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Rainfall, Streamflow, and Water-Quality Data During Stormwater Monitoring, Halawa Stream Drainage Basin, Oahu, Hawaii, July 1, 2006 to June 30, 2007

Open-File Report 2007–1213

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Vertical coordinate information is referenced to mean sea level.

Horizontal coordinate information is referenced to Old Hawaiian Datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Rainfall, Streamflow, and Water-Quality Data During Stormwater Monitoring, Halawa Stream Drainage Basin, Oahu, Hawaii, July 1, 2006 to June 30, 2007

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Abstract

Storm runoff water-quality samples were collected as part of the State of Hawaii Department of Transportation Stormwater Monitoring Program. This program is designed to assess the effects of highway runoff and urban runoff on Halawa Stream. For this program, rainfall data were collected at two stations, continuous streamflow data at three stations, and water-quality data at five stations, which include the two continuous streamflow stations. This report summarizes rainfall, streamflow, and water-quality data collected between July 1, 2006 and June 30, 2007.

A total of 13 samples was collected over two storms during July 1, 2006 to June 30, 2007. The goal was to collect grab samples nearly simultaneously at all five stations and flow-weighted time-composite samples at the three stations equipped with automatic samplers. Samples were analyzed for total suspended solids, total dissolved solids, nutrients, chemical oxygen demand, and selected trace metals (cadmium, chromium, copper, lead, nickel, and zinc). Additionally, grab samples were analyzed for oil and grease, total petroleum hydrocarbons, fecal coliform, and biological oxygen demand. Quality-assurance/quality-control samples were also collected during storms and during routine maintenance to verify analytical procedures and check the effectiveness of equipment-cleaning procedures.

Introduction

The State of Hawaii Department of Transportation (DOT) Stormwater Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2006) was implemented on January 1, 2001 to monitor the Halawa Stream drainage basin, Oahu, Hawaii. The Stormwater Monitoring Program Plan was designed to fulfill part of the permit requirements for the National Pollutant Discharge Elimination System program and is revised yearly. The Stormwater Monitoring Program Plan includes the collection of rainfall, streamflow, and water-quality data at selected stations in the Halawa Stream drainage basin.

This report summarizes water-quality data collected by the U.S. Geological Survey (USGS) as part of the Stormwater Monitoring Program Plan. This report also presents rainfall and streamflow data collected from July 1, 2006 to June 30, 2007. Descriptions of the sampling techniques are included with the water-quality data.

Two storms were sampled during the period of July 1, 2006 to June 30, 2007. A total of 13 samples was collected during the two storms. In addition, 3 quality-assurance/quality-control (QA/QC) samples were collected: 2 samples were collected concurrently with storm samples and 1 sample was collected between storms during routine cleaning of the sampling equipment. Water-quality data for the QA/QC samples are not published in this report, but are available upon request from the USGS Pacific Islands Water Science Center in Honolulu, Hawaii.

Data-Collection Network

Stream-stage, stream-discharge, rainfall, and water-quality data were collected at selected stations in the Halawa Stream drainage basin (fig. 1). Rainfall data were collected at two stations, 212428157511201, North Halawa Valley rain gage at H-3 tunnel portal (abbreviated to Tunnel rain gage) and 212304157542201, North Halawa rain gage near Honolulu (abbreviated to Xeriscape garden rain gage). Rainfall data have been collected at the Tunnel and Xeriscape garden rain gages since July 1998 and May 1983, respectively.

Streamflow data were collected at three stations in North Halawa Valley since 1998, 1983, and 2001, respectively for station 212353157533001, Storm drain C; and streamflow-gaging stations 16226200, North Halawa Stream near Honolulu (abbreviated to Xeriscape garden); and 16226400, North Halawa Stream at Quarantine Station (abbreviated to Quarantine). Storm drain C, Xeriscape garden, and Quarantine stations are equipped with automatic samplers. The Quarantine station gagehouse and equipment were destroyed on December 7, 2003 and rebuilt in June 2005.

Rainfall and streamflow data were collected using variable sampling intervals depending on rainfall or streamflow rates. Data from the two rain gages and the two streamflow-gaging stations are transferred to the USGS National Water Information System (NWIS) database using cellular-phone. Data from Quarantine station are transferred to the NWIS database hourly via satellite telemetery. Recent data can be viewed at *http://hi.water.usgs.gov/* under “Real-Time Data (from NWISWeb)” by selecting “Streamflow” or “Rainfall”, and then selecting the approriate USGS station numbers. Historic rainfall and streamflow data can be accessed through the website *http://hi.water.usgs.gov/* under “Historical Data (from NWISWeb)” by selecting “Streamflow” or “Rainfall” and then selecting “Daily Data” and then entering the appropriate USGS station numbers.

Water-quality data were collected at five stations (fig. 1): 212356157531801, North Halawa Stream at Bridge 8 near Halawa (abbreviated to Bridge 8); Storm drain C; Xeriscape garden; Quarantine; and 16227100, Halawa Stream below H-1 (abbreviated to Stadium). The Bridge 8 station is about 0.75 mi upstream from the discharge point of Storm drain C on North Halawa Stream. Storm drain C collects runoff from an approximately 4-mi length of freeway starting at the leeward tunnel portal and extending to mid-valley and discharges directly to North Halawa Stream (fig. 1). The Xeriscape garden station is directly upstream from a light-industrial area near North Halawa Stream, and about 0.75 mi downstream of the discharge point of Storm drain C. The Quarantine station is about 1 mi downstream of Xeriscape garden and near the downstream end of the light-industrial area that borders the North Halawa Stream. The Stadium station is about 1.5 mi downstream of the Quarantine station downstream from the confluence of North and South Halawa Streams, downstream from the crossing of H-1 freeway, and directly upstream from the mouth at Pearl Harbor. Water-quality data have been previously collected at stations Storm drain C (1998-present), Xeriscape garden (1983-present), and Stadium (1988-present) by the USGS as part of the H-3 freeway construction monitoring study and can be viewed website *http://hi.water.usgs.gov/* under “Historical Data (from NWISWeb)” by selecting “Water Quality” and then selecting either “Field/lab samples” or “Daily Data” and then entering the appropriate USGS station numbers.

Water-Quality Sampling Techniques

Water-quality samples include grab samples collected manually; grab samples collected by an automatic sampler, and flow-weighted time-composite samples collected by an automatic sampler. Each grab and composite sample is assigned a median sampling time based on the start and finish time of the grab sampling process, or the times of collection of the sample bottles used for the grab or composite sample from the automatic sampler.

Sampling requirements

The DOT Stormwater Monitoring Program Plan states that water-quality samples will be collected at least once per quarter during periods of storm runoff from each of the five water-quality monitoring stations (fig. 1). The plan also states that efforts will be made to sample all five water-quality monitoring stations during the same storm, and if a storm does not occur during a quarter, no samples will be collected.

A complete set of samples for a storm consists of five grab samples (one from each of the five stations), three flow-weighted time-composite samples (one each from Storm drain C, Xeriscape garden, and Quarantine stations), and one QA/QC sample. However, some storms are brief and do not produce adequate runoff to sample all five stations and collect all samples. In practice, these storms have been sampled as thoroughly as possible and analyzed for as many constituents as practical.

Storm criteria

The U.S. Environmental Protection Agency’s (USEPA) Storm Water Sampling Guidance Manual (U.S. Environmental Protection Agency, Office of Water, 1993) provides criteria for stormwater-sampling. The first criterion requires at least 0.1 in. of accumulated rainfall within a storm event. Rainfall accumulations have exceeded 0.1 in. at the Tunnel rain gage and Xeriscape garden rain gage when stormwater sampling was conducted. The second criterion requires that samples be collected only for storms preceded by at least 72 hours of dry weather. The second criterion would prevent sampling of most storms on North Halawa Stream because the Halawa Stream drainage basin, as well as many other parts of Oahu, receives tradewind showers almost daily.

In practice, criteria used to initiate sampling of the stream and storm drain were based on the rate of rainfall accumulation and the rise of stage in Storm drain C, Xeriscape garden, and Quarantine stations. Each automatic sampler is triggered at predetermined, station-specific, stream-stage thresholds.

Sample collection

In general, grab samples were collected manually using isokinetic, depth-integrating samplers and equal-width increment (EWI) or single vertical sampling techniques (Wilde and others, 1998). Samplers are made of high-density polyethylene (HDPE) that collect water in an isokinetic manner, in which water enters the sampler at the same velocity as the stream at the sampling point.

The EWI sampling technique utilizes evenly spaced sampling increments along the cross section of the stream. The volume of sample collected at each increment is proportional to the discharge at that increment. Samples collected at each increment are combined in an HDPE churn. An EWI sample is practical when depths are greater than 0.5 ft and the stream

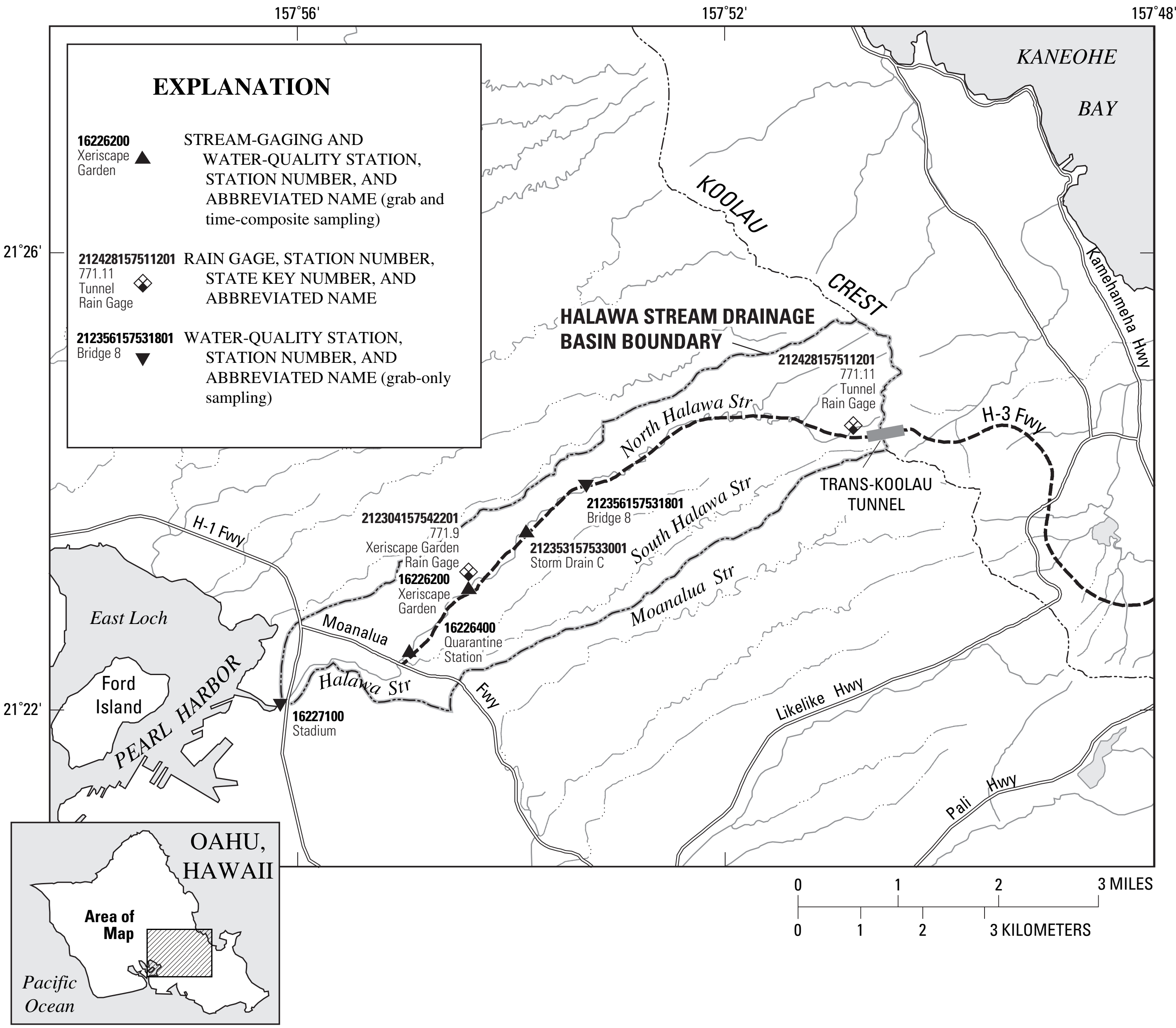

Figure 1. Stream-gaging stations, rain gages, and water-quality sampling stations in the Halawa drainage basin, Oahu, Hawaii.

is wadeable. During storms with high discharge, streams were not waded for safety reasons. However, if the stream appears to be sufficiently well mixed during high-discharge storms at each station, use of the EWI method would not be necessary. At such times, a grab sample was collected with the isokinetic sampler at the estimated centroid of flow of a single vertical section in the stream. Sub-samples from the single-vertical technique were combined in a HDPE churn.

A flow-weighted, time-composite sample is created by combining, in a HDPE churn, all or part of the samples collected by the automatic samplers. The desired volume of water from each sample is proportional to the volume of stream-discharge between sample-collection times. Composite samples were collected over time periods that sometimes lasted several hours.

Automatic samplers collect water from a fixed point in the stream channel after pre-determined stage thresholds are met. The automatic samplers have a capacity of 24, 1-liter bottles. When the first threshold has been met, the automatic samplers are programmed to collect water samples every two minutes for the first five samples, and then every 15 minutes for the remaining 19 samples. The first stage thresholds for the samplers correspond to discharges of 3, 40, and 30 ft3/s for Storm drain C, Xeriscape garden, and Quarantine stations, respectively. In order to collect enough water in each sample during storms with quick rising and falling stream stages, or greater overall flow, a second set of stage thresholds, corresponding to higher discharges, is used to trigger the samplers to sample every 7 minutes. These higher stage thresholds correspond to discharges of 16, 90 and 108 ft3/s for Storm drain C, Xeriscape garden, and Quarantine stations, respectively.

The first three automatic samples were collected in teflon bags and the remaining 21 automatic samples were collected in low density polyethylene (LDPE) bags. In storms where a composite sample could not be created due to insufficient automatic samples (5 samples), the automatic samples collected in teflon bags were analyzed for oil and grease (O+G) and total petroleum hydrocarbon (TPH). No other constituents would be analyzed due to low sample volume. In storms where a manual grab sample could not be collected or the first automatic samples are representative of the first rise of the stage and flow, the automatic samples collected in teflon bags would be used for O+G and TPH analyses and the remaining automatic samples would be combined to be analyzed for total suspended solids (TSS), total dissolved solids (TDS), nutrients, chemical oxygen demand (COD), and selected trace metals (cadmium, chromium, copper, lead, nickel, and zinc). Fecal coliform (FC) and biological oxygen demand (BOD) would not be analyzed in this case because the “holding times” for these constituents would likely be exceeded.

The main limitation associated with using samples from the automatic sampler to replace grab samples is that some constituents require the sample to be chilled prior to analysis or analyzed within a certain time after collection, known as the holding time. The automatic samplers were not equipped with refrigeration units, and thus holding times for selected constituents can be exceeded. Additionally, the automatic samplers can decrease the concentration of constituents if the constituent bonds to the teflon tubing of the intake line and the silicon tubing of the peristaltic pump. Nutrient, FC, and BOD analyses would be the most susceptible to holding time and refrigeration problems, whereas O+G and TPH analyses are the most susceptible to problems associated with the constituent bonding to tubing.

Some storms are difficult to sample due to the timing and distribution of discharge. Situations in which the storm samples deviate from the sampling requirements outlined in the sampling plan occurred when there were multiple peaks in discharge, if stream discharge had decreased too much after a storm to collect a grab sample, or if a small peak in discharge was followed by a much larger peak discharge. In these cases, deviation from the sampling requirements include: (1) one or more grab samples will be made from the samples collected by the automatic sampler, or (2) a composite sample will be made from fewer than 24 samples if a gap of a few or more hours elapse between the times at which the samples from the automatic sampler were collected.

Determination of discharge for samples

At Bridge 8, Storm drain C, Xeriscape garden, and Quarantine stations, discharge associated with each sample was determined using a streamflow rating, created for the station, or by direct measurement using a current meter. Streamflow ratings were developed using measurements and results from hydraulic models that were verified by subsequent measurements. At the Stadium station, the wide and curving concrete-lined channel and shallow and swift streamflow preclude development of an accurate streamflow rating. When possible discharge at this station was measured using a current meter. At higher flows, discharge was measured either by using float-measurement techniques or a radar gun. The float-measurement technique involves timing floating bottles over a known distance to determine water velocity. The radar gun measures surface velocity at multiple points in the cross section. In both techniques, the area of the cross section was estimated using measured water depths and surveyed dimensions of the channel. USGS practices for making discharge measurements and streamflow ratings can be found in Rantz and others (1982).

An average-discharge value was calculated for each composite sample. The average-discharge value was equal to the total volume of water that flowed by the gaging station during sample collection, divided by the total elapsed time required to collect the automatic samples. To determine the volume of water that passed the station for each sample, the discharge at the time of sample collection was multiplied by the elapsed time. The elapsed time is computed by taking the difference between the times of the samples taken before and after the sample in questions and dividing by two. To compute the elapsed time of the first and last samples, the difference between the time of the sample and next/previous sample is divided by two. These volumes were summed, and the total volume was divided by the sum of all the time increments. A similar method, the mid-section method, is used when computing the width between sections in discharge measurments is described in Rantz and others (1982, P.80).

Measured, streamflow-rating, and averaged discharge values are reported to appropriate number of significant figures. These discharge values and the corresponding values of constituent concentration are used to compute loads. Reported discharge values and the calculation of loads are discussed in appendix A.

Sample processing, analysis, and quality assurance/quality control

USGS water-quality sampling methods (Wilde and others, 1998) were followed to prevent possible contamination during sample processing. Both grab and composite samples were processed using churns to mix and suspend sediment while delivering the sample to specific bottles for the various constituent analyses. The time assigned to each grab and composite sample is the median time of the sample collection.

As required by the DOT Stormwater Sampling Program Plan, each composite and grab sample was analyzed for temperature, pH, specific conductance, TSS, TDS, nutrients, COD, and selected trace metals (cadmium, chromium, copper, lead, nickel, and zinc). Chromium and nickel were added to the analyses starting in July 2004. Each grab sample was also analyzed for O+G, TPH, FC, and BOD. USGS personnel made field measurements of temperature, pH, and specific conductance. The minimum reporting levels for each of the analyzed properties and constituents are listed in table 1 and are based on values published by the USGS National Water Quality Laboratory (NWQL). Calculated values, organic nitrogen and total nitrogen, do not have minimum reporting levels. More information about minimum reporting levels and how they are determined by NWQL can be found in Childress and others (1999).

FC and BOD analyses were performed by Aecos Incorporated, a private laboratory on Oahu. QA/QC practices are conducted at Aecos Incorporated, but are not published. For storm-sample events that occurred on a weekend or holiday, no FC or BOD samples were collected because Aecos Incorporated was closed and holding times for these constituents would be exceeded.

All other analyses were performed at the USGS NWQL, in Denver, Colorado. The methods used for analyses of all water-quality constituents and quality-control practices at NWQL are documented in Friedman and Erdmann (1982), Fishman and Friedman (1989), Pritt and Raese (1992), Patton and Truitt (1992), and Fishman (1993).

A duplicate sample, field or laboratory, is required by the Stormwater Sampling Program Plan for each storm sample. A field duplicate is a sample that is collected concurrently or split with a grab sample and the analytical results are used to verify the sampling method. A laboratory duplicate is a sample that is split into two equal parts during sample processing and the results are used to verify the precision of the laboratory. Field duplicate QA/QC samples were collected at Xeriscape garden and Quarantine stations during the storm of November 1, 2006. No QA/QC sample was collected for the storm of June 5, 2007 due to low sample volume.

During the period between storms, non-dedicated and non-disposable equipment, such as churns, isokinetic samplers, automatic-sampler-intake lines, and teflon automatic-sampler bottle liners, were cleaned following procedures in Wilde and others (1998). Field-blank samples were collected on January 9, 2007. Inorganic blank water (IBW), free of inorganic constituents, was passed through the automatic sampler and collected. The IBW field-blank samples were analyzed for the same inorganic constituents as the storm samples.

Rainfall and Streamflow Data

Hydrographs of daily rainfall and daily mean streamflow for the period of July 1, 2006 through June 30, 2007 are shown in figure 2. A total of 101.6 in. of rain was recorded at the Tunnel rain gage and 23.3 in. of rain was recorded at Xeriscape garden rain gage during this period. The highest recorded daily rainfall at Tunnel rain gage was 5.2 in. on September 26, 2006 at the Xeriscape garden rain gage was 3.0 in. on November 2, 2006.

Halawa Stream is an intermittent stream. At Xeriscape garden station, the highest daily mean discharge was 90 ft^3/s on November 1, 2006. The longest period of zero daily mean discharge at this station was from August 9 to September 6, 2006. For Quarantine station, the highest daily mean discharge was 93 ft^3/s on November 1, 2006. The longest period of zero daily mean discharge at this station was from July 1 to August 22, 2006. For Storm drain C, the highest daily mean discharge was 1.7 ft^3/s on September 26, 2006. The longest period of zero daily mean discharge at this station was from June 17-24, 2007.

Stormwater Sampling: Conditions And Results

During the period July 1, 2006 through June 30, 2007, six storms occurred with sufficient runoff to trigger the automatic samplers at the predetermined thresholds at Storm drain C, Xeriscape garden and Quarantine stations. Of these storms, two were sampled: November 1, 2006 and June 5, 2007. Water-quality data presented in this report are provisional and subject to revision.

Table 1. Minimum reporting levels of properties and constituents for all samples collected from Halawa Stream drainage basin from July 1, 2006 to June 30, 2007, Oahu, Hawaii

[std., standard; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; °C, degrees Celsius; µg/L, micrograms per liter; --, no minimum reporting level, computed value; MPN/100mL, most probable number (of colonies) per 100 milliliters]

Property or constituent	Minimum reporting levels
pH	0.1 std. units
Specific conductance	2.6 µS/cm
Temperature	0.5oC
Total suspended solids	10 mg/L
Total dissolved solids	10 mg/L
Total nitrogen[a]	--
Organic nitrogen[b]	--
Ammonia dissolved[c]	0.02 mg/L
Nitrogen, total organic + ammonia (Kjeldahl)	0.10 mg/L
Nitrogen, nitrite + nitrate dissolved	0.060 mg/L
Phosphorus dissolved	0.04 mg/L
Total phosphorus	0.040 mg/L
Chemical oxygen demand	10 mg/L
Total cadmium	0.018 µg/L
Total chromium	0.8 µg/L
Total copper	1.2 µg/L
Total lead	0.06 µg/L
Total nickel	0.16 µg/L
Total zinc	2 µg/L
Oil and grease	7 mg/L
Total petroleum hydrocarbons	2 mg/L
Biological oxygen demand	1 mg/L
Fecal coliform	2MPN/100mL

[a]Total nitrogen is calculated by adding nitrogen, total organic+ammonia (Kjeldahl) to nitrogen, nitrite+nitrate, dissolved.

[b]Organic nitrogen is calculated by subtracting nitrogen ammonia, dissolved, from nitrogen, total organic+ammonia (Kjeldahl).

[c]Ammonia, dissolved is reported as nitrogen

Third Quarter 2006 – July 1 to September 30, 2006

Hydrographs of discharge during the third quarter 2006 for Storm drain C, Xeriscape garden, and Quarantine stations are shown in Figure 3. No storms were sampled during this quarter. One storm occurred on September 26, 2006 had peak discharges that exceeded the sampling thresholds at Storm drain C, Xeriscape garden and Quarantine stations (fig. 3). However due to the flashiness of flow and rapid decrease in stage at Storm drain C and Quarantine stations, a sufficient number of automatic samples was not collected in order to create a composite sample that represented the storm.

Fourth Quarter 2006 –October 1 to December 31, 2006

One storm, on November 1, 2006, was sampled during the fourth quarter 2006. A complete set of samples was collected for this storm.

Storm of November 1, 2006

A total of 2.7 in. of rain was recorded during November 1, 2006 at the Tunnel rain gage, resulting in sufficient runoff for a storm sample to be collected on this day. Hydrographs of discharge at Storm drain C, Xeriscape garden and Quarantine stations during October 1 to December 31, 2006 are shown in figure 4, 5, and 6. Discharges and analyzed constituents are shown in appendix B.

Composite samples were collected from Storm drain C, Xeriscape garden, and Quarantine stations. Manual grab samples were collected from all stations. Beginning and ending composite sample-collection times are displayed on the hydrographs in figures 4, 5, and 6. Samples were analyzed for all constituents listed in the Stormwater Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2006). Discharge, laboratory measurements of pH and specific-conductance values, constituent concentrations, loads for the grab samples, and average loads for the composite samples, are shown in appendix B.

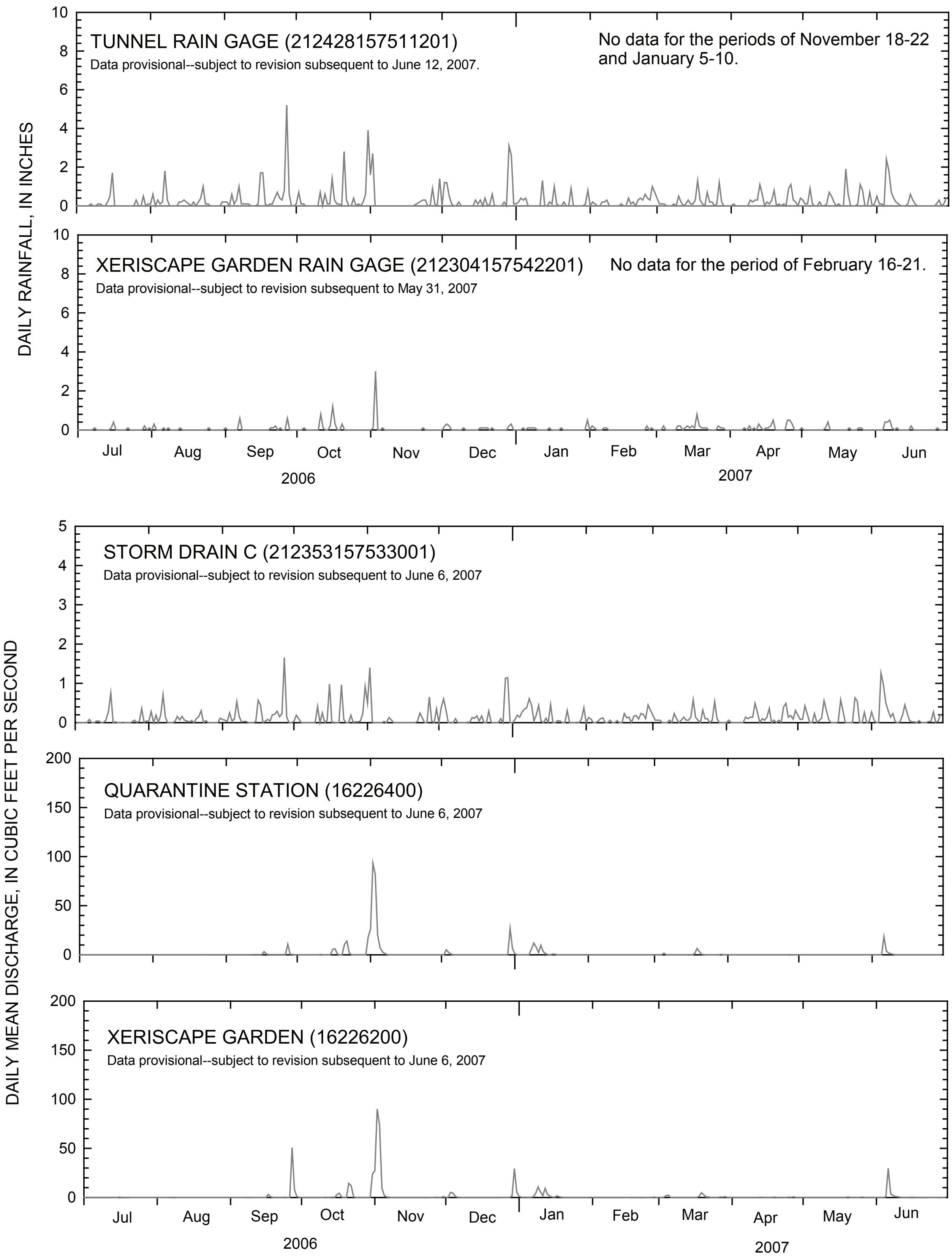

Figure 2. Rainfall and discharge for stations within the Halawa Stream drainage basin, Oahu, Hawaii, for July 1, 2006 to June 30, 2007.

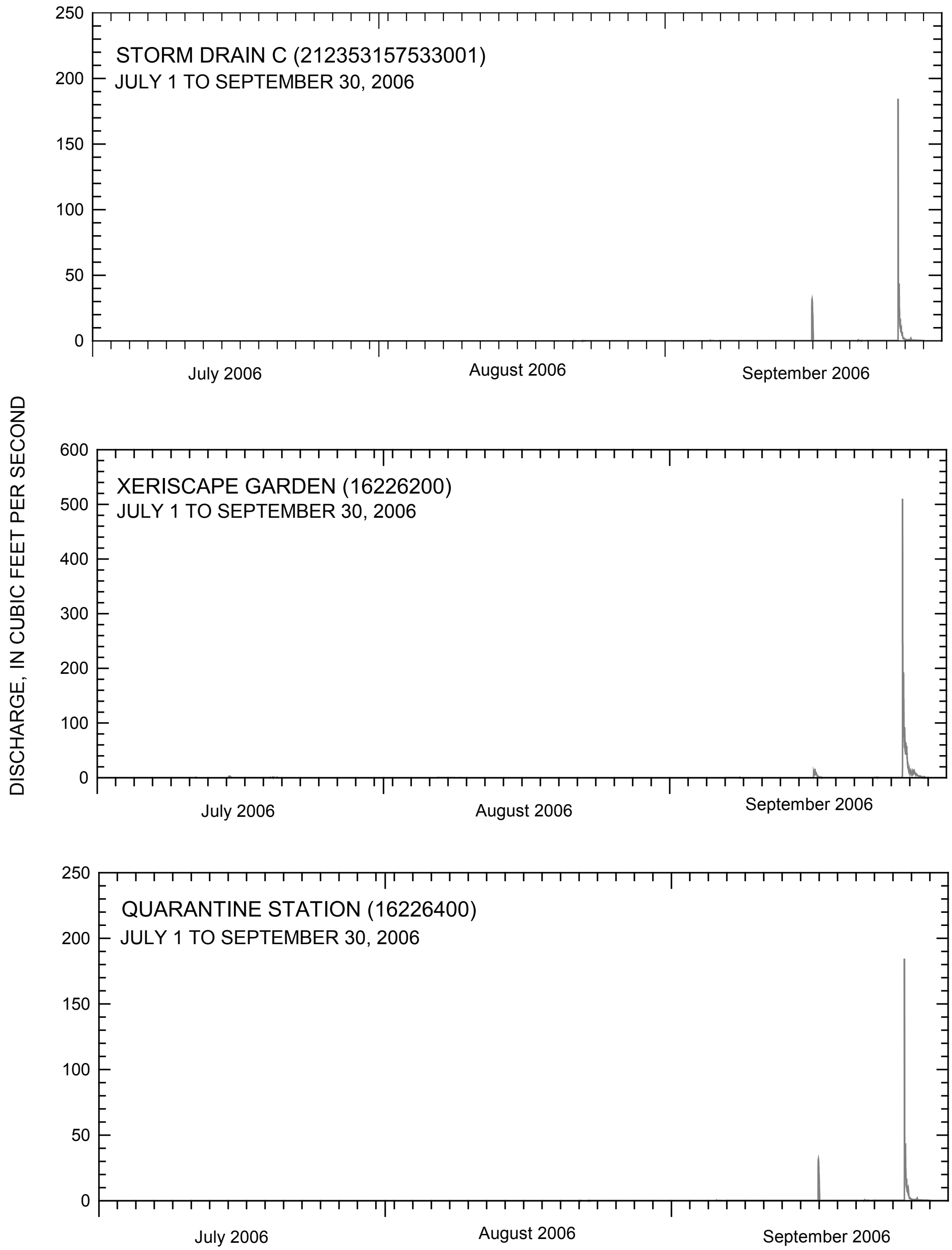

Figure 3. Discharge at Storm drain C (212353157533001), Xeriscape garden (16226200), and Quarantine stations (16226400) for July 1 to September 30, 2006, Oahu, Hawaii.

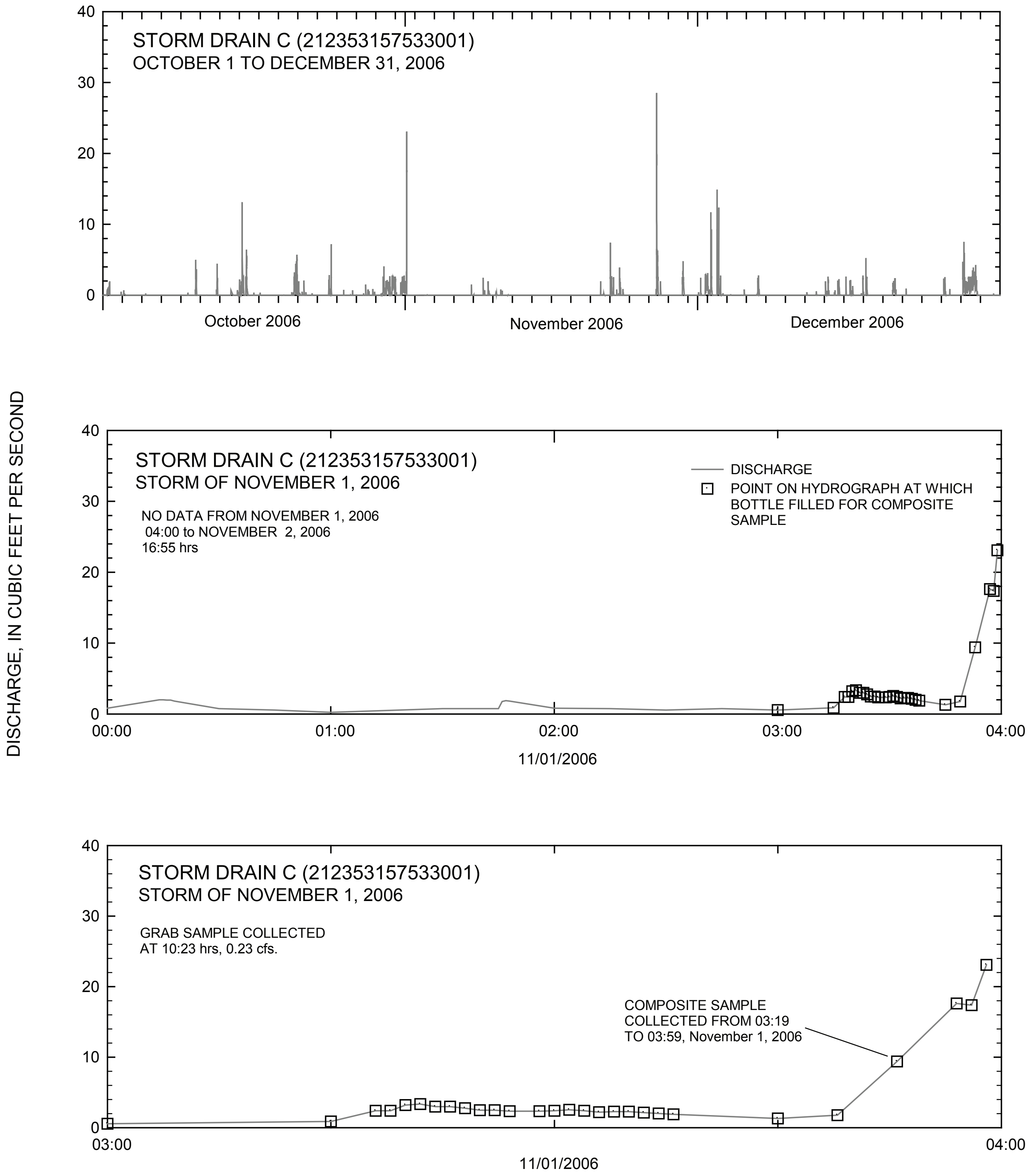

Figure 4. Discharge at Storm drain C station (212353157533001) for October 1 to December 31, 2006; detail of 4-hour period of November 1, 2006; and detail of the 1-hour period from 03:00 to 04:00 November 1, 2006, Oahu, Hawaii.

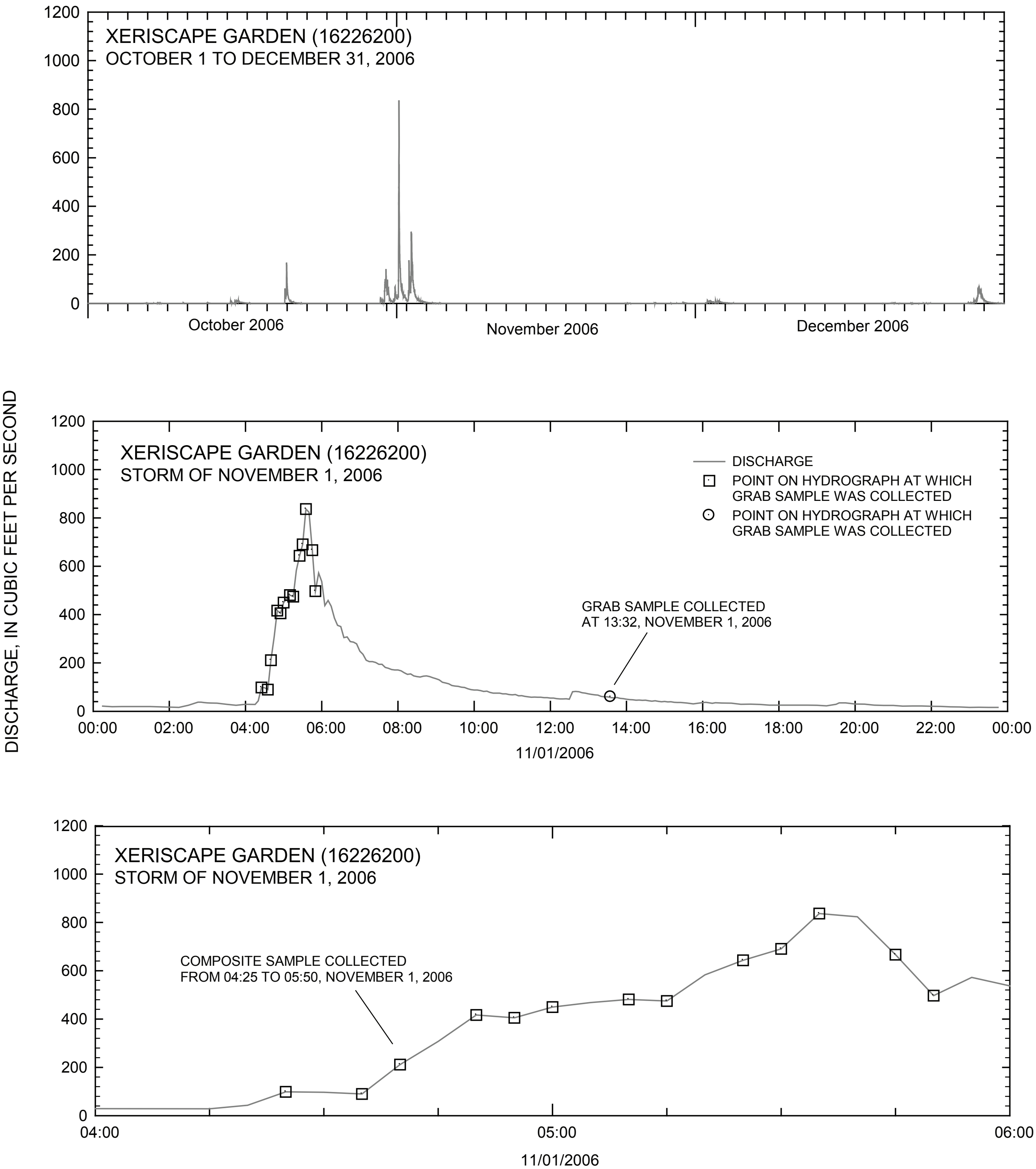

Figure 5. Stream discharge at Xeriscape garden station (16226200) for October 1 to December 31, 2006; detail of 1-day period of November 1, 2006; and detail of the 2-hour period from 04:00 to 06:00 November 1, 2006, Oahu, Hawaii.

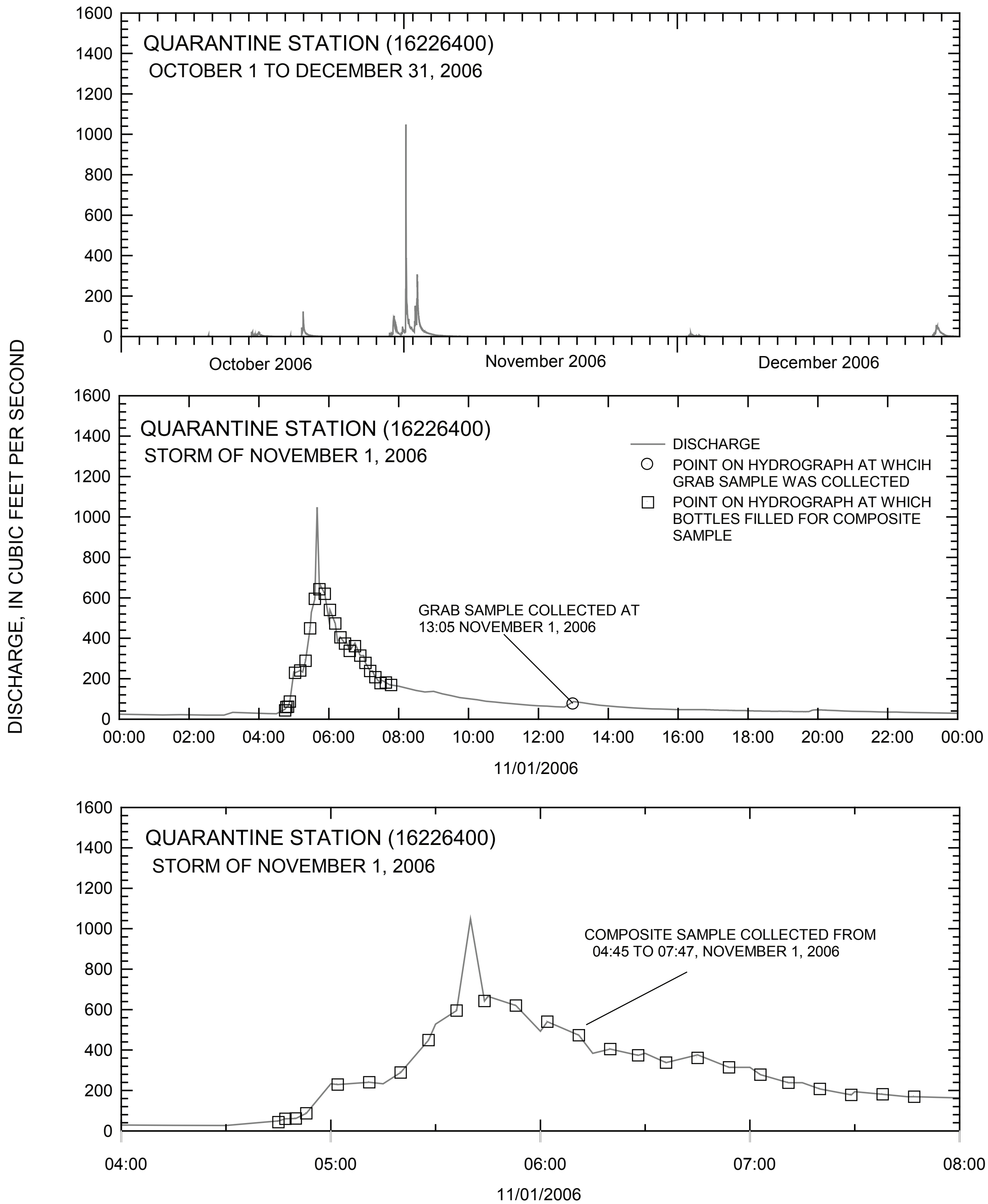

Figure 6. Stream discharge at Quarantine station (16226400) for October 1 to December 31, 2006; detail of 1-day period of November 1, 2006; and detail of the 4-hour period from 04:00 to 08:00 November 1, 2006, Oahu, Hawaii.

Bridge 8.--The grab sample was collected using the EWI method. The sampling cross section was about 19 ft wide, and was sampled at 1.0 ft intervals. A discharge of 93.2 ft^3/s was measured about 10 minutes after sampling using a current meter.

Storm drain C.-- One grab sample was collected at the centroid of flow in the storm drain by directly submersing the churn. At the time of the grab sample, the discharge was 0.23 ft^3/s (fig. 4). Discharge associated with the grab sample was determined using the stage at the median time of the grab-sample collection and the streamflow rating for this gage.

Storm drain C sampling and recording instruments experienced low power during the storm. The automatic sampler stopped after six samples were collected and the logger stopped recording at 04:00 hrs on November 1, 2006. The automatic samples, that were collected, may not have been at peak stages. The automatic sampler collected a total of six samples during the storm and all six samples were used to create a flow-weighted, time-composite sample. The peak discharge was 23 ft^3/s on November 1, 2006 at 03:59. The average discharge was computed to be 1.4 ft^3/s.

Xeriscape garden.-- One grab sample was collected by using the EWI method. The sampling cross section was 30 ft wide and was sampled at 2 ft intervals. The discharge measured was 59.0 ft^3/s (fig. 5) using a current meter. A field duplicate sample was collected from this site and analyzed for nutrients and metals.

The automatic sampler collected a total of 24 samples. However, the first 11 automatic samples were collected on October 31, 2006 and were omitted. The flow was flashy during the period when these samples were collected and resulted in an insufficient number of samples to create a composite sample. Automatic samples 12-24 were used to create a flow-weighted time-composite. The average discharge was computed to be 464 ft^3/s (fig. 5). The peak discharge was 837 ft^3/s (05:35) on November 1, 2006.

Quarantine station.--A grab sample was collected at the centroid of flow about 4 ft from the left bank at a cross section located at the gage. The stream was unwadable at time of sample collection. A field duplicate was submitted and analyzed for O+G and TPH only. A stream discharge of 73.0 ft^3/s (fig. 6) was measured concurrently with sampling using a current meter at a cross section located downstream from the gage .

The automatic sampler collected 24 samples and all were used to create a flow-weighted time-composite. The average discharge was computed to be 338 ft^3/s (fig. 6). The peak discharge was 1,050 ft^3/s on November 1, 2006 at 05:40.

Stadium.--A grab sample was collected using the EWI method. The sample cross section was 53 ft wide, and was sampled at 1 ft intervals. A stream discharge of 129 ft^3/s was measured concurrently with sampling using a current meter.

First Quarter 2007 – January 1 to March 31, 2007

Hydrographs showing discharge during the first quarter 2007 for Storm drain C, Xeriscape garden, and Quarantine stations are shown in Figure 7. No storms were sampled during this quarter. One storm occurred on January 8, 2007, had peak discharges that exceeded the sampling thresholds at Xeriscape garden and Quarantine stations (fig. 7). However due to the flashiness of flow and rapid decrease in stage at Storm drain C and Quarantine stations, a sufficient number of automatic samples was not collected to create a composite sample that represented the storm.

Second Quarter 2007 – April 1 to June 30, 2007

One storm was sampled during the second quarter 2007 on June 5. A partial set of samples was collected due to lack of flow at the time of sampling at all sites. Automatic samples were collected at Storm drain C, Xeriscape garden, and Quarantine stations. However at Storm drain C, the automatic sample stage thresholds were exceeded in the days prior to the sampling day which resulted in all 24 automatic samples being filled prior to the June 5 storm. A sufficient number of automatic samples were collected at Xeriscape garden to create a composite sample. At Quarantine station, the automatic sample stage thresholds were exceeded for a short period and resulted in three automatic samples being collected. No FC or BOD was analyzed since only automatic samples were collected and holding times for these constituents were exceeded.

Storm of June 5, 2007

Xeriscape garden.-- The automatic sampler collected a total of 22 samples. The first two automatic samples were used to create a grab samples to analyzed for O+G and TPH. The remaining 20 automatic samples were used to create a flow-weighted time-composite. The average discharge for this sample was 86 ft^3/s (fig. 8). The peak discharge was 117 ft^3/s (03:55) on June 5, 2007.

Quarantine station.-- The automatic sampler collected three samples. The first two automatic samples were used to create grab samples and were analyzed for O+G and TPH. The third automatic sample was not used since there was sufficient sample volume for the O+G and TPH bottles. The average discharge was computed to be 30 ft^3/s (fig. 9). The peak discharge was 44 ft^3/s on June 5, 2007 at 07:45.

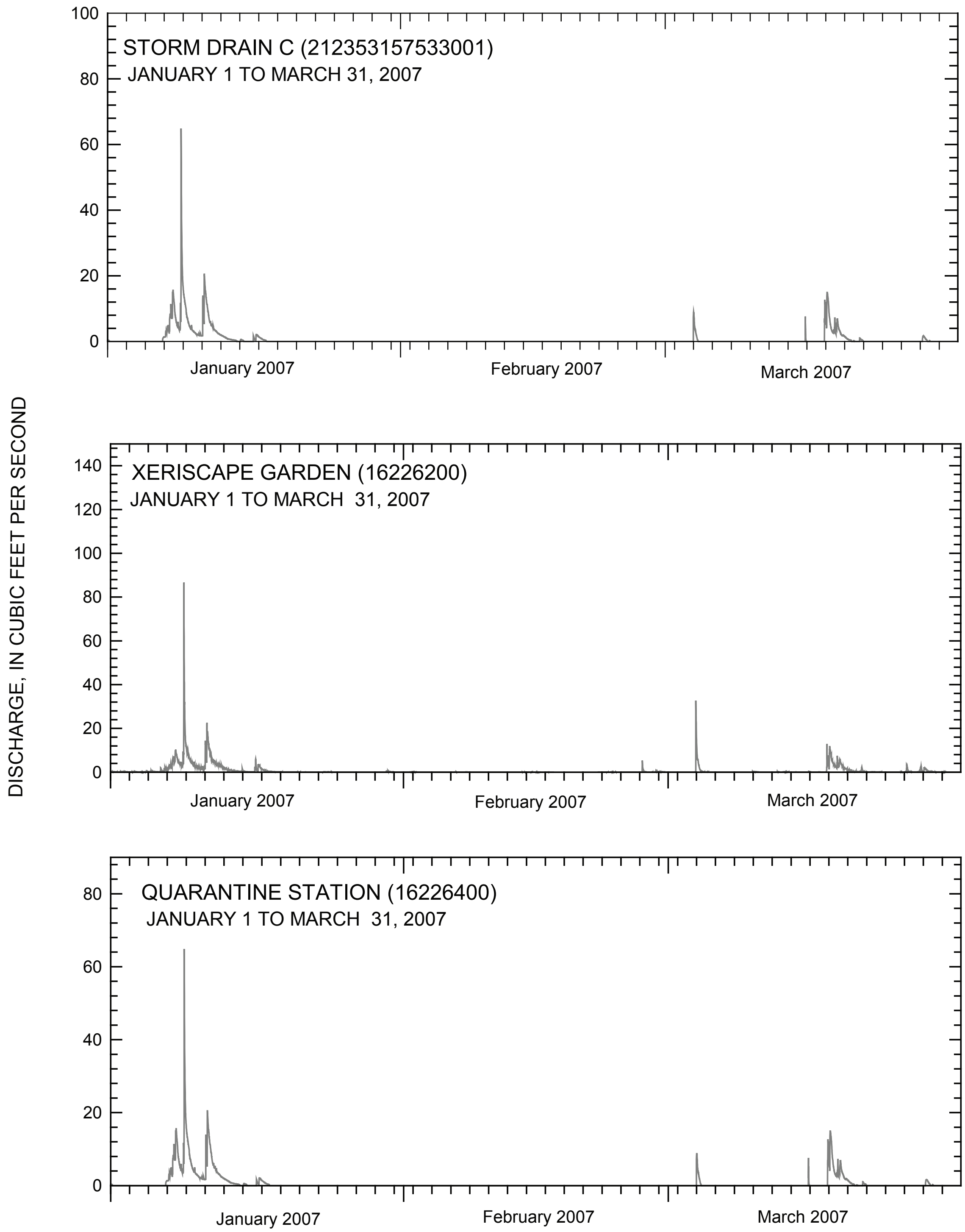

Figure 7. Discharge at Storm drain C (212353157533001), Xeriscape garden (16226200), and Quarantine stations (16226400) for January 1 to March 31, 2007, Oahu, Hawaii.

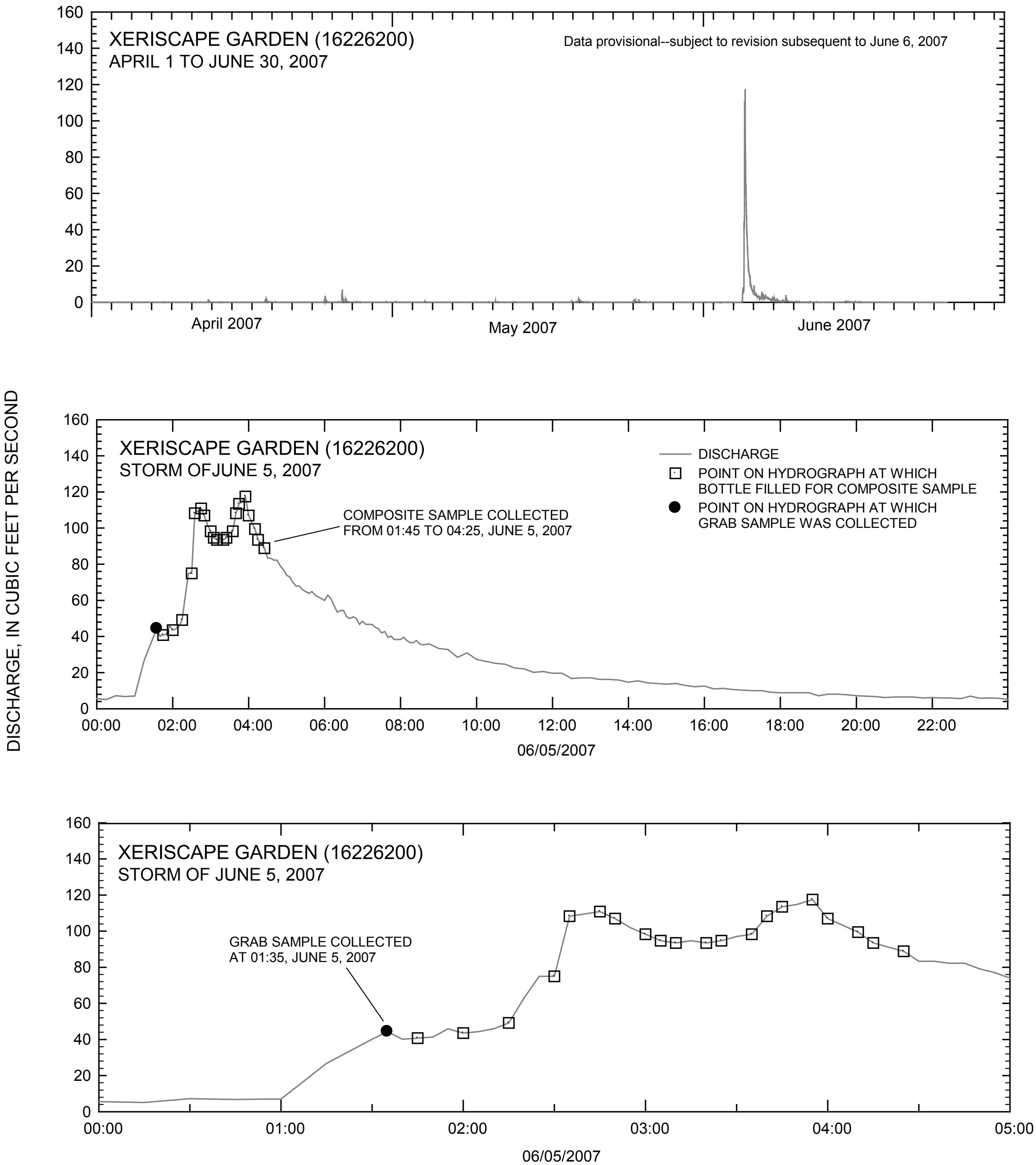

Figure 8. Stream discharge at Xeriscape garden station (16226200) for April 1 to June 30, 2007; detail of 1-day period of June 5, 2007; and detail of the 5-hour period from 00:00 to 05:00 June 5, 2007, Oahu, Hawaii.

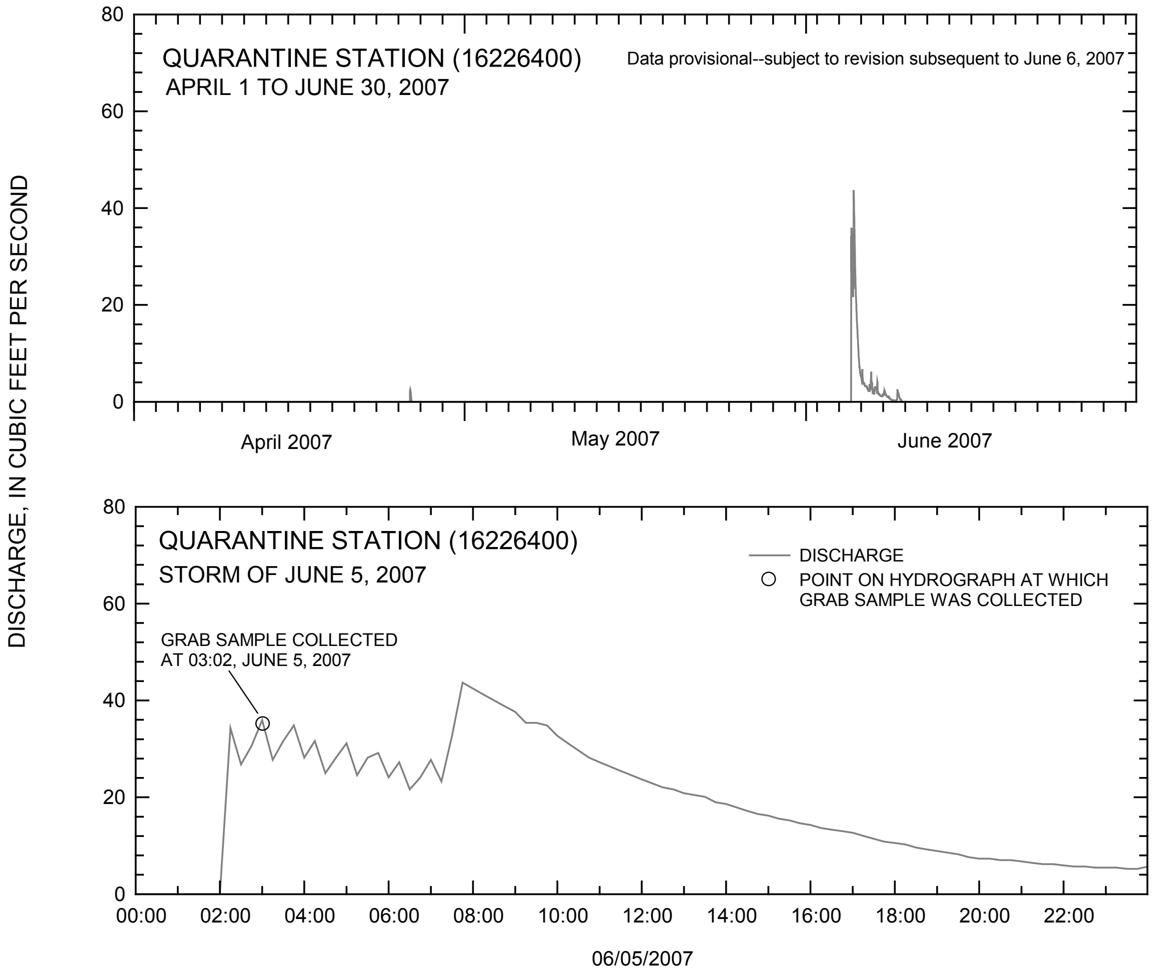

Figure 9. Stream discharge at Quarantine station (16226400) for April 1 to June 30, 2007 and detail of 1-day period of June 5, 2007, Oahu, Hawaii.

Quality Assurance

Field and laboratory quality-assurance procedures were implemented as described in the DOT Storm Water Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2006). Three quality-assurance samples were collected: two field-duplicate samples were collected during one of the two of the storms, and one inorganic-blank-water (IBW) sample was collected between storms after routine cleaning of the sampling equipment. Results are not published in this report, but are available from the USGS Pacific Islands Water Science Center upon request.

All grab-sample-collection and sample processing equipment were cleaned prior to use. The automatic-sampler intake lines were cleaned three times during the year at Storm drain C, and two times at Xeriscape garden and Quarantine stations. The automatic sampler conducts a rinse cycle prior to every sample collected. The rinse cycle routine is as follows: (1) sample line is first purged by air, (2) water is pumped up the line to a sensor located before the pump, (3) water is purged out, and (4) the sample is then collected.

IBW field-blank samples from the automatic samplers were collected at Storm Drain C on January 9, 2007. Intake lines were cleaned prior to the collection of IBW field-blank samples. The field-blank samples were analyzed for inorganic constituents only, which consisted of nutrients, cadmium, copper, lead, chromium, nickel, and zinc. Results are not published in this report, but are available from the USGS Pacific Islands Water Science Center upon request.

Inorganic constituents were detected at levels at or below the minimum reporting levels for most constituents, which are listed in Table 1. Lead and zinc were detected in the field blank collected on January 9, 2007 at concentrations above the minimum reporting levels.

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Appendix A: Discharge-Reporting and Load-Calculation Methods

This appendix further defines the methods used for reporting discharge data and constituent-concentration data and the methods for calculating constituent loads. Discharge and water-quality-data values are rounded off to the number of significant figures that best describe the precision of the measurement.

Discharge data.--Table 2 shows the number of significant figures and rounding limits for the range of discharges used in this study. Discharges measured by current meter or float-measurement techniques follow guidelines for measured discharges. Discharges determined by streamflow rating or by averaging follow guidelines for daily mean discharges (Sauer, 2002). Measured discharges may have more significant figures because they are considered more precise than averaged discharges.

Table 2. Significant figures and rounding limits for measured, streamflow-rating, and averaged discharges

[ft^3/s, cubic feet per second; <, actual value is less than shown; ≥ actual value is greater than or equal to value shown]

Range of discharge (ft3/s)	Measured discharge		Streamflow-rating and averaged discharges	
	Significant figures	Rounding limit	Significant figures	Rounding limit
<0.10	2	thousandths	1	hundredths
≥ 0.10 and <1.0	2	hundredths	2	hundredths
≥ 1.0 and < 10	3	hundredths	2	tenths
≥ 10 and < 100	3	tenths	2	units
≥ 100	3	variable	3	variable

Calculation of loads.--Table 3 shows the conversion factors used for determining constituent loads. Constituent loads for all analyses are reported as pounds per day (lbs/day) except for fecal coliform, which is reported as billion colonies per day. All loads are the product of constituent concentration multiplied by associated discharge and the appropriate conversion factor (equation 1). Concentrations are reported in milligrams per liter (mg/L) or micrograms per liter (µg/L), except for fecal coliform, which is reported in most probable number (of colonies) per 100 milliliters (MPN/100 ml). Four significant figures are used for the conversion factors; however, the load value is reported with the lesser number of significant figures of the values of concentration and discharge.

$$Q\ (C)\ K = L \qquad (1)$$

Where

Q = discharge ($^{ft^3}/_{s}$)
C = constituent concentration ($^{mg}/_{L}$, $^{\mu g}/_{L}$, or $^{MPN}/_{100ml}$)
K = conversion factor
L = constituent load ($^{lbs}/_{day}$ or billion colonies per day)

Table 3. Conversion factors for computing daily loads from constituent concentration and discharge

[mg/L, milligrams per liter; µg/L, micrograms per liter; MPN/100mL, most probable number (of colonies) per 100 milliliters; lbs/day, pounds per day]

Unit of concentration	Conversion factora	Load unit
mg/L	5.394	lbs/day
µg/L	0.005394	lbs/day
MPN/100mL	0.02447	billion colonies per day

[a]All conversion factors are based on discharge in cubic feet per second.

Appendix B: Physical Properties, Concentrations, and Loads for All Samples Collected from Halawa Stream Drainage Basin During the Period from July 1, 2006 to June 30, 2007, Oahu, Hawaii

Appendix B. Physical properties, concentrations, and loads for all samples collected from Halawa Stream drainage basin during the period from July 1, 2006 to June 30, 2007, Oahu, Hawaii

[hh:mm, hours and minutes; Instant., value of instantaneous discharge; Avg., value of average discharge for flow-weighted time-composite samples; Conc., concentration; Load, computed from concentration value and discharge value for each sample, loads associated with grab samples are instantaneous loads, loads associated with composite samples are average loads; <, actual value is less than the value shown; ≤, actual value is less than or equal to the value shown; #, discharge value from streamflow rating, all others are measured; e, value is estimated; --, not analyzed or measured; composite, flow-weighted time-composite sample; µS/cm, microsiemens per centimeter; ºC, degrees Celsius; ft^3/s, cubic feet per second; mg/L,milligrams per liter; lbs/day, pounds per day; µg/L,micrograms per liter; MPN/100 mL, most probable number (of colonies) per 100 milliliters]

Station name	Date	Median time (hh:mm)	Sample type	Discharge (ft^3/s)		pH, lab reporting to nearest 0.1	Specific conductance (µS/cm at 25°C) reporting to nearest whole number	Temperature (°C) reporting to nearest 0.5 °C	Total suspended solids		Total dissolved solids		Total nitrogen[a]	
				Instant.	Avg.				Conc. (mg/L)	Load (lbs/day)	Conc. (mg/L)	Load (lbs/day)	Conc. (mg/L as N)	Load (lbs/day)
Storm of November 1, 2006														
Bridge 8	November 1, 2006	12:00	Grab	93.2		7.1	95	22.4	30	15,000	56	28,000	0.31	160
Storm drain	November 1, 2006	03:40	Composite		#7.8	8.2	36	--	<10	<420	28	1,200	e0.20	e8.4
Storm drain	November 1, 2006	10:23	Grab	#0.23		7.7	147	23.8	<10	<12	93	120	0.59	0.73
Xeriscape	November 1, 2006	05:03	Composite		#464	1.5	e 21,900	--	2,160	5,410,000	34	85,000	<5.86	<14,700
Xeriscape	November 1, 2006	13:32	Grab	59.0		7.2	93	22.4	51	16,000	51	16,000	0.40	130
Quarantine	November 1, 2006	06:16	Composite		#338	7.6	94	--	1,810	3,300,000	36	66,000	4.76	8,680
Quarantine	November 1, 2006	13:05	Grab	73.0		6.7	96	22.4	63	25,000	51	20,000	0.45	180
Stadium	November 1, 2006	11:29	Grab	129		7.6	93	22.6	106	73,800	59	41,000	0.59	410
Storm of June 5, 2007														
Xeriscape	June 5, 2007	01:35	Grab		#40	--	--	--	--	--	--	--	--	--
Xeriscape	June 5, 2007	03:05	Composite		#86	7.8	78	--	122	57,000	70	32,000	1.40	650
Quarantine	June 5, 2007	03:02	Grab		#30	--	--	--	--	--	--	--	--	--

Appendix B. Physical properties, concentrations, and loads for all samples collected from Halawa Stream drainage basin during the period from July 1, 2006 to June 30, 2007, Oahu, Hawaii--Continued

[hh:mm, hours and minutes; Instant., value of instantaneous discharge; Avg., value of average discharge for flow-weighted time-composite samples; Conc., concentration; Load, computed from concentration value and discharge value for each sample, loads associated with grab samples are instantaneous loads, loads associated with composite samples are average loads; <, actual value is less than the value shown; ≤, actual value is less than or equal to the value shown; #, discharge value from streamflow rating, all others are measured; e, value is estimated; --, not analyzed or measured; composite, flow-weighted time-composite sample; µS/cm, microsiemens per centimeter; ºC, degrees Celsius; ft^3/s, cubic feet per second; mg/L,milligrams per liter; lbs/day, pounds per day; µg/L,micrograms per liter; MPN/100 mL, most probable number (of colonies) per 100 milliliters]

Station name	Date	Median time (hh:mm)	Sample Type	Organic nitrogen[b]		Ammonia dissolved		Nitrogen, total organic + ammonia		Nitrogen, nitrite + nitrate dissolved		Phosphorus dissolved	
				Conc. (mg/L as N)	Load (lbs/day)	Conc. (mg/L as N)	Load (lbs/day)	Conc. (mg/L as N)	Load (lbs/day)	Conc. (mg/L as N)	Load (lbs/day)	Conc. (mg/L as P)	Load (lbs/day)
Storm of November 1, 2006													
Bridge 8	November 1, 2006	12:00	Grab	≤ 0.19	≤ 96	<0.02	<10	0.19	96	0.12	60	<0.04	<20
Storm drain	November 1, 2006	03:40	Composite	0.15	6.3	0.025	1.1	0.17	7.2	e0.03	e1	<0.04	<2
Storm drain	November 1, 2006	10:23	Grab	≤ 0.19	≤ 0.24	<0.02	<0.02	0.19	0.24	0.40	0.50	e0.03	e0.04
Xeriscape	November 1, 2006	05:03	Composite	≤ 5.8	≤14,000	<0.02	<50	5.8	15,000	<0.06	<200	e0.02	e50
Xeriscape	November 1, 2006	13:32	Grab	≤ 0.28	≤ 89	<0.02	<6	0.28	89	0.12	38	<0.04	<10
Quarantine	November 1, 2006	06:16	Composite	≤ 4.7	≤ 8,600	<0.02	<40	4.7	8,600	0.06	100	<0.04	<70
Quarantine	November 1, 2006	13:05	Grab	≤ 0.33	≤ 130	<0.02	<8	0.33	130	0.12	47	<0.04	<20
Stadium	November 1, 2006	11:29	Grab	≤ 0.45	≤ 310	<0.02	<10	0.45	310	0.14	97	<0.04	<30
Storm of June 5, 2007													
Xeriscape	June 5, 2007	01:35	Grab	--	--	--	--	--	--	--	--	--	--
Xeriscape	June 5, 2007	03:05	Composite	≤ 1.3	≤ 600	<0.02	<9	1.3	600	0.10	46	e0.02	e9
Quarantine	June 5, 2007	03:02	Grab	--	--	--	--	--	--	--	--	--	--

Appendix B. Physical properties, concentrations, and loads for all samples collected from Halawa Stream drainage basin during the period from July 1, 2006 to June 30, 2007, Oahu, Hawaii--Continued

[hh:mm, hours and minutes; Instant., value of instantaneous discharge; Avg., value of average discharge for flow-weighted time-composite samples; Conc., concentration; Load, computed from concentration value and discharge value for each sample, loads associated with grab samples are instantaneous loads, loads associated with composite samples are average loads; <, actual value is less than the value shown; ≤, actual value is less than or equal to the value shown; #, discharge value from streamflow rating, all others are measured; e, value is estimated; --, not analyzed or measured; composite, flow-weighted time-composite sample; µS/cm, microsiemens per centimeter; ºC, degrees Celsius; ft^3/s, cubic feet per second; mg/L,milligrams per liter; lbs/day, pounds per day; µg/L,micrograms per liter; MPN/100 mL, most probable number (of colonies) per 100 milliliters]

Station name	Date	Median time (hh:mm)	Sample type	Total phosphorus		Chemical oxygen demand		Total cadmium		Total chromium	
				Conc. (mg/L as P)	Load (lbs/day)	Conc (mg/L)	Load (lbs/day)	Conc. (µg/L as Cd)	Load (lbs/day)	Conc. (µg/L as Cr)	Load (lbs/day)
Storm of November 1, 2006											
Bridge 8	November 1, 2006	12:00	Grab	e0.04	e20	<10	<5,000	<0.02	<0.01	6	3
Storm drain	November 1, 2006	03:40	Composite	e0.03	e1	<10	<400	0.03	0.001	2	0.08
Storm drain	November 1, 2006	10:23	Grab	0.05	0.06	<10	<10	0.02	0.00002	5	0.006
Xeriscape	November 1, 2006	05:03	Composite	2.11	5,280	220	550,000	0.36	0.9	202	506
Xeriscape	November 1, 2006	13:32	Grab	0.07	20	<10	<3,000	e0.01	e0.003	9	3
Quarantine	November 1, 2006	06:16	Composite	1.86	3,390	170	310,000	0.30	0.55	153	279
Quarantine	November 1, 2006	13:05	Grab	0.10	39	10	4,000	e0.01	e0.004	11	4.3
Stadium	November 1, 2006	11:29	Grab	0.14	97	20	10,000	e0.01	e0.007	15	10
Storm of June 5, 2007											
Xeriscape	June 5, 2007	01:35	Grab	--	--	--	--	--	--	--	--
Xeriscape	June 5, 2007	03:05	Composite	0.23	110	60	30,000	0.10	0.046	13	6
Quarantine	June 5, 2007	03:02	Grab	--	--	--	--	--	--	--	--

Appendix B. Physical properties, concentrations, and loads for all samples collected from Halawa Stream drainage basin during the period from July 1, 2006 to June 30, 2007, Oahu, Hawaii--Continued

[hh:mm, hours and minutes; Instant., value of instantaneous discharge; Avg., value of average discharge for flow-weighted time-composite samples; Conc., concentration; Load, computed from concentration value and discharge value for each sample, loads associated with grab samples are instantaneous loads, loads associated with composite samples are average loads; <, actual value is less than the value shown; ≤, actual value is less than or equal to the value shown; #, discharge value from streamflow rating, all others are measured; e, value is estimated; --, not analyzed or measured; composite, flow-weighted time-composite sample; µS/cm, microsiemens per centimeter; ºC, degrees Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; lbs/day, pounds per day; µg/L, micrograms per liter; MPN/100 mL, most probable number (of colonies) per 100 milliliters]

Station name	Date	Median time (hh:mm)	Sample Type	Total copper		Total lead		Total nickel		Total zinc	
				Conc. (µg/L as Cu)	Load (lbs/day)	Conc. (µg/L as Pb)	Load (lbs/day)	Conc. (µg/L as Ni)	Load (lbs/day)	Conc. (µg/L as Zn)	Load (lbs/day)
Storm of November 1, 2006											
Bridge 8	November 1, 2006	12:00	Grab	3.8	1.9	0.11	0.055	3.42	1.72	4	2
Storm drain	November 1, 2006	03:40	Composite	5.2	0.22	1.51	0.064	1.50	0.063	26	1.1
Storm drain	November 1, 2006	10:23	Grab	5.2	0.0065	0.37	0.00046	1.08	0.0013	13	0.016
Xeriscape	November 1, 2006	05:03	Composite	133	333	9.78	24.5	126	315	143	358
Xeriscape	November 1, 2006	13:32	Grab	5.6	1.8	0.23	0.073	5.17	1.65	13	4.1
Quarantine	November 1, 2006	06:16	Composite	113	206	8.00	14.6	94.4	172	127	231
Quarantine	November 1, 2006	13:05	Grab	7.4	2.9	0.40	0.16	6.89	2.71	8	3
Stadium	November 1, 2006	11:29	Grab	9.5	6.6	0.56	0.39	9.11	6.3	11	7.7
Storm of June 5, 2007											
Xeriscape	June 5, 2007	01:35	Grab	--	--	--	--	--	--	--	--
Xeriscape	June 5, 2007	03:05	Composite	20.8	9.6	3.34	1.5	9.1	4.2	49.8	23
Quarantine	June 5, 2007	03:02	Grab	--	--	--	--	--	--	--	--

Appendix B. Physical properties, concentrations, and loads for all samples collected from Halawa Stream drainage basin during the period from July 1, 2006 to June 30, 2007, Oahu, Hawaii--Continued

[hh:mm, hours and minutes; Instant., value of instantaneous discharge; Avg., value of average discharge for flow-weighted time-composite samples; Conc., concentration; Load, computed from concentration value and discharge value for each sample, loads associated with grab samples are instantaneous loads, loads associated with composite samples are average loads; <, actual value is less than the value shown; ≤, actual value is less than or equal to the value shown; #, discharge value from streamflow rating, all others are measured; e, value is estimated; --, not analyzed or measured; composite, flow-weighted time-composite sample; µS/cm, microsiemens per centimeter; ºC, degrees Celsius; ft^3/s, cubic feet per second; mg/L,milligrams per liter; lbs/day, pounds per day; µg/L,micrograms per liter; MPN/100 mL, most probable number (of colonies) per 100 milliliters]

Station name	Date	Median time (hh:mm)	Sample type	Oil and grease		Total petroleum hydrocarbons		Biological oxygen demand		Fecal coliform	
				Conc. (mg/L)	Load (lbs/day)	Conc. (mg/L)	Load (lbs/day)	Conc. (mg/L)	Load (lbs/day)	Conc. (MPN/100 mL)	Load (billion colonies per day)
Storm of November 1, 2006											
Bridge 8	November 1, 2006	12:00	Grab	<7	<4,000	<2	<1,000	<1	<500	600	1,000
Storm drain	November 1, 2006	03:40	Composite	--	--	--	--	--	--	--	--
Storm drain	November 1, 2006	10:23	Grab	<7	<9	<2	<2	<1	<1	16,000	90
Xeriscape	November 1, 2006	05:03	Composite	--	--	--	--	--	--	--	--
Xeriscape	November 1, 2006	13:32	Grab	<7	<2,000	<2	<600	<1	<300	700	1,000
Quarantine	November 1, 2006	06:16	Composite	--	--	--	--	--	--	--	--
Quarantine	November 1, 2006	13:05	Grab	e4	e2,000	2	800	<1	<400	1,600	2,900
Stadium	November 1, 2006	11:29	Grab	<7	<5,000	2	1,000	<1	<700	2,200	6,900
Storm of June 5, 2007											
Xeriscape	June 5, 2007	01:35	Grab	e6	e1,000	4	900	--	--	--	--
Xeriscape	June 5, 2007	03:05	Composite	--	--	--	--	--	--	--	--
Quarantine	June 5, 2007	03:02	Grab	e4	e600	2	300	--	--	--	--

[a] Total nitrogen is calculated by adding nitrogen, total organic + ammonia (Kjeldahl), to nitrogen, nitrite + nitrate, dissolved. If the concentration value of nitrogen, nitrite + nitrate dissolved, is estimated and below the minimum reporting level, the concentration value of total nitrogen is reported as the sum of the values shown for nitrogen, total organic + ammonia and nitrogen, nitrite + nitrate dissolved, and noted as estimated. If the concentration value of nitrogen, nitrite + nitrate, dissolved is below the minimum reporting level, the concentration value of total nitrogen is reported as less than the sum of the values shown for nitrogen, total organic + ammonia and nitrogen, nitrite + nitrate dissolved, which represents the maximum possible value for total nitrogen.

[b] Organic nitrogen is calculated by subtracting nitrogen ammonia, dissolved, from total organic + ammonia (Kjeldahl). If the concentration value of nitrogen ammonia, dissolved is below the minimum reporting level, the concentration value for organic nitrogen is reported as less than or equal to the value of total organic + ammonia (Kjeldahl), which represents the maximum possible value for organic nitrogen. If the concentration value of nitrogen ammonia, dissolved is estimated and below the minimum reporting level, the concentration value of organic nitrogen is reported as the difference between the values shown for nitrogen, total organic + ammonia (Kjeldahl), and nitrogen ammonia, dissolved, and noted as estimated.

USGS

Young and Jamison—**Rainfall, Streamflow, and Water-Quality Data During Stormwater Monitoring, Halawa Stream Drainage Basin, Oahu, Hawaii, July 1, 2006 to June 30, 2007**—Open-File Report 2007–1213