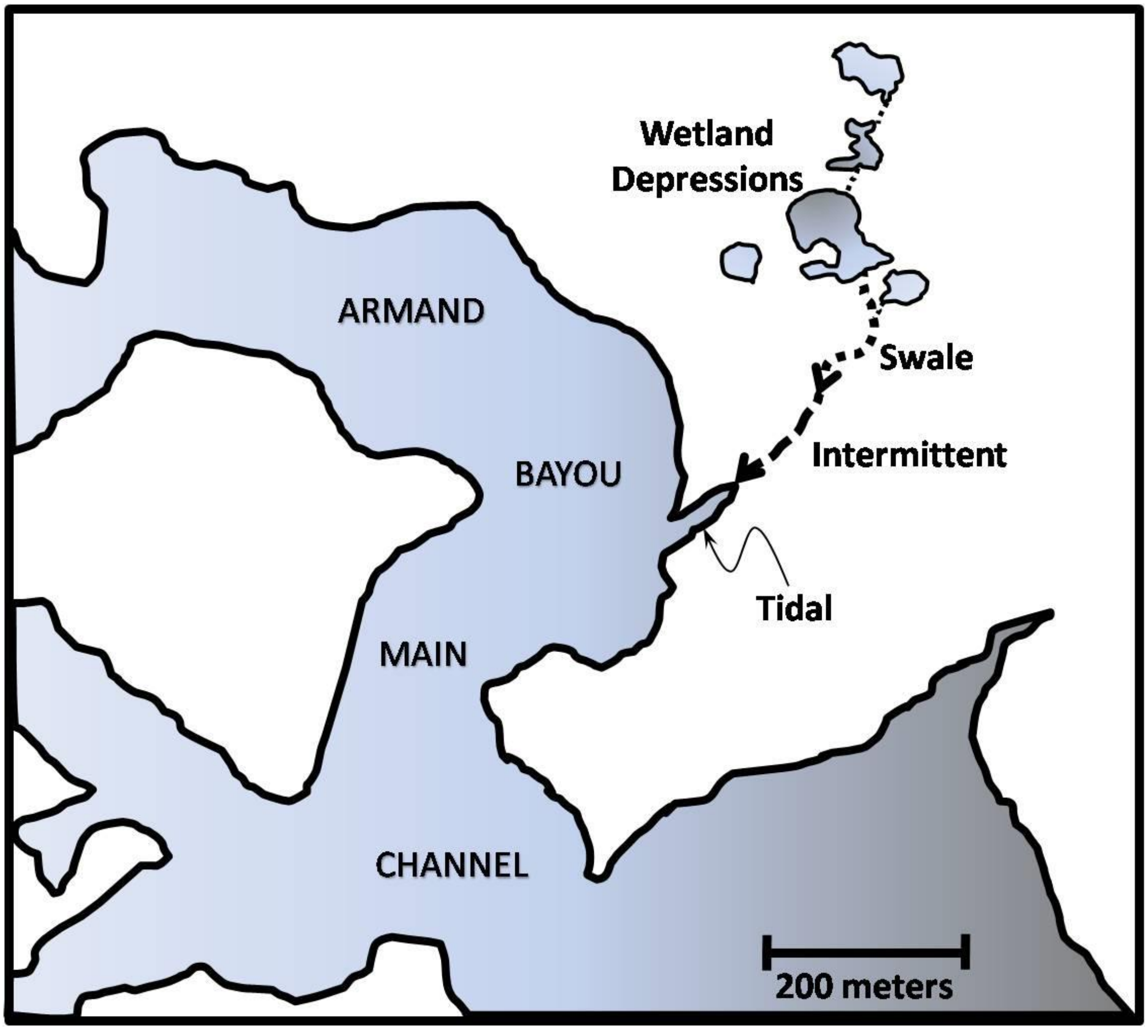


Fig. 23. Landscape context of the study wetland under the Clean Water Act. Important wet features are presented in gray. Short dashes represent swales and other small concentrated flow paths. Long dashes represent intermittent waters with an ordinary high water mark. Flow from wetland depressions travels through a network of swales to an intermittent channel, then to the tidal bayou.

Although the clarity of guidance improved from the 2008 guidance to the draft guidance released in 2011, the 2011 guidance relied heavily on the concept of a "nearest jurisdictional water." Though the nearest jurisdictional water concept is probably more reliable than the 100-year floodplain concept, it comes with several issues. For example, what happens for wetlands like those in this study, where the nearest jurisdictional water is non-navigable, but the wetlands might also be adjacent to a navigable waterway that is slightly farther away? The decision process proposed in this thesis eliminates these kinds of issues.

Several recent press articles suggest that rule amendments recently developed by the Environmental Protection Agency and the Corps of Engineers are intended to further a regulatory agenda that was never intended by the statutory language of the Clean Water Act (Price 2014). However, the goals established by Congress in the text of the Clean Water Act make the intent of Congress abundantly clear. The goals established by Congress in the Clean Water Act are: (1) to eliminate the discharge of pollutants into navigable waters by 1985 (Clean Water Act §101(a)(1)), and (2) that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983 (Clean Water Act §101(a)(2)). The most important thing that needs to be accomplished through the rulemaking is to establish a decision-making process that is reliable, consistent, and true to the law.

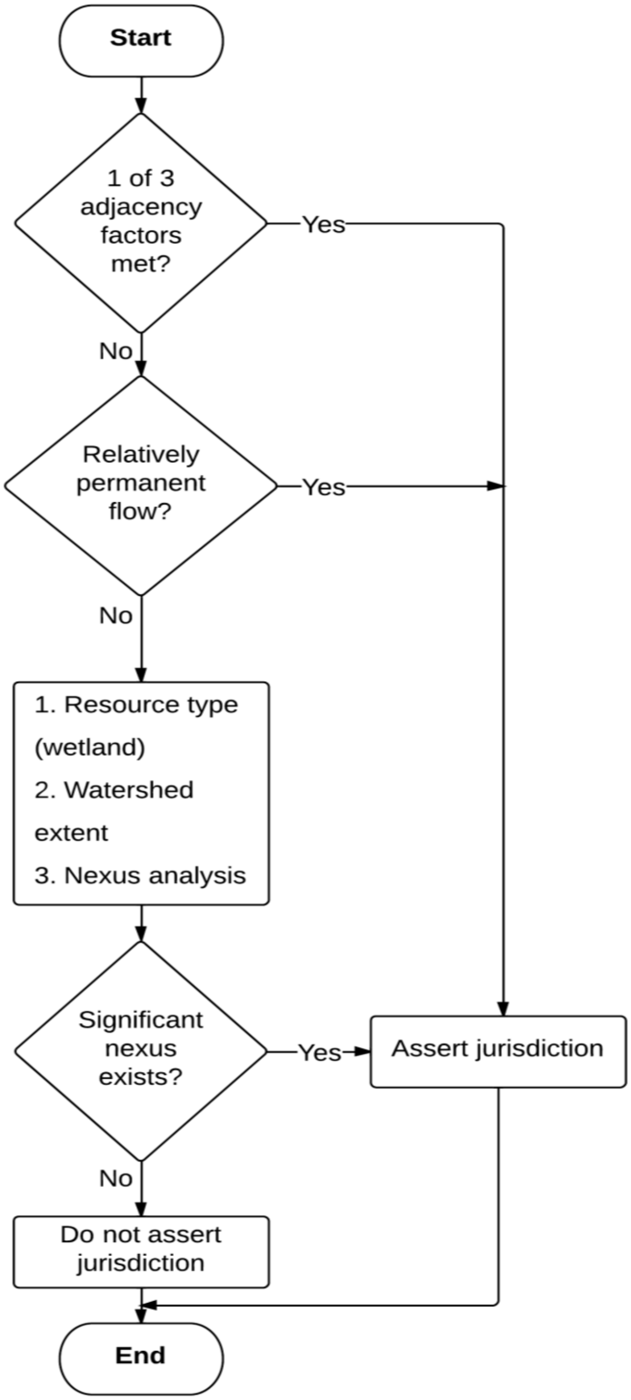


Fig. 24. Proposed process for jurisdictional determinations (see page 65 for adjacency criteria).

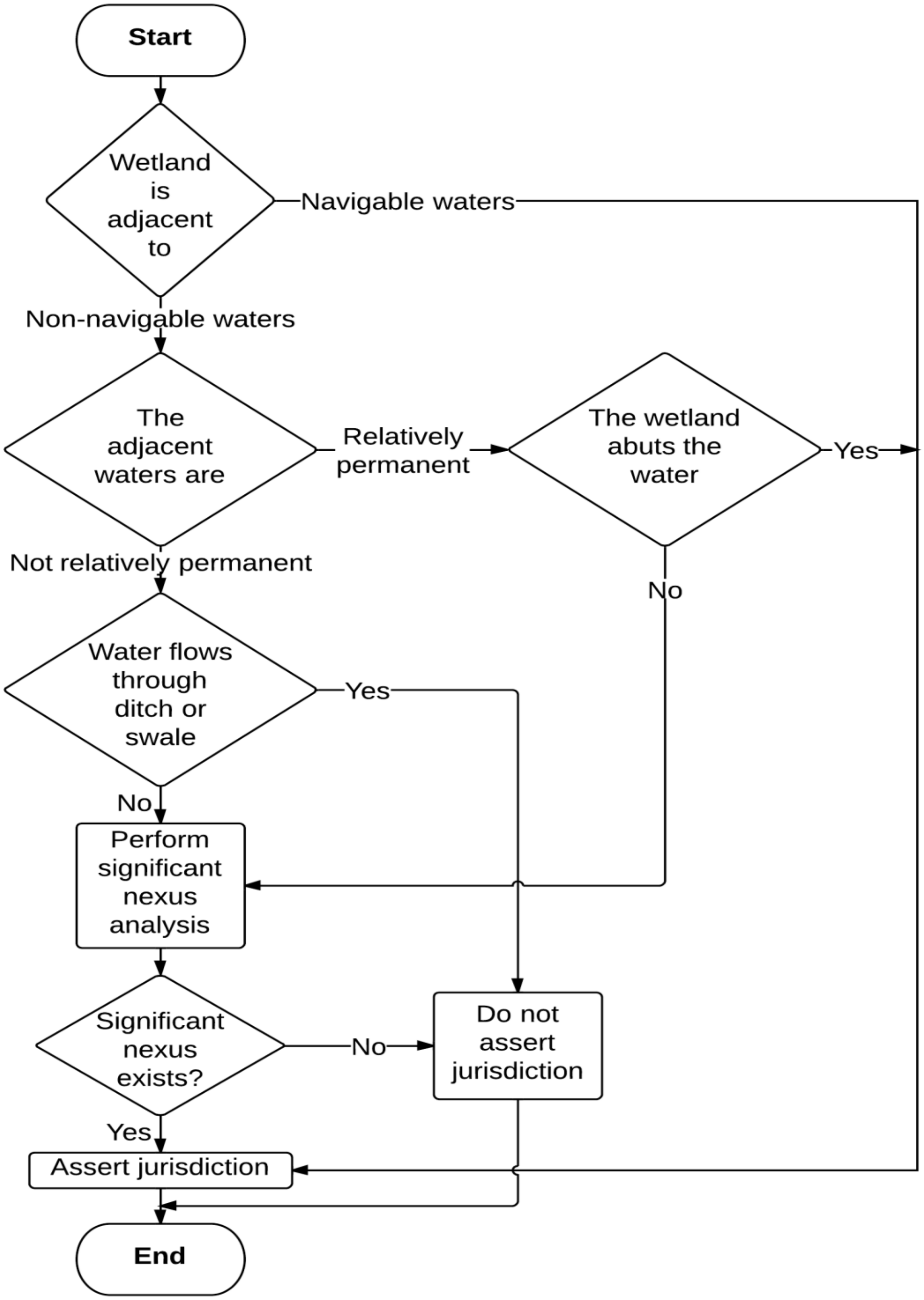


Fig. 25. One possible interpretation of the jurisdictional decision process based on the 2008 guidance.

Other inconsistencies that require attention

Aside from the issues of process raised earlier, the guidance documents contain some inconsistencies that need to be addressed, preferably through public-noticed rules.

For example, the 2008 guidance states that the controlling legal principles from the *Rapanos* case are those espoused by five or more justices. If that is true, then staff who drafted the second section of the guidance (Relatively Permanent Non-navigable Tributaries of Traditional Navigable Waters and Wetlands with a Continuous Surface Connection with Such Tributaries) erred legally and scientifically by resting on Justice Scalia's argument that continuous surface connections require direct abutment to a tributary. The agencies erred in their interpretation of the *Rapanos* case by placing this requirement on wetlands adjacent to tributaries, because five justices rejected Justice Scalia's limitation of continuous surface connection to physically abutting waters. Therefore wetlands do not need to abut tributaries for significant nexus to be presumed. Now research clearly demonstrates that the agencies also erred scientifically. Wetlands adjacent a tributary, but which do not directly abut it, can and do form hydrologic connections with the tributary. This point may raise issue in some parts of the country where non-navigable tributaries can be tens or even hundreds of miles long. However, many tributaries on the Texas Gulf Coast and in other similar regions are more appropriately measured in meters than in miles.

The 2008 guidance also contradicts the federal rules by stating that, "in assessing whether a wetland is reasonably close to a jurisdictional water, the proximity of the wetland (including all parts of a single wetland that has been divided by road crossings, ditches, berms, etc.) in question will be evaluated and shall not be evaluated together with other wetlands in the area." In contrast, 33 CFR §320.4 shows clear intent that wetlands should be evaluated cumulatively, stating, "…the cumulative effect of numerous piecemeal changes can result in a major impairment of wetland resources. Thus, the particular wetland site for which an application is made will be evaluated with the recognition that it may be part of a complete and interrelated wetland area."

Another example related to wetlands adjacent to non-navigable streams can be found in the draft 2011 guidance, which contradicts 33 CFR § 328 by stating that "a finding that a particular wetland is adjacent to a jurisdictional waterbody other than a traditional navigable water … is not sufficient in and of itself to establish Clean Water Act jurisdiction over that wetland." The rules in 33 CFR § 328 explicitly state that Clean Water Act jurisdiction extends beyond the ordinary high water mark of covered waters to encompass their adjacent wetlands.

A Case for Why the "Isolated" Wetlands in This Study Should be Jurisdictional

The study wetland meets the criteria for adjacency in 33 CFR. This research project documented that the wetland passed the unbroken surface connection test (see Wilcox et al. 2011). Specifically, water flowed from the wetland to an intermittent channel, and then to a navigable water through defined courses. By defined courses, we did not mean watercourses with bed and banks, but rather that water flows through the same discernible pathways every time. This meaning is not inconsistent with the Clean Water Act definition of a point source.

Several facts distinguish the wetlands in this study from those considered by the Supreme Court in the *Rapanos* case. These facts, in addition to the observed presence of biota and scientific findings of other researchers in the area, make for a compelling argument that the study wetland complex passes the reasonable proximity test.

First, according to the facts of the *Rapanos* case, those wetlands were adjacent to man-made drainage ditches. This study documented real discharges directly to a natural watercourse, although it should be noted that man-made ditches can and do carry water from one place to another. Second, the wetlands filled by Carabell in the *Rapanos* case were separated from the adjacent drainage ditch by an impermeable berm. Although a natural levee separates the wetlands in this study from the navigable bayou nearby, the levee is cut through by natural watercourses, and did not prevent wetland discharges from flowing to the bayou through those watercourses. Third, the sets of wetlands filled by Rapanos in the *Rapanos* case were 11 and 20 *miles* away from the nearest navigable watercourse. In stark contrast, the wetlands in this study were entirely situated within a range of approximately 125 to 375 *meters* from the navigable bayou. In fact, the distance between the study wetlands and the navigable Bayou closely resembles the distance between the wetlands on the Riverside Bayview Homes, Inc. property and Black Creek on the western side of Lake St. Clair—wetlands which the U.S. Supreme Court determined fell within the jurisdiction of the Clean Water Act.

According to the 2008 guidance, scientists have already demonstrated ecological interdependence between waters and adjacent wetlands, leading to the ability to apply a scientifically-supported presumption of nexus. This study supports that scientific presumption. The wetlands in the study watershed have hosted gambusia, tadpoles, and aquatic insect eggs within the depressions. The wetlands from this study send a substantial percentage of the water they receive to the bayou. Forbes et al. (2010) stated that coastal prairie wetlands are an integral part of the Galveston Bay ecosystem, and further observed that the cumulative impact of wetland losses could also have substantial detrimental impacts on the hydrology, water quality, and general ecosystem health of nearby aquatic systems, particularly in Galveston Bay and its tributaries. These observations by Forbes et al. also support the science-based inference that wetlands in the region have an effect on the ecology of jurisdictional waters, and the idea that wetlands in the region are important to the public interest (see 33 CFR §320.4(b)(2)).

CHAPTER IV

SUMMARY[*]

Wetland Hydrology

The wetland complex in this study was not an isolated system—the wetland depressions were in fact hydrologically and ecologically woven into the fabric of their surroundings. More importantly, these research findings likely have applications that are broader than the immediate study area. The depressions, swales, and similar hydrologic features of the wetland complex used in this study are common across the Texas Gulf Coast region. Moreover, surface connections between "isolated" wetlands and jurisdictional waters have been observed in other research findings related to wetlands on the Texas Gulf Coast and in findings from the larger body of wetland science. Further confirmation of surface hydrological connectivity on the Texas Gulf Coast was provided by Forbes et al. (2009), who monitored outflow for one year at six wetland locations on the Texas Gulf Coast and reported that runoff occurred from all of the monitored locations. Coupled with these observations, our findings provide strong evidence that shallow wetland depressions on the Texas Coastal Plain are not closed systems, and that swales provide clear evidence of substantial surface connectivity.

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[*] Portions of this chapter are reprinted or adapted from *Wetlands*, vol. 31, 2011, pp. 451-458, Evidence of surface connectivity for Texas Gulf Coast depressional wetlands, Bradford P. Wilcox, Dex D. Dean, John S. Jacob, and Andrew Sipocz, with consent of the authors and with kind permission from Springer Science and Business Media.

Wetlands on the Texas Gulf Coast are not expressly seasonal. Rather, they can produce flow in any season, depending on the rainfall pattern in a particular year. One shortcoming of Justice Scalia's hydrologic permanence test from the *Rapanos* case overlooks the real-world truth that regional precipitation patterns are not identical and that precipitation is not uniform. Wetlands on the Texas Gulf Coast do not flow continuously, nor should they be expected to do so. During most years, a substantial portion of the annual rainfall comes from just few major storm events. During the study period, runoff-producing storms accounted for large portions of the total annual rainfall (37% to 62% of annual rainfall).

Contrary to expectations, groundwater did not follow the shortest path to Armand Bayou, but ran generally parallel to the bayou. This observation is not inconsistent with other studies that observed localized groundwater flow nearest the surface, with more regional groundwater flow at greater depths. Regional groundwater flow between separate watersheds or even separate basins is common in a wide variety of topographic and hydrogeologic settings (Winter et al. 2003, Gleeson and Manning 2008). Additional study will be needed to confirm whether deeper groundwater at the study site is most connected with the Armand Bayou, Clear Lake, Galveston Bay, or the Gulf Coast Aquifer.

This study demonstrated that deciduous trees impact the saturation state of surface soils in Texas's forested wetlands. As a result, wetlands that have standing water during one month can appear totally dry the next. The important message is that jurisdictional decisions must take weather patterns into account. Wetlands that are not isolated may appear isolated during dry months and the wet-to-dry transition can happen rapidly on the Texas Gulf Coast. Rainfall patterns on the Texas coast can restore surface saturation and reducing soil conditions during any season.

Temporal patterns of runoff from the study wetland and the urbanized Vince Bayou watershed were very similar. However, the urbanized watershed produced peak flows that were more than four times greater in magnitude than the greatest peak flow from the wetlands during the same time period. This observation supports the scientific conclusion that wetlands substantially dampen peak flows. Additionally, there were events where Vince Bayou's flow increased after relatively small rainfall events. The wetlands often did not respond during the same rainfall event, emphasizing their ability to contain first-flush runoff.

Wetlands and the Clean Water Act Regulatory Framework

The hydrologic findings of this study suggest that many wetlands along the Texas Gulf Coast may be overlooked during implementation of the Clean Water Act, although those wetlands actually affect navigable waterways. Specifically, the use of heuristics and the lack of a clear progression in decision-making processes are known to cause inconsistency, leaving room for unnecessary variability in jurisdictional determinations. A close review of the Clean Water Act, rules, and case law, paired with the hydrologic findings of this study, revealed that there is a strong case that the "isolated" wetlands examined in this study should actually be considered jurisdictional by virtue of adjacency with a navigable waterway. This thesis proposes that a sequential decision-making progression, which should begin with decisions that would readily identify hydrologic nexus and end with the decision that would least readily identify hydrologic nexus— will eliminate heuristics that produce variability in decision-making, thus leading to more accurate and consistent jurisdictional determinations. This is essentially a diagnostic approach that focuses on broad questions before honing in on specific issues; it eliminates the temptation to skip past the broad but vitally important questions (such as identifying whether a wetland is adjacent to a navigable water) in favor of a quick and easy answer that based on incomplete and often misrepresentative information.

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APPENDIX A

RAINFALL AND RUNOFF DATA

Table A - 1. Rainfall and runoff data notes and their meanings.

NOTE	MEANING
A	Rainfall data incomplete, no substitution
B	Rainfall data incomplete, data substituted using Houston NWSO weather station data
C	Runoff data incomplete, no substitution
D	Runoff data incomplete, data substituted as described in main text
T	Trace runoff (< 0.01 mm)

Table A - 2. Daily totals for rainfall and runoff.

DATE M/DD/YYYY	RAINFALL [MM]	RUNOFF [MM]	NOTES
3/31/2005	0	0	B C
4/1/2005	0	0	
4/2/2005	0	0	
4/3/2005	0	0	
4/4/2005	0	0	
4/5/2005	0	0	
4/6/2005	0.02	0	
4/7/2005	0	0	
4/8/2005	0	0	
4/9/2005	0	0	
4/10/2005	0	0	
4/11/2005	0.33	0	
4/12/2005	0	0	
4/13/2005	0	0	
4/14/2005	0	0	
4/15/2005	0	0	
4/16/2005	0	0	
4/17/2005	0	0	
4/18/2005	0	0	
4/19/2005	0	0	
4/20/2005	0	0	

Table A - 2 (continued).

DATE M/DD/YYYY	RAINFALL [MM]	RUNOFF [MM]	NOTES
4/21/2005	0	0	
4/22/2005	0.05	0	
4/23/2005	0	0	
4/24/2005	0	0	
4/25/2005	0.87	0	
4/26/2005	0	0	
4/27/2005	0.01	0	
4/28/2005	0	0	
4/29/2005	0	0	
4/30/2005	0	0	
5/1/2005	0	0	
5/2/2005	0	0	
5/3/2005	0	0	
5/4/2005	0.1	0	
5/5/2005	0	0	
5/6/2005	0	0	
5/7/2005	0	0	
5/8/2005	1.31	0	
5/9/2005	0	0	B C
5/10/2005	0	0	B C
5/11/2005	0	0	B C
5/12/2005	0	0	B C
5/13/2005	0	0	
5/14/2005	0	0	
5/15/2005	0	0	
5/16/2005	0	0	
5/17/2005	0.02	0	
5/18/2005	0	0	
5/19/2005	0	0	
5/20/2005	0	0	
5/21/2005	0	0	
5/22/2005	0	0	
5/23/2005	0	0	
5/24/2005	0	0	
5/25/2005	0	0	
5/26/2005	0.09	0	

5/27/2005	0	0	
5/28/2005	0	0	
5/29/2005	1.11	0	
5/30/2005	0.16	0	
5/31/2005	0	0	
6/1/2005	0.26	0	
6/2/2005	0	0	
6/3/2005	0	0	
6/4/2005	0	0	
6/5/2005	0	0	
6/6/2005	0.04	0	
6/7/2005	0.14	0	
6/8/2005	0	0	B C
6/9/2005	6.9	0	B C
6/10/2005	0	0	B C
6/11/2005	0	0	C
6/12/2005	0	0	
6/13/2005	0	0	
6/14/2005	0	0	
6/15/2005	0.01	0	
6/16/2005	0	0	
6/17/2005	0	0	
6/18/2005	0	0	
6/19/2005	0	0	
6/20/2005	0	0	
6/21/2005	0	0	
6/22/2005	0	0	
6/23/2005	0	0	
6/24/2005	0	0	
6/25/2005	0.05	0	
6/26/2005	0	0	
6/27/2005	0	0	
6/28/2005	0	0	
6/29/2005	0	0	
6/30/2005	0	0	
7/1/2005	0.45	0	
7/2/2005	0	0	
7/3/2005	0	0	
7/4/2005	0	0	
7/5/2005	0	0	

7/6/2005	0.53	0	
7/7/2005	0.02	0	
7/8/2005	5.3	0	B C
7/9/2005	1	0	B C
7/10/2005	0	0	B C
7/11/2005	0	0	B C
7/12/2005	10.2	0	B C
7/13/2005	0.3	0	B C
7/14/2005	29.2	0	B C
7/15/2005	85.3	0	B C
7/16/2005	1.3	0	B C
7/17/2005	9.1	0	B C
7/18/2005	0	0	B C
7/19/2005	0.8	0	B C
7/20/2005	2.3	0	B C
7/21/2005	1	0	B C
7/22/2005	0	0	B C
7/23/2005	0	0	B C
7/24/2005	0	0	
7/25/2005	0	0	
7/26/2005	0	0	
7/27/2005	0	0	
7/28/2005	0	0	
7/29/2005	0.03	0	
7/30/2005	0.01	0	
7/31/2005	0	0	
8/1/2005	0	0	
8/2/2005	0	0	
8/3/2005	0	0	
8/4/2005	0	0	
8/5/2005	0.45	0	
8/6/2005	0.02	0	
8/7/2005	0	0	
8/8/2005	0.07	0	
8/9/2005	0.34	0	
8/10/2005	0.01	0	
8/11/2005	0	0	
8/12/2005	0.19	0	
8/13/2005	0	0	
8/14/2005	0	0	

8/15/2005	0	0	
8/16/2005	0.01	0	
8/17/2005	0.73	0	
8/18/2005	0	0	B C
8/19/2005	0	0	B C
8/20/2005	0	0	B C
8/21/2005	0	0	
8/22/2005	0	0	
8/23/2005	0	0	
8/24/2005	0	0	
8/25/2005	0.07	0	
8/26/2005	0.01	0	
8/27/2005	0.09	0	
8/28/2005	0.77	0	
8/29/2005	0	0	
8/30/2005	0	0	
8/31/2005	0	0	
9/1/2005	0.92	0	
9/2/2005	0.17	0	
9/3/2005	1.32	0	
9/4/2005	0.01	0	
9/5/2005	0	0	
9/6/2005	0	0	
9/7/2005	0	0	
9/8/2005	0	0	
9/9/2005	0	0	
9/10/2005	0.4	0	
9/11/2005	0	0	
9/12/2005	0.04	0	
9/13/2005	0.32	0	
9/14/2005	0	0	
9/15/2005	0	0	B C
9/16/2005	22.6	0	B C
9/17/2005	0	0	B C
9/18/2005	0	0	B C
9/19/2005	0	0	B C
9/20/2005	0	0	B C
9/21/2005	0	0	B C
9/22/2005	0	0	B C
9/23/2005	16.3	0	B C

9/24/2005	12.4	0	B C
9/25/2005	0	0	
9/26/2005	0.01	0	
9/27/2005	0	0	
9/28/2005	0	0	
9/29/2005	0.05	0	
9/30/2005	0	0	
10/1/2005	0	0	
10/2/2005	0.03	0	
10/3/2005	0	0	
10/4/2005	0.06	0	
10/5/2005	0.05	0	
10/6/2005	0	0	
10/7/2005	0	0	
10/8/2005	0	0	
10/9/2005	0	0	
10/10/2005	0.25	0	
10/11/2005	0.19	0	
10/12/2005	0.06	0	
10/13/2005	0.03	0	
10/14/2005	0.01	0	
10/15/2005	0	0	
10/16/2005	0	0	
10/17/2005	0	0	
10/18/2005	0	0	
10/19/2005	0	0	
10/20/2005	0.01	0	
10/21/2005	0	0	
10/22/2005	0	0	
10/23/2005	0	0	
10/24/2005	0	0	
10/25/2005	0	0	
10/26/2005	0	0	
10/27/2005	0	0	
10/28/2005	0	0	
10/29/2005	0	0	
10/30/2005	0	0	
10/31/2005	0.03	0	
11/1/2005	0.01	0	
11/2/2005	0	0	

11/3/2005	0.01	0	
11/4/2005	0.04	0	
11/5/2005	0.02	0	
11/6/2005	0.01	0	
11/7/2005	0.01	0	
11/8/2005	0.01	0	
11/9/2005	0	0	
11/10/2005	0	0	
11/11/2005	0	0	
11/12/2005	0	0	
11/13/2005	0	0	
11/14/2005	0	0	
11/15/2005	0	0	
11/16/2005	0	0	B
11/17/2005	0	0	B
11/18/2005	0	0	B
11/19/2005	0.3	0	B
11/20/2005	5.6	0	B
11/21/2005	0	0	B
11/22/2005	0	0	B
11/23/2005	0	0	B
11/24/2005	0	0	
11/25/2005	0.01	0	
11/26/2005	2.24	0	
11/27/2005	0.01	0	
11/28/2005	0.01	0	
11/29/2005	0	0	
11/30/2005	0	0	
12/1/2005	0	0	
12/2/2005	0	0	
12/3/2005	0.01	0	
12/4/2005	0.06	0	
12/5/2005	0.01	0	
12/6/2005	0	0	
12/7/2005	0.1	0	
12/8/2005	0	0	
12/9/2005	0	0	
12/10/2005	0	0	
12/11/2005	0	0	
12/12/2005	0	0	

12/13/2005	0.01	0	
12/14/2005	3.36	0.5110143	
12/15/2005	0	0	B C
12/16/2005	0	0	B C
12/17/2005	8.4	0	B C
12/18/2005	0	0	B C
12/19/2005	0	0	B C
12/20/2005	0	0	
12/21/2005	0	0	
12/22/2005	0	0	
12/23/2005	0.01	0	
12/24/2005	0	0	
12/25/2005	0	0	
12/26/2005	0	0	
12/27/2005	0	0	
12/28/2005	0.01	0	
12/29/2005	0	0	
12/30/2005	0	0	
12/31/2005	0.01	0	C
1/1/2006	0.00	0.00	
1/2/2006	0.00	0.00	
1/3/2006	0.00	0.00	
1/4/2006	0.01	0.00	
1/5/2006	0.00	0.00	
1/6/2006	0.00	0.00	
1/7/2006	0.00	0.00	
1/8/2006	0.00	0.00	
1/9/2006	0.00	0.00	
1/10/2006	0.01	0.00	
1/11/2006	0.01	0.00	
1/12/2006	0.01	0.00	
1/13/2006	0.00	0.00	
1/14/2006	0.00	0.00	
1/15/2006	0.00	0.00	
1/16/2006	0.74	0.00	
1/17/2006	0.44	0.00	
1/18/2006	0.00	0.00	
1/19/2006	0.00	0.00	
1/20/2006	0.00	0.00	
1/21/2006	0.01	0.00	

1/22/2006	0.85	0.00	T
1/23/2006	0.00	0.00	T
1/24/2006	0.00	0.00	
1/25/2006	0.00	0.00	
1/26/2006	0.00	0.00	
1/27/2006	0.00	0.00	
1/28/2006	0.29	0.00	
1/29/2006	0.02	0.00	
1/30/2006	0.00	0.00	
1/31/2006	0.00	0.00	
2/1/2006	0.31	0.00	
2/2/2006	0.01	0.00	
2/3/2006	0.00	0.00	
2/4/2006	0.00	0.00	
2/5/2006	0.00	0.00	
2/6/2006	0.00	0.00	
2/7/2006	0.00	0.00	
2/8/2006	0.00	0.00	
2/9/2006	0.00	0.00	
2/10/2006	0.54	0.00	
2/11/2006	0.00	0.00	
2/12/2006	0.00	0.00	
2/13/2006	0.00	0.00	
2/14/2006	0.00	0.00	
2/15/2006	0.00	0.00	
2/16/2006	0.00	0.00	
2/17/2006	0.00	0.00	
2/18/2006	0.26	0.00	
2/19/2006	0.02	0.00	
2/20/2006	0.00	0.00	
2/21/2006	0.01	0.00	
2/22/2006	0.01	0.00	
2/23/2006	0.00	0.00	
2/24/2006	0.01	0.00	
2/25/2006	0.49	0.00	
2/26/2006	0.00	0.00	
2/27/2006	0.01	0.00	
2/28/2006	0.00	0.00	
3/1/2006	0.01	0.00	
3/2/2006	0.01	0.00	

3/3/2006	0.00	0.00
3/4/2006	0.00	0.00
3/5/2006	0.00	0.00
3/6/2006	0.00	0.00
3/7/2006	0.01	0.00
3/8/2006	0.01	0.00
3/9/2006	0.04	0.00
3/10/2006	0.00	0.00
3/11/2006	0.00	0.00
3/12/2006	0.00	0.00
3/13/2006	0.02	0.00
3/14/2006	0.00	0.00
3/15/2006	0.00	0.00
3/16/2006	0.00	0.00
3/17/2006	0.01	0.00
3/18/2006	0.00	0.00
3/19/2006	0.00	0.00
3/20/2006	0.06	0.00
3/21/2006	0.00	0.00
3/22/2006	0.02	0.00
3/23/2006	0.03	0.00
3/24/2006	0.00	0.00
3/25/2006	0.00	0.00
3/26/2006	0.00	0.00
3/27/2006	0.00	0.00
3/28/2006	0.60	0.00
3/29/2006	0.29	0.00
3/30/2006	0.01	0.00
3/31/2006	0.00	0.00
4/1/2006	0.00	0.00
4/2/2006	0.00	0.00
4/3/2006	0.00	0.00
4/4/2006	0.00	0.00
4/5/2006	0.01	0.00
4/6/2006	0.00	0.00
4/7/2006	0.00	0.00
4/8/2006	0.00	0.00
4/9/2006	0.00	0.00
4/10/2006	0.00	0.00
4/11/2006	0.00	0.00

4/12/2006	0.00	0.00	
4/13/2006	0.00	0.00	
4/14/2006	0.01	0.00	
4/15/2006	0.01	0.00	
4/16/2006	0.00	0.00	
4/17/2006	0.00	0.00	
4/18/2006	0.01	0.00	
4/19/2006	0.00	0.00	
4/20/2006	0.00	0.00	
4/21/2006	0.57	0.00	
4/22/2006	0.04	0.00	
4/23/2006	0.00	0.00	
4/24/2006	0.01	0.00	
4/25/2006	0.05	0.00	
4/26/2006	0.10	0.00	
4/27/2006	0.00	0.00	
4/28/2006	0.00	0.00	
4/29/2006	0.73	0.00	
4/30/2006	0.00	0.00	
5/1/2006	0.01	0.00	
5/2/2006	0.02	0.00	
5/3/2006	0.00	0.00	
5/4/2006	0.33	0.00	
5/5/2006	0.00	0.00	
5/6/2006	0.65	0.00	
5/7/2006	0.00	0.00	
5/8/2006	0.00	0.00	
5/9/2006	0.00	0.00	
5/10/2006	0.00	0.00	
5/11/2006	0.00	0.00	B C
5/12/2006	0.00	0.00	B C
5/13/2006	0.00	0.00	B C
5/14/2006	0.70	0.00	
5/15/2006	0.00	0.00	
5/16/2006	0.00	0.00	
5/17/2006	0.00	0.00	
5/18/2006	0.00	0.00	
5/19/2006	0.01	0.00	
5/20/2006	0.00	0.00	
5/21/2006	0.00	0.00	

5/22/2006	0.01	0.00	
5/23/2006	0.00	0.00	
5/24/2006	0.00	0.00	
5/25/2006	0.00	0.00	
5/26/2006	0.00	0.00	
5/27/2006	0.00	0.00	
5/28/2006	0.02	0.00	
5/29/2006	1.22	0.00	
5/30/2006	0.00	0.00	
5/31/2006	1.93	0.00	
6/1/2006	0.01	0.00	
6/2/2006	0.00	0.00	
6/3/2006	0.00	0.00	
6/4/2006	0.00	0.00	
6/5/2006	0.00	0.00	
6/6/2006	0.00	0.00	
6/7/2006	0.00	0.00	
6/8/2006	0.43	0.00	C
6/9/2006	0.00	0.00	C
6/10/2006	0.00	0.00	C
6/11/2006	0.00	0.00	C
6/12/2006	0.00	0.00	C
6/13/2006	0.07	0.00	C
6/14/2006	0.01	0.00	C
6/15/2006	0.00	0.00	C
6/16/2006	0.01	0.00	C
6/17/2006	0.07	0.00	C
6/18/2006	1.10	0.00	C
6/19/2006	3.90	9.86	C
6/20/2006	0.67	5.46	C
6/21/2006	0.00	1.73	C
6/22/2006	0.00	0.10	C
6/23/2006	0.00	0.00	C
6/24/2006	0.00	0.00	C
6/25/2006	0.00	0.00	C
6/26/2006	0.00	0.00	C
6/27/2006	0.00	0.00	C
6/28/2006	0.00	0.00	C
6/29/2006	0.00	0.00	C
6/30/2006	0.00	0.00	C

7/1/2006	0.14	0.00	C
7/2/2006	0.02	0.00	C
7/3/2006	0.38	0.00	C
7/4/2006	1.13	0.00	C
7/5/2006	1.00	1.10	C
7/6/2006	0.10	0.24	
7/7/2006	0.00	0.01	T
7/8/2006	0.02	0.00	
7/9/2006	0.01	0.00	
7/10/2006	0.00	0.00	
7/11/2006	0.00	0.00	
7/12/2006	0.00	0.00	
7/13/2006	0.00	0.00	A C
7/14/2006	0.00	0.00	
7/15/2006	0.00	0.00	
7/16/2006	0.00	0.00	
7/17/2006	0.00	0.00	
7/18/2006	0.75	0.00	
7/19/2006	0.01	0.00	
7/20/2006	0.00	0.00	
7/21/2006	0.00	0.00	
7/22/2006	0.01	0.00	
7/23/2006	0.05	0.00	
7/24/2006	0.00	0.00	
7/25/2006	2.28	0.83	
7/26/2006	1.26	8.30	
7/27/2006	0.00	2.92	
7/28/2006	0.00	0.57	
7/29/2006	0.00	0.06	
7/30/2006	0.00	0.00	
7/31/2006	0.04	0.00	
8/1/2006	0.00	0.00	
8/2/2006	0.00	0.00	
8/3/2006	0.00	0.00	
8/4/2006	0.00	0.00	
8/5/2006	0.00	0.00	
8/6/2006	1.51	0.33	
8/7/2006	0.08	0.00	
8/8/2006	0.00	0.00	
8/9/2006	0.00	0.00	

8/10/2006	0.09	0.00	
8/11/2006	0.01	0.00	A C
8/12/2006	0.00	0.00	B C
8/13/2006	0.00	0.00	
8/14/2006	0.00	0.00	
8/15/2006	0.01	0.00	
8/16/2006	0.00	0.00	
8/17/2006	0.00	0.00	
8/18/2006	0.00	0.00	
8/19/2006	0.48	0.00	
8/20/2006	0.00	0.00	
8/21/2006	0.00	0.00	
8/22/2006	0.01	0.00	
8/23/2006	0.79	0.00	
8/24/2006	0.01	0.00	
8/25/2006	0.00	0.00	
8/26/2006	0.02	0.00	
8/27/2006	0.00	0.00	
8/28/2006	0.02	0.00	
8/29/2006	0.01	0.00	
8/30/2006	0.00	0.00	
8/31/2006	0.00	0.00	
9/1/2006	0.00	0.00	
9/2/2006	0.00	0.00	
9/3/2006	0.00	0.00	
9/4/2006	0.00	0.00	
9/5/2006	0.01	0.00	
9/6/2006	0.01	0.00	
9/7/2006	0.00	0.00	
9/8/2006	0.30	0.00	B C
9/9/2006	6.10	0.00	B C
9/10/2006	5.60	0.00	B C
9/11/2006	3.30	0.00	B C
9/12/2006	43.90	0.00	B C
9/13/2006	0.00	0.00	B C
9/14/2006	0.00	0.00	B C
9/15/2006	0.38	0.00	
9/16/2006	0.09	0.00	
9/17/2006	0.40	0.00	
9/18/2006	0.10	0.00	

9/19/2006	0.00	0.00	
9/20/2006	0.00	0.00	
9/21/2006	0.04	0.00	
9/22/2006	0.00	0.00	
9/23/2006	0.46	0.00	
9/24/2006	0.49	0.00	
9/25/2006	0.00	0.00	
9/26/2006	0.00	0.00	
9/27/2006	0.00	0.00	
9/28/2006	0.00	0.00	
9/29/2006	0.00	0.00	
9/30/2006	0.00	0.00	
10/1/2006	0.01	0.00	
10/2/2006	0.00	0.00	
10/3/2006	0.00	0.00	
10/4/2006	0.01	0.00	
10/5/2006	0.01	0.00	
10/6/2006	0.00	0.00	
10/7/2006	0.00	0.00	
10/8/2006	0.00	0.00	
10/9/2006	0.00	0.00	
10/10/2006	1.06	0.00	
10/11/2006	0.01	0.00	
10/12/2006	1.89	0.00	
10/13/2006	0.00	0.00	
10/14/2006	0.00	0.00	
10/15/2006	2.20	0.59	
10/16/2006	3.83	34.87	
10/17/2006	0.01	15.24	
10/18/2006	0.00	1.31	
10/19/2006	0.06	0.17	
10/20/2006	0.00	0.00	T
10/21/2006	0.03	0.00	
10/22/2006	0.12	0.00	
10/23/2006	0.00	0.00	
10/24/2006	0.00	0.00	
10/25/2006	0.00	0.00	
10/26/2006	3.36	22.49	
10/27/2006	0.53	31.79	
10/28/2006	0.00	2.06	

10/29/2006	0.00	0.22	
10/30/2006	0.01	0.01	T
10/31/2006	0.00	0.00	B C
11/1/2006	0.00	0.00	B C
11/2/2006	0.00	0.00	
11/3/2006	0.00	0.00	
11/4/2006	0.00	0.00	
11/5/2006	0.02	0.00	
11/6/2006	0.12	0.00	
11/7/2006	0.01	0.00	
11/8/2006	0.01	0.00	
11/9/2006	0.01	0.00	
11/10/2006	0.07	0.00	
11/11/2006	0.00	0.00	
11/12/2006	0.00	0.00	
11/13/2006	0.00	0.00	
11/14/2006	0.02	0.00	
11/15/2006	0.00	0.00	
11/16/2006	0.00	0.00	
11/17/2006	0.00	0.00	
11/18/2006	0.01	0.00	
11/19/2006	0.00	0.00	
11/20/2006	0.00	0.00	
11/21/2006	0.00	0.00	
11/22/2006	0.00	0.00	
11/23/2006	0.01	0.00	
11/24/2006	0.01	0.00	
11/25/2006	0.01	0.00	
11/26/2006	0.01	0.00	
11/27/2006	0.23	0.00	
11/28/2006	0.01	0.00	
11/29/2006	0.01	0.00	
11/30/2006	0.01	0.00	
12/1/2006	0.00	0.00	
12/2/2006	0.00	0.00	
12/3/2006	0.00	0.00	
12/4/2006	0.00	0.00	
12/5/2006	0.00	0.00	
12/6/2006	0.00	0.00	
12/7/2006	0.00	0.00	

12/8/2006	0.00	0.00	
12/9/2006	0.00	0.00	
12/10/2006	0.01	0.00	
12/11/2006	1.66	0.52	
12/12/2006	0.01	0.19	
12/13/2006	0.00	0.01	
12/14/2006	0.01	0.00	
12/15/2006	0.00	0.00	
12/16/2006	0.01	0.00	
12/17/2006	0.01	0.00	
12/18/2006	0.06	0.00	
12/19/2006	0.00	0.00	
12/20/2006	0.04	0.00	
12/21/2006	0.38	0.00	
12/22/2006	0.00	0.00	B C
12/23/2006	9.40	0.00	B C T
12/24/2006	0.57	0.83	
12/25/2006	0.01	0.20	
12/26/2006	0.00	0.03	
12/27/2006	0.00	0.05	
12/28/2006	0.01	0.00	T
12/29/2006	1.70	3.91	
12/30/2006	0.32	24.16	
12/31/2006	0.01	2.23	
1/1/2007	0.00	0.41	
1/2/2007	0.00	0.11	
1/3/2007	0.13	0.05	
1/4/2007	0.88	10.19	
1/5/2007	0.00	3.03	
1/6/2007	0.01	0.89	
1/7/2007	0.19	0.62	
1/8/2007	0.00	0.18	
1/9/2007	0.00	0.09	
1/10/2007	0.00	0.04	
1/11/2007	0.01	0.03	
1/12/2007	0.00	0.03	
1/13/2007	0.02	0.07	
1/14/2007	0.35	0.30	
1/15/2007	0.44	1.80	
1/16/2007	0.05	0.30	

1/17/2007	0.05	0.15	
1/18/2007	0.22	0.41	
1/19/2007	0.05	1.05	
1/20/2007	0.12	0.65	
1/21/2007	0.06	0.88	
1/22/2007	0.00	0.49	
1/23/2007	0.57	0.91	
1/24/2007	0.86	21.07	
1/25/2007	0.01	6.13	
1/26/2007	0.00	1.58	
1/27/2007	0.63	9.08	
1/28/2007	0.00	3.08	
1/29/2007	0.00	0.86	
1/30/2007	0.32	1.95	
1/31/2007	0.18	1.37	
2/1/2007	0.03	1.41	
2/2/2007	0.00	0.65	
2/3/2007	0.00	0.29	
2/4/2007	0.00	0.18	
2/5/2007	0.01	0.11	
2/6/2007	0.01	0.08	
2/7/2007	0.00	0.13	
2/8/2007	0.01	0.07	
2/9/2007	0.00	0.03	
2/10/2007	0.00	0.02	
2/11/2007	0.00	0.03	
2/12/2007	1.26	10.88	
2/13/2007	0.10	5.53	A C
2/14/2007	0.00	0.19	B C
2/15/2007	0.00	0.40	B C
2/16/2007	0.00	0.14	B C
2/17/2007	0.00	0.08	B C
2/18/2007	0.00	0.02	B C
2/19/2007	0.00	0.03	B C
2/20/2007	0.00	0.04	B C
2/21/2007	3.00	0.12	B C
2/22/2007	0.00	0.06	B C
2/23/2007	0.00	0.04	B C
2/24/2007	0.80	0.06	B C
2/25/2007	0.00	0.03	B C

2/26/2007	0.00	0.02	B C
2/27/2007	0.50	0.01	B C
2/28/2007	0.00	0.01	B C
3/1/2007	0.00	0.02	B C
3/2/2007	0.00	0.00	B C
3/3/2007	0.00	0.00	B C
3/4/2007	0.00	0.00	B C
3/5/2007	0.00	0.00	B C
3/6/2007	0.00	0.00	B C
3/7/2007	0.00	0.00	B C
3/8/2007	0.00	0.00	B C
3/9/2007	0.00	0.00	B C
3/10/2007	0.00	0.00	B C
3/11/2007	0.00	0.00	B C
3/12/2007	46.50	1.14	B C
3/13/2007	6.40	0.05	B C
3/14/2007	72.40	21.56	B C
3/15/2007	0.01	15.19	
3/16/2007	0.01	1.36	
3/17/2007	0.29	0.40	
3/18/2007	0.00	0.18	
3/19/2007	0.00	0.09	
3/20/2007	0.00	0.08	
3/21/2007	0.00	0.04	
3/22/2007	0.01	0.03	
3/23/2007	0.00	0.00	T
3/24/2007	0.02	0.00	
3/25/2007	0.00	0.00	
3/26/2007	0.03	0.00	
3/27/2007	0.04	0.00	
3/28/2007	0.00	0.00	
3/29/2007	0.00	0.00	
3/30/2007	0.00	0.00	
3/31/2007	2.67	32.30	
4/1/2007	0.30	8.39	
4/2/2007	0.01	1.99	
4/3/2007	0.00	1.24	
4/4/2007	0.32	1.19	
4/5/2007	0.00	0.69	
4/6/2007	0.00	0.29	

4/7/2007	0.40	0.04	
4/8/2007	0.29	0.91	
4/9/2007	0.00	0.30	
4/10/2007	0.25	0.42	
4/11/2007	0.00	0.09	
4/12/2007	0.00	0.02	
4/13/2007	0.15	0.06	
4/14/2007	0.79	5.32	
4/15/2007	0.00	0.66	
4/16/2007	0.00	0.15	
4/17/2007	0.47	0.30	
4/18/2007	0.01	0.77	
4/19/2007	0.00	0.12	
4/20/2007	0.00	0.02	
4/21/2007	0.01	0.00	T
4/22/2007	0.00	0.00	
4/23/2007	0.00	0.00	
4/24/2007	0.00	0.00	
4/25/2007	0.66	0.48	
4/26/2007	0.01	0.10	
4/27/2007	0.00	0.00	T
4/28/2007	0.00	0.00	
4/29/2007	0.01	0.00	
4/30/2007	0.00	0.00	
5/1/2007	0.00	0.00	
5/2/2007	0.00	0.00	
5/3/2007	0.49	0.02	
5/4/2007	0.00	0.00	
5/5/2007	0.00	0.00	
5/6/2007	0.02	0.00	
5/7/2007	0.00	0.00	
5/8/2007	0.00	0.00	
5/9/2007	0.00	0.00	
5/10/2007	0.65	0.00	
5/11/2007	0.33	0.00	
5/12/2007	0.00	0.00	
5/13/2007	0.00	0.00	
5/14/2007	0.01	0.00	
5/15/2007	0.06	0.00	
5/16/2007	0.00	0.00	

5/17/2007	0.00	0.00	
5/18/2007	0.00	0.00	
5/19/2007	0.00	0.00	
5/20/2007	0.00	0.00	
5/21/2007	0.00	0.00	
5/22/2007	0.37	0.00	
5/23/2007	0.00	0.00	
5/24/2007	0.00	0.00	
5/25/2007	0.00	0.00	
5/26/2007	0.86	0.00	
5/27/2007	0.01	0.00	
5/28/2007	2.36	0.00	
5/29/2007	0.02	0.00	
5/30/2007	0.01	0.20	
5/31/2007	0.00	0.17	
6/1/2007	0.00	0.01	T
6/2/2007	0.62	0.46	
6/3/2007	0.01	0.36	
6/4/2007	0.04	0.01	T
6/5/2007	0.00	0.00	
6/6/2007	0.00	0.00	
6/7/2007	0.00	0.00	
6/8/2007	0.00	0.00	
6/9/2007	0.00	0.00	
6/10/2007	0.01	0.00	
6/11/2007	0.00	0.00	
6/12/2007	0.00	0.00	
6/13/2007	0.02	0.00	
6/14/2007	0.01	0.00	
6/15/2007	0.34	0.00	
6/16/2007	0.10	0.00	
6/17/2007	0.01	0.00	
6/18/2007	0.00	0.00	
6/19/2007	0.00	0.00	
6/20/2007	0.00	0.00	
6/21/2007	0.00	0.00	
6/22/2007	0.00	0.00	
6/23/2007	0.00	0.00	
6/24/2007	0.00	0.00	
6/25/2007	0.39	0.00	

6/26/2007	0.20	0.00	
6/27/2007	0.00	0.00	
6/28/2007	0.00	0.00	
6/29/2007	0.57	0.00	
6/30/2007	0.14	0.00	
7/1/2007	0.41	0.00	
7/2/2007	1.21	0.42	
7/3/2007	0.45	0.02	
7/4/2007	0.50	0.56	
7/5/2007	1.56	18.61	
7/6/2007	0.73	13.78	
7/7/2007	1.43	18.06	
7/8/2007	0.00	10.70	
7/9/2007	0.00	1.17	
7/10/2007	0.00	0.28	
7/11/2007	0.00	0.04	
7/12/2007	0.00	0.00	
7/13/2007	0.00	0.00	
7/14/2007	0.00	0.00	
7/15/2007	0.33	0.00	
7/16/2007	0.17	0.00	
7/17/2007	0.06	0.00	
7/18/2007	0.10	0.00	
7/19/2007	0.67	0.13	
7/20/2007	1.50	13.89	C
7/21/2007	0.00	3.87	
7/22/2007	1.11	9.53	
7/23/2007	0.01	4.14	
7/24/2007	0.00	0.69	
7/25/2007	0.00	0.20	
7/26/2007	1.02	3.33	
7/27/2007	2.01	30.87	
7/28/2007	0.00	3.92	
7/29/2007	0.82	10.32	
7/30/2007	0.00	3.74	
7/31/2007	0.00	0.83	
8/1/2007	0.99	3.97	
8/2/2007	0.85	22.62	
8/3/2007	0.00	4.67	
8/4/2007	0.02	0.69	

8/5/2007	0.01	0.27	
8/6/2007	0.00	0.09	
8/7/2007	0.02	0.02	
8/8/2007	0.00	0.00	
8/9/2007	0.00	0.00	
8/10/2007	0.00	0.00	
8/11/2007	0.00	0.00	
8/12/2007	0.11	0.00	
8/13/2007	0.00	0.00	
8/14/2007	0.00	0.00	
8/15/2007	0.09	0.00	
8/16/2007	4.53	36.43	
8/17/2007	0.00	8.68	
8/18/2007	0.65	5.75	
8/19/2007	0.04	2.26	
8/20/2007	0.26	0.89	
8/21/2007	0.00	0.30	
8/22/2007	0.00	0.03	
8/23/2007	0.00	0.00	
8/24/2007	0.00	0.00	
8/25/2007	0.26	0.00	
8/26/2007	0.00	0.00	
8/27/2007	0.01	0.00	
8/28/2007	0.01	0.00	
8/29/2007	0.54	0.00	
8/30/2007	0.09	0.00	
8/31/2007	0.63	0.00	
9/1/2007	0.01	0.00	T
9/2/2007	0.18	0.00	
9/3/2007	0.39	0.12	
9/4/2007	0.21	0.02	
9/5/2007	0.44	0.10	
9/6/2007	0.01	0.00	
9/7/2007	0.06	0.00	
9/8/2007	0.03	0.00	
9/9/2007	0.00	0.00	
9/10/2007	0.00	0.00	
9/11/2007	0.00	0.00	B C
9/12/2007	47.80	0	B C
9/13/2007	0.00	0	B C

9/14/2007	0.00	0.01	B C
9/15/2007	0.00	0.00	B T
9/16/2007	0.00	0.00	T
9/17/2007	0.00	0.00	
9/18/2007	0.00	0.00	
9/19/2007	0.03	0.00	
9/20/2007	0.01	0.00	
9/21/2007	0.00	0.00	
9/22/2007	0.01	0.00	
9/23/2007	0.00	0.00	
9/24/2007	0.00	0.00	
9/25/2007	0.29	0.00	
9/26/2007	0.04	0.00	
9/27/2007	3.24	6.13	
9/28/2007	0.01	0.87	
9/29/2007	0.73	0.04	
9/30/2007	2.13	14.13	
10/1/2007	0.00	0.13	
10/2/2007	0.01	0.01	
10/3/2007	0.00	0.06	
10/4/2007	0.01	0.33	
10/5/2007	0.56	0.05	
10/6/2007	0.98	9.40	
10/7/2007	0.29	4.41	
10/8/2007	0.01	2.25	
10/9/2007	0.01	0.92	
10/10/2007	0.00	0.33	
10/11/2007	0.00	0.06	B C
10/12/2007	0.00	0	B C
10/13/2007	0.00	0	B C
10/14/2007	0.00	0	B C
10/15/2007	0.00	0	B C
10/16/2007	0.00	0	B C
10/17/2007	0.00	0	B C
10/18/2007	0.00	0	B C
10/19/2007	0.00	0	B C
10/20/2007	0.00	0	B C
10/21/2007	0.00	0	B C
10/22/2007	2.80	0	B C
10/23/2007	0.00	0	B C

10/24/2007	0.00	0.00	B C
10/25/2007	0.00	0.00	
10/26/2007	0.00	0.00	
10/27/2007	0.00	0.00	
10/28/2007	0.00	0.00	
10/29/2007	0.00	0.00	
10/30/2007	0.00	0.00	
10/31/2007	0.00	0.00	
11/1/2007	0.01	0.00	
11/2/2007	0.01	0.00	
11/3/2007	0.00	0.00	
11/4/2007	0.01	0.00	
11/5/2007	0.01	0.00	
11/6/2007	0.00	0.00	
11/7/2007	0.00	0.00	
11/8/2007	0.00	0.00	
11/9/2007	0.00	0.00	
11/10/2007	0.04	0.00	
11/11/2007	0.01	0.00	
11/12/2007	0.01	0.00	
11/13/2007	0.15	0.00	
11/14/2007	0.02	0.00	
11/15/2007	0.00	0.00	
11/16/2007	0.00	0.00	
11/17/2007	0.03	0.00	
11/18/2007	2.13	1.46	
11/19/2007	0.00	0.02	
11/20/2007	0.03	0.00	A C
11/21/2007	8.40	0	B C
11/22/2007	0.00	0	B C
11/23/2007	0.30	0.00	B C
11/24/2007	1.21	2.25	
11/25/2007	0.08	1.64	
11/26/2007	0.00	0.77	
11/27/2007	0.00	0.27	
11/28/2007	0.00	0.06	
11/29/2007	0.00	0.01	
11/30/2007	0.01	0.00	T
12/1/2007	0.00	0.00	T
12/2/2007	0.01	0.00	

12/3/2007	0.00	0.00	
12/4/2007	0.00	0.00	
12/5/2007	0.00	0.00	
12/6/2007	0.01	0.00	
12/7/2007	0.01	0.00	
12/8/2007	0.00	0.00	
12/9/2007	0.00	0.00	
12/10/2007	0.12	0.00	
12/11/2007	0.01	0.00	
12/12/2007	0.00	0.00	
12/13/2007	0.06	0.00	
12/14/2007	0.02	0.00	
12/15/2007	0.64	0.14	
12/16/2007	0.00	0.00	
12/17/2007	0.00	0.00	
12/18/2007	0.00	0.00	
12/19/2007	0.08	0.00	
12/20/2007	0.50	0.00	B C
12/21/2007	0.00	0.00	B C
12/22/2007	0.25	0.00	T
12/23/2007	0.00	0.00	
12/24/2007	0.00	0.00	
12/25/2007	0.00	0.00	
12/26/2007	0.32	0.03	
12/27/2007	0.00	0.00	
12/28/2007	0.59	2.53	
12/29/2007	0.00	1.14	
12/30/2007	0.00	0.12	
12/31/2007	0.01	0.03	
1/1/2008	0.00	0.00	
1/2/2008	0.00	0.00	
1/3/2008	0.00	0.00	
1/4/2008	0.00	0.00	
1/5/2008	0.14	0.00	
1/6/2008	0.01	0.00	
1/7/2008	0.01	0.00	
1/8/2008	0.11	0.00	
1/9/2008	0.00	0.00	
1/10/2008	0.00	0.00	
1/11/2008	0.00	0.00	

1/12/2008	0.15	0.00	
1/13/2008	0.00	0.00	
1/14/2008	0.00	0.00	
1/15/2008	0.54	0.11	
1/16/2008	1.26	20.36	
1/17/2008	2.15	2.16	A C
1/18/2008	0.00	0.00	B C
1/19/2008	20.46	0.00	B C
1/20/2008	3.03	0.00	B C
1/21/2008	1.16	0.00	B C
1/22/2008	0.78	0.00	B C
1/23/2008	7.55	0.00	B C
1/24/2008	7.76	0.00	B C
1/25/2008	10.62	0.00	B C
1/26/2008	4.67	0.00	B C
1/27/2008	1.60	0.00	B C
1/28/2008	1.01	0.00	B C
1/29/2008	0.69	0.00	B C
1/30/2008	0.28	0.00	B C
1/31/2008	14.17	0.00	B C
2/1/2008	0.00	3.58	B C
2/2/2008	0.00	1.31	B C
2/3/2008	1.80	0.89	B C
2/4/2008	0.00	0.78	B C
2/5/2008	0.30	0.56	B C
2/6/2008	0.00	0.20	B C
2/7/2008	0.00	0.07	B C
2/8/2008	0.00	0.02	B C
2/9/2008	0.00	0.01	B C
2/10/2008	0.00	0.00	B C
2/11/2008	2.80	0.01	B C
2/12/2008	11.70	0.15	B C
2/13/2008	0.00	0.04	B C
2/14/2008	0.00	0.05	B C
2/15/2008	8.10	0.08	B C
2/16/2008	33.50	4.76	B C
2/17/2008	0.00	16.02	B C
2/18/2008	0.00	1.88	B C
2/19/2008	0.00	0.75	B C
2/20/2008	14.50	1.74	B C

2/21/2008	3.00	3.16	B C
2/22/2008	0.00	1.67	B C
2/23/2008	0.00	0.70	B C
2/24/2008	0.00	0.40	B C
2/25/2008	0.00	0.25	B C
2/26/2008	0.30	0.19	B C
2/27/2008	0.00	0.06	B C
2/28/2008	0.00	0.03	B C
2/29/2008	0.00	0.03	B C
3/1/2008	0.00	0.02	B C
3/2/2008	0.00	0.02	B C
3/3/2008	4.30	0.46	B C
3/4/2008	0.00	0.21	B C
3/5/2008	0.00	0.10	B C
3/6/2008	26.20	3.38	B C
3/7/2008	0.00	4.89	B C
3/8/2008	0.00	1.22	B C
3/9/2008	0.00	0.80	B C
3/10/2008	23.40	4.23	B C
3/11/2008	0.00	2.93	B C
3/12/2008	0.00	0	B C
3/13/2008	0.00	0.60	B C
3/14/2008	0.00	0.71	B
3/15/2008	0.00	0.38	B
3/16/2008	0.00	0.40	B
3/17/2008	0.00	0.38	B
3/18/2008	2.50	0.26	B
3/19/2008	0.00	0.12	B
3/20/2008	0.00	0.00	B T
3/21/2008	0.00	0.00	B
3/22/2008	0.00	0.00	B
3/23/2008	0.00	0.00	B
3/24/2008	0.00	0.00	B
3/25/2008	0.00	0.00	B
3/26/2008	0.00	0.00	B
3/27/2008	0.00	0.00	B
3/28/2008	0.00	0.00	B
3/29/2008	0.30	0.00	B
3/30/2008	2.00	0.00	B
3/31/2008	0.30	0.00	B

4/1/2008	0.00	0.00	B
4/2/2008	0.30	0.00	B
4/3/2008	0.00	0.00	B
4/4/2008	1.30	0.00	B
4/5/2008	0.00	0.00	B
4/6/2008	0.00	0.00	B
4/7/2008	0.00	0.00	B
4/8/2008	0.00	0.00	B
4/9/2008	0.00	0.00	B
4/10/2008	0.00	0.00	B
4/11/2008	0.00	0.00	B
4/12/2008	0.00	0.00	B
4/13/2008	0.00	0.00	B
4/14/2008	0.00	0.00	B
4/15/2008	0.00	0.00	B
4/16/2008	0.00	0.00	B
4/17/2008	0.00	0.00	B
4/18/2008	20.80	0.00	B
4/19/2008	0.00	0.00	B
4/20/2008	0.00	0.00	B
4/21/2008	0.00	0.00	B
4/22/2008	0.00	0.00	B
4/23/2008	0.00	0.00	B
4/24/2008	0.00	0.00	B
4/25/2008	0.00	0.00	B
4/26/2008	17.30	0.00	B
4/27/2008	15.20	0.00	B
4/28/2008	0.00	0.00	B
4/29/2008	0.00	0.00	B
4/30/2008	0.00	0.00	B
5/1/2008	0.80	0.00	B
5/2/2008	0.00	0.00	B
5/3/2008	0.00	0.00	B
5/4/2008	0.00	0.00	B
5/5/2008	4.80	0.00	B
5/6/2008	0.00	0.00	B
5/7/2008	0.00	0.00	B
5/8/2008	0.00	0.00	B
5/9/2008	0.00	0.00	B
5/10/2008	0.00	0.00	B

5/11/2008	0.00	0.00	B
5/12/2008	0.00	0.00	B
5/13/2008	0.00	0.00	B
5/14/2008	0.50	0.00	B
5/15/2008	10.90	0.00	B
5/16/2008	3.00	0.00	B
5/17/2008	0.00	0.00	B
5/18/2008	0.00	0.00	B
5/19/2008	0.00	0.00	B
5/20/2008	0.00	0.00	B
5/21/2008	0.00	0.00	B
5/22/2008	0.00	0.00	B
5/23/2008	0.00	0.00	B
5/24/2008	0.00	0.00	B
5/25/2008	0.00	0.00	B
5/26/2008	0.00	0.00	B
5/27/2008	0.00	0.00	B
5/28/2008	9.40	0.00	B
5/29/2008	0.00	0.00	B
5/30/2008	0.00	0.00	B
5/31/2008	0.00	0.00	B
6/1/2008	0.00	0.00	B
6/2/2008	0.00	0.00	B
6/3/2008	0.00	0.00	B
6/4/2008	0.00	0.00	B
6/5/2008	0.00	0.00	B
6/6/2008	0.50	0.00	B
6/7/2008	0.50	0.00	B
6/8/2008	0.00	0.00	B
6/9/2008	0.00	0.00	B
6/10/2008	40.90	0.00	B C
6/11/2008	0.00	0.00	B C
6/12/2008	2.80	0.00	B C
6/13/2008	0.30	0.00	B C
6/14/2008	0.00	0.00	B C
6/15/2008	0.00	0.00	B C
6/16/2008	0.00	0.00	B C
6/17/2008	21.80	0.00	B C
6/18/2008	0.00	0.00	B C
6/19/2008	0.00	0.00	B C

6/20/2008	7.10	0.00	B C
6/21/2008	5.30	0.00	B C
6/22/2008	0.00	0.00	B C
6/23/2008	1.50	0.00	B C
6/24/2008	0.50	0.00	B C
6/25/2008	9.70	0.00	B C
6/26/2008	0.00	0.00	B C
6/27/2008	0.00	0.00	B C
6/28/2008	21.30	0.00	B C
6/29/2008	0.00	0.00	B C
6/30/2008	1.30	0.00	B C
7/1/2008	2.30	0.00	B C
7/2/2008	0.00	0.00	B C
7/3/2008	0.00	0.00	B C
7/4/2008	70.40	0.00	B C
7/5/2008	0.00	0.00	B C
7/6/2008	0.00	0.00	B C
7/7/2008	0.00	0.00	B C
7/8/2008	0.00	0.00	B C
7/9/2008	0.00	0.00	B C
7/10/2008	0.30	0.00	B C
7/11/2008	0.00	0.00	B C
7/12/2008	0.00	0.00	B C
7/13/2008	0.00	0.00	B C
7/14/2008	0.00	0.00	B C
7/15/2008	0.00	0.00	B C
7/16/2008	0.00	0.00	B
7/17/2008	0.00	0.00	B
7/18/2008	0.00	0.00	B
7/19/2008	0.00	0.00	B
7/20/2008	0.00	0.00	B
7/21/2008	0.00	0.00	B
7/22/2008	0.00	0.00	B
7/23/2008	10.70	0.00	B
7/24/2008	35.80	0.12	B
7/25/2008	0.00	0.00	B
7/26/2008	0.00	0.00	B
7/27/2008	0.00	0.00	B
7/28/2008	0.00	0.00	B
7/29/2008	0.00	0.00	B

7/30/2008	0.00	0.00	B
7/31/2008	0.00	0.00	B
8/1/2008	0.00	0.00	B
8/2/2008	0.00	0.00	B
8/3/2008	1.80	0.00	B
8/4/2008	0.00	0.00	B
8/5/2008	44.20	3.52	B
8/6/2008	2.30	0.66	B
8/7/2008	1.00	0.03	B
8/8/2008	0.00	0.00	B
8/9/2008	0.00	0.00	B
8/10/2008	0.00	0.00	B
8/11/2008	0.00	0.00	B
8/12/2008	0.00	0.00	B
8/13/2008	3.00	0.00	B
8/14/2008	0.00	0.00	B
8/15/2008	0.30	0.00	B
8/16/2008	12.70	0.00	B
8/17/2008	8.90	0.00	B
8/18/2008	1.50	0.00	B
8/19/2008	29.70	0.00	B
8/20/2008	51.80	0.00	B
8/21/2008	37.10	0.44	B
8/22/2008	0.00	0.20	B
8/23/2008	4.60	0.11	B
8/24/2008	0.00	0.27	B
8/25/2008	0.00	0.00	B T
8/26/2008	2.00	0.00	B
8/27/2008	0.50	0.00	B
8/28/2008	0.00	0.00	B
8/29/2008	0.00	0.00	B
8/30/2008	0.00	0.00	B
8/31/2008	0.00	0.00	B
9/1/2008	0.00	0.00	B
9/2/2008	1.50	0.00	B
9/3/2008	0.00	0.00	B
9/4/2008	0.00	0.00	B
9/5/2008	0.00	0.00	B
9/6/2008	0.00	0.00	B
9/7/2008	0.00	0.00	B

9/8/2008	0.00	0.00	B
9/9/2008	0.00	0.00	B
9/10/2008	0.00	0.00	B
9/11/2008	8.60	0.00	B
9/12/2008	54.60	0.00	B
9/13/2008	170.40	44.25	B
9/14/2008	96.30	41.29	B
9/15/2008	0.00	7.19	B
9/16/2008	0.00	0.99	B
9/17/2008	0.00	0.26	B
9/18/2008	0.30	0.04	B
9/19/2008	0.00	0.00	B T
9/20/2008	0.00	0.00	B
9/21/2008	0.00	0.00	B
9/22/2008	0.00	0.00	B
9/23/2008	0.00	0.00	B
9/24/2008	0.00	0.00	B
9/25/2008	0.00	0.00	B
9/26/2008	0.00	0.00	B
9/27/2008	0.00	0.00	B
9/28/2008	0.00	0.00	B
9/29/2008	0.00	0.00	B
9/30/2008	0.00	0.00	B
10/1/2008	0.00	0.00	B
10/2/2008	0.00	0.00	B
10/3/2008	0.00	0.00	B
10/4/2008	0.00	0.00	B
10/5/2008	0.00	0.00	B
10/6/2008	0.00	0.00	B
10/7/2008	22.90	0.00	B
10/8/2008	0.00	0.00	B
10/9/2008	0.00	0.00	B
10/10/2008	0.00	0.00	B
10/11/2008	0.00	0.00	B
10/12/2008	0.30	0.00	B
10/13/2008	0.00	0.00	B
10/14/2008	3.80	0.00	B
10/15/2008	2.50	0.00	B
10/16/2008	16.30	0.00	B
10/17/2008	0.00	0.00	B

10/18/2008	0.00	0.00	B
10/19/2008	0.00	0.00	B
10/20/2008	0.00	0.00	B
10/21/2008	0.00	0.00	B
10/22/2008	3.00	0.00	B
10/23/2008	0.30	0.00	B
10/24/2008	0.00	0.00	B
10/25/2008	0.00	0.00	B
10/26/2008	0.00	0.00	B
10/27/2008	0.00	0.00	B
10/28/2008	0.00	0.00	B
10/29/2008	0.00	0.00	B
10/30/2008	0.00	0.00	B
10/31/2008	0.00	0.00	B
11/1/2008	0.00	0.00	B
11/2/2008	0.00	0.00	B
11/3/2008	0.00	0.00	B
11/4/2008	0.00	0.00	B
11/5/2008	1.50	0.00	B
11/6/2008	0.00	0.00	B
11/7/2008	4.30	0.00	B
11/8/2008	0.00	0.00	B
11/9/2008	0.00	0.00	B
11/10/2008	47.20	0.00	B C
11/11/2008	27.20	0.00	B C
11/12/2008	53.10	0.00	B C
11/13/2008	3.30	0.00	B C
11/14/2008	0.00	0.00	B C
11/15/2008	0.00	0.00	B C
11/16/2008	0.00	0.00	B C
11/17/2008	0.00	0.00	B C
11/18/2008	0.00	0.00	B C
11/19/2008	0.00	0.00	B C
11/20/2008	0.00	0.00	B C
11/21/2008	0.00	0.00	B
11/22/2008	0.00	0.00	B
11/23/2008	0.00	0.00	B
11/24/2008	0.00	0.00	B
11/25/2008	0.00	0.00	B
11/26/2008	0.00	0.00	B

11/27/2008	0.00	0.00	B
11/28/2008	0.80	0.00	B
11/29/2008	3.60	0.00	B
11/30/2008	0.00	0.00	B
12/1/2008	0.00	0.00	B
12/2/2008	0.00	0.00	B
12/3/2008	3.60	0.00	B
12/4/2008	0.00	0.00	B
12/5/2008	0.00	0.00	B
12/6/2008	0.00	0.00	B
12/7/2008	0.00	0.00	B
12/8/2008	0.00	0.00	B
12/9/2008	5.10	0.00	B
12/10/2008	6.10	0.00	B
12/11/2008	0.00	0.00	B
12/12/2008	0.00	0.00	B
12/13/2008	0.00	0.00	B
12/14/2008	0.80	0.00	B
12/15/2008	0.00	0.00	B
12/16/2008	2.80	0.00	B
12/17/2008	0.00	0.00	B
12/18/2008	2.30	0.00	B
12/19/2008	0.00	0.00	B
12/20/2008	0.00	0.00	B
12/21/2008	0.00	0.00	B
12/22/2008	0.30	0.00	B
12/23/2008	7.90	0.00	B
12/24/2008	1.80	0.00	B
12/25/2008	0.00	0.00	B
12/26/2008	0.00	0.00	B
12/27/2008	2.80	0.00	B
12/28/2008	1.00	0.00	B
12/29/2008	0.00	0.00	B
12/30/2008	0.00	0.00	B
12/31/2008	0.00	0.00	B
1/1/2009	0.00	0.00	B
1/2/2009	0.00	0.00	B
1/3/2009	0.00	0.00	B
1/4/2009	0.00	0.00	B
1/5/2009	0.00	0.00	B

1/6/2009	4.60	0.00	B
1/7/2009	0.00	0.00	B
1/8/2009	0.00	0.00	B
1/9/2009	0.00	0.00	B
1/10/2009	0.50	0.00	B
1/11/2009	0.00	0.00	B
1/12/2009	0.00	0.00	B
1/13/2009	0.00	0.00	B
1/14/2009	0.00	0.00	B
1/15/2009	0.00	0.00	B
1/16/2009	0.00	0.00	B
1/17/2009	0.00	0.00	B
1/18/2009	0.00	0.00	B
1/19/2009	0.00	0.00	B
1/20/2009	0.00	0.00	B
1/21/2009	0.00	0.00	B
1/22/2009	0.00	0.00	B
1/23/2009	0.00	0.00	B
1/24/2009	0.00	0.00	B
1/25/2009	0.00	0.00	B
1/26/2009	0.00	0.00	B
1/27/2009	0.00	0.00	B
1/28/2009	1.50	0.00	B
1/29/2009	0.00	0.00	B
1/30/2009	0.00	0.00	B
1/31/2009	0.00	0.00	B
2/1/2009	4.80	0.00	B
2/2/2009	0.50	0.00	B
2/3/2009	0.00	0.00	B
2/4/2009	0.00	0.00	B
2/5/2009	0.00	0.00	B
2/6/2009	0.00	0.00	B
2/7/2009	0.00	0.00	B
2/8/2009	0.00	0.00	B
2/9/2009	3.30	0.00	B
2/10/2009	0.80	0.00	B
2/11/2009	1.50	0.00	B
2/12/2009	0.00	0.00	B
2/13/2009	0.30	0.00	B
2/14/2009	26.40	0.00	B

2/15/2009	0.30	0.00	B
2/16/2009	0.00	0.00	B
2/17/2009	0.80	0.00	B
2/18/2009	0.30	0.00	B C
2/19/2009	0.00	0.00	B C
2/20/2009	0.00	0.00	B C
2/21/2009	0.50	0.00	B C
2/22/2009	0.00	0.00	B C
2/23/2009	0.00	0.00	B C
2/24/2009	0.00	0.00	B C
2/25/2009	0.00	0.00	B C
2/26/2009	0.00	0.00	B C
2/27/2009	0.00	0.00	B C
2/28/2009	0.80	0.00	B C
3/1/2009	0.00	0.00	B C
3/2/2009	0.00	0.00	B C
3/3/2009	0.00	0.00	B C
3/4/2009	0.00	0.00	B C
3/5/2009	0.00	0.00	B C
3/6/2009	0.00	0.00	B C
3/7/2009	0.00	0.00	B C
3/8/2009	0.00	0.00	B C
3/9/2009	0.00	0.00	B C
3/10/2009	0.00	0.00	B C
3/11/2009	0.00	0.00	B C
3/12/2009	1.00	0.00	B C
3/13/2009	4.60	0.00	B C
3/14/2009	13.20	0.00	B C
3/15/2009	5.10	0.00	B C
3/16/2009	0.00	0.00	B C
3/17/2009	0.00	0.00	B C
3/18/2009	0.00	0.00	B C
3/19/2009	0.00	0.00	B C
3/20/2009	0.00	0.00	B C
3/21/2009	0.00	0.00	B C
3/22/2009	0.00	0.00	B C
3/23/2009	0.00	0.00	B C
3/24/2009	0.30	0.00	B C
3/25/2009	8.40	0.00	B C
3/26/2009	19.10	0.00	B C

3/27/2009	1.80	0.00	B C
3/28/2009	0.00	0.00	B C
3/29/2009	0.00	0.00	B C
3/30/2009	0.00	0.00	B C
3/31/2009	1.80	0.00	B C
4/1/2009	0.00	0.00	B C
4/2/2009	7.10	0.00	B C
4/3/2009	0.00	0.00	B C
4/4/2009	0.00	0.00	B C
4/5/2009	0.00	0.00	B C
4/6/2009	0.00	0.00	B C
4/7/2009	0.00	0.00	B C
4/8/2009	0.00	0.00	B C
4/9/2009	0.00	0.00	B C
4/10/2009	0.00	0.00	B C
4/11/2009	0.00	0.00	B C
4/12/2009	7.90	0.00	B C
4/13/2009	0.00	0.00	B C
4/14/2009	0.00	0.00	B C
4/15/2009	0.00	0.00	B C
4/16/2009	2.80	0.00	B C
4/17/2009	45.00	0.00	B C
4/18/2009	200.20	0.00	B C
4/19/2009	0.00	0.00	B C
4/20/2009	0.00	0.00	B C
4/21/2009	0.00	0.00	B C
4/22/2009	0.00	0.00	B C
4/23/2009	0.00	0.00	B C
4/24/2009	49.80	0.00	B C
4/25/2009	2.00	0.00	B C
4/26/2009	0.00	0.00	B C
4/27/2009	31.20	0.00	B C
4/28/2009	0.30	0.00	B C
4/29/2009	0.00	0.00	B C
4/30/2009	0.00	0.00	B C
5/1/2009	0.00	0.00	B C
5/2/2009	0.00	0.00	B C
5/3/2009	0.00	0.00	B C
5/4/2009	0.00	0.00	B C
5/5/2009	0.00	0.00	B C

5/6/2009	0.00	0.00	B C
5/7/2009	0.00	0.00	B C
5/8/2009	0.00	0.00	B C
5/9/2009	0.00	0.00	B C
5/10/2009	0.00	0.00	B C
5/11/2009	0.00	0.00	B C
5/12/2009	0.00	0.00	B
5/13/2009	0.00	0.00	B
5/14/2009	0.00	0.00	B
5/15/2009	0.00	0.00	B
5/16/2009	0.00	0.00	B
5/17/2009	0.00	0.00	B
5/18/2009	0.00	0.00	B
5/19/2009	0.00	0.00	B
5/20/2009	0.00	0.00	B
5/21/2009	0.00	0.00	B
5/22/2009	0.00	0.00	B
5/23/2009	0.00	0.00	B
5/24/2009	36.30	0.00	B
5/25/2009	0.00	0.00	B
5/26/2009	0.00	0.00	B
5/27/2009	1.30	0.00	B
5/28/2009	0.00	0.00	B
5/29/2009	0.00	0.00	B
5/30/2009	0.00	0.00	B
5/31/2009	0.00	0.00	B
6/1/2009	0.00	0.00	B
6/2/2009	19.60	0.00	B
6/3/2009	1.50	0.00	B
6/4/2009	0.00	0.00	B
6/5/2009	0.00	0.00	B
6/6/2009	0.00	0.00	B
6/7/2009	0.00	0.00	B
6/8/2009	0.00	0.00	B
6/9/2009	0.00	0.00	B
6/10/2009	0.00	0.00	B
6/11/2009	0.00	0.00	B
6/12/2009	0.00	0.00	B
6/13/2009	0.00	0.00	B
6/14/2009	0.00	0.00	B

6/15/2009	0.00	0.00	B
6/16/2009	0.00	0.00	B
6/17/2009	0.00	0.00	B
6/18/2009	0.00	0.00	B
6/19/2009	0.00	0.00	B
6/20/2009	0.00	0.00	B
6/21/2009	0.00	0.00	B
6/22/2009	0.00	0.00	B
6/23/2009	0.00	0.00	B
6/24/2009	0.00	0.00	B
6/25/2009	0.00	0.00	B
6/26/2009	0.00	0.00	B
6/27/2009	0.00	0.00	B
6/28/2009	0.00	0.00	B
6/29/2009	0.00	0.00	B
6/30/2009	1.00	0.00	B
7/1/2009	0.00	0.00	B
7/2/2009	0.00	0.00	B
7/3/2009	0.00	0.00	B
7/4/2009	0.00	0.00	B
7/5/2009	0.00	0.00	B
7/6/2009	0.00	0.00	B
7/7/2009	5.60	0.00	B
7/8/2009	0.00	0.00	B
7/9/2009	0.00	0.00	B
7/10/2009	0.00	0.00	B
7/11/2009	0.00	0.00	B
7/12/2009	0.00	0.00	B
7/13/2009	0.00	0.00	B
7/14/2009	0.00	0.00	B
7/15/2009	0.00	0.00	B
7/16/2009	10.40	0.00	B
7/17/2009	8.90	0.00	B
7/18/2009	44.20	0.00	B
7/19/2009	3.60	0.00	B
7/20/2009	9.40	0.00	B
7/21/2009	17.00	0.00	B
7/22/2009	0.00	0.00	B
7/23/2009	1.50	0.00	B
7/24/2009	0.30	0.00	B

7/25/2009	0.00	0.00	B
7/26/2009	0.00	0.00	B
7/27/2009	4.10	0.00	B
7/28/2009	0.00	0.00	B
7/29/2009	0.00	0.00	B
7/30/2009	0.00	0.00	B
7/31/2009	4.60	0.00	B
8/1/2009	0.00	0.00	B
8/2/2009	0.00	0.00	B
8/3/2009	0.00	0.00	B
8/4/2009	0.00	0.00	B
8/5/2009	27.20	0.00	B
8/6/2009	0.00	0.00	B
8/7/2009	7.90	0.00	B
8/8/2009	0.00	0.00	B
8/9/2009	1.50	0.00	B
8/10/2009	0.00	0.00	B
8/11/2009	2.30	0.00	B
8/12/2009	2.30	0.00	B
8/13/2009	1.50	0.00	B
8/14/2009	0.00	0.00	B
8/15/2009	3.30	0.00	B
8/16/2009	0.00	0.00	B
8/17/2009	0.30	0.00	B
8/18/2009	48.30	0.00	B
8/19/2009	0.00	0.00	B
8/20/2009	0.30	0.00	B
8/21/2009	2.80	0.00	B
8/22/2009	0.00	0.00	B
8/23/2009	2.50	0.00	B
8/24/2009	0.00	0.00	B
8/25/2009	0.50	0.00	B
8/26/2009	0.00	0.00	B
8/27/2009	0.00	0.00	B
8/28/2009	8.10	0.00	B
8/29/2009	0.00	0.00	B
8/30/2009	9.70	0.00	B
8/31/2009	0.00	0.00	B
9/1/2009	0.00	0.00	B
9/2/2009	0.00	0.00	B

9/3/2009	0.00	0.00	B
9/4/2009	0.00	0.00	B
9/5/2009	0.00	0.00	B
9/6/2009	0.00	0.00	B
9/7/2009	0.00	0.00	B
9/8/2009	0.00	0.00	B
9/9/2009	1.30	0.00	B
9/10/2009	8.40	0.00	B
9/11/2009	37.10	0.00	B
9/12/2009	5.10	0.00	B
9/13/2009	1.50	0.00	B
9/14/2009	0.00	0.00	B
9/15/2009	0.00	0.00	B
9/16/2009	0.00	0.00	B
9/17/2009	0.00	0.00	B
9/18/2009	0.00	0.00	B
9/19/2009	0.00	0.00	B
9/20/2009	0.00	0.00	B
9/21/2009	8.10	0.00	B
9/22/2009	15.70	0.00	B
9/23/2009	0.00	0.00	B
9/24/2009	0.50	0.00	B
9/25/2009	0.00	0.00	B
9/26/2009	0.00	0.00	B
9/27/2009	0.00	0.00	B
9/28/2009	9.10	0.00	B
9/29/2009	0.00	0.00	B
9/30/2009	0.00	0.00	B
10/1/2009	77.50	0.00	B
10/2/2009	31.50	0.03	B
10/3/2009	5.30	0.00	B
10/4/2009	12.20	0.00	B
10/5/2009	0.00	0.00	B
10/6/2009	0.00	0.00	B
10/7/2009	1.80	0.00	B
10/8/2009	0.00	0.00	B
10/9/2009	44.70	0.00	B
10/10/2009	0.00	0.00	B
10/11/2009	0.00	0.00	B
10/12/2009	11.90	0.00	B

10/13/2009	6.90	0.05	B
10/14/2009	0.50	0.00	B
10/15/2009	0.00	0.00	B
10/16/2009	0.00	0.00	B
10/17/2009	0.00	0.00	B
10/18/2009	0.00	0.00	B
10/19/2009	0.00	0.00	B
10/20/2009	0.00	0.00	B
10/21/2009	3.60	0.00	B
10/22/2009	78.20	34.40	B
10/23/2009	0.00	7.59	B
10/24/2009	0.00	1.60	B
10/25/2009	0.00	0.66	B
10/26/2009	70.40	12.33	B
10/27/2009	0.00	10.46	B
10/28/2009	0.80	3.65	B
10/29/2009	14.20	2.70	B
10/30/2009	12.20	15.24	B
10/31/2009	0.00	5.57	B
11/1/2009	0.00	1.87	B
11/2/2009	0.00	0.95	B
11/3/2009	0.00	0.18	B
11/4/2009	0.00	0.00	B
11/5/2009	0.00	0.00	B
11/6/2009	0.00	0.00	B
11/7/2009	0.00	0.00	B
11/8/2009	1.50	0.00	B
11/9/2009	2.00	0.00	B
11/10/2009	0.00	0.00	B
11/11/2009	0.00	0.00	B
11/12/2009	0.00	0.00	B
11/13/2009	0.00	0.00	B
11/14/2009	0.00	0.00	B
11/15/2009	0.00	0.00	B
11/16/2009	3.60	0.00	B
11/17/2009	0.00	0.00	B
11/18/2009	0.00	0.00	B
11/19/2009	0.00	0.00	B
11/20/2009	37.10	0.35	B
11/21/2009	5.30	1.56	B

11/22/2009	0.00	0.55	B
11/23/2009	0.00	0.00	B
11/24/2009	1.00	0.00	B
11/25/2009	0.00	0.00	B
11/26/2009	0.00	0.00	B
11/27/2009	0.00	0.00	B
11/28/2009	0.00	0.00	B
11/29/2009	0.00	0.00	B
11/30/2009	10.70	0.00	B
12/1/2009	23.40	1.61	B
12/2/2009	0.00	6.63	B
12/3/2009	0.00	1.76	B
12/4/2009	10.70	2.34	B
12/5/2009	0.00	1.95	B
12/6/2009	35.80	3.34	B
12/7/2009	9.10	16.22	B
12/8/2009	1.80	6.90	B

12/9/2009	0.00	0.78	B
12/10/2009	0.00	0.00	B
12/11/2009	0.50	0.00	B
12/12/2009	3.00	0.14	B
12/13/2009	0.00	0.00	B
12/14/2009	11.70	0.00	B
12/15/2009	1.50	0.00	B
12/16/2009	0.00	0.00	B
12/17/2009	22.60	8.33	B
12/18/2009	0.00	5.64	B
12/19/2009	0.00	0.37	B
12/20/2009	0.00	0.00	B
12/21/2009	0.00	0.00	B
12/22/2009	2.30	0.00	B
12/23/2009	7.40	0.00	B
12/24/2009	8.10	5.35	B
12/25/2009	0.00	0.68	B
12/26/2009	1.80	0.00	B
12/27/2009	0.00	0.00	B
12/28/2009	0.00	0.00	B
12/29/2009	2.00	0.00	B
12/30/2009	26.20	9.88	B
12/31/2009	1.30	0.00	B

Table A - 3. Kindsvater-Shen equation conversion factors and constants for calculating runoff over the V-notch weir.

KINDSVATER-SHEN EQUATION CONVERSIONS AND CONSTANTS		NOTES
Inches per foot =	12	
Seconds per minute =	60	
Millimeters per inch =	25.4	
Square feet per acre =	43560	
Acres =	20	
Offset inches =	-0.95	For calibration, see Jan. 18, 2007 field notes.
Ten minutes =	10	Variable, based on time step
KS constant A =	2.473433	Includes 4.28*Ce* tan(theta)/2
KS constant k =	0.002903	feet
KS exponent =	2.5	
KS theta =	90	degrees
KS constant C =	0.577905	

Table A - 3. Sample runoff calculations for January 1, 2007.

TIME	WATER LEVEL	CORRECTED WATER LEVEL	Q	Q	Q	Q
HH:MM:SS	INCHES	INCHES (SEE JAN. 18, 2007 FIELD NOTES)	CFS	CF PER 10 MINUTES	INCHES	MM
00:00:00	2.83	1.88	0.024122	14.47331	0.000199	0.005064
00:10:00	2.79	1.84	0.022861	13.71684	0.000189	0.004799
00:20:00	2.79	1.84	0.022861	13.71684	0.000189	0.004799
00:30:00	2.83	1.88	0.024122	14.47331	0.000199	0.005064
00:40:00	2.83	1.88	0.024122	14.47331	0.000199	0.005064
00:50:00	2.83	1.88	0.024122	14.47331	0.000199	0.005064
01:00:00	2.83	1.88	0.024122	14.47331	0.000199	0.005064
01:10:00	2.83	1.88	0.024122	14.47331	0.000199	0.005064
01:20:00	2.94	1.99	0.027801	16.68067	0.00023	0.005836
01:30:00	2.87	1.92	0.025424	15.25427	0.00021	0.005337
01:40:00	2.79	1.84	0.022861	13.71684	0.000189	0.004799
01:50:00	2.87	1.92	0.025424	15.25427	0.00021	0.005337
02:00:00	2.79	1.84	0.022861	13.71684	0.000189	0.004799
02:10:00	2.71	1.76	0.020461	12.27634	0.000169	0.004295
02:20:00	2.83	1.88	0.024122	14.47331	0.000199	0.005064
02:30:00	2.71	1.76	0.020461	12.27634	0.000169	0.004295
02:40:00	2.67	1.72	0.01932	11.59178	0.00016	0.004056
02:50:00	2.67	1.72	0.01932	11.59178	0.00016	0.004056
03:00:00	2.67	1.72	0.01932	11.59178	0.00016	0.004056
03:10:00	2.67	1.72	0.01932	11.59178	0.00016	0.004056
03:20:00	2.63	1.68	0.018218	10.93064	0.000151	0.003824
03:30:00	2.67	1.72	0.01932	11.59178	0.00016	0.004056
03:40:00	2.67	1.72	0.01932	11.59178	0.00016	0.004056
03:50:00	2.67	1.72	0.01932	11.59178	0.00016	0.004056
04:00:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601
04:10:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601
04:20:00	2.63	1.68	0.018218	10.93064	0.000151	0.003824
04:30:00	2.63	1.68	0.018218	10.93064	0.000151	0.003824
04:40:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601
04:50:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601
05:00:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601

Table A - 4 (continued).

TIME	WATER LEVEL	CORRECTED WATER LEVEL	Q	Q	Q	Q
HH:MM:SS	INCHES	INCHES (SEE JAN. 18, 2007 FIELD NOTES)	CFS	CF PER 10 MINUTES	INCHES	MM
05:10:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601
05:20:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601
05:30:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
05:40:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
05:50:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
06:00:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
06:10:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
06:20:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
06:30:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
06:40:00	2.48	1.53	0.014426	8.65535	0.000119	0.003028
06:50:00	2.48	1.53	0.014426	8.65535	0.000119	0.003028
07:00:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
07:10:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
07:20:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
07:30:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
07:40:00	2.36	1.41	0.011766	7.059578	9.72E-05	0.00247
07:50:00	2.36	1.41	0.011766	7.059578	9.72E-05	0.00247
08:00:00	2.4	1.45	0.012616	7.569888	0.000104	0.002648
08:10:00	2.36	1.41	0.011766	7.059578	9.72E-05	0.00247
08:20:00	2.2	1.25	0.008712	5.227469	7.2E-05	0.001829
08:30:00	2.2	1.25	0.008712	5.227469	7.2E-05	0.001829
08:40:00	2.4	1.45	0.012616	7.569888	0.000104	0.002648
08:50:00	2.36	1.41	0.011766	7.059578	9.72E-05	0.00247
09:00:00	2.44	1.49	0.013503	8.101714	0.000112	0.002834
09:10:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601
09:20:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
09:30:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
09:40:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
09:50:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
10:00:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
10:10:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
10:20:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
10:30:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
10:40:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179

Table A - 4 (continued).

TIME	WATER LEVEL	CORRECTED WATER LEVEL	Q	Q	Q	Q
HH:MM:SS	INCHES	INCHES (SEE JAN. 18, 2007 FIELD NOTES)	CFS	CF PER 10 MINUTES	INCHES	MM
10:50:00	2.4	1.45	0.012616	7.569888	0.000104	0.002648
11:00:00	2.4	1.45	0.012616	7.569888	0.000104	0.002648
11:10:00	2.44	1.49	0.013503	8.101714	0.000112	0.002834
11:20:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
11:30:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
11:40:00	2.79	1.84	0.022861	13.71684	0.000189	0.004799
11:50:00	2.94	1.99	0.027801	16.68067	0.00023	0.005836
12:00:00	2.79	1.84	0.022861	13.71684	0.000189	0.004799
12:10:00	2.71	1.76	0.020461	12.27634	0.000169	0.004295
12:20:00	2.71	1.76	0.020461	12.27634	0.000169	0.004295
12:30:00	2.67	1.72	0.01932	11.59178	0.00016	0.004056
12:40:00	2.79	1.84	0.022861	13.71684	0.000189	0.004799
12:50:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601
13:00:00	2.59	1.64	0.017154	10.29266	0.000142	0.003601
13:10:00	2.44	1.49	0.013503	8.101714	0.000112	0.002834
13:20:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
13:30:00	2.36	1.41	0.011766	7.059578	9.72E-05	0.00247
13:40:00	2.36	1.41	0.011766	7.059578	9.72E-05	0.00247
13:50:00	2.51	1.56	0.015142	9.085064	0.000125	0.003179
14:00:00	2.44	1.49	0.013503	8.101714	0.000112	0.002834
14:10:00	2.44	1.49	0.013503	8.101714	0.000112	0.002834
14:20:00	2.4	1.45	0.012616	7.569888	0.000104	0.002648
14:30:00	2.4	1.45	0.012616	7.569888	0.000104	0.002648
14:40:00	2.44	1.49	0.013503	8.101714	0.000112	0.002834
14:50:00	2.28	1.33	0.010171	6.10231	8.41E-05	0.002135
15:00:00	2.44	1.49	0.013503	8.101714	0.000112	0.002834
15:10:00	2.4	1.45	0.012616	7.569888	0.000104	0.002648
15:20:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
15:30:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
15:40:00	2.48	1.53	0.014426	8.65535	0.000119	0.003028
15:50:00	2.55	1.6	0.016129	9.677564	0.000133	0.003386
16:00:00	2.24	1.29	0.009425	5.654741	7.79E-05	0.001978
16:10:00	2.2	1.25	0.008712	5.227469	7.2E-05	0.001829
16:20:00	2.12	1.17	0.007388	4.432544	6.11E-05	0.001551

Table A - 4 (continued).

Time	Water Level	Corrected Water Level	Q	Q	Q	Q
hh:mm:ss	inches	Inches (See Jan. 18, 2007 Field Notes)	CFS	CF per 10 minutes	inches	mm
16:30:00	2.08	1.13	0.006774	4.064243	5.6E-05	0.001422
16:40:00	2.08	1.13	0.006774	4.064243	5.6E-05	0.001422
16:50:00	2.08	1.13	0.006774	4.064243	5.6E-05	0.001422
17:00:00	2.01	1.06	0.005775	3.465228	4.77E-05	0.001212
17:10:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
17:20:00	1.89	0.94	0.004281	2.568415	3.54E-05	0.000899
17:30:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
17:40:00	1.89	0.94	0.004281	2.568415	3.54E-05	0.000899
17:50:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
18:00:00	1.89	0.94	0.004281	2.568415	3.54E-05	0.000899
18:10:00	1.85	0.9	0.003841	2.304626	3.17E-05	0.000806
18:20:00	1.85	0.9	0.003841	2.304626	3.17E-05	0.000806
18:30:00	1.89	0.94	0.004281	2.568415	3.54E-05	0.000899
18:40:00	1.89	0.94	0.004281	2.568415	3.54E-05	0.000899
18:50:00	1.93	0.98	0.004749	2.849538	3.92E-05	0.000997
19:00:00	2.08	1.13	0.006774	4.064243	5.6E-05	0.001422
19:10:00	1.89	0.94	0.004281	2.568415	3.54E-05	0.000899
19:20:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
19:30:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
19:40:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
19:50:00	2.08	1.13	0.006774	4.064243	5.6E-05	0.001422
20:00:00	2.08	1.13	0.006774	4.064243	5.6E-05	0.001422
20:10:00	2.01	1.06	0.005775	3.465228	4.77E-05	0.001212
20:20:00	2.12	1.17	0.007388	4.432544	6.11E-05	0.001551
20:30:00	2.12	1.17	0.007388	4.432544	6.11E-05	0.001551
20:40:00	2.12	1.17	0.007388	4.432544	6.11E-05	0.001551
20:50:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
21:00:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
21:10:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
21:20:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
21:30:00	2.01	1.06	0.005775	3.465228	4.77E-05	0.001212
21:40:00	2.01	1.06	0.005775	3.465228	4.77E-05	0.001212
21:50:00	2.01	1.06	0.005775	3.465228	4.77E-05	0.001212
22:00:00	2.01	1.06	0.005775	3.465228	4.77E-05	0.001212

Table A - 4 (continued).

TIME	WATER LEVEL	CORRECTED WATER LEVEL	Q	Q	Q	Q
HH:MM:SS	INCHES	INCHES (SEE JAN. 18, 2007 FIELD NOTES)	CFS	CF PER 10 MINUTES	INCHES	MM
22:10:00	2.01	1.06	0.005775	3.465228	4.77E-05	0.001212
22:20:00	2.01	1.06	0.005775	3.465228	4.77E-05	0.001212
22:30:00	2.01	1.06	0.005775	3.465228	4.77E-05	0.001212
22:40:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
22:50:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
23:00:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
23:10:00	2.04	1.09	0.006192	3.71494	5.12E-05	0.0013
23:20:00	1.97	1.02	0.005247	3.148356	4.34E-05	0.001101
23:30:00	1.97	1.02	0.005247	3.148356	4.34E-05	0.001101
23:40:00	1.97	1.02	0.005247	3.148356	4.34E-05	0.001101
23:50:00	1.97	1.02	0.005247	3.148356	4.34E-05	0.001101

APPENDIX B

GROUNDWATER DATA

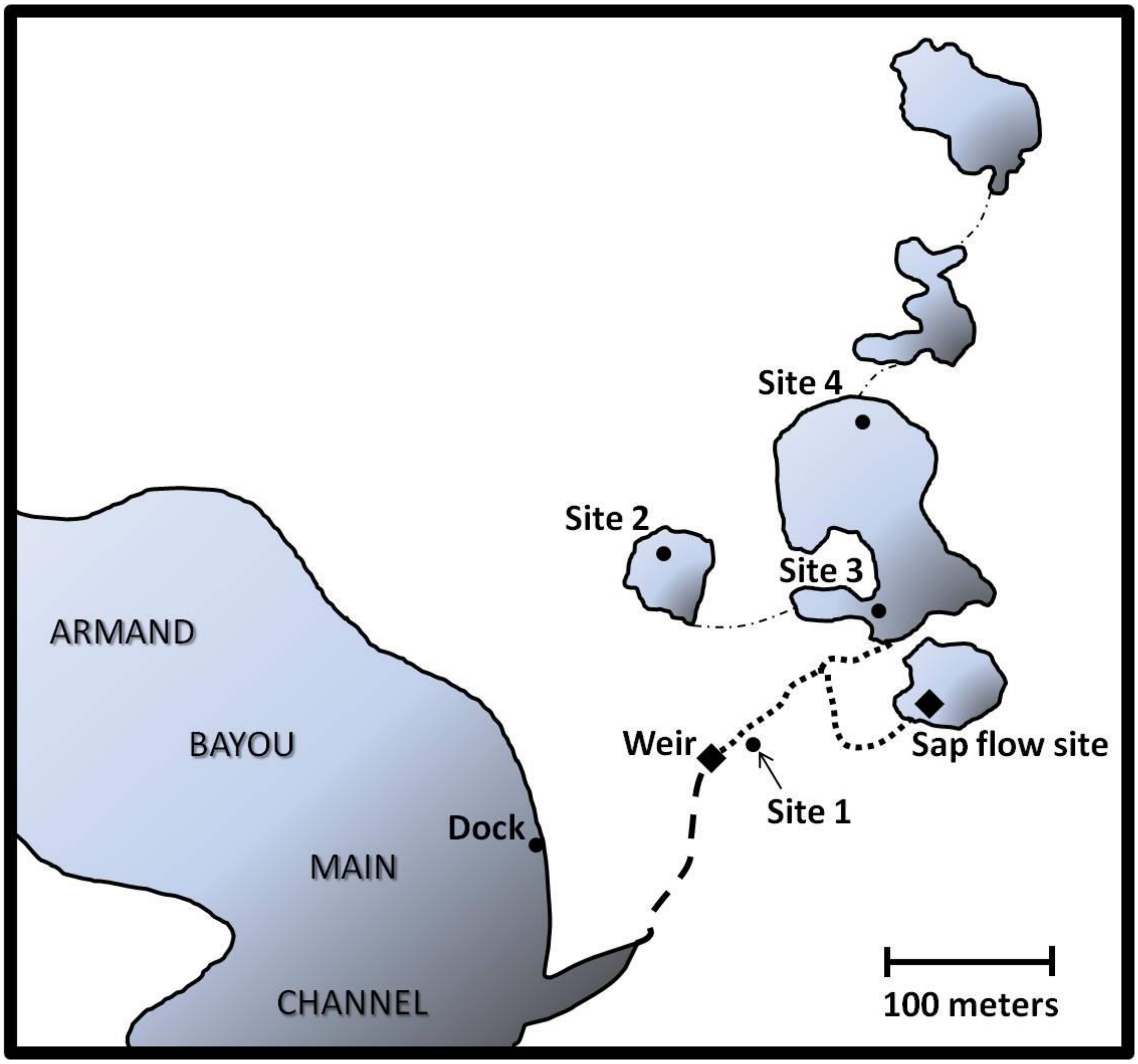

Fig. B - 1. Site locations of groundwater monitoring wells (Dock, Site 1, Site 1, Site 3, and Site 4). The relative positions of other important features, such as the weir and the sap flow site, are provided for reference.

Table B - 1. Coordinates and elevations of groundwater monitoring well sites and the bayou level reference.

SITE NAME	COORDINATES	MEAN SEA LEVEL [METERS]
Site 1	29°35'31.94"N -95° 4'40.58"W	3.889
Site 2	29°35'35.91"N -95° 4'42.61"W	4.098
Site 3	29°35'34.75"N - 95° 4'37.47"W	4.139
Site 4	29°35'38.66"N - 95° 4'37.84"W	4.746
Dock (used as a bayou level reference)	29°35'29.82"N - 95° 4'45.47"W	1.515

Note: Mean seal level was estimated at a control point on the survey to +/- one foot using topographic maps, aerial imaging systems, and National Geodetic Survey metadata. Decimals represent the survey's precision.

Table B - 2. Total depth of well casing (including well screen) for each well, and the length of casing above and below grade, presented in U.S. units.

SITE NAME	TOTAL DEPTH [FEET]		ABOVE GRADE [INCHES]		BELOW GRADE [FEET]	
	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW
Site 1	14.83	4.67	34	34	12.00	1.83
Site 2	16.25	3.54	24	24	14.25	1.54
Site 3	15.80	5.22	32	32	13.13	2.55
Site 4	14.56	3.71	21 1/4	24 9/16	12.79	2.19
Dock	8.60	-----	39 5/8	-----	5.30	----

Table B - 3. Raw groundwater level data, presented in U.S. units, with the length of well casing above grade included in the measurement. The term "Surf. Sat." means "surface saturated". A "Y" means "yes" and an "N" means "no".

Date	Boat Dock	Site 1				Site 2				Site 3				Site 4			
		Deep	Shallow	Surf. Sat.	Ponding	Deep	Shallow	Surf. Sat.	Ponding	Deep	Shallow	Surf. Sat.	Ponding	Deep	Shallow	Surf. Sat.	Ponding
M/DD/YYYY	[feet]	[feet]	[feet]	Y/N	[inches]	[feet]	[feet]	Y/N	[inches]	[feet]	[feet]	Y/N	[inches]	[feet]	[feet]	Y/N	[inches]
1/13/2010	No Data	15.35	4.7	N	None	12.25	Dry	Y	1 to 2	No Data	No Data	Y	> 2	No Data	No Data	No Data	No Data
1/23/2010	5.23	11.4	4.6	N	None	8.08	Dry	Y	0 to 1	10.42	2.84	Y	None	No Data	No Data	No Data	No Data
1/28/2010	5.86	10.38	4.6	N	None	8.08	Dry	Y	None	9.62	2.86	Y	None	No Data	No Data	No Data	No Data
2/6/2010	7.27	8.2	4.32	N	None	6.3	3.28	Y	2	8.24	2.75	Y	None	No Data	No Data	No Data	No Data
3/4/2010	6.26	5.86	3.9	Y	2	5.26	3.03	N	None	6.29	2.8	Y	< 1/2	No Data	No Data	No Data	No Data
3/30/2010	6.59	6.11	4.04	N	None	5.5	2.87	Y	None	5.62	2.96	Y	None	No Data	No Data	No Data	No Data
4/23/2010	5.87	8.06	4.7	N	None	6.2	3.23	N	None	6.94	5.9	N	None	No Data	No Data	No Data	No Data
5/11/2010	4.99	9.52	4.7	N	None	6.47	3.23	N	None	8.21	4.9	N	None	No Data	No Data	No Data	No Data
6/11/2010	5.12	11.04	4.51	N	None	7.07	2.8	N	None	10.01	4.4	N	None	No Data	No Data	No Data	No Data
7/3/2010	4.74	11.75	4.64	Y	None	7.86	2.4	Y	Y	10.75	3.44	Y	None	No Data	No Data	No Data	No Data
7/9/2010	4.42	11.25	4.4	N	None	7.3	2.02	Y	Y	10.96	3.4	N	None	9.1	1.8	N	Y
7/16/2010	6.71	11.7	4.68	N	None	7.48	2.75	N	None	10.71	4.6	N	None	9.77	3.55	N	None
7/23/2010	4.45	11.31	4.69	N	None	7.59	2.42	N	None	10.85	4.08	N	None	9.85	3.4	N	None

Table B - 3 (continued).

DATE	BOAT DOCK	SITE 1				SITE 2				SITE 3				SITE 4			
		DEEP	SHAL-LOW	SURF. SAT.	POND-ING	DEEP	SHAL-LOW	SURF. SAT.	POND-ING	DEEP	SHAL-LOW	SURF. SAT.	POND-ING	DEEP	SHAL-LOW	SURF. SAT.	POND-ING
M/DD/YYYY	[FEET]	[FEET]	[FEET]	Y/N	[INCHES]	[FEET]	[FEET]	Y/N	[INCHES]	[FEET]	[FEET]	Y/N	[INCHES]	[FEET]	[FEET]	Y/N	[INCHES]
7/30/2010	6.35	11.35	4.69	N	None	7.74	2.62	N	None	11.01	4.23	N	None	10	3.4	N	None
8/6/2010	5.68	11.56	4.71	N	None	7.92	3.13	N	None	11.12	4.66	N	None	10.35	3.59	N	None
8/13/2010	5.59	11.86	4.71	N	None	8.11	3.15	N	None	11.32	4.81	N	None	10.76	3.58	N	None
5/20/2011	5	13.36	Dry	N	None	11.57	3.33	N	None	13.12	Dry	N	None	12.51	3.59	N	None
5/27/2011	6.13	13.58	Dry	N	None	11.65	3.31	N	None	13.36	5.06	N	None	12.77	3.28	N	None
6/3/2011	5.57	13.86	Dry	N	None	11.73	3.37	N	None	13.6	Dry	N	None	13.08	Dry	N	None
6/10/2011	5.4	14.07	Dry	N	None	11.84	3.44	N	None	13.79	Dry	N	None	13.29	Dry	N	None
6/17/2011	5.94	14.35	Dry	N	None	11.93	3.51	N	None	13.95	Dry	N	None	13.49	Dry	N	None
6/24/2011	5.15	14.73	Dry	N	None	11.94	3.51	N	None	14.06	5.04	N	None	13.61	Dry	N	None
7/1/2011	5.59	14.55	Dry	N	None	12.02	3.52	N	None	14.18	5.08	N	None	13.69	3.71	N	None
7/9/2011	5.58	14.61	4.74	N	None	11.11	3.43	N	None	14.3	5.08	N	None	13.88	3.62	N	None
7/15/2011	5.15	14.76	4.73	N	None	12.19	3.45	N	None	14.38	5.08	N	None	14.01	3.61	N	None
7/22/2011	5.76	14.7	4.72	N	None	12.25	3.48	N	None	14.47	5.08	N	None	14.01	3.87	N	None
7/29/2011	4.88	14.88	4.7	N	None	12.35	3.42	N	None	14.6	Dry	N	None	14.15	3.61	N	None

Table B - 3 (continued).

Date	Boat Dock	Site 1				Site 2				Site 3				Site 4			
		Deep	Shallow	Surf. Sat.	Ponding	Deep	Shallow	Surf. Sat.	Ponding	Deep	Shallow	Surf. Sat.	Ponding	Deep	Shallow	Surf. Sat.	Ponding
M/DD/YYYY	[feet]	[feet]	[feet]	Y/N	[inches]	[feet]	[feet]	Y/N	[inches]	[feet]	[feet]	Y/N	[inches]	[feet]	[feet]	Y/N	[inches]
8/5/2011	5.89	15.04	4.73	N	None	12.47	3.52	N	None	14.68	5.07	N	None	14.3	3.61	N	None
8/12/2011	5.88	15.21	4.72	N	None	12.58	3.51	N	None	14.8	Dry	N	None	14.47	3.61	N	None
8/19/2011	6.04	15.35	4.73	N	None	12.67	3.53	N	None	14.86	5.08	N	None	14.56	3.61	N	None

Table B - 4. Groundwater level observed at each well (January 2010 through August 2011).

DATE	BOAT DOCK	SITE 1		SITE 2		SITE 3		SITE 4	
		DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW
[M/DD/YYYY]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]
1/13/2010	No Data	0.07	3.32	0.97	Dry	No Data	No Data	No Data	No Data
1/23/2010	0.93	1.28	3.35	2.24	Dry	1.78	4.09	No Data	No Data
1/28/2010	0.73	1.59	3.35	2.24	Dry	2.02	4.08	No Data	No Data
2/6/2010	0.31	2.25	3.44	2.79	3.71	2.44	4.11	No Data	No Data
3/4/2010	0.61	2.97	3.56	3.10	3.78	3.03	4.10	No Data	No Data
3/30/2010	0.51	2.89	3.52	3.03	3.83	3.24	4.05	No Data	No Data
4/23/2010	0.73	2.30	3.32	2.82	3.72	2.84	3.15	No Data	No Data
5/11/2010	1.00	1.85	3.32	2.74	3.72	2.45	3.46	No Data	No Data
6/11/2010	0.96	1.39	3.38	2.55	3.85	1.90	3.61	No Data	No Data
7/3/2010	1.08	1.17	3.34	2.31	3.98	1.68	3.90	No Data	No Data
7/9/2010	1.17	1.32	3.41	2.48	4.09	1.61	3.92	2.51	4.82
7/16/2010	0.48	1.19	3.33	2.43	3.87	1.69	3.55	2.31	4.29
7/23/2010	1.16	1.30	3.32	2.39	3.97	1.64	3.71	2.28	4.33
7/30/2010	0.59	1.29	3.32	2.35	3.91	1.60	3.66	2.24	4.33
8/6/2010	0.79	1.23	3.32	2.29	3.75	1.56	3.53	2.13	4.28
8/13/2010	0.82	1.14	3.32	2.24	3.75	1.50	3.49	2.01	4.28
5/20/2011	1.00	0.68	Dry	1.18	3.69	0.95	Dry	1.47	4.28
5/27/2011	0.65	0.61	Dry	1.16	3.70	0.88	3.41	1.39	4.37
6/3/2011	0.82	0.53	Dry	1.13	3.68	0.81	Dry	1.30	Dry
6/10/2011	0.88	0.46	Dry	1.10	3.66	0.75	Dry	1.23	Dry
6/17/2011	0.82	0.32	Dry	1.04	3.63	0.63	3.40	1.11	4.24

Table B - 4 (continued).

DATE	BOAT DOCK	SITE 1		SITE 2		SITE 3		SITE 4	
		DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW
[M/DD/YYYY]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]
7/9/2011	0.71	0.38	Dry	1.07	3.64	0.70	3.42	1.17	Dry
6/24/2011	0.95	0.26	Dry	1.07	3.64	0.67	3.40	1.14	Dry
7/1/2011	0.82	0.30	3.31	1.32	3.66	0.59	3.40	1.05	4.27
7/15/2011	0.95	0.25	3.31	0.99	3.66	0.57	3.40	1.02	4.27
7/22/2011	0.77	0.27	3.31	0.97	3.65	0.54	Dry	1.02	4.19
7/29/2011	1.03	0.22	3.32	0.94	3.66	0.50	3.41	0.97	4.27
8/5/2011	0.73	0.17	3.31	0.91	3.63	0.48	Dry	0.93	4.27
8/12/2011	0.73	0.12	3.31	0.87	3.64	0.44	3.66	0.88	4.27
8/19/2011	0.68	0.07	3.31	0.85	3.63	0.42	Dry	0.85	4.27

The groundwater flow direction was calculated based on the standard approach to solving 3-point well problems (Heath 1983). This approach was generalized for multiple wells in by replacing the hydraulic grade line approach that Heath employed with the two-point form of a line in three-dimensional space. The two-point form of a line is given by:

$$\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1} = \frac{z - z_1}{z_2 - z_1}$$

in three dimensions. Coordinates (x and y) for the wells in this generalized approach are given in FIG. B -2. The z-coordinates are the variable water elevations at each well. An equipotential line runs from the well with an intermediate water level to a point with on the opposite side of the triangle (x',y',z'), and is perpendicular to the flow direction.

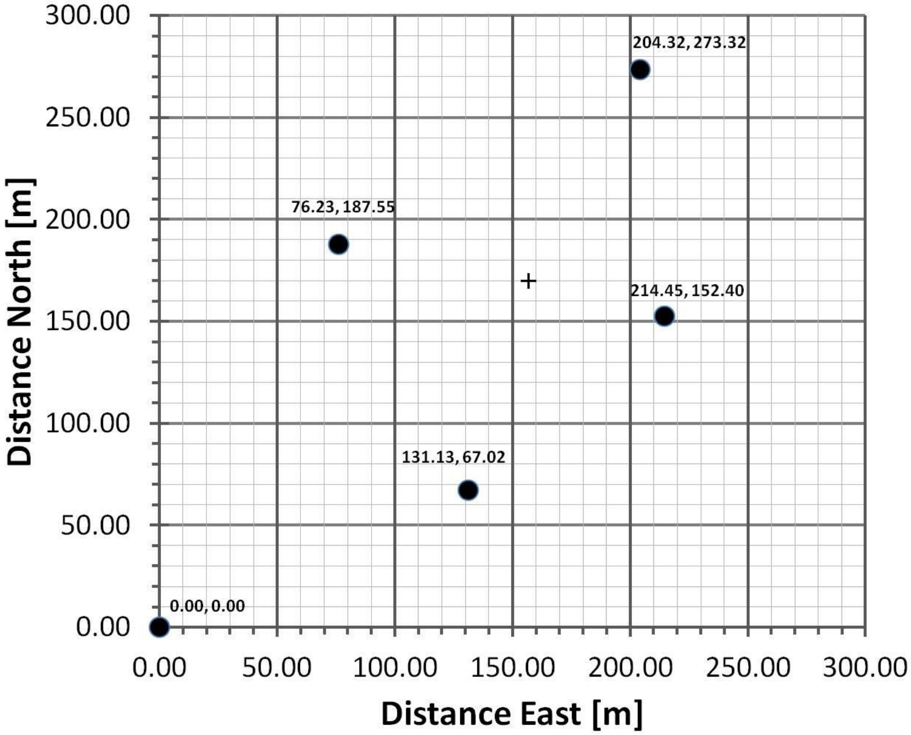

Fig. B - 2. Graphical layout of groundwater monitoring well sites for determining flow direction. The southwestern-most well, which was the reference well at the boat dock, is given the x-y coordinate pairing (0.00, 0.00). The "+" indentifies the center of the four-well array of groundwater monitoring wells.

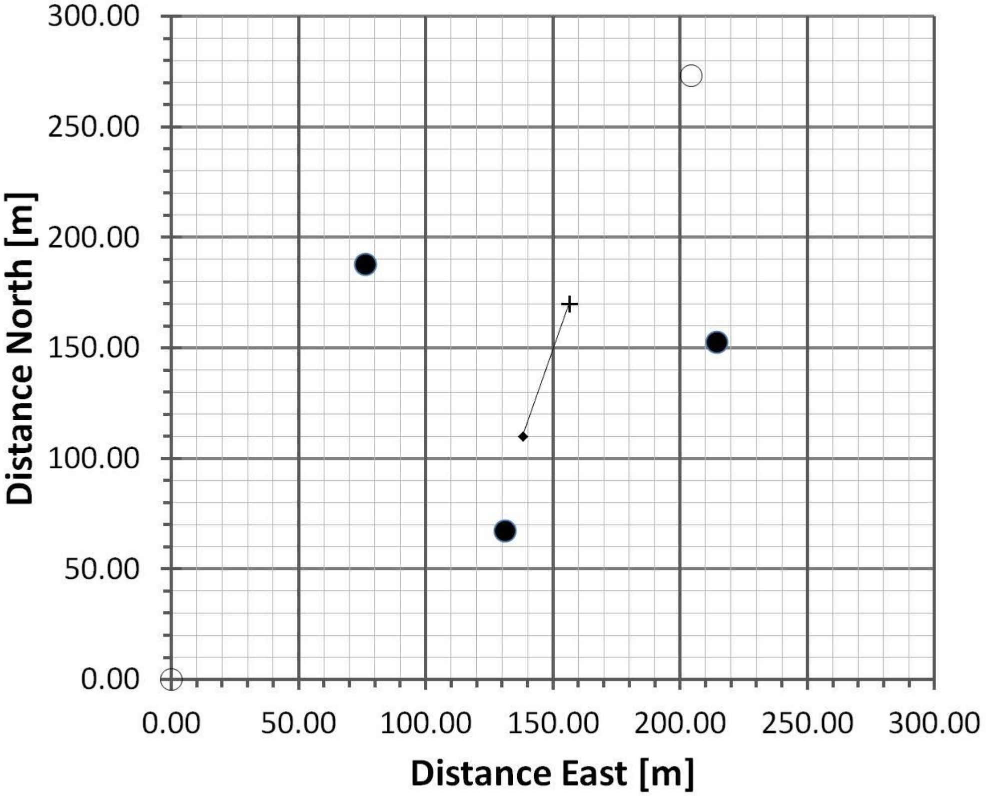

Fig. B - 3. Average direction of surface gradient using Site 1, Site 2, and Site 3. Well locations used in the calculations are represented as dark circles. The average direction of the surface gradient was 202 degrees (north reference).

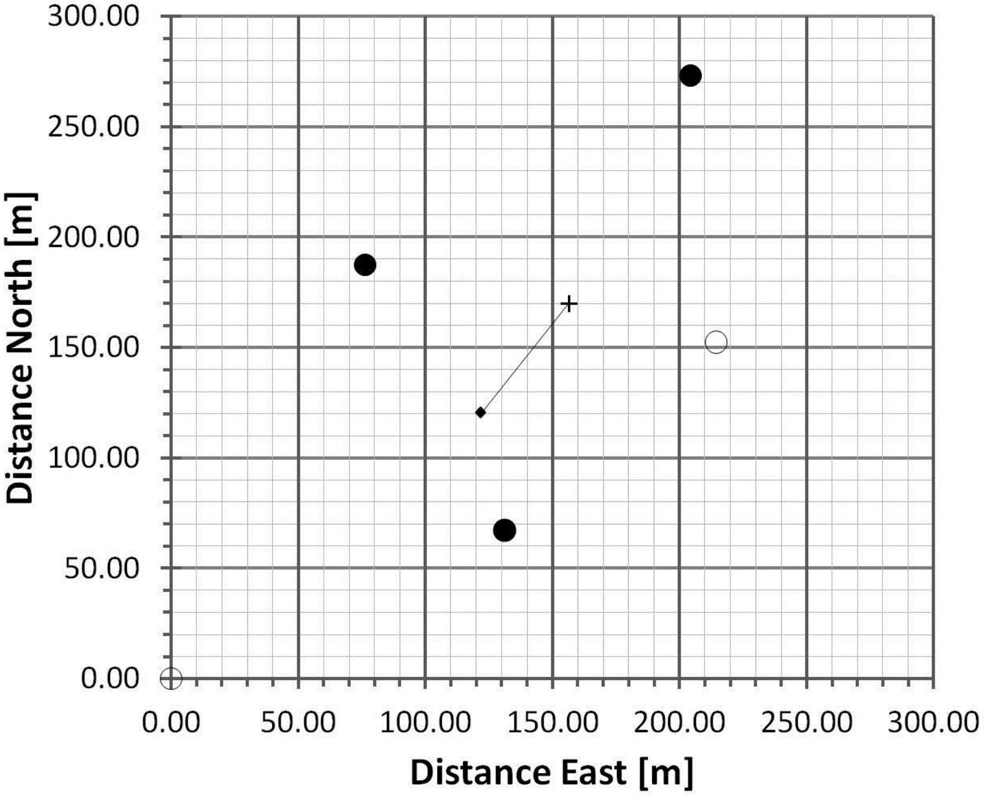

Fig. B - 4. Average direction of surface gradient using Site 1, Site 2, and Site 4. Well locations used in the calculations are represented as dark circles. The average direction of the surface gradient was 224 degrees (north reference).

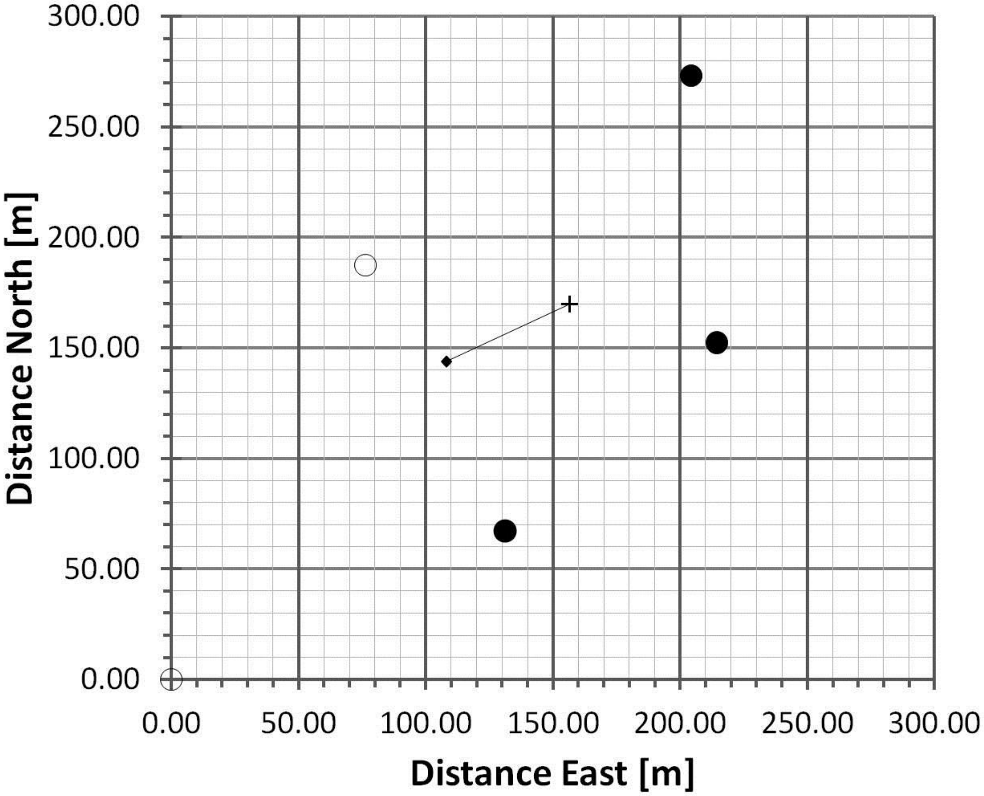

Fig. B - 5. Average direction of surface gradient using Site 1, Site 3, and Site 4. Well locations used in the calculations are represented as dark circles. The average direction of the surface gradient was 255 degrees (north reference).

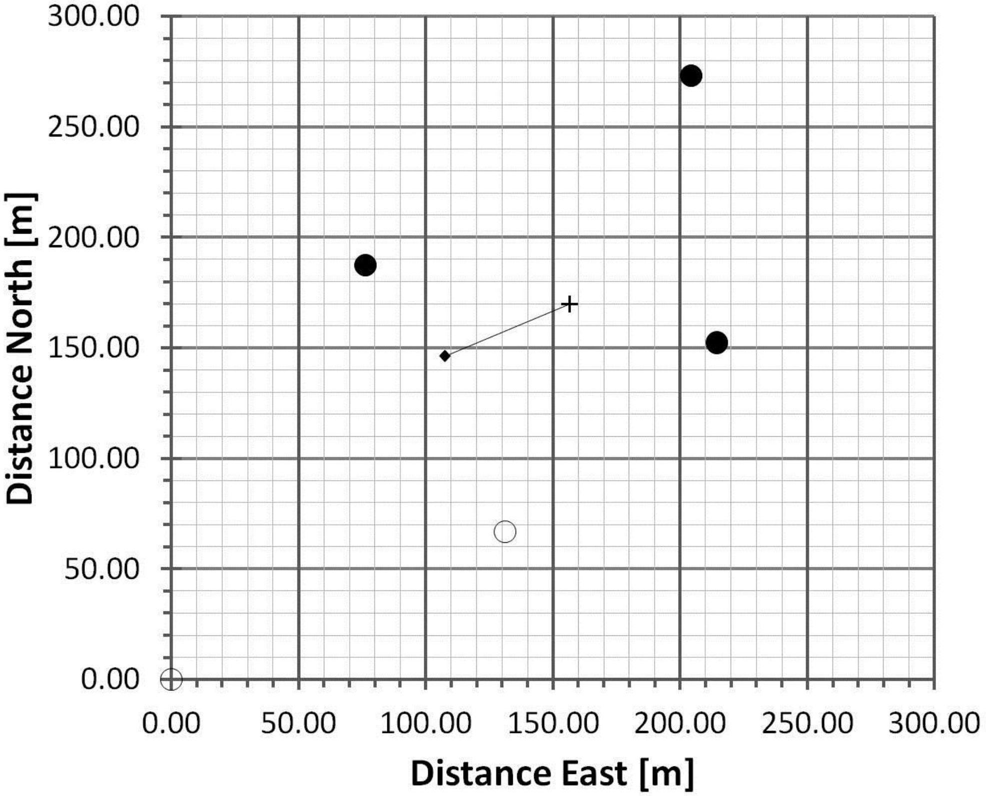

Fig. B - 6. Average direction of surface gradient using Site 1, Site 3, and Site 4. Well locations used in the calculations are represented as dark circles. The average direction of the surface gradient was 258 degrees (north reference).

Table B - 5. Calculations summary for groundwater flow direction using the deep wells at Site 1, Site 2, and Site 3.

DATE	*Z1*	*Z2*	*Z3*	*Z' (MEDIAN Z)*	*X'*	*Y'*	*THETA'*	*FLOW DIRECTION*
M/DD/YYYY	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	DEGREES (GRAPHICAL REFERENCE)	DEGREES (NORTH REFERENCE)
1/13/2010	0.07	0.97	No Data	No Data	No Data	No Data	No Data	No Data
1/23/2010	1.28	2.24	1.78	1.78	102.85	129.11	11.79	101.79
1/28/2010	1.59	2.24	2.02	2.02	95.06	146.21	2.97	177.03
2/6/2010	2.25	2.79	2.44	2.44	111.89	109.26	22.81	157.19
3/4/2010	2.97	3.10	3.03	3.03	103.92	126.75	13.07	166.93
3/30/2010	2.89	3.03	3.24	3.03	164.82	101.54	-44.16	224.16
4/23/2010	2.30	2.82	2.84	2.82	211.55	149.43	-15.73	195.73
5/11/2010	1.85	2.74	2.45	2.45	93.98	148.59	1.81	178.19
6/11/2010	1.39	2.55	1.90	1.90	106.94	120.13	16.71	163.29
7/3/2010	1.17	2.31	1.68	1.68	106.86	120.29	16.62	163.38
7/9/2010	1.32	2.48	1.61	1.61	117.50	96.95	29.77	150.23
7/16/2010	1.19	2.43	1.69	1.69	108.96	115.68	19.19	160.81
7/23/2010	1.30	2.39	1.64	1.64	114.01	104.61	25.44	154.56
7/30/2010	1.29	2.35	1.60	1.60	115.36	101.63	27.13	152.87
8/6/2010	1.23	2.29	1.56	1.56	113.93	104.78	25.35	154.65
8/13/2010	1.14	2.24	1.50	1.50	112.93	106.97	24.11	155.89
5/20/2011	0.68	1.18	0.95	0.95	101.24	132.64	9.90	170.10
5/27/2011	0.61	1.16	0.88	0.88	104.20	126.13	13.40	166.60

Table B - 5 (continued).

DATE	*Z1*	*Z2*	*Z3*	*Z' (MEDIAN Z)*	*X'*	*Y'*	*THETA'*	*FLOW DIRECTION*
M/DD/YYYY	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	DEGREES (GRAPHICAL REFERENCE)	DEGREES (NORTH REFERENCE)
6/3/2011	0.53	1.13	0.81	0.81	105.81	122.60	15.34	164.66
6/10/2011	0.46	1.10	0.75	0.75	106.50	121.09	16.17	163.83
6/17/2011	0.38	1.07	0.70	0.70	105.66	122.93	15.16	164.84
6/24/2011	0.26	1.07	0.67	0.67	103.62	127.42	12.70	167.30
7/1/2011	0.32	1.04	0.63	0.63	107.53	118.83	17.43	162.57
7/9/2011	0.30	1.32	0.59	0.59	115.34	101.69	27.10	152.90
7/15/2011	0.25	0.99	0.57	0.57	107.69	118.48	17.63	162.37
7/22/2011	0.27	0.97	0.54	0.54	110.05	113.31	20.53	159.47
7/29/2011	0.22	0.94	0.50	0.50	109.60	114.28	19.98	160.02
8/5/2011	0.17	0.91	0.48	0.48	108.14	117.48	18.18	161.82
8/12/2011	0.12	0.87	0.44	0.44	107.59	118.69	17.51	162.49
8/19/2011	0.07	0.85	0.42	0.42	106.33	121.48	15.96	164.04

Table B - 6. Calculations summary for groundwater flow direction using the deep wells at Site 1, Site 2, and Site 4.

Date	Z1	Z2	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
1/13/2010	0.07	0.97	No Data	No Data	No Data	No Data	No Data	No Data
1/23/2010	1.28	2.24	No Data	No Data	No Data	No Data	No Data	No Data
1/28/2010	1.59	2.24	No Data	No Data	No Data	No Data	No Data	No Data
2/6/2010	2.25	2.79	No Data	No Data	No Data	No Data	No Data	No Data
3/4/2010	2.97	3.10	No Data	No Data	No Data	No Data	No Data	No Data
3/30/2010	2.89	3.03	No Data	No Data	No Data	No Data	No Data	No Data
4/23/2010	2.30	2.82	No Data	No Data	No Data	No Data	No Data	No Data
5/11/2010	1.85	2.74	No Data	No Data	No Data	No Data	No Data	No Data
6/11/2010	1.39	2.55	No Data	No Data	No Data	No Data	No Data	No Data
7/3/2010	1.17	2.31	No Data	No Data	No Data	No Data	No Data	No Data
7/9/2010	1.32	2.48	2.51	2.48	202.50	268.19	32.57	147.43
7/16/2010	1.19	2.43	2.31	2.31	81.53	175.91	38.42	141.58
7/23/2010	1.30	2.39	2.28	2.28	81.81	175.30	38.66	141.34
7/30/2010	1.29	2.35	2.24	2.24	81.99	174.91	38.82	141.18
8/6/2010	1.23	2.29	2.13	2.13	84.61	169.15	41.03	138.97
8/13/2010	1.14	2.24	2.01	2.01	87.71	162.35	43.58	136.42
5/20/2011	0.68	1.18	1.47	1.18	177.38	197.38	5.55	174.45

Table B - 6 (continued).

Date	Z1	Z2	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
5/27/2011	0.61	1.16	1.39	1.16	182.10	210.70	12.34	167.66
6/3/2011	0.53	1.13	1.30	1.13	188.50	228.72	20.14	159.86
6/10/2011	0.46	1.10	1.23	1.10	191.39	236.87	23.19	156.81
6/17/2011	0.38	1.07	1.17	1.07	194.87	246.69	26.49	153.51
6/24/2011	0.26	1.07	1.14	1.07	198.53	257.01	29.59	150.41
7/1/2011	0.32	1.04	1.11	1.04	197.96	255.38	29.13	150.87
7/9/2011	0.30	1.32	1.05	1.05	90.53	156.16	45.84	134.16
7/15/2011	0.25	0.99	1.02	0.99	202.07	266.98	32.26	147.74
7/22/2011	0.27	0.97	1.02	0.97	200.21	261.75	30.90	149.10
7/29/2011	0.22	0.94	0.97	0.94	201.46	265.26	31.82	148.18
8/5/2011	0.17	0.91	0.93	0.91	202.35	267.78	32.46	147.54
8/12/2011	0.12	0.87	0.88	0.87	204.12	272.75	33.67	146.33
8/19/2011	0.07	0.85	0.85	0.85	204.12	272.76	33.68	146.32

Table B - 7. Calculations summary for groundwater flow direction using the deep wells at Site 1, Site 3, and Site 4.

Date	Z1	Z3	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
1/13/2010	0.07	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1/23/2010	1.28	1.78	No Data	No Data	No Data	No Data	No Data	No Data
1/28/2010	1.59	2.02	No Data	No Data	No Data	No Data	No Data	No Data
2/6/2010	2.25	2.44	No Data	No Data	No Data	No Data	No Data	No Data
3/4/2010	2.97	3.03	No Data	No Data	No Data	No Data	No Data	No Data
3/30/2010	2.89	3.24	No Data	No Data	No Data	No Data	No Data	No Data
4/23/2010	2.30	2.84	No Data	No Data	No Data	No Data	No Data	No Data
5/11/2010	1.85	2.45	No Data	No Data	No Data	No Data	No Data	No Data
6/11/2010	1.39	1.90	No Data	No Data	No Data	No Data	No Data	No Data
7/3/2010	1.17	1.68	No Data	No Data	No Data	No Data	No Data	No Data
7/9/2010	1.32	1.61	2.51	1.61	148.85	116.97	47.09	132.91
7/16/2010	1.19	1.69	2.31	1.69	163.84	159.21	29.25	150.75
7/23/2010	1.30	1.64	2.28	1.64	156.54	138.64	40.18	139.82
7/30/2010	1.29	1.60	2.24	1.60	154.61	133.20	42.25	137.75
8/6/2010	1.23	1.56	2.13	1.56	158.19	143.30	38.19	141.81
8/13/2010	1.14	1.50	2.01	1.50	161.81	153.48	32.91	147.09
5/20/2011	0.68	0.95	1.47	0.95	156.31	137.99	40.44	139.56
5/27/2011	0.61	0.88	1.39	0.88	156.13	137.49	40.64	139.36

Table B - 7 (continued).

DATE	Z1	Z3	Z4	Z' (MEDIAN Z)	X'	Y'	THETA'	FLOW DIRECTION
M/DD/YYYY	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	DEGREES (GRAPHICAL REFERENCE)	DEGREES (NORTH REFERENCE)
6/3/2011	0.53	0.81	1.30	0.81	157.58	141.59	38.95	141.05
6/10/2011	0.46	0.75	1.23	0.75	158.16	143.22	38.23	141.77
6/17/2011	0.38	0.70	1.17	0.70	160.70	150.37	34.67	145.33
6/24/2011	0.26	0.67	1.14	0.67	164.91	162.23	27.07	152.93
7/1/2011	0.32	0.63	1.11	0.63	159.86	148.00	35.93	144.07
7/9/2011	0.30	0.59	1.05	0.59	159.59	147.25	36.30	143.70
7/15/2011	0.25	0.57	1.02	0.57	161.42	152.39	33.55	146.45
7/22/2011	0.27	0.54	1.02	0.54	157.66	141.80	38.86	141.14
7/29/2011	0.22	0.50	0.97	0.50	158.71	144.75	37.52	142.48
8/5/2011	0.17	0.48	0.93	0.48	160.95	151.07	34.29	145.71
8/12/2011	0.12	0.44	0.88	0.44	162.42	155.22	31.86	148.14
8/19/2011	0.07	0.42	0.85	0.42	164.11	159.95	28.71	151.29

Table B - 8. Calculations summary for groundwater flow direction using the deep wells at Site 2, Site 3, and Site 4.

Date	Z2	Z3	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
1/13/2010	0.97	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1/23/2010	2.24	1.78	No Data	No Data	No Data	No Data	No Data	No Data
1/28/2010	2.24	2.02	No Data	No Data	No Data	No Data	No Data	No Data
2/6/2010	2.79	2.44	No Data	No Data	No Data	No Data	No Data	No Data
3/4/2010	3.10	3.03	No Data	No Data	No Data	No Data	No Data	No Data
3/30/2010	3.03	3.24	No Data	No Data	No Data	No Data	No Data	No Data
4/23/2010	2.82	2.84	No Data	No Data	No Data	No Data	No Data	No Data
5/11/2010	2.74	2.45	No Data	No Data	No Data	No Data	No Data	No Data
6/11/2010	2.55	1.90	No Data	No Data	No Data	No Data	No Data	No Data
7/3/2010	2.31	1.68	No Data	No Data	No Data	No Data	No Data	No Data
7/9/2010	2.48	1.61	2.51	2.48	204.65	270.51	32.86	147.14
7/16/2010	2.43	1.69	2.31	2.31	98.61	187.55	39.05	140.95
7/23/2010	2.39	1.64	2.28	2.28	96.65	187.55	38.54	141.46
7/30/2010	2.35	1.60	2.24	2.24	96.57	187.55	38.52	141.48
8/6/2010	2.29	1.56	2.13	2.13	106.96	187.55	41.38	138.62
8/13/2010	2.24	1.50	2.01	2.01	119.46	187.55	45.30	134.70
5/20/2011	1.18	0.95	1.47	1.18	210.00	225.19	15.72	164.28
5/27/2011	1.16	0.88	1.39	1.16	208.99	233.78	19.20	160.80

Table B - 8 (continued).

Date	Z2	Z3	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
6/3/2011	1.13	0.81	1.30	1.13	207.75	244.28	23.33	156.67
6/10/2011	1.10	0.75	1.23	1.10	207.16	249.29	25.25	154.75
6/17/2011	1.07	0.70	1.17	1.07	206.51	254.74	27.28	152.72
6/24/2011	1.07	0.67	1.14	1.07	205.81	260.73	29.46	150.54
7/1/2011	1.04	0.63	1.11	1.04	205.77	261.04	29.57	150.43
7/9/2011	1.32	0.59	1.05	1.05	126.76	187.55	47.88	132.12
7/15/2011	0.99	0.57	1.02	0.99	204.85	268.82	32.29	147.71
7/22/2011	0.97	0.54	1.02	0.97	205.21	265.77	31.24	148.76
7/29/2011	0.94	0.50	0.97	0.94	204.95	267.94	31.99	148.01
8/5/2011	0.91	0.48	0.93	0.91	204.78	269.43	32.50	147.50
8/12/2011	0.87	0.44	0.88	0.87	204.37	272.91	33.67	146.33
8/19/2011	0.85	0.42	0.85	0.85	204.37	272.90	33.67	146.33

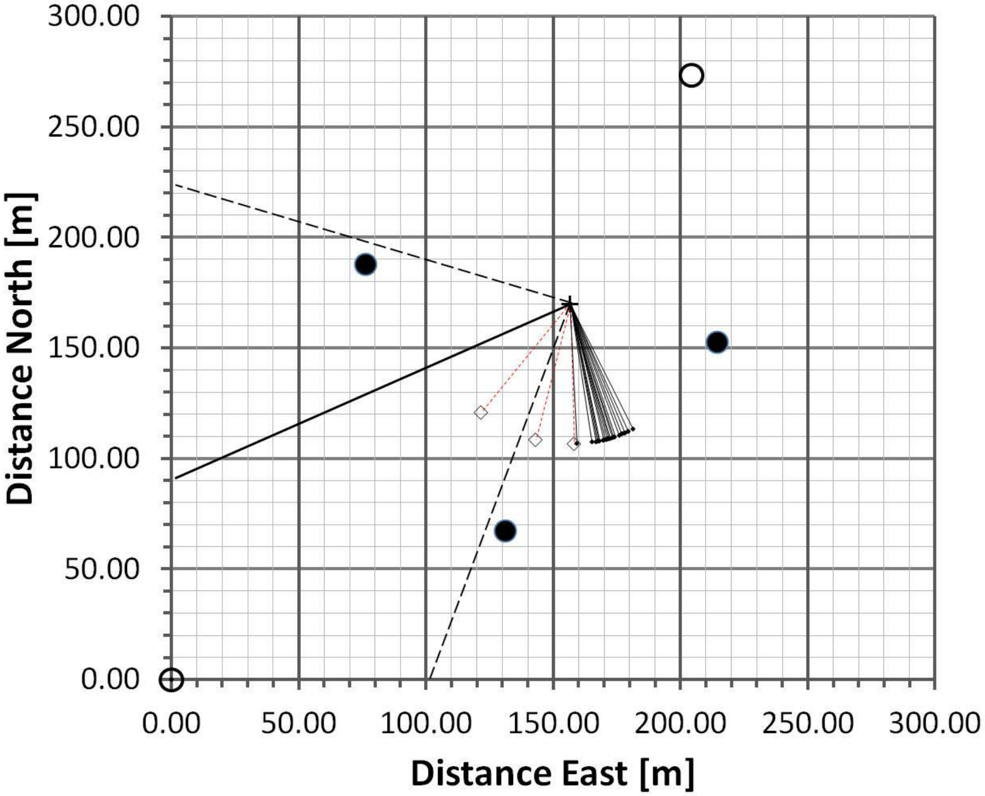

Fig. B - 7. Graphical summary of calculated deep groundwater flow direction on each date where complete data was available for Site 1, Site 2, and Site 3. Wells used in the calculations are represented as dark circles. Four dates resulted in questionable groundwater flow directions, for the reasons noted in the main body of this thesis, and the endpoints of these flow direction lines are open diamonds. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou and ± 45 degrees, respectively.

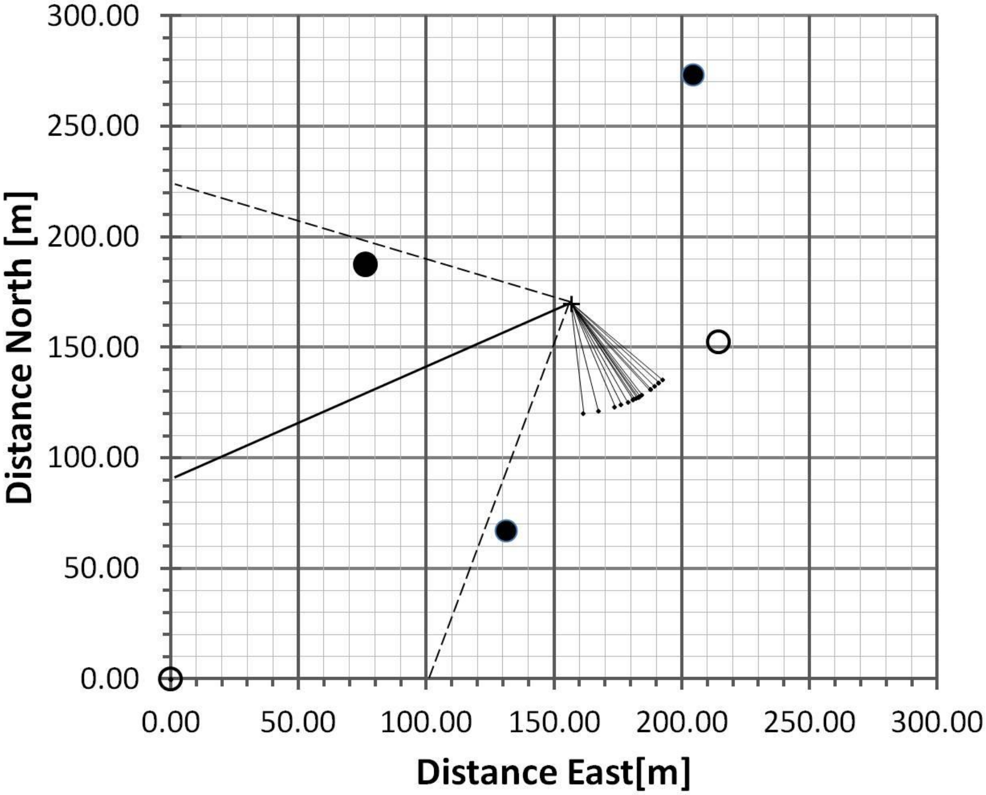

Fig. B - 8. Graphical summary of calculated deep groundwater flow direction on each date where complete data was available for Site 1, Site 2, and Site 4. Wells used in the calculations are represented as dark circles. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou and ± 45 degrees, respectively.

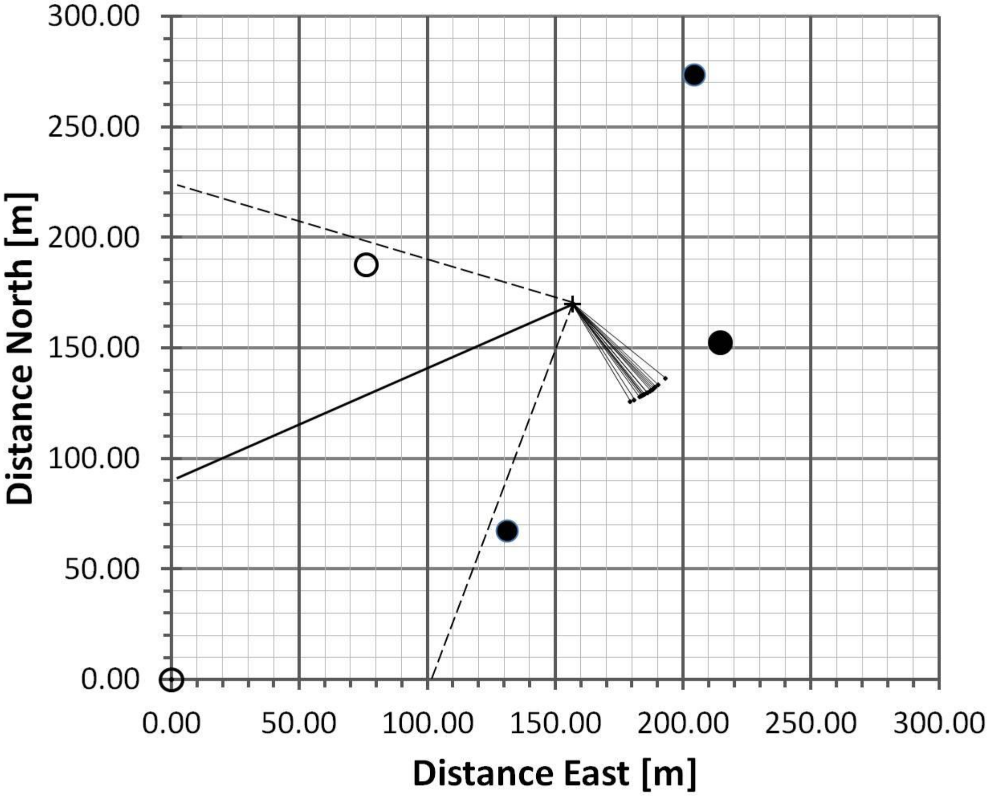

Fig. B - 9. Graphical summary of calculated deep groundwater flow direction on each date where complete data was available for Site 1, Site 3, and Site 4. Wells used in the calculations are represented as dark circles. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou and ± 45 degrees, respectively.

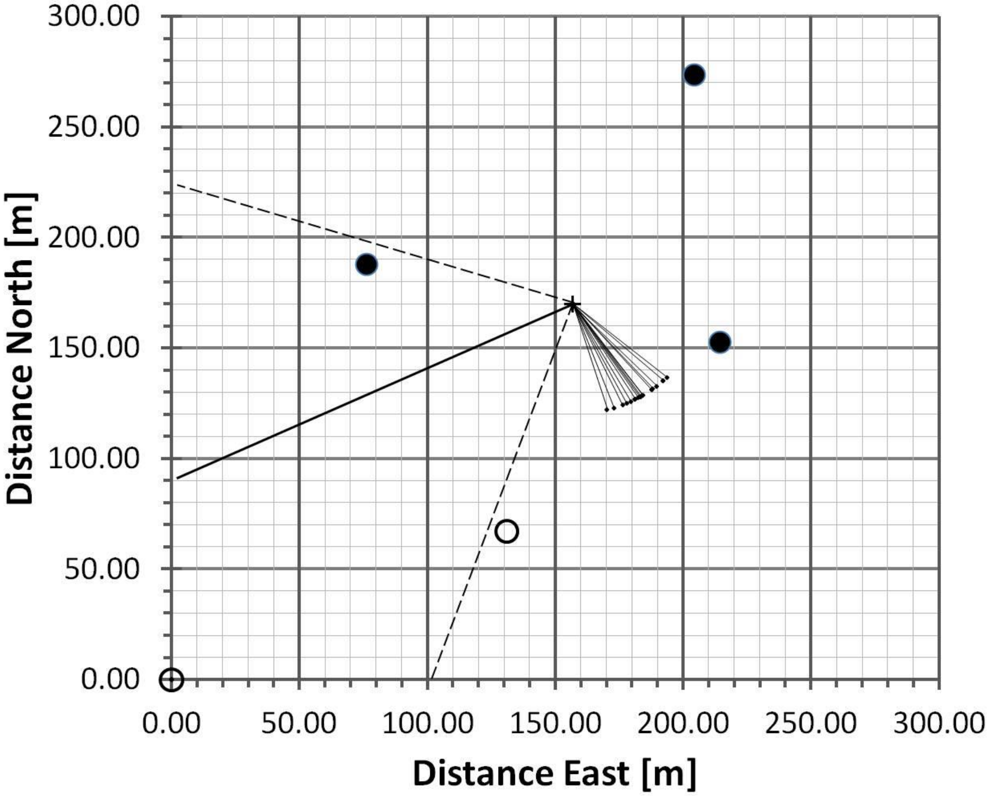

Fig. B - 10. Graphical summary of calculated deep groundwater flow direction on each date where complete data was available for Site 2, Site 3, and Site 4. Wells used in the calculations are represented as dark circles. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou and ± 45 degrees, respectively.

Table B - 9. Calculations summary for groundwater flow direction using the shallow wells at Site 1, Site 2, and Site 3.

Date	*Z1*	*Z2*	*Z3*	*Z'* (*Median Z*)	*X'*	*Y'*	*Theta'*	*Flow Direction*
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
1/13/2010	3.32	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1/23/2010	3.35	4.09	No Data	No Data	No Data	No Data	No Data	No Data
1/28/2010	3.32	0.00	0.00	0.00	76.23	187.55	No Data	No Data
2/6/2010	3.35	0.00	4.09	3.35	189.56	158.73	57.50	147.50
3/4/2010	3.35	0.00	4.08	3.35	189.72	158.69	57.41	122.59
3/30/2010	3.44	3.71	4.11	3.71	164.57	101.28	-44.32	224.32
4/23/2010	3.56	3.78	4.10	3.78	165.45	102.19	-43.73	223.73
5/11/2010	3.52	3.83	4.05	3.83	180.26	117.36	-34.01	214.01
6/11/2010	3.32	3.72	3.15	3.32	174.08	162.67	65.82	114.18
7/3/2010	3.32	3.72	3.46	3.46	112.27	108.42	23.29	156.71
7/9/2010	3.38	3.85	3.61	3.61	104.28	125.97	13.49	166.51
7/16/2010	3.34	3.98	3.90	3.90	82.48	173.82	-9.22	189.22
7/23/2010	3.41	4.09	3.92	3.92	90.45	156.33	-1.81	181.81
7/30/2010	3.33	3.87	3.55	3.55	108.52	116.67	18.64	161.36
8/6/2010	3.32	3.97	3.71	3.71	98.43	138.81	6.68	173.32
8/13/2010	3.32	3.91	3.66	3.66	99.31	136.87	7.68	172.32
5/20/2011	3.32	3.75	3.53	3.53	104.14	126.27	13.33	166.67
5/27/2011	3.32	3.75	3.49	3.49	109.59	114.31	19.96	160.04

Table B - 9 (continued).

Date	*Z1*	*Z2*	*Z3*	*Z' (Median Z)*	*X'*	*Y'*	*Theta'*	*Flow Direction*
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
6/3/2011	3.66	3.69	3.66	3.66	131.13	67.02	No Data	No Data
6/10/2011	Dry	3.70	Dry	No Data	131.13	67.02	No Data	No Data
6/17/2011	Dry	3.68	3.66	3.66	76.57	186.81	-14.01	194.01
6/24/2011	Dry	3.66	Dry	No Data	No Data	No Data	No Data	No Data
7/1/2011	Dry	3.64	Dry	No Data	No Data	No Data	No Data	No Data
7/9/2011	Dry	3.64	Dry	No Data	No Data	No Data	No Data	No Data
7/15/2011	Dry	3.63	3.40	3.40	79.72	179.88	-11.53	191.53
7/22/2011	Dry	3.66	3.40	3.40	80.11	179.04	-11.22	191.22
7/29/2011	3.31	3.66	3.40	3.40	116.38	99.40	28.39	151.61
8/5/2011	3.31	3.65	3.40	3.40	116.34	99.48	28.34	151.66
8/12/2011	3.32	3.66	3.66	3.66	77.40	185.00	-13.38	193.38
8/19/2011	3.31	3.63	Dry	3.31	88.55	184.42	-70.07	250.07

Table B - 10. Calculations summary for groundwater flow direction using the shallow wells at Site 1, Site 2, and Site 4.

Date	Z1	Z2	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
1/13/2010	3.32	No Data	No Data	No Data	No Data	No Data	No Data	No Data
1/23/2010	3.35	4.09	No Data	No Data	No Data	No Data	No Data	No Data
1/28/2010	3.32	0.00	No Data	No Data	No Data	No Data	No Data	No Data
2/6/2010	3.35	0.00	No Data	No Data	No Data	No Data	No Data	No Data
3/4/2010	3.35	0.00	No Data	No Data	No Data	No Data	No Data	No Data
3/30/2010	3.44	3.71	No Data	No Data	No Data	No Data	No Data	No Data
4/23/2010	3.56	3.78	No Data	No Data	No Data	No Data	No Data	No Data
5/11/2010	3.52	3.83	No Data	No Data	No Data	No Data	No Data	No Data
6/11/2010	3.32	3.72	No Data	No Data	No Data	No Data	No Data	No Data
7/3/2010	3.32	3.72	No Data	No Data	No Data	No Data	No Data	No Data
7/9/2010	3.38	3.85	No Data	3.38	92.06	198.15	No Data	No Data
7/16/2010	3.34	3.98	No Data	3.34	96.78	201.31	No Data	No Data
7/23/2010	3.41	4.09	4.82	4.09	166.46	166.59	-13.08	193.08
7/30/2010	3.33	3.87	4.29	3.87	172.48	183.56	-2.37	182.37
8/6/2010	3.32	3.97	4.33	3.97	177.99	199.09	6.47	173.53
8/13/2010	3.32	3.91	4.33	3.91	173.57	186.65	-0.53	180.53
5/20/2011	3.32	3.75	4.28	3.75	164.46	160.98	-16.76	196.76

Table B - 10 (continued).

Date	Z1	Z2	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
M/DD/YYYY	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
5/27/2011	3.66	3.69	4.28	3.69	135.25	78.62	-61.55	241.55
6/3/2011	Dry	3.70	4.37	3.70	193.07	241.62	24.83	155.17
6/10/2011	Dry	3.68	3.66	3.66	76.57	186.81	34.10	145.90
6/17/2011	Dry	3.66	Dry	Dry	131.13	67.02	No Data	No Data
6/24/2011	Dry	3.64	Dry	Dry	131.13	67.02	No Data	No Data
7/1/2011	Dry	3.64	Dry	Dry	131.13	67.02	No Data	No Data
7/9/2011	Dry	3.63	Dry	Dry	131.13	67.02	No Data	No Data
7/15/2011	Dry	3.66	4.27	3.66	193.95	244.09	25.66	154.34
7/22/2011	3.31	3.66	4.27	3.66	157.48	141.30	-29.65	209.65
7/29/2011	3.31	3.65	4.19	3.65	158.94	145.41	-27.00	207.00
8/5/2011	3.32	3.66	4.27	3.66	157.74	142.02	-29.19	209.19
8/12/2011	3.31	3.63	4.27	3.63	155.85	136.71	-32.56	212.56
8/19/2011	3.66	3.69	4.28	3.69	135.25	78.62	-61.55	241.55

Table B - 11. Calculations summary for groundwater flow direction using the shallow wells at Site 1, Site 3, and Site 4.

Date	Z1	Z3	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
1/13/2010	3.32	No Data	No Data	0.00	214.45	187.55	No Data	No Data
1/23/2010	3.35	No Data	No Data	3.35	212.62	203.00	No Data	No Data
1/28/2010	3.32	0.00	No Data	3.35	212.64	202.89	No Data	No Data
2/6/2010	3.35	4.09	No Data	3.44	212.78	201.69	No Data	No Data
3/4/2010	3.35	4.08	No Data	3.56	213.13	198.74	No Data	No Data
3/30/2010	3.44	4.11	No Data	3.52	213.13	198.75	No Data	No Data
4/23/2010	3.56	4.10	No Data	3.15	134.80	77.35	No Data	No Data
5/11/2010	3.52	4.05	No Data	3.32	214.04	190.98	No Data	No Data
6/11/2010	3.32	3.15	No Data	3.38	213.79	193.08	No Data	No Data
7/3/2010	3.32	3.46	No Data	3.34	212.98	199.97	No Data	No Data
7/9/2010	3.38	3.61	No Data	3.92	157.31	140.80	39.29	140.71
7/16/2010	3.34	3.90	No Data	3.55	148.16	115.02	47.57	132.43
7/23/2010	3.41	3.92	4.82	3.71	159.04	145.69	37.07	142.93
7/30/2010	3.33	3.55	4.29	3.66	155.73	136.35	41.09	138.91
8/6/2010	3.32	3.71	4.33	3.53	147.52	113.21	48.00	132.00
8/13/2010	3.32	3.66	4.33	3.49	143.99	103.26	50.11	129.89
5/20/2011	3.32	3.53	4.28	0.00	214.45	187.55	No Data	No Data
5/27/2011	3.32	3.49	4.28	3.35	212.62	203.00	No Data	No Data

Table B - 11 (continued).

DATE	Z1	Z3	Z4	Z' (MEDIAN Z)	X'	Y'	THETA'	FLOW DIRECTION
M/DD/YYYY	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	[METERS]	DEGREES (GRAPHICAL REFERENCE)	DEGREES (NORTH REFERENCE)
6/3/2011	3.66	3.66	4.28	3.66	131.13	67.02	No Data	No Data
6/10/2011	Dry	Dry	4.37	0.00	131.13	67.02	No Data	No Data
6/17/2011	Dry	3.66	3.66	3.66	214.45	187.55	No Data	No Data
6/24/2011	Dry	Dry	Dry	0.00	No Data	No Data	No Data	No Data
7/1/2011	Dry	Dry	Dry	0.00	No Data	No Data	No Data	No Data
7/9/2011	Dry	Dry	Dry	0.00	No Data	No Data	No Data	No Data
7/15/2011	Dry	3.40	Dry	0.00	131.13	67.02	No Data	No Data
7/22/2011	Dry	3.40	4.27	3.40	189.51	231.59	-60.48	240.48
7/29/2011	3.31	3.40	4.27	3.40	138.21	86.98	52.84	127.16
8/5/2011	3.31	3.40	4.19	3.40	138.62	88.13	52.67	127.33
8/12/2011	3.32	3.66	4.27	3.66	157.17	140.43	39.45	140.55
8/19/2011	3.31	Dry	4.27	3.31	206.59	254.06	68.03	111.97

Table B - 12. Calculations summary for groundwater flow direction using the shallow wells at Site 2, Site 3, and Site 4.

Date	Z2	Z3	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
1/13/2010	No Data	No Data	No Data	0.00	No Data	No Data	No Data	No Data
1/23/2010	4.09	No Data	No Data	0.00	76.23	187.55	No Data	No Data
1/28/2010	0.00	0.00	No Data	0.00	76.23	187.55	No Data	No Data
2/6/2010	0.00	4.09	No Data	3.71	213.45	196.01	No Data	No Data
3/4/2010	0.00	4.08	No Data	3.78	213.67	194.13	No Data	No Data
3/30/2010	3.71	4.11	No Data	3.83	213.91	192.14	No Data	No Data
4/23/2010	3.78	4.10	No Data	3.15	95.83	200.67	No Data	No Data
5/11/2010	3.83	4.05	No Data	3.46	85.34	193.65	No Data	No Data
6/11/2010	3.72	3.15	No Data	3.61	84.32	192.97	No Data	No Data
7/3/2010	3.72	3.46	No Data	3.90	78.57	189.12	No Data	No Data
7/9/2010	3.85	3.61	No Data	4.09	212.48	204.24	6.99	173.01
7/16/2010	3.98	3.90	No Data	3.87	210.06	224.69	15.51	164.49
7/23/2010	4.09	3.92	4.82	3.97	210.21	223.44	15.00	165.00
7/30/2010	3.87	3.55	4.29	3.91	210.73	219.05	13.18	166.82
8/6/2010	3.97	3.71	4.33	3.75	211.43	213.14	10.72	169.28
8/13/2010	3.91	3.66	4.33	3.75	211.11	215.85	11.85	168.15
5/20/2011	3.75	3.53	4.28	0.00	No Data	No Data	No Data	No Data
5/27/2011	3.75	3.49	4.28	0.00	76.23	187.55	No Data	No Data

Table B - 12 (continued).

Date	Z2	Z3	Z4	Z' (Median Z)	X'	Y'	Theta'	Flow Direction
m/dd/yyyy	[meters]	[meters]	[meters]	[meters]	[meters]	[meters]	Degrees (Graphical Reference)	Degrees (North Reference)
6/3/2011	3.69	3.66	4.28	3.69	213.88	192.37	2.01	177.99
6/10/2011	3.70	Dry	4.37	3.70	205.87	260.14	29.25	150.75
6/17/2011	3.68	3.66	3.66	3.66	214.45	187.55	No Data	No Data
6/24/2011	3.66	Dry	Dry	0.00	214.45	187.55	No Data	No Data
7/1/2011	3.64	Dry	Dry	0.00	214.45	187.55	No Data	No Data
7/9/2011	3.64	Dry	Dry	0.00	214.45	187.55	No Data	No Data
7/15/2011	3.63	3.40	Dry	3.40	84.38	193.00	-2.40	182.40
7/22/2011	3.66	3.40	4.27	3.66	211.41	213.25	10.76	169.24
7/29/2011	3.66	3.40	4.27	3.66	211.49	212.55	10.47	169.53
8/5/2011	3.65	3.40	4.19	3.65	211.32	214.08	11.11	168.89
8/12/2011	3.66	3.66	4.27	3.66	214.33	188.58	0.43	179.57
8/19/2011	3.63	Dry	4.27	3.63	205.82	260.56	29.40	150.60

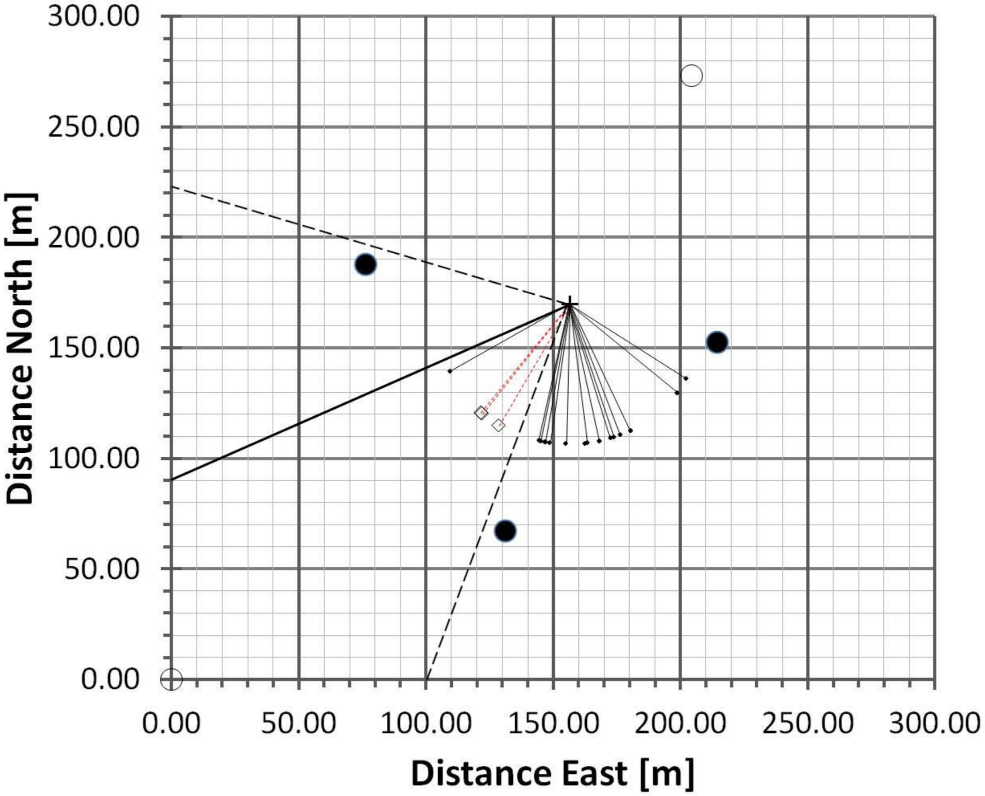

Fig. B -11. Graphical summary of calculated shallow groundwater flow direction on each date where complete data was available for Site 1, Site 2, and Site 3. Wells used in the calculations are represented as dark circles. Four dates resulted in questionable groundwater flow directions, for the reasons noted in the main body of this thesis, and the endpoints of these flow direction lines are open diamonds. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou and ± 45 degrees, respectively.

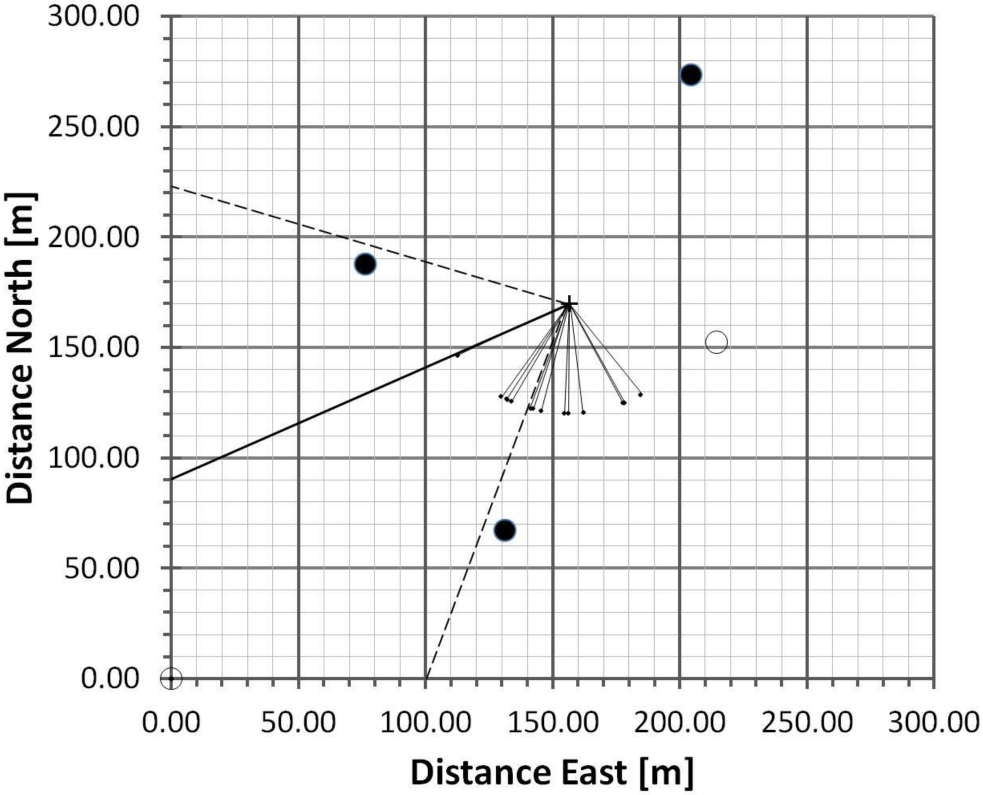

Fig. B - 12. Graphical summary of calculated shallow groundwater flow direction on each date where complete data was available for Site 1, Site 2, and Site 4. Wells used in the calculations are represented as dark circles. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou and ± 45 degrees, respectively.

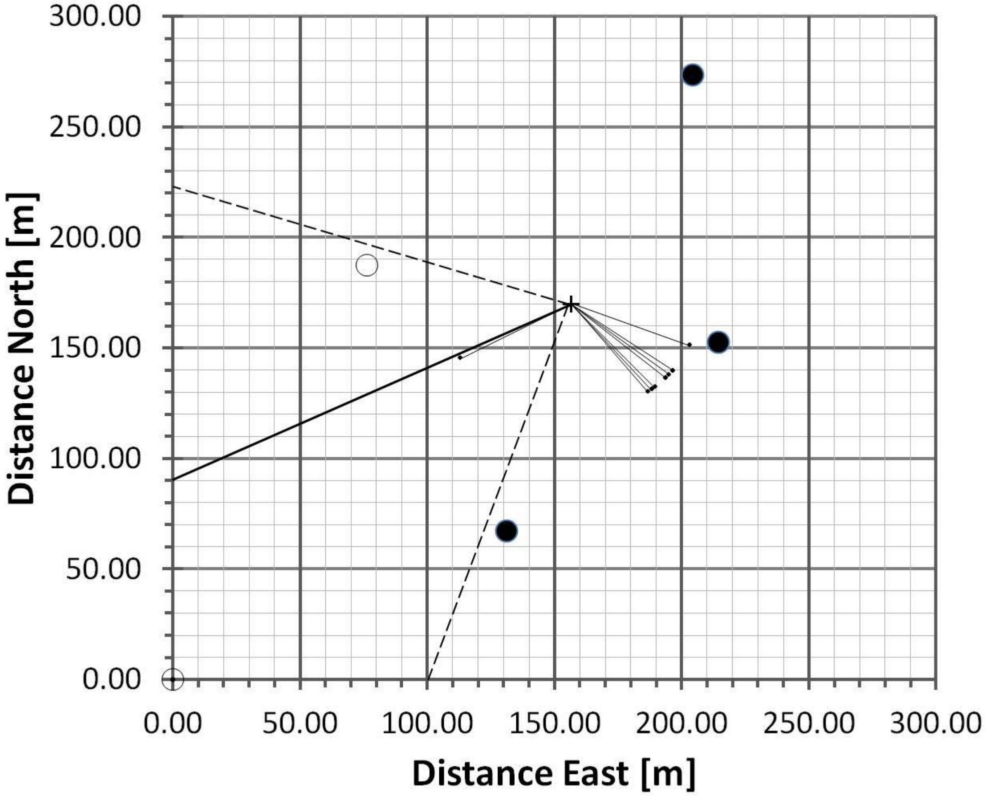

Fig. B - 13. Graphical summary of calculated shallow groundwater flow direction on each date where complete data was available for Site 1, Site 3, and Site 4. Wells used in the calculations are represented as dark circles. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou and ± 45 degrees, respectively.

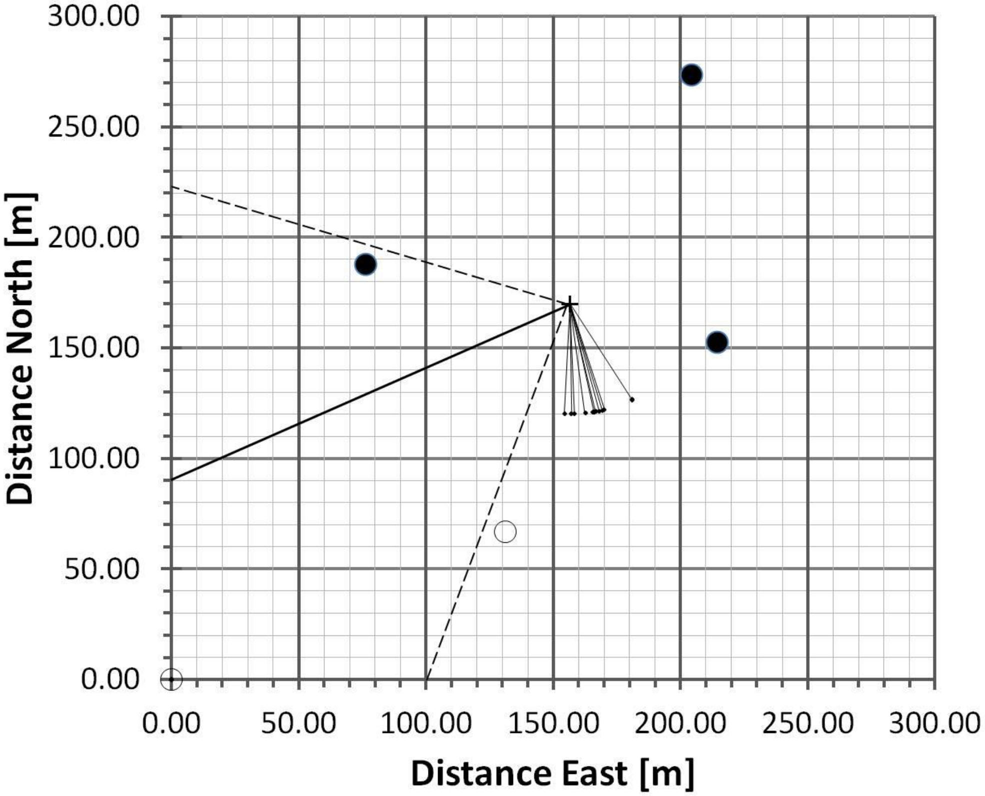

Fig. B - 14. Graphical summary of calculated shallow groundwater flow direction on each date where complete data was available for Site 2, Site 3, and Site 4. Wells used in the calculations are represented as dark circles. The solid and dashed lines that touch the axes represent the shortest flow path to Armand Bayou and ± 45 degrees, respectively.

APPENDIX C

SAP FLUX DATA

Table C - 1. Raw voltage readings, sap flux equation components, and results for the Water Oak (*Q. nigra*) specimen.

Date & Time	Δ V	Δ T	K	U	F	F
	[millivolts]	[°C]		[m/s]	[m^3/s]	[L/Hr.]
3/30/10 12:00	0.217	5.59	5.02E-01	5.10E-05	1.20E-06	4.33E+00
3/30/10 12:30	0.217	5.59	5.02E-01	5.10E-05	1.20E-06	4.33E+00
3/30/10 13:00	0.217	5.59	5.02E-01	5.10E-05	1.20E-06	4.33E+00
3/30/10 13:30	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
3/30/10 14:00	No Data					
3/30/10 14:30	No Data					
3/30/10 15:00	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
3/30/10 15:30	0.224	5.77	4.56E-01	4.52E-05	1.07E-06	3.84E+00
3/30/10 16:00	0.227	5.85	4.36E-01	4.29E-05	1.01E-06	3.64E+00
3/30/10 16:30	0.234	6.03	3.94E-01	3.78E-05	8.92E-07	3.21E+00
3/30/10 17:00	0.244	6.28	3.37E-01	3.12E-05	7.36E-07	2.65E+00
3/30/10 17:30	0.254	6.54	2.85E-01	2.53E-05	5.98E-07	2.15E+00
3/30/10 18:00	0.264	6.79	2.36E-01	2.02E-05	4.76E-07	1.71E+00
3/30/10 18:30	0.274	7.05	1.92E-01	1.56E-05	3.68E-07	1.32E+00
3/30/10 19:00	0.287	7.38	1.38E-01	1.04E-05	2.45E-07	8.84E-01
3/30/10 19:30	0.297	7.63	1.00E-01	7.00E-06	1.65E-07	5.95E-01
3/30/10 20:00	0.3	7.71	8.92E-02	6.07E-06	1.43E-07	5.16E-01
3/30/10 20:30	0.303	7.79	7.85E-02	5.19E-06	1.22E-07	4.41E-01
3/30/10 21:00	0.303	7.79	7.85E-02	5.19E-06	1.22E-07	4.41E-01
3/30/10 21:30	0.307	7.89	6.45E-02	4.08E-06	9.63E-08	3.47E-01
3/30/10 22:00	0.307	7.89	6.45E-02	4.08E-06	9.63E-08	3.47E-01
3/30/10 22:30	0.307	7.89	6.45E-02	4.08E-06	9.63E-08	3.47E-01
3/30/10 23:00	0.31	7.97	5.43E-02	3.30E-06	7.79E-08	2.80E-01
3/30/10 23:30	0.31	7.97	5.43E-02	3.30E-06	7.79E-08	2.80E-01
3/31/10 0:00	0.31	7.97	5.43E-02	3.30E-06	7.79E-08	2.80E-01
3/31/10 0:30	0.313	8.04	4.43E-02	2.57E-06	6.06E-08	2.18E-01
3/31/10 1:00	0.313	8.04	4.43E-02	2.57E-06	6.06E-08	2.18E-01
3/31/10 1:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 2:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 2:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 3:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 3:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 4:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [ºC]	K	U [M/S]	F [M^3/S]	F [L/HR.]
3/31/10 4:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 5:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 5:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 6:00	0.32	8.22	2.17E-02	1.06E-06	2.51E-08	9.04E-02
3/31/10 6:30	0.32	8.22	2.17E-02	1.06E-06	2.51E-08	9.04E-02
3/31/10 7:00	0.32	8.22	2.17E-02	1.06E-06	2.51E-08	9.04E-02
3/31/10 7:30	0.323	8.30	1.23E-02	5.28E-07	1.25E-08	4.49E-02
3/31/10 8:00	0.323	8.30	1.23E-02	5.28E-07	1.25E-08	4.49E-02
3/31/10 8:30	0.327	8.40	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3/31/10 9:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 9:30	0.3	7.71	8.92E-02	6.07E-06	1.43E-07	5.16E-01
3/31/10 10:00	0.27	6.95	2.09E-01	1.73E-05	4.09E-07	1.47E+00
3/31/10 10:30	0.231	5.95	4.12E-01	3.99E-05	9.42E-07	3.39E+00
3/31/10 11:00	0.224	5.77	4.56E-01	4.52E-05	1.07E-06	3.84E+00
3/31/10 11:30	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
3/31/10 12:00	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
3/31/10 12:30	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
3/31/10 13:00	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
3/31/10 13:30	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
3/31/10 14:00	0.224	5.77	4.56E-01	4.52E-05	1.07E-06	3.84E+00
3/31/10 14:30	0.224	5.77	4.56E-01	4.52E-05	1.07E-06	3.84E+00
3/31/10 15:00	0.224	5.77	4.56E-01	4.52E-05	1.07E-06	3.84E+00
3/31/10 15:30	0.224	5.77	4.56E-01	4.52E-05	1.07E-06	3.84E+00
3/31/10 16:00	0.231	5.95	4.12E-01	3.99E-05	9.42E-07	3.39E+00
3/31/10 16:30	0.237	6.10	3.76E-01	3.57E-05	8.43E-07	3.04E+00
3/31/10 17:00	0.247	6.36	3.21E-01	2.94E-05	6.93E-07	2.50E+00
3/31/10 17:30	0.264	6.79	2.36E-01	2.02E-05	4.76E-07	1.71E+00
3/31/10 18:00	0.277	7.12	1.79E-01	1.43E-05	3.38E-07	1.22E+00
3/31/10 18:30	0.283	7.28	1.54E-01	1.19E-05	2.81E-07	1.01E+00
3/31/10 19:00	0.29	7.46	1.26E-01	9.33E-06	2.20E-07	7.93E-01
3/31/10 19:30	0.3	7.71	8.92E-02	6.07E-06	1.43E-07	5.16E-01
3/31/10 20:00	0.303	7.79	7.85E-02	5.19E-06	1.22E-07	4.41E-01
3/31/10 20:30	0.31	7.97	5.43E-02	3.30E-06	7.79E-08	2.80E-01
3/31/10 21:00	0.31	7.97	5.43E-02	3.30E-06	7.79E-08	2.80E-01

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[°C]		[M/S]	[M^3/S]	[L/HR.]
3/31/10 21:30	0.313	8.04	4.43E-02	2.57E-06	6.06E-08	2.18E-01
3/31/10 22:00	0.313	8.04	4.43E-02	2.57E-06	6.06E-08	2.18E-01
3/31/10 22:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 23:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
3/31/10 23:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 0:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 0:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 1:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 1:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 2:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 2:30	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 3:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 3:30	0.32	8.22	2.17E-02	1.06E-06	2.51E-08	9.04E-02
4/1/10 4:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 4:30	0.32	8.22	2.17E-02	1.06E-06	2.51E-08	9.04E-02
4/1/10 5:00	0.32	8.22	2.17E-02	1.06E-06	2.51E-08	9.04E-02
4/1/10 5:30	0.323	8.30	1.23E-02	5.28E-07	1.25E-08	4.49E-02
4/1/10 6:00	0.323	8.30	1.23E-02	5.28E-07	1.25E-08	4.49E-02
4/1/10 6:30	0.323	8.30	1.23E-02	5.28E-07	1.25E-08	4.49E-02
4/1/10 7:00	0.323	8.30	1.23E-02	5.28E-07	1.25E-08	4.49E-02
4/1/10 7:30	0.32	8.22	2.17E-02	1.06E-06	2.51E-08	9.04E-02
4/1/10 8:00	0.317	8.14	3.13E-02	1.67E-06	3.94E-08	1.42E-01
4/1/10 8:30	0.307	7.89	6.45E-02	4.08E-06	9.63E-08	3.47E-01
4/1/10 9:00	0.293	7.53	1.15E-01	8.30E-06	1.96E-07	7.05E-01
4/1/10 9:30	0.284	7.30	1.50E-01	1.15E-05	2.72E-07	9.79E-01
4/1/10 10:00	0.264	6.79	2.36E-01	2.02E-05	4.76E-07	1.71E+00
4/1/10 10:30	0.227	5.85	4.36E-01	4.29E-05	1.01E-06	3.64E+00
4/1/10 11:00	0.217	5.59	5.02E-01	5.10E-05	1.20E-06	4.33E+00
4/1/10 11:30	0.217	5.59	5.02E-01	5.10E-05	1.20E-06	4.33E+00
4/1/10 12:00	0.217	5.59	5.02E-01	5.10E-05	1.20E-06	4.33E+00
4/1/10 12:30	0.217	5.59	5.02E-01	5.10E-05	1.20E-06	4.33E+00
4/1/10 13:00	0.224	5.77	4.56E-01	4.52E-05	1.07E-06	3.84E+00
4/1/10 13:30	0.227	5.85	4.36E-01	4.29E-05	1.01E-06	3.64E+00
4/1/10 14:00	0.227	5.85	4.36E-01	4.29E-05	1.01E-06	3.64E+00

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[°C]		[M/S]	[M^3/S]	[L/HR.]
4/1/10 14:30	0.237	6.10	3.76E-01	3.57E-05	8.43E-07	3.04E+00
4/1/10 15:00	0.244	6.28	3.37E-01	3.12E-05	7.36E-07	2.65E+00
4/1/10 15:30	0.244	6.28	3.37E-01	3.12E-05	7.36E-07	2.65E+00
4/1/10 16:00	0.25	6.44	3.05E-01	2.76E-05	6.52E-07	2.35E+00
4/1/10 16:30	0.25	6.44	3.05E-01	2.76E-05	6.52E-07	2.35E+00
4/1/10 17:00	0.257	6.61	2.70E-01	2.37E-05	5.60E-07	2.02E+00
4/1/10 17:30	0.264	6.79	2.36E-01	2.02E-05	4.76E-07	1.71E+00
4/1/10 18:00	0.277	7.12	1.79E-01	1.43E-05	3.38E-07	1.22E+00
4/1/10 18:30	0.287	7.38	1.38E-01	1.04E-05	2.45E-07	8.84E-01
4/1/10 19:00	0.293	7.53	1.15E-01	8.30E-06	1.96E-07	7.05E-01
4/1/10 19:30	0.297	7.63	1.00E-01	7.00E-06	1.65E-07	5.95E-01
4/1/10 20:00	0.3	7.71	8.92E-02	6.07E-06	1.43E-07	5.16E-01
4/1/10 20:30	0.303	7.79	7.85E-02	5.19E-06	1.22E-07	4.41E-01
4/1/10 21:00	0.303	7.79	7.85E-02	5.19E-06	1.22E-07	4.41E-01
4/1/10 21:30	0.303	7.79	7.85E-02	5.19E-06	1.22E-07	4.41E-01
4/1/10 22:00	0.303	7.79	7.85E-02	5.19E-06	1.22E-07	4.41E-01
4/1/10 22:30	0.303	7.79	7.85E-02	5.19E-06	1.22E-07	4.41E-01
4/1/10 23:00	0.303	7.79	7.85E-02	5.19E-06	1.22E-07	4.41E-01
4/1/10 23:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 0:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 0:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 1:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/2/10 1:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 2:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 2:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/2/10 3:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/2/10 3:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/2/10 4:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/2/10 4:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/2/10 5:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/2/10 5:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/2/10 6:00	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/2/10 6:30	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/2/10 7:00	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[^{o}C]		[M/S]	[M^3/S]	[L/HR.]
4/2/10 7:30	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/2/10 8:00	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/2/10 8:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/2/10 9:00	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/2/10 9:30	0.283	7.28	1.19E-01	8.67E-06	2.05E-07	7.36E-01
4/2/10 10:00	0.277	7.12	1.43E-01	1.09E-05	2.57E-07	9.24E-01
4/2/10 10:30	0.267	6.87	1.86E-01	1.50E-05	3.53E-07	1.27E+00
4/2/10 11:00	0.254	6.54	2.46E-01	2.12E-05	4.99E-07	1.80E+00
4/2/10 11:30	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/2/10 12:00	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/2/10 12:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/2/10 13:00	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/2/10 13:30	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/2/10 14:00	0.254	6.54	2.46E-01	2.12E-05	4.99E-07	1.80E+00
4/2/10 14:30	0.27	6.95	1.73E-01	1.37E-05	3.23E-07	1.16E+00
4/2/10 15:00	0.283	7.28	1.19E-01	8.67E-06	2.05E-07	7.36E-01
4/2/10 15:30	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/2/10 16:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/2/10 16:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/2/10 17:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/2/10 17:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/2/10 18:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 18:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 19:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 19:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 20:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 20:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 21:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 21:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 22:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 22:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/2/10 23:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/2/10 23:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 0:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [°C]	K	U [M/S]	F [M^3/S]	F [L/HR.]
4/3/10 0:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 1:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 1:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 2:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 2:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 3:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 3:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 4:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 4:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 5:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 5:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 6:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 6:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 7:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/3/10 7:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/3/10 8:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 8:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 9:00	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/3/10 9:30	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/3/10 10:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/3/10 10:30	0.264	6.79	1.99E-01	1.63E-05	3.85E-07	1.39E+00
4/3/10 11:00	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/3/10 11:30	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/3/10 12:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/3/10 12:30	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/3/10 13:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/3/10 13:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/3/10 14:00	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/3/10 14:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/3/10 15:00	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/3/10 15:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/3/10 16:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/3/10 16:30	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/3/10 17:00	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [°C]	K	U [M/S]	F [M^3/S]	F [L/HR.]
4/3/10 17:30	0.247	6.36	2.81E-01	2.49E-05	5.88E-07	2.12E+00
4/3/10 18:00	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/3/10 18:30	0.267	6.87	1.86E-01	1.50E-05	3.53E-07	1.27E+00
4/3/10 19:00	0.28	7.20	1.31E-01	9.74E-06	2.30E-07	8.28E-01
4/3/10 19:30	0.287	7.38	1.04E-01	7.30E-06	1.72E-07	6.20E-01
4/3/10 20:00	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/3/10 20:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/3/10 21:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/3/10 21:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/3/10 22:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/3/10 22:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/3/10 23:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/3/10 23:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/4/10 0:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 0:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 1:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 1:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 2:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 2:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 3:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 3:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 4:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 4:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 5:00	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/4/10 5:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 6:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 6:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 7:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 7:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 8:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 8:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 9:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 9:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 10:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [ºC]	K	U [M/S]	F [M^3/S]	F [L/HR.]
4/4/10 10:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/4/10 11:00	0.306	7.86	3.56E-02	1.96E-06	4.63E-08	1.67E-01
4/4/10 11:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/4/10 12:00	0.264	6.79	1.99E-01	1.63E-05	3.85E-07	1.39E+00
4/4/10 12:30	0.244	6.28	2.96E-01	2.66E-05	6.29E-07	2.26E+00
4/4/10 13:00	0.231	5.95	3.69E-01	3.49E-05	8.23E-07	2.96E+00
4/4/10 13:30	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/4/10 14:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/4/10 14:30	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/4/10 15:00	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/4/10 15:30	0.247	6.36	2.81E-01	2.49E-05	5.88E-07	2.12E+00
4/4/10 16:00	0.247	6.36	2.81E-01	2.49E-05	5.88E-07	2.12E+00
4/4/10 16:30	0.244	6.28	2.96E-01	2.66E-05	6.29E-07	2.26E+00
4/4/10 17:00	0.25	6.44	2.66E-01	2.33E-05	5.49E-07	1.98E+00
4/4/10 17:30	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/4/10 18:00	0.27	6.95	1.73E-01	1.37E-05	3.23E-07	1.16E+00
4/4/10 18:30	0.28	7.20	1.31E-01	9.74E-06	2.30E-07	8.28E-01
4/4/10 19:00	0.287	7.38	1.04E-01	7.30E-06	1.72E-07	6.20E-01
4/4/10 19:30	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/4/10 20:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/4/10 20:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/4/10 21:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/4/10 21:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/4/10 22:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/4/10 22:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/4/10 23:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/4/10 23:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 0:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 0:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 1:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 1:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 2:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/5/10 2:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/5/10 3:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [°C]	K	U [M/S]	F [M^3/S]	F [L/HR.]
4/5/10 3:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/5/10 4:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/5/10 4:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/5/10 5:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/5/10 5:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/5/10 6:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/5/10 6:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/5/10 7:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/5/10 7:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/5/10 8:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/5/10 8:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/5/10 9:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 9:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/5/10 10:00	0.287	7.38	1.04E-01	7.30E-06	1.72E-07	6.20E-01
4/5/10 10:30	0.26	6.69	2.17E-01	1.82E-05	4.29E-07	1.54E+00
4/5/10 11:00	0.247	6.36	2.81E-01	2.49E-05	5.88E-07	2.12E+00
4/5/10 11:30	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/5/10 12:00	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/5/10 12:30	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/5/10 13:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/5/10 13:30	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/5/10 14:00	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/5/10 14:30	0.214	5.51	4.77E-01	4.78E-05	1.13E-06	4.06E+00
4/5/10 15:00	0.214	5.51	4.77E-01	4.78E-05	1.13E-06	4.06E+00
4/5/10 15:30	0.214	5.51	4.77E-01	4.78E-05	1.13E-06	4.06E+00
4/5/10 16:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/5/10 16:30	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/5/10 17:00	0.24	6.18	3.18E-01	2.90E-05	6.85E-07	2.47E+00
4/5/10 17:30	0.25	6.44	2.66E-01	2.33E-05	5.49E-07	1.98E+00
4/5/10 18:00	0.264	6.79	1.99E-01	1.63E-05	3.85E-07	1.39E+00
4/5/10 18:30	0.273	7.02	1.60E-01	1.24E-05	2.94E-07	1.06E+00
4/5/10 19:00	0.283	7.28	1.19E-01	8.67E-06	2.05E-07	7.36E-01
4/5/10 19:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/5/10 20:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [ºC]	K	U [M/S]	F [M^3/S]	F [L/HR.]
4/5/10 20:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/5/10 21:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/5/10 21:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 22:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 22:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 23:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/5/10 23:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/6/10 0:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/6/10 0:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/6/10 1:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/6/10 1:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/6/10 2:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/6/10 2:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 3:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 3:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 4:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 4:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 5:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 5:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 6:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 6:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 7:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 7:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 8:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/6/10 8:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/6/10 9:00	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/6/10 9:30	0.277	7.12	1.43E-01	1.09E-05	2.57E-07	9.24E-01
4/6/10 10:00	0.267	6.87	1.86E-01	1.50E-05	3.53E-07	1.27E+00
4/6/10 10:30	0.25	6.44	2.66E-01	2.33E-05	5.49E-07	1.98E+00
4/6/10 11:00	0.241	6.21	3.12E-01	2.84E-05	6.71E-07	2.42E+00
4/6/10 11:30	0.231	5.95	3.69E-01	3.49E-05	8.23E-07	2.96E+00
4/6/10 12:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/6/10 12:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/6/10 13:00	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00

Table C - 1 (continued).

Date & Time	Δ V	Δ T	K	U	F	F
	[millivolts]	[^{o}C]		[M/S]	[M^3/S]	[L/Hr.]
4/6/10 13:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/6/10 14:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/6/10 14:30	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/6/10 15:00	0.231	5.95	3.69E-01	3.49E-05	8.23E-07	2.96E+00
4/6/10 15:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/6/10 16:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/6/10 16:30	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/6/10 17:00	0.244	6.28	2.96E-01	2.66E-05	6.29E-07	2.26E+00
4/6/10 17:30	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/6/10 18:00	0.26	6.69	2.17E-01	1.82E-05	4.29E-07	1.54E+00
4/6/10 18:30	0.27	6.95	1.73E-01	1.37E-05	3.23E-07	1.16E+00
4/6/10 19:00	0.283	7.28	1.19E-01	8.67E-06	2.05E-07	7.36E-01
4/6/10 19:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/6/10 20:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/6/10 20:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/6/10 21:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/6/10 21:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/6/10 22:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/6/10 22:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/6/10 23:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/6/10 23:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/7/10 0:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/7/10 0:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/7/10 1:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/7/10 1:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/7/10 2:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/7/10 2:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/7/10 3:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/7/10 3:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/7/10 4:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/7/10 4:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/7/10 5:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/7/10 5:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/7/10 6:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[°C]		[M/S]	[M^3/S]	[L/HR.]
4/7/10 6:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/7/10 7:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/7/10 7:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/7/10 8:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/7/10 8:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/7/10 9:00	0.28	7.20	1.31E-01	9.74E-06	2.30E-07	8.28E-01
4/7/10 9:30	0.27	6.95	1.73E-01	1.37E-05	3.23E-07	1.16E+00
4/7/10 10:00	0.267	6.87	1.86E-01	1.50E-05	3.53E-07	1.27E+00
4/7/10 10:30	0.25	6.44	2.66E-01	2.33E-05	5.49E-07	1.98E+00
4/7/10 11:00	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/7/10 11:30	0.231	5.95	3.69E-01	3.49E-05	8.23E-07	2.96E+00
4/7/10 12:00	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/7/10 12:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/7/10 13:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/7/10 13:30	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/7/10 14:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/7/10 14:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/7/10 15:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/7/10 15:30	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/7/10 16:00	0.231	5.95	3.69E-01	3.49E-05	8.23E-07	2.96E+00
4/7/10 16:30	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/7/10 17:00	0.244	6.28	2.96E-01	2.66E-05	6.29E-07	2.26E+00
4/7/10 17:30	0.254	6.54	2.46E-01	2.12E-05	4.99E-07	1.80E+00
4/7/10 18:00	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/7/10 18:30	0.267	6.87	1.86E-01	1.50E-05	3.53E-07	1.27E+00
4/7/10 19:00	0.28	7.20	1.31E-01	9.74E-06	2.30E-07	8.28E-01
4/7/10 19:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/7/10 20:00	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/7/10 20:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/7/10 21:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/7/10 21:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/7/10 22:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/7/10 22:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/7/10 23:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[ºC]		[M/S]	[M^3/S]	[L/HR.]
4/7/10 23:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/8/10 0:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/8/10 0:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/8/10 1:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/8/10 1:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 2:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 2:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 3:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 3:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 4:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 4:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 5:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 5:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 6:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 6:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 7:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/8/10 7:30	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/8/10 8:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/8/10 8:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/8/10 9:00	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/8/10 9:30	0.287	7.38	1.04E-01	7.30E-06	1.72E-07	6.20E-01
4/8/10 10:00	0.274	7.05	1.56E-01	1.20E-05	2.84E-07	1.02E+00
4/8/10 10:30	0.254	6.54	2.46E-01	2.12E-05	4.99E-07	1.80E+00
4/8/10 11:00	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/8/10 11:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/8/10 12:00	0.218	5.62	4.50E-01	4.45E-05	1.05E-06	3.78E+00
4/8/10 12:30	0.211	5.44	4.98E-01	5.04E-05	1.19E-06	4.29E+00
4/8/10 13:00	0.211	5.44	4.98E-01	5.04E-05	1.19E-06	4.29E+00
4/8/10 13:30	0.208	5.36	5.19E-01	5.31E-05	1.25E-06	4.51E+00
4/8/10 14:00	0.208	5.36	5.19E-01	5.31E-05	1.25E-06	4.51E+00
4/8/10 14:30	0.204	5.26	5.49E-01	5.69E-05	1.34E-06	4.83E+00
4/8/10 15:00	0.208	5.36	5.19E-01	5.31E-05	1.25E-06	4.51E+00
4/8/10 15:30	0.211	5.44	4.98E-01	5.04E-05	1.19E-06	4.29E+00
4/8/10 16:00	0.211	5.44	4.98E-01	5.04E-05	1.19E-06	4.29E+00

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[ºC]		[M/S]	[M^3/S]	[L/HR.]
4/8/10 16:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/8/10 17:00	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/8/10 17:30	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/8/10 18:00	0.241	6.21	3.12E-01	2.84E-05	6.71E-07	2.42E+00
4/8/10 18:30	0.247	6.36	2.81E-01	2.49E-05	5.88E-07	2.12E+00
4/8/10 19:00	0.267	6.87	1.86E-01	1.50E-05	3.53E-07	1.27E+00
4/8/10 19:30	0.284	7.30	1.15E-01	8.32E-06	1.96E-07	7.07E-01
4/8/10 20:00	0.287	7.38	1.04E-01	7.30E-06	1.72E-07	6.20E-01
4/8/10 20:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/8/10 21:00	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/8/10 21:30	0.294	7.56	7.75E-02	5.11E-06	1.21E-07	4.34E-01
4/8/10 22:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/8/10 22:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/8/10 23:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/8/10 23:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/9/10 0:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/9/10 0:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/9/10 1:00	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/9/10 1:30	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/9/10 2:00	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/9/10 2:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/9/10 3:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/9/10 3:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/9/10 4:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/9/10 4:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/9/10 5:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/9/10 5:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/9/10 6:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/9/10 6:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/9/10 7:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/9/10 7:30	0.314	8.07	9.47E-03	3.84E-07	9.06E-09	3.26E-02
4/9/10 8:00	0.317	8.14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4/9/10 8:30	0.314	8.07	9.47E-03	3.84E-07	9.06E-09	3.26E-02
4/9/10 9:00	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[ºC]		[M/S]	[M^3/S]	[L/HR.]
4/9/10 9:30	0.271	6.97	1.68E-01	1.33E-05	3.13E-07	1.13E+00
4/9/10 10:00	0.247	6.36	2.81E-01	2.49E-05	5.88E-07	2.12E+00
4/9/10 10:30	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/9/10 11:00	0.218	5.62	4.50E-01	4.45E-05	1.05E-06	3.78E+00
4/9/10 11:30	0.214	5.51	4.77E-01	4.78E-05	1.13E-06	4.06E+00
4/9/10 12:00	0.214	5.51	4.77E-01	4.78E-05	1.13E-06	4.06E+00
4/9/10 12:30	0.214	5.51	4.77E-01	4.78E-05	1.13E-06	4.06E+00
4/9/10 13:00	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/9/10 13:30	0.214	5.51	4.77E-01	4.78E-05	1.13E-06	4.06E+00
4/9/10 14:00	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/9/10 14:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/9/10 15:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/9/10 15:30	0.231	5.95	3.69E-01	3.49E-05	8.23E-07	2.96E+00
4/9/10 16:00	0.231	5.95	3.69E-01	3.49E-05	8.23E-07	2.96E+00
4/9/10 16:30	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/9/10 17:00	0.244	6.28	2.96E-01	2.66E-05	6.29E-07	2.26E+00
4/9/10 17:30	0.25	6.44	2.66E-01	2.33E-05	5.49E-07	1.98E+00
4/9/10 18:00	0.267	6.87	1.86E-01	1.50E-05	3.53E-07	1.27E+00
4/9/10 18:30	0.28	7.20	1.31E-01	9.74E-06	2.30E-07	8.28E-01
4/9/10 19:00	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/9/10 19:30	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/9/10 20:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/9/10 20:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/9/10 21:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/9/10 21:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/9/10 22:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/9/10 22:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/9/10 23:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/9/10 23:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/10/10 0:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/10/10 0:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/10/10 1:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 1:30	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/10/10 2:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[ºC]		[M/S]	[M^3/S]	[L/HR.]
4/10/10 2:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 3:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 3:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 4:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 4:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 5:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 5:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 6:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 6:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/10/10 7:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/10/10 7:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/10/10 8:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/10/10 8:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/10/10 9:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/10/10 9:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/10/10 10:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/10/10 10:30	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/10/10 11:00	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/10/10 11:30	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/10/10 12:00	0.313	8.04	1.27E-02	5.49E-07	1.30E-08	4.67E-02
4/10/10 12:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/10/10 13:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/10/10 13:30	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/10/10 14:00	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/10/10 14:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/10/10 15:00	0.27	6.95	1.73E-01	1.37E-05	3.23E-07	1.16E+00
4/10/10 15:30	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/10/10 16:00	0.247	6.36	2.81E-01	2.49E-05	5.88E-07	2.12E+00
4/10/10 16:30	0.244	6.28	2.96E-01	2.66E-05	6.29E-07	2.26E+00
4/10/10 17:00	0.247	6.36	2.81E-01	2.49E-05	5.88E-07	2.12E+00
4/10/10 17:30	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/10/10 18:00	0.26	6.69	2.17E-01	1.82E-05	4.29E-07	1.54E+00
4/10/10 18:30	0.267	6.87	1.86E-01	1.50E-05	3.53E-07	1.27E+00
4/10/10 19:00	0.277	7.12	1.43E-01	1.09E-05	2.57E-07	9.24E-01

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [°C]	K	U [M/S]	F [M^3/S]	F [L/HR.]
4/10/10 19:30	0.287	7.38	1.04E-01	7.30E-06	1.72E-07	6.20E-01
4/10/10 20:00	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/10/10 20:30	0.294	7.56	7.75E-02	5.11E-06	1.21E-07	4.34E-01
4/10/10 21:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/10/10 21:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/10/10 22:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/10/10 22:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/10/10 23:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/10/10 23:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/11/10 0:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/11/10 0:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/11/10 1:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/11/10 1:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/11/10 2:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/11/10 2:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/11/10 3:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/11/10 3:30	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/11/10 4:00	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/11/10 4:30	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/11/10 5:00	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/11/10 5:30	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/11/10 6:00	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/11/10 6:30	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/11/10 7:00	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/11/10 7:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/11/10 8:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/11/10 8:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/11/10 9:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/11/10 9:30	0.277	7.12	1.43E-01	1.09E-05	2.57E-07	9.24E-01
4/11/10 10:00	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/11/10 10:30	0.241	6.21	3.12E-01	2.84E-05	6.71E-07	2.42E+00
4/11/10 11:00	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/11/10 11:30	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/11/10 12:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[ºC]		[M/S]	[M^3/S]	[L/HR.]
4/11/10 12:30	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/11/10 13:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/11/10 13:30	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/11/10 14:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/11/10 14:30	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/11/10 15:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/11/10 15:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/11/10 16:00	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/11/10 16:30	0.231	5.95	3.69E-01	3.49E-05	8.23E-07	2.96E+00
4/11/10 17:00	0.24	6.18	3.18E-01	2.90E-05	6.85E-07	2.47E+00
4/11/10 17:30	0.25	6.44	2.66E-01	2.33E-05	5.49E-07	1.98E+00
4/11/10 18:00	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/11/10 18:30	0.26	6.69	2.17E-01	1.82E-05	4.29E-07	1.54E+00
4/11/10 19:00	0.274	7.05	1.56E-01	1.20E-05	2.84E-07	1.02E+00
4/11/10 19:30	0.283	7.28	1.19E-01	8.67E-06	2.05E-07	7.36E-01
4/11/10 20:00	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/11/10 20:30	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/11/10 21:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/11/10 21:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/11/10 22:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/11/10 22:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/11/10 23:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/11/10 23:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/12/10 0:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/12/10 0:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 1:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 1:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 2:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 2:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 3:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 3:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 4:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 4:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 5:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [°C]	K	U [M/S]	F [M^3/S]	F [L/HR.]
4/12/10 5:30	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/12/10 6:00	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/12/10 6:30	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/12/10 7:00	0.304	7.81	4.24E-02	2.43E-06	5.74E-08	2.06E-01
4/12/10 7:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/12/10 8:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/12/10 8:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/12/10 9:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/12/10 9:30	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/12/10 10:00	0.28	7.20	1.31E-01	9.74E-06	2.30E-07	8.28E-01
4/12/10 10:30	0.254	6.54	2.46E-01	2.12E-05	4.99E-07	1.80E+00
4/12/10 11:00	0.241	6.21	3.12E-01	2.84E-05	6.71E-07	2.42E+00
4/12/10 11:30	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/12/10 12:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/12/10 12:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/12/10 13:00	0.214	5.51	4.77E-01	4.78E-05	1.13E-06	4.06E+00
4/12/10 13:30	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/12/10 14:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/12/10 14:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/12/10 15:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/12/10 15:30	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/12/10 16:00	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/12/10 16:30	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/12/10 17:00	0.241	6.21	3.12E-01	2.84E-05	6.71E-07	2.42E+00
4/12/10 17:30	0.25	6.44	2.66E-01	2.33E-05	5.49E-07	1.98E+00
4/12/10 18:00	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/12/10 18:30	0.27	6.95	1.73E-01	1.37E-05	3.23E-07	1.16E+00
4/12/10 19:00	0.283	7.28	1.19E-01	8.67E-06	2.05E-07	7.36E-01
4/12/10 19:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/12/10 20:00	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/12/10 20:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/12/10 21:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/12/10 21:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/12/10 22:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [°C]	K	U [M/S]	F [M^3/S]	F [L/HR.]
4/12/10 22:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 23:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/12/10 23:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/13/10 0:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/13/10 0:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/13/10 1:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/13/10 1:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 2:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 2:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 3:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 3:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 4:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 4:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 5:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/13/10 5:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 6:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 6:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 7:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 7:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/13/10 8:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/13/10 8:30	0.284	7.30	1.15E-01	8.32E-06	1.96E-07	7.07E-01
4/13/10 9:00	0.27	6.95	1.73E-01	1.37E-05	3.23E-07	1.16E+00
4/13/10 9:30	0.26	6.69	2.17E-01	1.82E-05	4.29E-07	1.54E+00
4/13/10 10:00	0.244	6.28	2.96E-01	2.66E-05	6.29E-07	2.26E+00
4/13/10 10:30	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/13/10 11:00	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/13/10 11:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/13/10 12:00	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/13/10 12:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/13/10 13:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/13/10 13:30	0.217	5.59	4.57E-01	4.53E-05	1.07E-06	3.85E+00
4/13/10 14:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/13/10 14:30	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/13/10 15:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[ºC]		[M/S]	[M^3/S]	[L/HR.]
4/13/10 15:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/13/10 16:00	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/13/10 16:30	0.234	6.03	3.51E-01	3.29E-05	7.75E-07	2.79E+00
4/13/10 17:00	0.247	6.36	2.81E-01	2.49E-05	5.88E-07	2.12E+00
4/13/10 17:30	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/13/10 18:00	0.267	6.87	1.86E-01	1.50E-05	3.53E-07	1.27E+00
4/13/10 18:30	0.277	7.12	1.43E-01	1.09E-05	2.57E-07	9.24E-01
4/13/10 19:00	0.283	7.28	1.19E-01	8.67E-06	2.05E-07	7.36E-01
4/13/10 19:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/13/10 20:00	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/13/10 20:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/13/10 21:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/13/10 21:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/13/10 22:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/13/10 22:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/13/10 23:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/13/10 23:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/14/10 0:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/14/10 0:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/14/10 1:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/14/10 1:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/14/10 2:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/14/10 2:30	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/14/10 3:00	0.307	7.89	3.23E-02	1.74E-06	4.10E-08	1.48E-01
4/14/10 3:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/14/10 4:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/14/10 4:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/14/10 5:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/14/10 5:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/14/10 6:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/14/10 6:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/14/10 7:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/14/10 7:30	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02
4/14/10 8:00	0.31	7.97	2.24E-02	1.11E-06	2.61E-08	9.41E-02

Table C - 1 (continued).

DATE & TIME	Δ V [MILLIVOLTS]	Δ T [°C]	K	U [M/S]	F [M^3/S]	F [L/HR.]
4/14/10 8:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/14/10 9:00	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/14/10 9:30	0.29	7.46	9.23E-02	6.33E-06	1.49E-07	5.38E-01
4/14/10 10:00	0.283	7.28	1.19E-01	8.67E-06	2.05E-07	7.36E-01
4/14/10 10:30	0.274	7.05	1.56E-01	1.20E-05	2.84E-07	1.02E+00
4/14/10 11:00	0.257	6.61	2.31E-01	1.96E-05	4.63E-07	1.67E+00
4/14/10 11:30	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/14/10 12:00	0.241	6.21	3.12E-01	2.84E-05	6.71E-07	2.42E+00
4/14/10 12:30	0.237	6.10	3.34E-01	3.09E-05	7.30E-07	2.63E+00
4/14/10 13:00	0.241	6.21	3.12E-01	2.84E-05	6.71E-07	2.42E+00
4/14/10 13:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/14/10 14:00	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/14/10 14:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/14/10 15:00	0.221	5.69	4.30E-01	4.22E-05	9.95E-07	3.58E+00
4/14/10 15:30	0.224	5.77	4.11E-01	3.99E-05	9.41E-07	3.39E+00
4/14/10 16:00	0.227	5.85	3.93E-01	3.77E-05	8.89E-07	3.20E+00
4/14/10 16:30	0.231	5.95	3.69E-01	3.49E-05	8.23E-07	2.96E+00
4/14/10 17:00	0.24	6.18	3.18E-01	2.90E-05	6.85E-07	2.47E+00
4/14/10 17:30	0.254	6.54	2.46E-01	2.12E-05	4.99E-07	1.80E+00
4/14/10 18:00	0.264	6.79	1.99E-01	1.63E-05	3.85E-07	1.39E+00
4/14/10 18:30	0.273	7.02	1.60E-01	1.24E-05	2.94E-07	1.06E+00
4/14/10 19:00	0.283	7.28	1.19E-01	8.67E-06	2.05E-07	7.36E-01
4/14/10 19:30	0.287	7.38	1.04E-01	7.30E-06	1.72E-07	6.20E-01
4/14/10 20:00	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/14/10 20:30	0.293	7.53	8.12E-02	5.41E-06	1.28E-07	4.60E-01
4/14/10 21:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/14/10 21:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/14/10 22:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/14/10 22:30	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/14/10 23:00	0.297	7.63	6.67E-02	4.25E-06	1.00E-07	3.61E-01
4/14/10 23:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/15/10 0:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/15/10 0:30	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01
4/15/10 1:00	0.3	7.71	5.62E-02	3.44E-06	8.11E-08	2.92E-01

Table C - 1 (continued).

DATE & TIME	Δ V	Δ T	K	U	F	F
	[MILLIVOLTS]	[°C]		[M/S]	[M^3/S]	[L/HR.]
4/15/10 1:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 2:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 2:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 3:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 3:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 4:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 4:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 5:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 5:30	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 6:00	0.303	7.79	4.58E-02	2.67E-06	6.31E-08	2.27E-01
4/15/10 6:30	No Data					
4/15/10 7:00	No Data					
4/15/10 7:30	No Data					
4/15/10 8:00	No Data					
4/15/10 8:30	No Data					
4/15/10 9:00	No Data					
4/15/10 9:30	0.293	7.53	1.15E-01	8.30E-06	1.96E-07	7.05E-01
4/15/10 10:00	0.27	6.95	2.09E-01	1.73E-05	4.09E-07	1.47E+00
4/15/10 10:30	0.247	6.36	3.21E-01	2.94E-05	6.93E-07	2.50E+00
4/15/10 11:00	0.234	6.03	3.94E-01	3.78E-05	8.92E-07	3.21E+00
4/15/10 11:30	0.227	5.85	4.36E-01	4.29E-05	1.01E-06	3.64E+00
4/15/10 12:00	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
4/15/10 12:30	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
4/15/10 13:00	0.221	5.69	4.75E-01	4.76E-05	1.12E-06	4.05E+00
4/15/10 13:30	0.217	5.59	5.02E-01	5.10E-05	1.20E-06	4.33E+00
4/15/10 14:00	0.24	6.18	3.59E-01	3.37E-05	7.96E-07	2.87E+00
4/15/10 14:30	0.227	5.85	4.36E-01	4.29E-05	1.01E-06	3.64E+00
4/15/10 15:00	0.227	5.85	4.36E-01	4.29E-05	1.01E-06	3.64E+00
4/15/10 15:30	0.231	5.95	4.12E-01	3.99E-05	9.42E-07	3.39E+00

APPENDIX D

EVAPOTRANSPIRATION DATA (HARGREAVES METHOD)

Table D - 1. Summary of calculated evapotranspiration values using the Hargreaves method. Formula components are presented on the right-hand side of the table.

DATE	*PET*	*FORMULA COMPONENTS*				
		Constant 1	Extraterrestrial Radiation	Monthly Temperature Difference	Daily Temperature Difference	Constant 2
	[mm/day]		[mm/day]	[Degrees Celsius]	[Degrees Celsius]	
12/23/2009	-10.9289	0.0023	195.02	9.0	9.7	17.8
12/24/2009	-11.6815	0.0023	195.195	9.0	9.15	17.8
12/25/2009	-13.1764	0.0023	195.335	9.0	8.05	17.8
12/26/2009	-19.2144	0.0023	195.58	9.0	3.6	17.8
12/27/2009	-19.9836	0.0023	195.825	9.0	3.05	17.8
12/28/2009	-9.09514	0.0023	196.21	9.0	11.1	17.8
12/29/2009	-4.55649	0.0023	196.595	9.0	14.45	17.8
12/30/2009	0.340703	0.0023	196.98	9.0	18.05	17.8
12/31/2009	-7.65072	0.0023	197.47	9.0	12.2	17.8
1/1/2010	-18.1604	0.0023	198.065	10.6	5.55	17.8
1/2/2010	-14.4874	0.0023	198.52	10.6	8.05	17.8
1/3/2010	-8.26995	0.0023	199.08	10.6	12.25	17.8
1/4/2010	-6.65301	0.0023	199.745	10.6	13.35	17.8
1/5/2010	-1.65062	0.0023	200.48	10.6	16.7	17.8
1/6/2010	-7.529	0.0023	201.18	10.6	12.8	17.8
1/7/2010	-13.4506	0.0023	201.915	10.6	8.9	17.8
1/8/2010	-13.8859	0.0023	202.755	10.6	8.65	17.8
1/9/2010	-8.45751	0.0023	203.595	10.6	12.25	17.8

Table D - 1 (continued).

DATE	*PET*	*FORMULA COMPONENTS*				
		Constant 1	Extraterrestrial Radiation	Monthly Temperature Difference	Daily Temperature Difference	Constant 2
	[mm/day]		[mm/day]	[Degrees Celsius]	[Degrees Celsius]	
1/10/2010	-10.6383	0.0023	204.505	10.6	10.85	17.8
1/11/2010	-14.1474	0.0023	205.45	10.6	8.6	17.8
1/12/2010	-11.5902	0.0023	206.465	10.6	10.3	17.8
1/13/2010	-0.07765	0.0023	207.48	10.6	17.75	17.8
1/14/2010	4.292237	0.0023	208.53	10.6	20.55	17.8
1/15/2010	-10.0395	0.0023	209.58	10.6	11.4	17.8
1/16/2010	-20.1897	0.0023	210.735	10.6	5	17.8
1/17/2010	-18.08	0.0023	211.89	10.6	6.4	17.8
1/18/2010	-14.6752	0.0023	213.115	10.6	8.6	17.8
1/19/2010	-17.4067	0.0023	214.34	10.6	6.95	17.8
1/20/2010	-20.6658	0.0023	215.705	10.6	5	17.8
1/21/2010	-14.0426	0.0023	216.895	10.6	9.15	17.8
1/22/2010	-14.9478	0.0023	218.26	10.6	8.65	17.8
1/23/2010	-18.3349	0.0023	219.695	10.6	6.65	17.8
1/24/2010	-20.2688	0.0023	221.06	10.6	5.55	17.8
1/25/2010	-16.2371	0.0023	222.495	10.6	8.05	17.8
1/26/2010	-21.9669	0.0023	224.035	10.6	4.7	17.8
1/27/2010	-24.3935	0.0023	225.54	10.6	3.35	17.8
1/28/2010	-19.4581	0.0023	227.045	10.6	6.35	17.8

Table D - 1 (continued).

DATE	*PET*	*FORMULA COMPONENTS*				
		CONSTANT 1	EXTRATERRESTRIAL RADIATION	MONTHLY TEMPERATURE DIFFERENCE	DAILY TEMPERATURE DIFFERENCE	CONSTANT 2
	[MM/DAY]		[MM/DAY]	[DEGREES CELSIUS]	[DEGREES CELSIUS]	
1/29/2010	-19.0768	0.0023	228.585	10.6	6.65	17.8
1/30/2010	-33.0811	0.0023	230.195	10.6	-1.4	17.8
1/31/2010	-31.8281	0.0023	231.735	10.6	-0.55	17.8
2/1/2010	-28.7631	0.0023	233.45	9.7	0.6	17.8
2/2/2010	-23.4014	0.0023	235.025	9.7	3.9	17.8
2/3/2010	-15.6017	0.0023	236.74	9.7	8.6	17.8
2/4/2010	-16.6542	0.0023	238.455	9.7	8.05	17.8
2/5/2010	-11.0106	0.0023	240.17	9.7	11.4	17.8
2/6/2010	-12.1254	0.0023	241.815	9.7	10.8	17.8
2/7/2010	-15.9689	0.0023	243.635	9.7	8.65	17.8
2/8/2010	-12.7456	0.0023	245.42	9.7	10.55	17.8
2/9/2010	-9.38527	0.0023	247.205	9.7	12.5	17.8
2/10/2010	1.962227	0.0023	249.025	9.7	18.9	17.8
2/11/2010	1.437504	0.0023	250.845	9.7	18.6	17.8
2/12/2010	1.447733	0.0023	252.63	9.7	18.6	17.8
2/13/2010	-4.10221	0.0023	254.52	9.7	15.55	17.8
2/14/2010	-3.58214	0.0023	256.445	9.7	15.85	17.8
2/15/2010	-5.73665	0.0023	258.335	9.7	14.7	17.8
2/16/2010	-12.9536	0.0023	260.19	9.7	10.85	17.8

Table D - 1 (continued).

DATE	*PET*	*FORMULA COMPONENTS*				
		Constant 1	Extraterrestrial Radiation	Monthly Temperature Difference	Daily Temperature Difference	Constant 2
	[mm/day]		[mm/day]	[Degrees Celsius]	[Degrees Celsius]	
2/17/2010	-12.1106	0.0023	262.115	9.7	11.35	17.8
2/18/2010	-6.33451	0.0023	263.97	9.7	14.45	17.8
2/19/2010	-3.80887	0.0023	265.86	9.7	15.8	17.8
2/20/2010	-12.2799	0.0023	267.855	9.7	11.4	17.8
2/21/2010	-27.3345	0.0023	269.675	9.7	3.65	17.8
2/22/2010	-29.2881	0.0023	271.67	9.7	2.75	17.8
2/23/2010	-22.8351	0.0023	273.63	9.7	6.15	17.8
2/24/2010	-15.9864	0.0023	275.52	9.7	9.7	17.8
2/25/2010	-16.1002	0.0023	277.48	9.7	9.7	17.8
2/26/2010	-15.011	0.0023	279.405	9.7	10.3	17.8
2/27/2010	-12.3954	0.0023	281.365	9.7	11.65	17.8
2/28/2010	-14.1036	0.0023	283.29	9.7	10.85	17.8
3/1/2010	-19.6315	0.0023	285.215	11.3	8.9	17.8
3/2/2010	-8.10743	0.0023	287.21	11.3	14.15	17.8
3/3/2010	-23.7027	0.0023	289.135	11.3	7.2	17.8
3/4/2010	-31.2812	0.0023	290.99	11.3	3.9	17.8
3/5/2010	-29.5697	0.0023	292.985	11.3	4.75	17.8
3/6/2010	-32.9649	0.0023	294.98	11.3	3.35	17.8
3/7/2010	-24.9137	0.0023	296.905	11.3	6.95	17.8

Table D - 1 (continued).

DATE	*PET*	*FORMULA COMPONENTS*				
		CONSTANT 1	EXTRATERRESTRIAL RADIATION	MONTHLY TEMPERATURE DIFFERENCE	DAILY TEMPERATURE DIFFERENCE	CONSTANT 2
	[MM/DAY]		[MM/DAY]	[DEGREES CELSIUS]	[DEGREES CELSIUS]	
3/8/2010	-13.5167	0.0023	298.76	11.3	11.95	17.8
3/9/2010	-26.5099	0.0023	300.685	11.3	6.4	17.8
3/10/2010	-26.6734	0.0023	302.54	11.3	6.4	17.8
3/11/2010	-24.253	0.0023	304.465	11.3	7.5	17.8
3/12/2010	-23.6982	0.0023	306.425	11.3	7.8	17.8
3/13/2010	-14.6576	0.0023	308.175	11.3	11.65	17.8
3/14/2010	-14.7475	0.0023	310.065	11.3	11.65	17.8
3/15/2010	-2.05047	0.0023	311.92	11.3	16.95	17.8
3/16/2010	-12.1333	0.0023	313.775	11.3	12.8	17.8
3/17/2010	-31.8552	0.0023	315.63	11.3	4.75	17.8
3/18/2010	-26.6377	0.0023	317.45	11.3	6.95	17.8
3/19/2010	-26.7874	0.0023	319.235	11.3	6.95	17.8
3/20/2010	-9.06183	0.0023	321.02	11.3	14.15	17.8
3/21/2010	-15.9793	0.0023	322.84	11.3	11.4	17.8
3/22/2010	-18.9548	0.0023	324.625	11.3	10.25	17.8
3/23/2010	-16.1526	0.0023	326.34	11.3	11.4	17.8
3/24/2010	-20.5505	0.0023	328.055	11.3	9.7	17.8
3/25/2010	-19.8949	0.0023	329.805	11.3	10	17.8
3/26/2010	-17.1745	0.0023	331.45	11.3	11.1	17.8

Table D - 1 (continued).

DATE	*PET*	*FORMULA COMPONENTS*				
		CONSTANT 1	EXTRATERRESTRIAL RADIATION	MONTHLY TEMPERATURE DIFFERENCE	DAILY TEMPERATURE DIFFERENCE	CONSTANT 2
	[MM/DAY]		[MM/DAY]	[DEGREES CELSIUS]	[DEGREES CELSIUS]	
3/27/2010	-15.0732	0.0023	333.165	11.3	11.95	17.8
3/28/2010	-15.1492	0.0023	334.845	11.3	11.95	17.8
3/29/2010	-8.0664	0.0023	336.455	11.3	14.7	17.8
3/30/2010	-5.88205	0.0023	338.03	11.3	15.55	17.8
3/31/2010	4.991751	0.0023	339.71	11.3	19.7	17.8
4/1/2010	3.196425	0.0023	341.32	9.1	19.15	17.8
4/2/2010	5.946012	0.0023	342.86	9.1	20.3	17.8
4/3/2010	-5.97333	0.0023	344.435	9.1	15.3	17.8
4/4/2010	-5.39894	0.0023	345.905	9.1	15.55	17.8
4/5/2010	-5.42297	0.0023	347.445	9.1	15.55	17.8
4/6/2010	-3.99367	0.0023	348.915	9.1	16.15	17.8
4/7/2010	-12.8822	0.0023	350.385	9.1	12.5	17.8
4/8/2010	-6.10261	0.0023	351.89	9.1	15.3	17.8
4/9/2010	-7.47333	0.0023	353.22	9.1	14.75	17.8
4/10/2010	-4.06017	0.0023	354.725	9.1	16.15	17.8
4/11/2010	-17.2913	0.0023	356.09	9.1	10.8	17.8
4/12/2010	-24.7941	0.0023	357.42	9.1	7.8	17.8
4/13/2010	-16.5494	0.0023	358.75	9.1	11.15	17.8
4/14/2010	-9.7426	0.0023	360.115	9.1	13.9	17.8
4/15/2010	-4.26205	0.0023	361.41	9.1	16.1	17.8

The extraterrestrial radiation component of the Hargreaves equation requires a daily input in millimeters per day. When using data from the National Solar Radiation Database (NSRDB), the hourly observations of extraterrestrial radiation on a horizontal surface at the top of the atmosphere must be summed to produce a daily extraterrestrial radiation value in watt-hours per square meter. The daily value obtained from summing the hourly totals must be multiplied by 0.035 to convert to millimeters per day of equivalent evapotranspiration. The NSRDB contains location-specific information for extraterrestrial radiation on a horizontal surface at the top of the atmosphere, so be sure to use the correct station when using NSRDB data.

Table D - 2. Daily maximum (T-MAX) and minimum (T-MIN) temperature values from the weather station at the Houston National Weather Service Office.

STATION	DATE	T-MAX	T-MAX	T-MIN	T-MIN
		1/10 DEGREE CELSIUS	DEGREES CELSIUS	1/10 DEGREE CELSIUS	DEGREES CELSIUS
GHCND:USC00414333	12/1/2009	111	11.1	83	8.3
GHCND:USC00414333	12/2/2009	122	12.2	61	6.1
GHCND:USC00414333	12/3/2009	128	12.8	33	3.3
GHCND:USC00414333	12/4/2009	83	8.3	-11	-1.1
GHCND:USC00414333	12/5/2009	94	9.4	-33	-3.3
GHCND:USC00414333	12/6/2009	161	16.1	61	6.1
GHCND:USC00414333	12/7/2009	161	16.1	128	12.8
GHCND:USC00414333	12/8/2009	233	23.3	128	12.8
GHCND:USC00414333	12/9/2009	194	19.4	50	5
GHCND:USC00414333	12/10/2009	89	8.9	22	2.2
GHCND:USC00414333	12/11/2009	94	9.4	67	6.7
GHCND:USC00414333	12/12/2009	167	16.7	78	7.8
GHCND:USC00414333	12/13/2009	189	18.9	78	7.8
GHCND:USC00414333	12/14/2009	217	21.7	117	11.7
GHCND:USC00414333	12/15/2009	167	16.7	89	8.9
GHCND:USC00414333	12/16/2009	111	11.1	67	6.7
GHCND:USC00414333	12/17/2009	106	10.6	67	6.7
GHCND:USC00414333	12/18/2009	189	18.9	56	5.6
GHCND:USC00414333	12/19/2009	178	17.8	39	3.9
GHCND:USC00414333	12/20/2009	150	15	22	2.2
GHCND:USC00414333	12/21/2009	189	18.9	17	1.7
GHCND:USC00414333	12/22/2009	211	21.1	144	14.4
GHCND:USC00414333	12/23/2009	233	23.3	178	17.8

Table D – 2 (continued).

STATION	DATE	T-MAX 1/10 DEGREE CELSIUS	T-MAX DEGREES CELSIUS	T-MIN 1/10 DEGREE CELSIUS	T-MIN DEGREES CELSIUS
GHCND:USC00414333	12/24/2009	206	20.6	22	2.2
GHCND:USC00414333	12/25/2009	106	10.6	-6	-0.6
GHCND:USC00414333	12/26/2009	106	10.6	22	2.2
GHCND:USC00414333	12/27/2009	144	14.4	28	2.8
GHCND:USC00414333	12/28/2009	117	11.7	22	2.2
GHCND:USC00414333	12/29/2009	89	8.9	11	1.1
GHCND:USC00414333	12/30/2009	111	11.1	72	7.2
GHCND:USC00414333	12/31/2009	117	11.7	56	5.6
GHCND:USC00414333	1/1/2010	122	12.2	11	1.1
GHCND:USC00414333	1/2/2010	111	11.1	0	0
GHCND:USC00414333	1/3/2010	111	11.1	50	5
GHCND:USC00414333	1/4/2010	83	8.3	11	1.1
GHCND:USC00414333	1/5/2010	89	8.9	-22	-2.2
GHCND:USC00414333	1/6/2010	144	14.4	-17	-1.7
GHCND:USC00414333	1/7/2010	144	14.4	-11	-1.1
GHCND:USC00414333	1/8/2010	11	1.1	-39	-3.9
GHCND:USC00414333	1/9/2010	56	5.6	-67	-6.7
GHCND:USC00414333	1/10/2010	56	5.6	-44	-4.4
GHCND:USC00414333	1/11/2010	128	12.8	-50	-5
GHCND:USC00414333	1/12/2010	172	17.2	0	0
GHCND:USC00414333	1/13/2010	150	15	11	1.1
GHCND:USC00414333	1/14/2010	128	12.8	100	10
GHCND:USC00414333	1/15/2010	122	12.2	94	9.4
GHCND:USC00414333	1/16/2010	106	10.6	67	6.7
GHCND:USC00414333	1/17/2010	172	17.2	39	3.9
GHCND:USC00414333	1/18/2010	206	20.6	44	4.4
GHCND:USC00414333	1/19/2010	228	22.8	150	15
GHCND:USC00414333	1/20/2010	211	21.1	161	16.1
GHCND:USC00414333	1/21/2010	261	26.1	111	11.1
GHCND:USC00414333	1/22/2010	233	23.3	78	7.8
GHCND:USC00414333	1/23/2010	211	21.1	106	10.6
GHCND:USC00414333	1/24/2010	211	21.1	83	8.3
GHCND:USC00414333	1/25/2010	189	18.9	28	2.8
GHCND:USC00414333	1/26/2010	183	18.3	44	4.4

Table D – 2 (continued).

STATION	DATE	T-MAX 1/10 DEGREE CELSIUS	T-MAX DEGREES CELSIUS	T-MIN 1/10 DEGREE CELSIUS	T-MIN DEGREES CELSIUS
GHCND:USC00414333	1/27/2010	200	20	89	8.9
GHCND:USC00414333	1/28/2010	172	17.2	144	14.4
GHCND:USC00414333	1/29/2010	189	18.9	39	3.9
GHCND:USC00414333	1/30/2010	67	6.7	6	0.6
GHCND:USC00414333	1/31/2010	44	4.4	11	1.1
GHCND:USC00414333	2/1/2010	106	10.6	17	1.7
GHCND:USC00414333	2/2/2010	111	11.1	83	8.3
GHCND:USC00414333	2/3/2010	111	11.1	83	8.3
GHCND:USC00414333	2/4/2010	117	11.7	89	8.9
GHCND:USC00414333	2/5/2010	161	16.1	72	7.2
GHCND:USC00414333	2/6/2010	178	17.8	39	3.9
GHCND:USC00414333	2/7/2010	117	11.7	61	6.1
GHCND:USC00414333	2/8/2010	200	20	83	8.3
GHCND:USC00414333	2/9/2010	111	11.1	33	3.3
GHCND:USC00414333	2/10/2010	67	6.7	11	1.1
GHCND:USC00414333	2/11/2010	67	6.7	28	2.8
GHCND:USC00414333	2/12/2010	50	5	17	1.7
GHCND:USC00414333	2/13/2010	122	12.2	17	1.7
GHCND:USC00414333	2/14/2010	211	21.1	28	2.8
GHCND:USC00414333	2/15/2010	111	11.1	17	1.7
GHCND:USC00414333	2/16/2010	139	13.9	-11	-1.1
GHCND:USC00414333	2/17/2010	156	15.6	-6	-0.6
GHCND:USC00414333	2/18/2010	156	15.6	0	0
GHCND:USC00414333	2/19/2010	150	15	83	8.3
GHCND:USC00414333	2/20/2010	172	17.2	61	6.1
GHCND:USC00414333	2/21/2010	206	20.6	133	13.3
GHCND:USC00414333	2/22/2010	178	17.8	78	7.8
GHCND:USC00414333	2/23/2010	78	7.8	17	1.7
GHCND:USC00414333	2/24/2010	128	12.8	11	1.1
GHCND:USC00414333	2/25/2010	156	15.6	-17	-1.7
GHCND:USC00414333	2/26/2010	211	21.1	72	7.2
GHCND:USC00414333	2/27/2010	167	16.7	61	6.1
GHCND:USC00414333	2/28/2010	172	17.2	33	3.3
GHCND:USC00414333	3/1/2010	156	15.6	72	7.2

Table D – 2 (continued).

STATION	DATE	T-MAX 1/10 DEGREE CELSIUS	T-MAX DEGREES CELSIUS	T-MIN 1/10 DEGREE CELSIUS	T-MIN DEGREES CELSIUS
GHCND:USC00414333	3/2/2010	150	15	44	4.4
GHCND:USC00414333	3/3/2010	172	17.2	28	2.8
GHCND:USC00414333	3/4/2010	172	17.2	50	5
GHCND:USC00414333	3/5/2010	172	17.2	67	6.7
GHCND:USC00414333	3/6/2010	178	17.8	61	6.1
GHCND:USC00414333	3/7/2010	194	19.4	100	10
GHCND:USC00414333	3/8/2010	172	17.2	139	13.9
GHCND:USC00414333	3/9/2010	233	23.3	161	16.1
GHCND:USC00414333	3/10/2010	222	22.2	161	16.1
GHCND:USC00414333	3/11/2010	256	25.6	150	15
GHCND:USC00414333	3/12/2010	200	20	106	10.6
GHCND:USC00414333	3/13/2010	228	22.8	83	8.3
GHCND:USC00414333	3/14/2010	244	24.4	67	6.7
GHCND:USC00414333	3/15/2010	206	20.6	117	11.7
GHCND:USC00414333	3/16/2010	139	13.9	111	11.1
GHCND:USC00414333	3/17/2010	217	21.7	89	8.9
GHCND:USC00414333	3/18/2010	217	21.7	78	7.8
GHCND:USC00414333	3/19/2010	217	21.7	106	10.6
GHCND:USC00414333	3/20/2010	183	18.3	33	3.3
GHCND:USC00414333	3/21/2010	139	13.9	17	1.7
GHCND:USC00414333	3/22/2010	206	20.6	17	1.7
GHCND:USC00414333	3/23/2010	217	21.7	61	6.1
GHCND:USC00414333	3/24/2010	178	17.8	144	14.4
GHCND:USC00414333	3/25/2010	200	20	106	10.6
GHCND:USC00414333	3/26/2010	206	20.6	67	6.7
GHCND:USC00414333	3/27/2010	228	22.8	106	10.6
GHCND:USC00414333	3/28/2010	206	20.6	89	8.9
GHCND:USC00414333	3/29/2010	233	23.3	61	6.1
GHCND:USC00414333	3/30/2010	222	22.2	100	10
GHCND:USC00414333	3/31/2010	233	23.3	100	10
GHCND:USC00414333	4/1/2010	228	22.8	161	16.1
GHCND:USC00414333	4/2/2010	233	23.3	178	17.8
GHCND:USC00414333	4/3/2010	267	26.7	183	18.3
GHCND:USC00414333	4/4/2010	256	25.6	189	18.9

Table D – 2 (continued).

STATION	DATE	T-MAX 1/10 DEGREE CELSIUS	T-MAX DEGREES CELSIUS	T-MIN 1/10 DEGREE CELSIUS	T-MIN DEGREES CELSIUS
GHCND:USC00414333	4/5/2010	250	25	189	18.9
GHCND:USC00414333	4/6/2010	250	25	189	18.9
GHCND:USC00414333	4/7/2010	256	25.6	172	17.2
GHCND:USC00414333	4/8/2010	217	21.7	89	8.9
GHCND:USC00414333	4/9/2010	206	20.6	61	6.1
GHCND:USC00414333	4/10/2010	189	18.9	117	11.7
GHCND:USC00414333	4/11/2010	228	22.8	111	11.1
GHCND:USC00414333	4/12/2010	228	22.8	111	11.1
GHCND:USC00414333	4/13/2010	244	24.4	161	16.1
GHCND:USC00414333	4/14/2010	239	23.9	178	17.8
GHCND:USC00414333	4/15/2010	239	23.9	189	18.9
GHCND:USC00414333	4/16/2010	244	24.4	178	17.8
GHCND:USC00414333	4/17/2010	239	23.9	172	17.2
GHCND:USC00414333	4/18/2010	228	22.8	161	16.1
GHCND:USC00414333	4/19/2010	211	21.1	161	16.1
GHCND:USC00414333	4/20/2010	244	24.4	150	15
GHCND:USC00414333	4/21/2010	256	25.6	133	13.3
GHCND:USC00414333	4/22/2010	250	25	150	15
GHCND:USC00414333	4/23/2010	256	25.6	217	21.7
GHCND:USC00414333	4/24/2010	289	28.9	156	15.6
GHCND:USC00414333	4/25/2010	283	28.3	133	13.3
GHCND:USC00414333	4/26/2010	294	29.4	111	11.1
GHCND:USC00414333	4/27/2010	250	25	128	12.8
GHCND:USC00414333	4/28/2010	261	26.1	100	10
GHCND:USC00414333	4/29/2010	267	26.7	172	17.2
GHCND:USC00414333	4/30/2010	244	24.4	217	21.7

Table D - 3. Monthly average maximum and minimum temperature values calculated from the weather station at the Houston National Weather Service Office presented in Table C-2.

MONTH	AVERAGE MAXIMUM TEMPERATURE	AVERAGE MINIMUM TEMPERATURE
	DEGREES CELSIUS	DEGREES CELSIUS
December 2009	14.8	5.7
January 2010	14.5	4.0
February 2010	14.0	4.3
March 2010	20.0	8.7
April 2010	24.5	15.4

APPENDIX E

SOIL MOISTURE DATA

Table E - 1. Soil moisture data.

DATE	CLAY			SILT		
	SURFACE	100 MM	150 MM	SURFACE	100 MM	150 MM
	Θ, V/V	Θ, V/V	Θ, V/V	Θ, V/V	Θ, V/V	Θ, V/V
12/23/2009	0.45	0.42	0.41	0.45	0.38	0.37
12/24/2009	0.45	0.42	0.40	0.45	0.38	0.37
12/25/2009	0.45	0.42	0.40	0.44	0.38	0.37
12/26/2009	0.45	0.42	0.40	0.44	0.38	0.37
12/27/2009	0.45	0.42	0.40	0.44	0.37	0.37
12/28/2009	0.45	0.42	0.40	0.45	0.39	0.37
12/29/2009	0.44	0.42	0.40	0.45	0.37	0.37
12/30/2009	0.45	0.42	0.42	0.44	0.39	0.38
12/31/2009	0.45	0.43	0.41	0.45	0.37	0.39
1/1/2010	0.45	0.43	0.41	0.45	0.37	0.39
1/2/2010	0.45	0.43	0.41	0.45	0.37	0.39
1/3/2010	0.45	0.43	0.41	0.45	0.37	0.39
1/4/2010	0.45	0.43	0.41	0.45	0.37	0.39
1/5/2010	0.45	0.43	0.41	0.45	0.37	0.39
1/6/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/7/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/8/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/9/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/10/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/11/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/12/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/13/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/14/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/15/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/16/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/17/2010	0.45	0.43	0.41	0.45	0.37	0.38
1/18/2010	0.45	0.43	0.41	0.45	0.38	0.38
1/19/2010	0.45	0.43	0.41	0.45	0.38	0.38
1/20/2010	0.45	0.43	0.41	0.45	0.38	0.38
1/21/2010	0.45	0.43	0.41	0.45	0.38	0.38
1/22/2010	0.45	0.43	0.41	0.45	0.38	0.38
1/23/2010	0.45	0.43	0.41	0.45	0.38	0.38

Table E - 1 (continued).

Date	Clay			Silt		
	Surface	100 mm	150 mm	Surface	100 mm	150 mm
	Θ, v/v	Θ, v/v	Θ, v/v	Θ, v/v	Θ, v/v	Θ, v/v
1/25/2010	0.45	0.42	0.41	0.45	0.38	0.37
1/24/2010	0.45	0.43	0.41	0.45	0.38	0.37
1/26/2010	0.45	0.42	0.41	0.44	0.38	0.37
1/27/2010	0.45	0.42	0.41	0.44	0.38	0.37
1/28/2010	0.45	0.42	0.41	0.44	0.38	0.37
1/29/2010	0.45	0.42	0.41	0.44	0.38	0.37
1/30/2010	0.45	0.42	0.41	0.44	0.38	0.37
1/31/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/1/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/2/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/3/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/4/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/5/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/6/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/7/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/8/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/9/2010	0.45	0.42	0.41	0.44	0.38	0.37
2/10/2010	0.46	0.42	0.41	0.44	0.38	0.37
2/11/2010	0.46	0.42	0.41	0.44	0.38	0.37
2/12/2010	0.46	0.42	0.41	0.44	0.38	0.37
2/13/2010	0.46	0.42	0.40	0.44	0.38	0.37
2/14/2010	0.46	0.42	0.40	0.44	0.38	0.37
2/15/2010	0.46	0.42	0.40	0.44	0.38	0.37
2/16/2010	0.46	0.42	0.40	0.44	0.38	0.37
2/17/2010	0.46	0.42	0.40	0.44	0.38	0.37
2/18/2010	0.46	0.42	0.40	0.44	0.38	0.37
2/19/2010	0.46	0.42	0.40	0.44	0.38	0.38
2/20/2010	0.47	0.42	0.40	0.44	0.38	0.38
2/21/2010	0.47	0.42	0.40	0.44	0.38	0.38
2/22/2010	0.47	0.42	0.40	0.44	0.38	0.38
2/23/2010	0.47	0.42	0.40	0.44	0.38	0.38
2/24/2010	0.47	0.42	0.40	0.44	0.38	0.38
2/25/2010	0.47	0.42	0.40	0.44	0.39	0.38
2/26/2010	0.47	0.42	0.40	0.44	0.39	0.38
2/27/2010	0.47	0.42	0.40	0.44	0.39	0.38

Table E - 1 (continued).

Date	Clay			Silt		
	Surface	100 mm	150 mm	Surface	100 mm	150 mm
	θ, v/v	θ, v/v	θ, v/v	θ, v/v	θ, v/v	θ, v/v
2/28/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/1/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/2/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/3/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/4/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/5/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/6/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/7/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/8/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/9/2010	0.47	0.42	0.40	0.44	0.38	0.37
3/10/2010	0.47	0.42	0.40	0.44	0.38	0.37
3/11/2010	0.48	0.42	0.40	0.44	0.38	0.38
3/12/2010	0.48	0.43	0.40	0.44	0.38	0.38
3/13/2010	0.48	0.42	0.40	0.44	0.39	0.38
3/14/2010	0.48	0.43	0.40	0.44	0.39	0.38
3/15/2010	0.48	0.43	0.40	0.44	0.39	0.38
3/16/2010	0.48	0.43	0.40	0.44	0.39	0.38
3/17/2010	0.48	0.43	0.40	0.44	0.39	0.38
3/18/2010	0.48	0.43	0.40	0.44	0.39	0.38
3/19/2010	0.48	0.42	0.40	0.44	0.39	0.38
3/20/2010	0.48	0.42	0.40	0.44	0.39	0.38
3/21/2010	0.49	0.43	0.40	0.44	0.39	0.38
3/22/2010	0.49	0.43	0.40	0.44	0.39	0.38
3/23/2010	0.49	0.42	0.40	0.44	0.39	0.38
3/24/2010	0.49	0.42	0.40	0.44	0.39	0.38
3/25/2010	0.49	0.42	0.40	0.44	0.39	0.38
3/26/2010	0.49	0.42	0.40	0.44	0.38	0.38
3/27/2010	0.49	0.42	0.40	0.44	0.38	0.38
3/28/2010	0.47	0.42	0.40	0.44	0.38	0.38
3/29/2010	0.43	0.42	0.40	0.44	0.38	0.37
3/30/2010	0.43	0.42	0.40	0.43	0.38	0.37
3/31/2010	0.42	0.42	0.40	0.43	0.38	0.37
4/1/2010	0.41	0.42	0.40	0.44	0.38	0.37
4/2/2010	0.41	0.43	0.40	0.44	0.38	0.37
4/3/2010	0.41	0.43	0.40	0.44	0.38	0.37

Table E - 1 (continued).

DATE	CLAY			SILT		
	SURFACE	100 MM	150 MM	SURFACE	100 MM	150 MM
	Θ, V/V	Θ, V/V	Θ, V/V	Θ, V/V	Θ, V/V	Θ, V/V
4/4/2010	0.41	0.43	0.40	0.44	0.38	0.37
4/5/2010	0.41	0.43	0.40	0.44	0.38	0.37
4/6/2010	0.40	0.42	0.40	0.44	0.37	0.37
4/7/2010	0.40	0.42	0.40	0.43	0.37	0.37
4/8/2010	0.39	0.41	0.39	0.42	0.37	0.36
4/9/2010	0.37	0.41	0.39	0.41	0.36	0.36
4/10/2010	0.36	0.40	0.39	0.40	0.36	0.36
4/11/2010	0.36	0.40	0.39	0.40	0.36	0.36
4/12/2010	0.35	0.40	0.39	0.39	0.36	0.35
4/13/2010	0.33	0.40	0.39	0.38	0.35	0.35
4/14/2010	0.32	0.39	0.38	0.37	0.34	0.35
4/15/2010	0.31	0.39	0.38	0.37	0.34	0.35

APPENDIX F

SWALE SURVEY

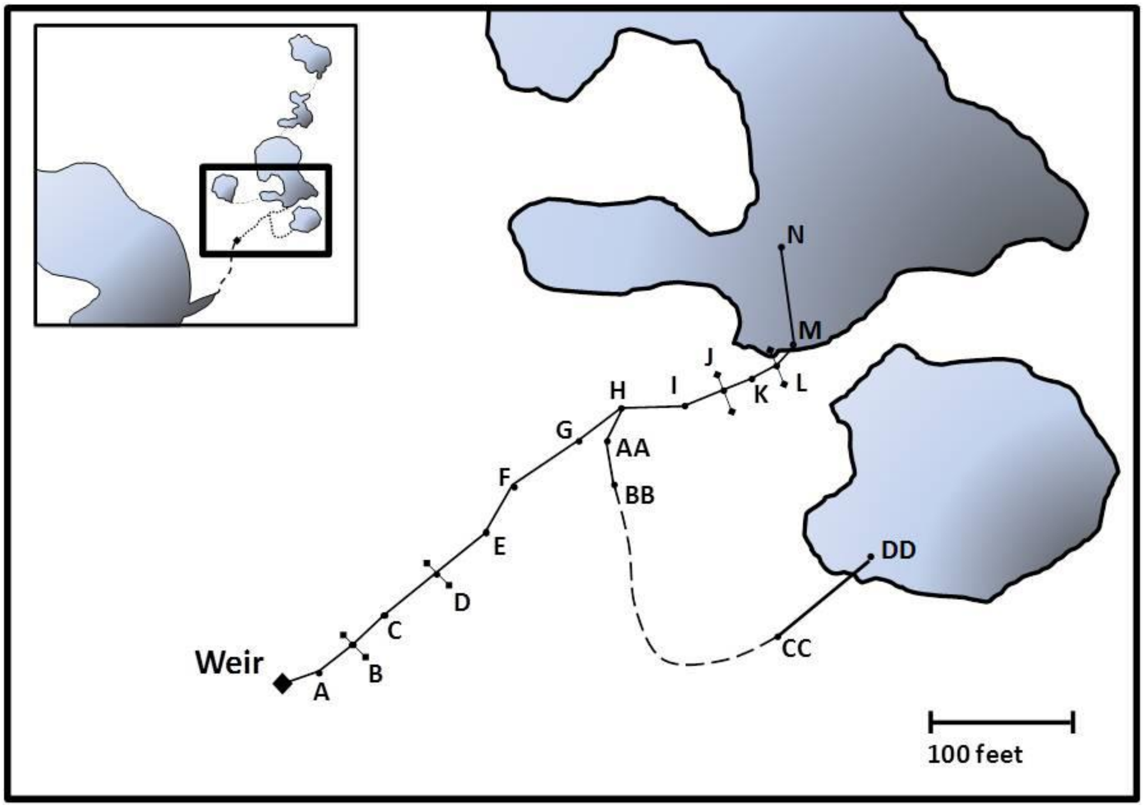

Fig. F - 1. Plan view and of the main swale and a tributary to the main swale. This survey included the main swale, which from the largest wetland depression in the watershed to the flow measuring weir, and ultimately to Armand Bayou. The survey began at the weir and moved upslope toward the main depression. Profiles of the swales and cross sections for Points B, D, J, and L are provided in subsequent figures. A tributary to the main swale, which flows from one of the smaller wetland depressions toward the main swale, was partially surveyed. The portion of the tributary swale from Point BB to Point CC could not be surveyed because of inclement weather.

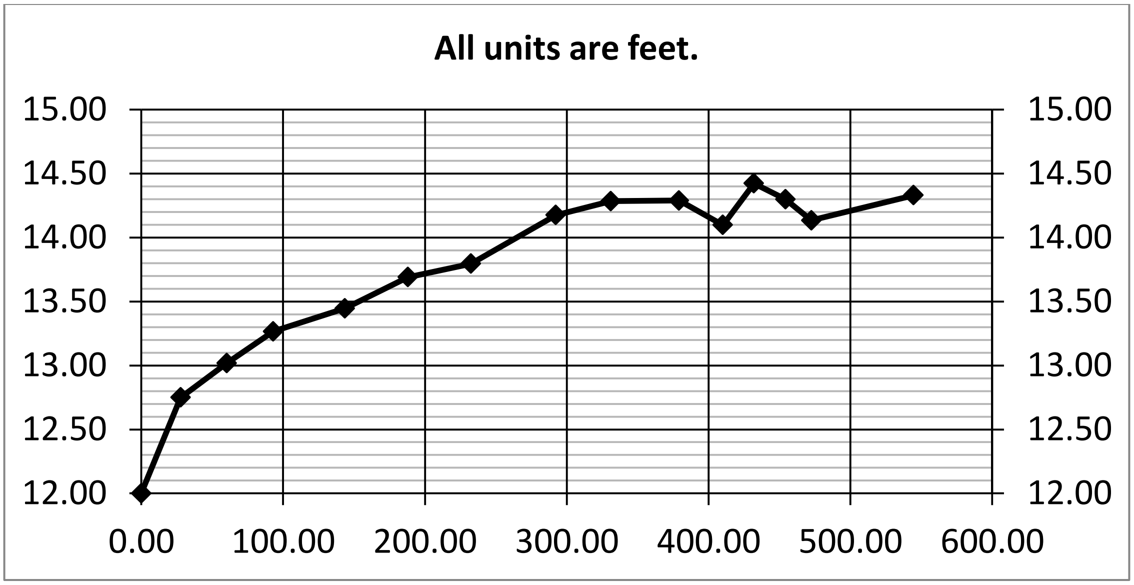

Fig. F - 2. Profile view of main swale, beginning at the weir and ending in the largest wetland depression.

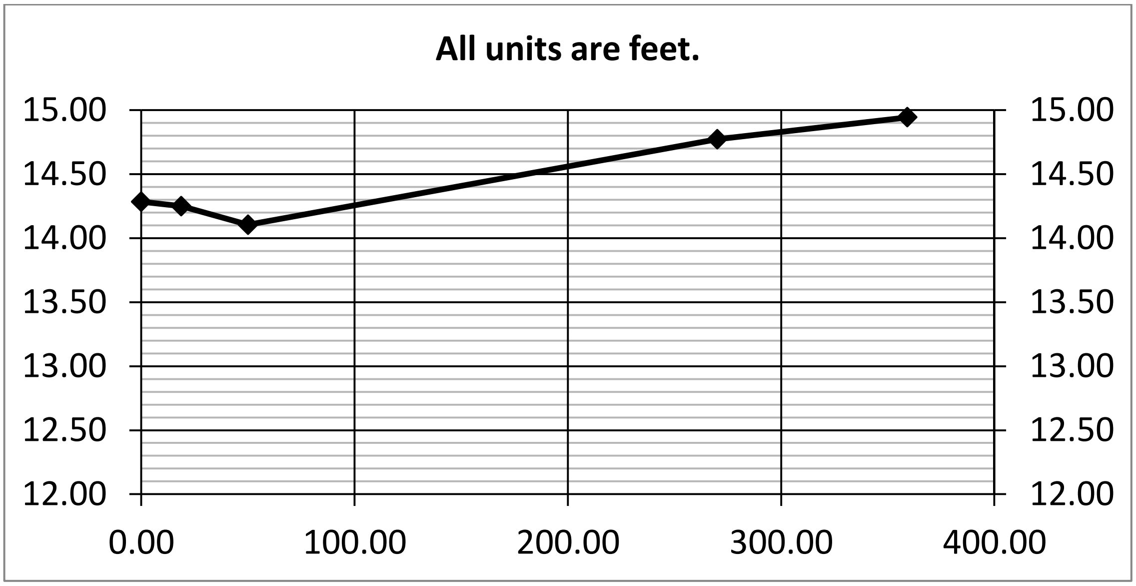

Fig. F - 3. Profile view of tributary to the main swale, beginning at the main swale and ending in the wetland depression southeast of the largest wetland depression.

Table F - 2. Survey index for the main swale.

POINT	ELEVATION [FEET]	HORIZONTAL DISTANCE [FEET]
Weir	12.000	0.00
A	12.750	27.76
B	13.018	60.32
C	13.266	93.11
D	13.446	143.67
E	13.690	187.93
F	13.795	232.45
G	14.176	292.38
H	14.285	331.18
I	14.289	379.17
J	14.098	410.12
K	14.423	431.99
L	14.299	454.27
M	14.135	472.53
N	14.331	544.61

Table F - 3. Survey index for the tributary to the main swale.

POINT	ELEVATION [FEET]	HORIZONTAL DISTANCE [FEET]
H	14.285	0.00
AA	14.249	18.79
BB	14.105	50.09
CC	14.772	270.09
DD	14.944	359.20

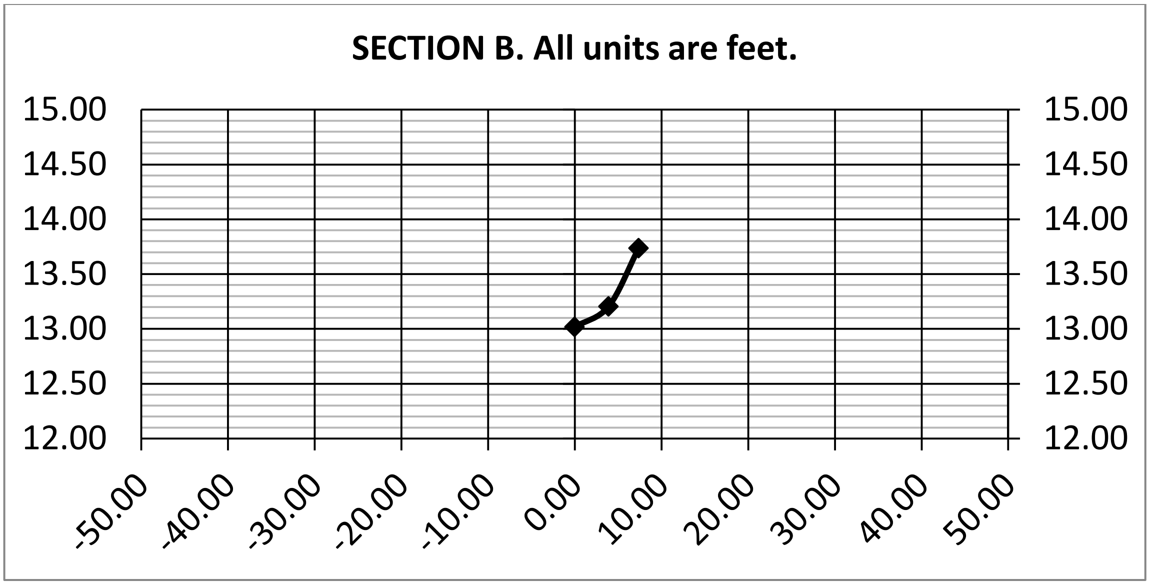

Fig. F - 4. Cross section of the main swale at Point B (looking upslope), from centerline to crest. The west side (left) was not surveyed because of dense foliage.

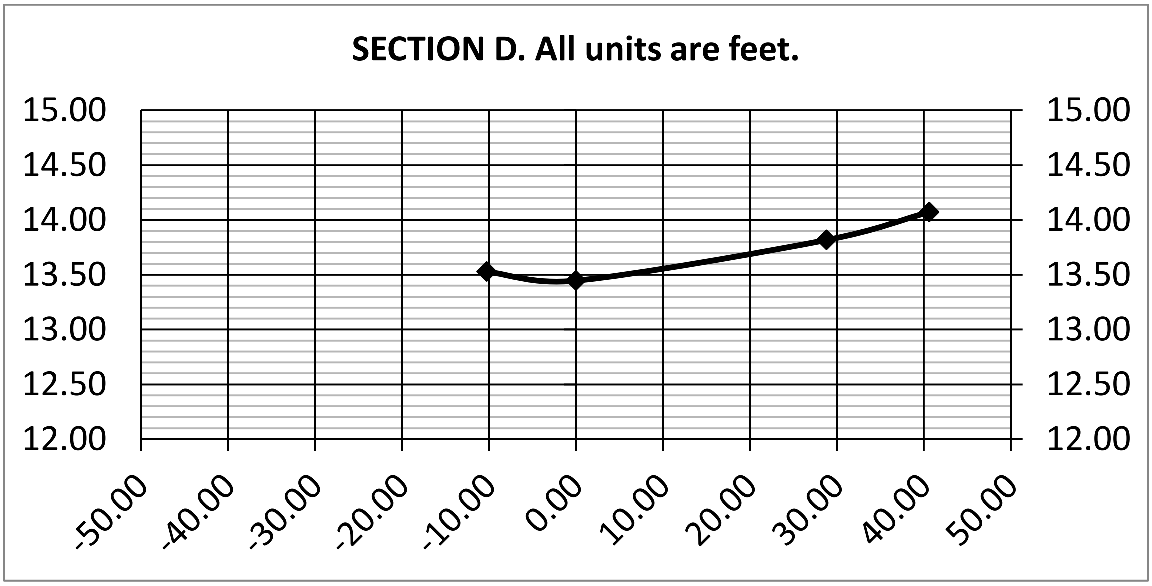

Fig. F - 5. Cross section of the main swale at Point D (looking upslope), from centerline to crest.

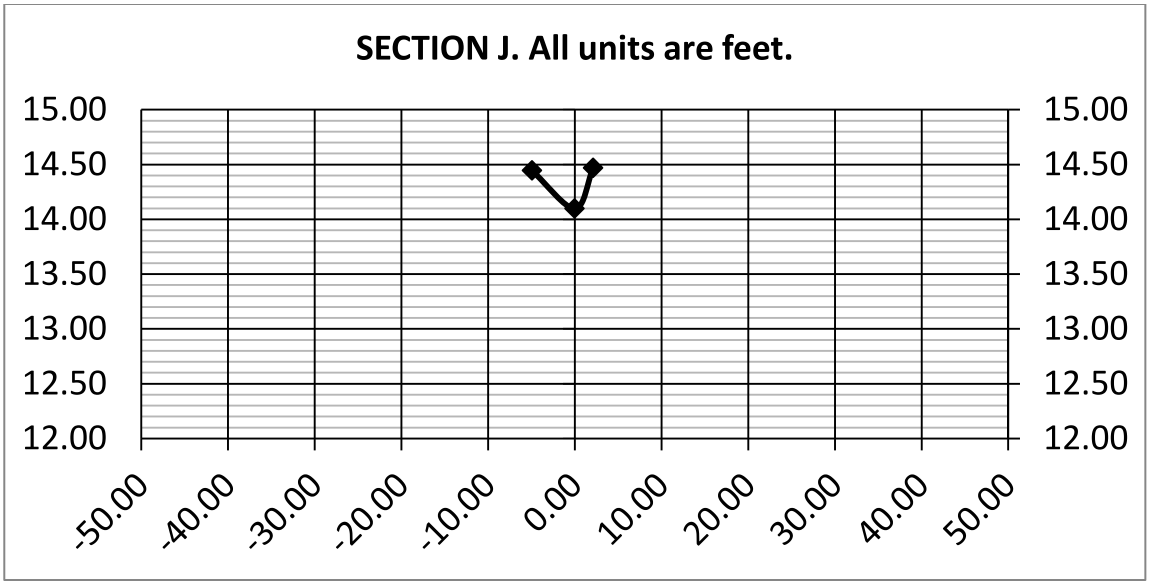

Fig. F - 6. Cross section of the main swale at Point J (looking upslope), from centerline to crest.

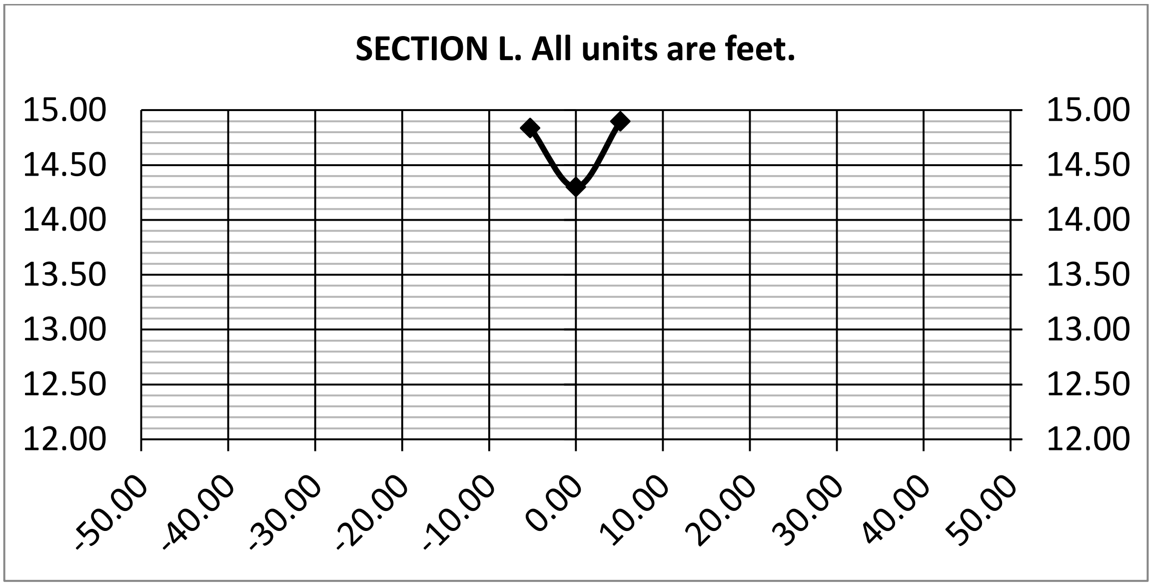

Fig. F - 7. Cross section of the main swale at Point L (looking upslope), from centerline to crest.

Table F - 4. Survey index for cross sections of the main swale. All cross sections included the centerline of the swale, and the crest on each side of the swale (except for the cross section at Point B, where the westward crest could not be surveyed because of dense vegetation. Negative distances are to the west and positive distances are to the east (looking upslope).

Point	Elevation	Horizontal Distance from Centerline
	[Feet]	[Feet]
Section B	13.018	0.00
	13.205	3.89
	13.735	7.36
Section D	13.527	-10.26
	13.446	0.00
	13.817	28.82
	14.072	40.62
Section J	14.444	-4.94
	14.098	0.00
	14.467	2.11
Section L	14.835	-5.24
	14.299	0.00
	14.898	5.13

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