NIAGARA POWER PROJECT

RELICENSING

WATER TEMPERATURES OF THE NIAGARA RIVER AND ITS U.S. TRIBUTARIES

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EXECUTIVE SUMMARY

This study was conducted to: 1) determine if water level fluctuations in the Niagara River affect water temperatures in the Niagara River, U.S. tributaries of the Niagara River, and Lewiston Reservoir, and, if so, 2) describe the nature and extent of the temperature effects and their potential influence on the behavior and survival of fish.

The study area extended from the head of the Niagara River to its mouth and was divided into six zones based on physical habitat characteristics (water depth, water velocity, substrate, presence of vegetation) that influence the distribution of fish species:

- Zone 1 - Buckhorn Marsh and tributaries of the Niagara River
- Zone 2 - Deeper portions of the upper Niagara River (the channel)
- Zone 3 - Shallower portions of the upper Niagara River (shoals)
- Zone 4 - The lower Niagara River between Niagara Falls and the tailrace of the Niagara Power Project (the gorge)
- Zone 5 - The lower Niagara River downstream of the tailrace of the Niagara Power Project
- Zone 6 - Lewiston Reservoir

The first objective was addressed by comparing portions of the six zones that were influenced by water level changes in the Niagara River with appropriate reference conditions to determine if there were differences in maximum and minimum water temperatures that occur daily and seasonally, the periodicity of temperature changes, and hourly rate of change in water temperature. The second objective was addressed by describing the temperatures in zones affected by water level changes in the Niagara River and assessing the potential for those temperature changes to affect the behavior and survival of fish from 18 species considered representative of their communities, listed as threatened or endangered species, or known to be the target of important recreational fisheries.

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Water level and water temperature data were collected from temporary gauges during 2002 and 2003. During 2002:

- Water temperature was recorded every 15-minutes from April to November 2002 at 21 sites in the upper and lower Niagara River, Woods Creek, Buckhorn Marsh, Burnt Ship Creek, Big Sixmile Creek, Gun Creek, Spicer Creek, and around Strawberry Island;
- Water level was recorded every 15-minutes from March to November 2002 at 10 temporary gauge locations in the upper and lower Niagara River, Woods Creek, Buckhorn Marsh, and Burnt Ship Creek;
- Water level was recorded at eight permanent water level gauges in the upper and lower Niagara River and Lewiston Reservoir.

During 2003, water temperature data were collected from February or March, to November in:

- Burnt Ship Creek, Buckhorn Marsh, Woods Creek, Gun Creek, Spicer Creek, Big Sixmile Creek, Tonawanda Creek, Ellicott Creek, Cayuga Creek, Gill Creek, Fish Creek, Lewiston Reservoir;
- The channel of the upper Niagara River upstream of the mouth of Spicer Creek, downstream of the mouth of Woods Creek, just upstream of the Niagara Power Project intakes, and near the Peace Bridge;
- The lower Niagara River upstream of the Niagara Power Project tailrace, in the tailrace, just downstream of the tailrace, at the Lewiston Landing, Artpark, Joseph Davis State Park, and the Youngstown Yacht Club.

Water level was recorded hourly during 2003 from February or March, to November in:

- Burnt Ship Creek, Buckhorn Marsh, Woods Creek, Gun Creek, Spicer Creek, Big Sixmile Creek, Tonawanda Creek, Ellicott Creek, Cayuga Creek;

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- The lower Niagara River upstream of the Niagara Power Project tailrace, Artpark, Lewiston Landing, Joseph Davis State Park, and near the Youngstown Yacht Club.

Data from permanent water level gauges in the upper Niagara River and Lewiston Reservoir were also collected in 2003 as in 2002. Water level data from Lewiston Reservoir, Material Dock, Slater's Point, NYPA Intake, Tonawanda Island, Huntley, Black Creek, Frenchman's Creek, Fort Erie, and Port Weller (Lake Ontario) were used in this analysis. Temporary water level gauge data were plotted in relation to permanent gauge data in the upper Niagara River, Lake Ontario or Lewiston Reservoir, as appropriate.

Hourly air temperature, relative humidity, barometric pressure, solar radiation, precipitation, and wind direction and speed data were collected at two local, National Oceanic and Atmospheric Administration (NOAA) weather stations (Niagara Falls International Airport and Buffalo Niagara International Airport) from March 2002 to November 2002 and from February 2003 to November 2003.

Water level fluctuations did not affect the normal range in seasonal and diurnal temperatures and did not affect the hourly rate of temperature change anywhere in Zones 2, 4, 5, and 6. However, water level fluctuations did cause more rapid changes in water temperature at several gauges in Zones 1 and 3. Zone 1 water temperature changes ranging from –6.5 to +2.3 ºC/hour occurred at 16 of 39 gauges, mostly in the lower reaches of tributaries near the confluence with the Niagara River. In Zone 3, water temperature changes ranging from -4.1 to +4.4 ºC/hour occurred at two of seven locations, both at or immediately downstream of tributary mouths. The areal extent of the hourly temperature changes was not evaluated.

The potential for water temperature changes of the magnitude that occurred during 2002 and 2003 to affect the behavior and survival of fishes in the study area appears relatively small. They are adapted to the range of daily and seasonal water temperatures that occur in the study area. The rate of change in water temperature at all locations was not large enough to potentially reduce survival rates because of cold shock or heat shock or to potentially cause avoidance behavior in most species and life stages. More

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frequent water temperature changes may displace fish in limited portions of the study area but the potential is considered relatively small.

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ABBREVIATIONS

Agencies

FERC	Federal Energy Regulatory Commission
IJC	International Joint Commission
INBC	International Niagara Board of Control
NOAA	National Oceanic and Atmospheric Administration
USFWS	United States Fish and Wildlife Service

Units of Measure

$\Delta°C_{AT}$	hourly change in air temperature in degrees Centigrade (positive or negative)
$\Delta°C_{WT}$	hourly change in water temperature in degrees Centigrade (positive or negative)
ΔT	change in temperature
ΔWL	hourly change in water level in feet (positive or negative)
C	Celsius, Centigrade
cfs	cubic feet per second
F	Fahrenheit
fps	feet per second

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ft	feet
MW	megawatt
psi	pounds per square inch
USLSD	U.S. Lake Survey Datum 1935

Environmental

DO	dissolved oxygen
EAV	emergent aquatic vegetation
LILT	lower incipient lethal temperature
SAV	submerged aquatic vegetation
UILT	upper incipient lethal temperature

Miscellaneous

LPGP	Lewiston Pump Generating Plant
NFIA	Niagara Falls International Airport
NYPA	New York Power Authority
OPG	Ontario Power Generation
RMNPP	Robert Moses Niagara Power Project

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1.0 INTRODUCTION

The New York Power Authority (NYPA) is engaged in the relicensing of the Niagara Power Project (NPP) in Lewiston, Niagara County, New York. The present operating license of the plant expires in August 2007. As part of its preparation for the relicensing of the Niagara Project, NYPA is developing information related to the ecological, engineering, recreational, cultural, and socioeconomic aspects of the Project.

The 1,880 megawatt (MW) (firm capacity) NPP is one of the largest non-federal hydroelectric facilities in North America. The Project was licensed to the Power Authority of the State of New York (now the New York Power Authority) in 1957. Construction of the Project began in 1958, and electricity was first produced in 1961.

The Project has several components. Twin intakes are located approximately 2.6 miles above Niagara Falls, in a portion of the river referred to as the Chippawa-Grass Island Pool. Water levels within the pool are managed using the International Niagara Control Structure, a partial dam across the river. Water levels in the pool are raised using this structure, and drawn into the intakes. The intake water is routed around the Falls via two large low-head conduits to a 1.8-billion-gallon forebay, lying on an east-west axis about 4 miles downstream of the Falls. The forebay is located on the east bank of the Niagara River. At the west end of the forebay, between the forebay itself and the river, is the Robert Moses Niagara Power Plant (RMNPP), NYPA's main generating plant at Niagara. This plant has 13 turbines that generate electricity from water stored in the forebay. Head is approximately 300 feet. At the east end of the forebay is the Lewiston Pump Generating Plant (LPGP). Under non-peak-usage conditions (i.e., at night and on weekends), water is pumped from the forebay via the plant's 12 pumps into the 22-billion-gallon Lewiston Reservoir, which lies east of the plant. During peak usage conditions (i.e., daytime Monday through Friday), the pumps are reversed for use as generators, and water is allowed to flow back through the plant, producing electricity. The forebay therefore serves as headwater for the RMNPP and tailwater from the LPGP. South of the forebay is a switchyard, which serves as the electrical interface between the Project and its service area. Water levels in the forebay, which are directly influenced by power generation, in turn influence water levels in the Chippawa-Grass Island Pool.

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For purposes of generating electricity using the Niagara River, two seasons are recognized: tourist season and non-tourist season. By the 1950 Niagara River Water Diversion Treaty, at least 100,000 cfs must be allowed to flow over Niagara Falls during daytime hours in the tourist season (April 1 – October 31), and at least 50,000 cfs at all other times. Canada and the United States are entitled by international treaty to produce hydroelectric power using the remaining flows, sharing equally.

Water level fluctuations in the Chippawa-Grass Island Pool are limited by an International Joint Commission (IJC) directive to 1.5 feet per day unless conditions triggering special provisions occur. Water level fluctuations in both the upper and lower Niagara River are caused by a number of factors other than operation of the Niagara Power Project. These include wind, natural flow and ice conditions, regional and long-term precipitation patterns that affect lake levels, control of Niagara Falls flow for scenic purposes, operation of power plants on the Canadian side of the river, and the backwater effect from Lake Ontario. Water level fluctuations in the upper Niagara River from all causes are normally less than 1.5 feet per day.

During tourist season, water level fluctuations in the lower Niagara River (upstream of the RMNPP tailrace) normally amount to 10-12 feet per day. Water level fluctuations downstream of the RMNPP tailrace are much smaller. The average daily water level fluctuation 1.4 miles downstream of the RMNPP tailrace, during the 2002 tourist season, was approximately 1.5 feet.

Operation of the NPP can result in water level fluctuations in the Lewiston Reservoir of 3-18 feet per day, and as much as 36 feet per week.

1.1 Objectives

The objectives of this study were to: 1) determine if water level fluctuations in the Niagara River affect water temperatures in the Niagara River, U.S. tributaries of the Niagara River, and Lewiston Reservoir, and, if so, 2) describe the nature and extent of the temperature effects and their potential influence on the behavior and survival of fish. Rather than consider all fish species occurring in the Niagara River, 18 species (focus species) considered representative of the fish community in the investigation area, listed as threatened or endangered species, or known to be the target of important

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recreational fisheries were selected (Table 1.1-1). These are the same fish species considered in an earlier report that assessed the effect of water level fluctuations on habitat (Stantec et al. 2005), however, rainbow (steelhead) trout was also included in the present report.

Water level and flow fluctuations in both the upper and lower Niagara River are caused by a number of factors. Natural factors include flow surges from Lake Erie caused by wind, ice conditions, and regional and long-term precipitation patterns that affect lake levels. Manmade factors include boat wakes, regulation of Niagara Falls flows for scenic purposes, operation of hydroelectric plants on the Canadian side of the river, and operation of the NPP. The sources and extent of water level fluctuations in the Niagara River and its tributaries were examined in detail as part of the FERC relicensing effort (URS et al. 2005a). Because changes in water level are the result of the complex interplay between natural and multiple anthropogenic causes, it is difficult to distinguish the extent of water level change attributable to U.S./Canadian power generation versus other sources. Therefore, while temperature effects related to water level fluctuations may be identified, it is difficult to fully quantify what proportion of these effects can be attributed to U.S./Canadian power generation.

1.2 Investigation Area and Period

The investigation area for this analysis included the Niagara River from the Peace Bridge to its mouth on Lake Ontario, it's U.S. tributaries, and the Lewiston Reservoir (Figure 1.2-1). The period of analysis considered is from March 1st to November 30th, 2002 and 2003, however, the period from April 1st to October 31st is a focus of particular interest. During this latter period, referred to as the 'tourist season', regular water level fluctuations occur between day and night due to treaty obligations requiring minimum flows of 100,000 cfs over Niagara Falls during daylight hours. Water level fluctuation in the upper Niagara River from all causes, including power production by both U.S. and Canadian plants and natural factors, normally amounts to less than 1.5 feet per day as measured at Material Dock, the official monitoring gauge. The 1.5 foot daily water level fluctuation is allowed by the 1993 Directive of the International Niagara Board of Control (INBC). The portion of upper-river water level changes attributable to power production is the result of varying withdrawals of water by NYPA and Ontario Power Generation (OPG). It was found that regulation of the Chippawa-Grass Island Pool water levels has a more pronounced effect during the tourist than the non-tourist period. The reason for this is that

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during non-tourist hours the pool is maintained at a lower water level so that the scenic Falls flow remains close to 50,000 cfs. To compensate for water levels lower than the long-term mean specified by the 1993 Directive, the pool elevation is higher during tourist hours.

Tributary streams considered in this investigation are Big Sixmile Creek, Spicer Creek, Gun Creek, and the Burnt Ship Creek/Woods Creek/Buckhorn Marsh complex on Grand Island; and Tonawanda Creek, Ellicott Creek and Cayuga Creek on the mainland. Sections of these tributary streams are exposed to water level fluctuations in the Chippawa-Grass Island Pool. Gill Creek is a mainland tributary that receives flow augmentation from Lewiston Reservoir during summer months, and may therefore also be subject to temperature effects.

In addition to these drainages, Fish Creek, a tributary to the lower Niagara River is also examined. However, there is no potential for direct effects on water temperature on Fish Creek from water level fluctuations in the Niagara River. Fish Creek is exposed to groundwater seepage from Lewiston Reservoir at both locations where temperatures were monitored in 2003 (URS et al. 2005b). This creek enters the lower Niagara River via a high gradient cascade and the limited area of channel exposed to water level fluctuations in the lower Niagara River does not provide suitable fish habitat.

1.3 Causes of Water Temperature Fluctuations in the Investigation Area

There are three causes of water temperature fluctuation in the Niagara River and its tributaries. These include: seasonal variations in meteorological factors; diurnal (daily) variations in meteorological factors; and mixing of different water bodies at different temperatures. These three sources of temperature fluctuation vary in terms of the rate at which temperature changes occur, and the extent of area affected.

Temperature changes due to mixing can be associated with large rainfall events, natural changes in river elevation (e.g., due to storm surges, ice flows, etc.), changes in river elevation due to U.S./Canadian power generation, and possibly other sources such as boat wakes. The degree of temperature change is most pronounced when the difference in temperature between the water bodies being mixed is greatest. Changes in water temperature resulting from mixing tend to occur much more

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rapidly than diurnal fluctuations. For example, if fluctuations in Niagara River water levels cause river water to flow into and recede from tributaries, and tributary water is much warmer or cooler than the river water, water temperatures in the zone of mixing can change dramatically in a short period of time. Similarly, if shallow water areas of the Niagara River are at different temperatures from the main channel, fluctuations in water level could lead to relatively rapid changes in water temperature at those shallow water locations. In contrast to seasonal and diurnal temperature fluctuations, which are widespread, large rapid changes in water temperature due to mixing are limited to the area in which the mixing occurs. It is not unusual for a tributary stream to be a different temperature than its associated larger river, and the mixing of tributary and river water at the mouth of a tributary is a natural occurrence.

The influence of natural factors as well as manmade factors on Niagara River water level fluctuations should be considered when examining the effect of U.S./Canadian power generation on water temperature conditions. In general, water level fluctuations in the upper Niagara River are normally less than 1.5 feet per day (URS et al. 2005a). However, most of the largest daily water level fluctuations observed upstream of the Chippawa-Grass Island Pool were caused by natural factors. URS et al. (2005a) investigated the causes of large daily water level fluctuations along the Niagara River at eleven gauges. Of the ten highest recorded fluctuations for each of the nine upper river gauges (Material Dock, Slater's Point, NYPA Intake, LaSalle, Black Creek, Tonawanda Island, Huntley, Frenchman's Creek, and Fort Erie), 84% were attributed to rapid flow surges at Fort Erie. The remaining 16% of the large fluctuations, which were primarily for gauges in the Chippawa-Grass Island Pool (i.e., Material Dock, Slater's Point, NYPA Intake, LaSalle) were conservatively attributed to regulation but may also be partially caused by localized environmental conditions such as wind and local runoff.

In the lower Niagara River at the Ashland Avenue gauge (upstream of the RMNPP tailrace), water levels are typically affected most by the change in treaty flow requirements that occurs between the daytime (100,000 cfs) and nighttime (50,000 cfs) flows during the tourist season. Daily fluctuations normally range between 10 and 12 feet. However nine of the ten largest daily water level fluctuations which were between 17 and 23 feet, were caused by high flow surges from Lake Erie (URS et al. 2005a).

Water levels downstream of the RMNPP tailrace are a function of Lake Ontario level, discharge from RMNPP and Canadian plants, and flow rate over Niagara Falls. In general, water levels

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downstream of the RMNPP tailrace fluctuate much less than the levels between the Falls and tailrace since the river is wider downstream of the tailrace, and is influenced by the water level of Lake Ontario. In general, the change in the Falls flow and power generation produce relatively predictable daily water level fluctuations. The average daily water level fluctuation during the 2002 tourist season at the gauge located 1.4 miles downstream of the RMNPP tailrace was approximately 1.5 feet with a range of 1.1 to 2.1 feet.

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TABLE 1.1-1

FOCUS FISH SPECIES

Common Name	Scientific Name
American eel	(*Anguilla rostrata*)
Bluntnose minnow	(*Pimephales notatus*)
Brown bullhead	(*Ameiurus nebulosus*)
Chinook salmon	(*Oncorhynchus tshawytscha*)
Emerald shiner	(*Notropis atherinoides*)
Greater redhorse	(*Moxostoma valenciennesi*)
Lake sturgeon	(*Acipenser fulvescens*)
Lake trout	(*Salvelinus namaycush*)
Largemouth bass	(*Micropterus salmoides*)
Muskellunge	(*Esox masquinongy*)
Northern pike	(*Esox lucius*)
Rainbow smelt	(*Osmerus mordax*)
Rainbow trout	(*Oncorhynchus mykiss*)
Rock bass	(*Ambloplites rupestris*)
Smallmouth bass	(*Micropterus dolomieui*)
Walleye	(*Sander vitreus*)
White sucker	(*Catostomus commersoni*)
Yellow perch	(*Perca flavescens*)

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This material is contained in:
Volume 2
Section: Water Temperatures of the Niagara River and its U.S. Tributaries

FIGURE 1.2-1

INVESTIGATION AREA

[NIP – General Location Maps]

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2.0 METHODS

This investigation examines the effect of water level fluctuations on water temperatures in the Niagara River by evaluating the effect of water level fluctuations on the hourly rate of change in water temperature and on seasonal and diurnal temperature fluctuations.

A combination of methods was used to determine if changes in water level associated with joint U.S. and Canadian hydropower operations and treaty flow requirements led to changes in water temperature of sufficient magnitude to affect the behavior and survival of fish. If temperature variations attributable to water level fluctuations were identified at a given location, the magnitude of these fluctuations were evaluated against tolerance thresholds for the life history stages of focus species likely to be present at the time the variations occur. The likely presence of focus fish species was determined based on field surveys of habitat suitability and fish presence determined during various studies conducted as part of the Niagara Power Project FERC relicensing process (Stantec et al. 2005, URS et al. 2002, EI 2001 and 2002, KA 2002).

The remainder of this section is organized as follows:

- Section 2.1: Data collection methods
- Section 2.2: Analysis zones defined for the investigation
- Section 2.3: Data analysis methods

2.1 Water Level, Water Temperature, and Meteorological Data Collection

Temperature and water level data were collected for the purpose of this investigation in 2002 and 2003 from a number of temporary and existing permanent gauge stations in the investigation area. A total of 39 temporary water temperature gauges were placed throughout the investigation area to collect water temperature data at 15-minute time increments between April 1st and November 30th of 2002, and March 1st to November 30th of 2003 (some locations began recording later in 2003). A total of 24 temporary water level gauges were placed to collect water elevation data over the same time increments and periods.

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The temporary water level gauges complemented data gathered from 10 existing permanent water level gauges present in the investigation area. Some temporary water level gauges were also configured to gather temperature data, providing a total of 64 gauge locations with available temperature data for analysis. Data from one of these gauge locations (TM-23) was later found to be unreliable and was removed from the analysis. In addition to the water level and water temperature data, NOAA meteorological data collected from two nearby locations was used to describe other environmental conditions that affect water temperatures. All data was subjected to rigorous QA/QC review to ensure the analysis was based on reliable and accurate information. Water level, water temperature and air temperature data were compiled as hourly averages and plotted by month and location to establish the existing patterns of seasonal and diurnal (daily) temperature fluctuation throughout the investigation period. The temperature and water level data set used in this investigation includes significant storm events that occurred in 2002 and 2003.

Water surface elevations were collected on a 15-minute time step at 24 temporary locations during 2003 using In-Situ miniTROLL, Professional Model (30 psi) gauges. These gauges also recorded water temperature on the same time step. Continuous water temperature data were collected from additional sites using Onset Computer Corporation's Optic StowAway Temp gauges. The continuous temperature data were collected using the In-Situ logger, the Onset logger, or both at a total of 39 locations in the Niagara River, Lewiston Reservoir and U.S. tributaries. Performance specifications (range, resolution and accuracy) for the monitoring equipment used in this study, and data quality assurance and quality control procedures are described in Appendix A.

Both water level and water temperature data were collected from the temporary data gauges in 2002 and 2003. In 2002, these data were collected from the following locations (Figure 2.1-1) and time increments:

- Water temperature collected at 15-minute increments from April to November 2002 at a total of 21 sites in the upper and lower Niagara River, Woods Creek, Buckhorn Marsh, Burnt Ship Creek, Big Sixmile Creek, Gun Creek, Spicer Creek, and around Strawberry Island;

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- Water level data collected at 15-minute intervals from March to November 2002 at a total of 10 temporary gauge locations in the upper and lower Niagara River, Woods Creek, Buckhorn Marsh, and Burnt Ship Creek;
- Hourly water level data collected at a total of 8 permanent water level gauge locations in the upper and lower Niagara River and Lewiston Reservoir in 2002.

In 2003, water temperature data were collected from February or March to November from the following locations (Figure 2.1-2) and time increments with the number of sites in each area in parentheses:

- Burnt Ship Creek (3), Buckhorn Marsh (2), Woods Creek (2), Gun Creek (2), Spicer Creek (2), Big Sixmile Creek (2), Tonawanda Creek (2), Ellicott Creek (2), Cayuga Creek (3), Gill Creek (2), Fish Creek (2), Lewiston Reservoir (1);
- The mainstem of the upper Niagara River upstream of the mouth of Spicer Creek (1), downstream of the mouth of Woods Creek (1), just upstream of the intakes (1), and near Peace Bridge (1);
- The mainstem of the lower Niagara River upstream of the tailrace (1), in the tailrace (1), just downstream of the tailrace (1), at the Lewiston Landing (1), Artpark (1), Joseph Davis State Park (1), and the Youngstown Yacht Club (1).

Water level data were collected hourly in 2003 from February or March to November in the following areas (Figure 2.1-2), with the number of sites in each area in parentheses:

- Burnt Ship Creek (3), Buckhorn Marsh (2), Woods Creek (2), Gun Creek (2), Spicer Creek (2), Big Sixmile Creek (2), Tonawanda Creek (1), Ellicott Creek (2), Cayuga Creek (3);

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- The mainstem of the lower Niagara River upstream of the tailraces (1), at Artpark (1), at Lewiston Landing (1), at Joseph Davis State Park (1), and near the Youngstown Yacht Club (1).

For tributary sites, water level and water temperature data were collected within and upstream of the areas influenced by water level fluctuations in the Niagara River. This provided a limited set of reference locations for tributary water temperatures.

Data from permanent water level gauges in the upper Niagara River and Lewiston Reservoir (Figure 2.1-1) were also collected in 2003 as in 2002. Water level data from Lewiston Reservoir, Material Dock, Slater's Point, NYPA Intake, Tonawanda Island, Huntley, Black Creek, Frenchman's Creek, Fort Erie, and Port Weller (Lake Ontario) were used in this analysis. Generally, temporary water level gauge data were plotted in relation to permanent gauge data in the upper Niagara River, Lake Ontario or Lewiston Reservoir, as appropriate.

Hourly air temperature, relative humidity, barometric pressure, solar radiation, precipitation, and wind direction and speed data collected at two local, NOAA weather stations from March 2002 to November 2002 and from February 2003 to November 2003. The exact weather stations from which data were obtained are shown in Figure 2.1-3. These stations include the Niagara Falls International Airport and Buffalo Niagara International Airport.

Charts of water level, water temperature, and air temperature data were developed for grouped locations in support of this analysis. The charts are presented in Appendix B of this report. A table of contents provides a listing of the charts developed, including the specific location, and gauge data shown on each chart.

All temperature gauges are identified with a unique alpha numeric code. Gauges collecting temperature data in 2002 begin with TM-, and are numbered 01 through 25 (e.g., TM-01) Gauges specifically collecting temperature data in 2003 have location codes beginning with T and specific to the area being surveyed (e.g., TUNR-01: Upper Niagara River location-01). Gauges collecting water level data in 2002 have two letter alpha numeric codes beginning with "S" (e.g., SD-01). Gauges collecting

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water level data in 2003 have three letter location specific identifiers not beginning with T (e.g., SMC-01, Big Sixmile Creek location –01). Note that these water level gauges also collected temperature data used in this investigation. Gauge location and type descriptions are in Table 2.1.1.

Throughout this report, all environmental data (water elevations, water temperatures, air temperatures) are in Eastern Standard Time, whereas descriptions of, and references to, the 1950 Niagara River Water Diversion Treaty are in Eastern Daylight Savings Time.

2.2 Analysis Zones

For the purpose of this analysis, the investigation area was divided into 6 distinct analysis zones. These analysis zones were developed based on physical habitat characteristics, and the extent of influence by water level fluctuations. The analysis zones are defined as follows:

1. Analysis Zone 1: Buckhorn Marsh and Niagara River Tributary Streams (see Figure 2.2-1)
2. Analysis Zone 2: Upper Niagara River – Main Channel (see Figure 2.2-2)
3. Analysis Zone 3: Upper Niagara River – Shallow Water Areas Off of Main Channel and Immediately Downstream of Tributaries (see Figure 2.2-3)
4. Analysis Zone 4: Lower Niagara River– Gorge Between Falls and Tailrace (see Figure 2.2-4)
5. Analysis Zone 5: Lower Niagara River– Below Tailrace (see Figure 2.2-5)
6. Analysis Zone 6: Lewiston Reservoir (see Figure 2.2-6)

2.3 Conceptual Approach to Data Analysis

The methods of data analysis used in this investigation were developed in part based on the findings of previous investigations of water level fluctuations in the Niagara River and its tributaries. The methodology used to analyze temperature effects on focus species was conducted to answer the following questions:

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1. Are observed water temperature fluctuations in the investigation area within the range of natural seasonal and diurnal variability?

2. Do rapid changes in water temperature due to mixing of water bodies occur regularly?

3. Do these rapid changes in water temperature potentially influence the behavior or survival of fish?

As implied, this evaluation involved three primary steps. The first step was to determine if water level fluctuations affect the normal range of seasonal and diurnal temperature fluctuations. The second step was to determine if the timing of water level fluctuations appear to be correlated with the timing of water temperature changes at specific times and locations, with effects occurring in the form of rapid, temporary temperature fluctuations. If such a relationship was identified, the third step was to determine if the extent of the identified temperature effect exceeds behavioral or survival thresholds for life history stages of focus species at the affected locations and times. These three steps are described in the following sections.

2.3.1 Temperature Effects Analysis Methodology

Using the data collected as described in Section 2.1, the relationship between water level fluctuations and water temperature was examined, and the results were used to infer the effects of U.S./Canadian power generation on water temperatures. This approach was sequential and used one or more of the following analytical methods:

First (visual assessment), graphs of the average hourly water levels, water temperatures, and air temperatures were created and a visual assessment of the graphs was used to examine the relationship between water level fluctuations and water temperatures and water temperature changes. The visual assessment was used to determine the locations and times in which water temperatures appeared to be and appeared not to be affected by water level fluctuations. Second, a correlation analysis (correlation

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analysis) was used to determine the relationships between water levels, water temperatures, and the meteorological factors described in Section 2.4 at those locations (and during those times) that water temperatures appeared to be and appeared not to be affected by water level fluctuations as identified during the visual assessment. Third, the seasonal and diurnal patterns (seasonal and diurnal patterns) in the hourly change in water temperature in degrees Centigrade (positive or negative) ($\Delta°C_{WT}$) were studied at locations affected by water level fluctuations in the Niagara River in relation to reference locations (independent of water level fluctuations in the Niagara River). This included a qualitative evaluation of seasonal and diurnal temperature fluctuation patterns between reference locations not affected by water level fluctuations, and locations that may be subject to water level fluctuations. This consists of two components: 1) determination of normal patterns of seasonal and diurnal temperature fluctuation based on reference locations, and; 2) comparison of annual patterns $\Delta°C_{WT}$ between reference and potentially affected locations. An example graph of annual $\Delta°C_{WT}$ at a reference location is shown in Figure 2.3.1-1. Fourth, (frequency distribution of hourly $\Delta°C_{WT}$) the frequency distributions of $\Delta°C_{WT}$ values by hour of day at locations that may be affected by water level fluctuations in the Niagara River were compared to those locations that may not be affected by water level fluctuations in the Niagara River. Fifth, the frequency distributions of hourly change in water level (ΔWL) values in feet by hour of day (frequency distribution of hourly ΔWL) at locations that may be affected by water level fluctuations in the Niagara River were compared to those locations not affected by water level fluctuations in the Niagara River.

The fourth and fifth methods above rely on frequency distribution boxplots of $\Delta°C_{WT}$ and ΔWL, respectively. Frequency distributions used in this analysis show standard boxplots of hourly temperature change values over the period of analysis by hour of day. An example standard boxplot is shown in Figure 2.3.1-2. Each standard boxplot consists of a center line (the median, or 50th percentile) splitting a rectangle defining the 25th to 75th percentile of values. In other words, 25 percent of the values in a given plot are above those represented by the range of the box, and 25 percent are below. The whiskers extend to the last value within 1.5 times the height of the box (1.5 times the range of 25th to 75th percentile values), and equal approximately the range of the 1st to the 99th percentile of values. Outlier values, represented by an 'x', occur less than one time in one hundred values in a normally distributed data set, and extreme values, which are not shown, occur so rarely that they are outside the predicted normal range of the population of values (Helsel and Hirsch 2002). In contrast to the graphs of annual patterns in $\Delta°C_{WT}$, the frequency distribution boxplots do not show the most extreme values. Extreme events are

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excluded from this analysis because they occur so rarely they are unlikely to be caused by human activities. Water level fluctuations follow a generally consistent daily pattern. The rarity of outlier and extreme events suggests they are unlikely to be caused by water level fluctuations due to U.S./Canadian power generation. Outlier and extreme events occur at a comparable frequency to large natural changes in river elevation and are consistent with the likely degree of effect. (Causes of natural changes in river elevation are described in Section 1.3.)

As mentioned, water level fluctuations in both the upper and lower Niagara River are caused by a number of factors. Natural factors include flow surges from Lake Erie, wind, ice conditions, and regional and long-term precipitation patterns that affect lake levels, while manmade factors include boat wakes, regulation of Niagara Falls flows for scenic purposes, operation of hydroelectric power plants on the Canadian side of the river, and operation of the Niagara Power Project. The influence of these factors on water levels is interrelated and dynamic. Because the water level in the Niagara River at any location at any time is a complex function of natural and manmade factors, distinguishing the exact amount of water level fluctuation attributable to each factor is difficult. Because rapid changes in water level at the Fort Erie gauge are due to environmental factors on Lake Erie (primarily wind events, see Section 1.3), the effects analysis attempted to distinguish between water temperature effects in the upper Niagara River caused by U.S./Canadian power generation from those caused by environmental factors on Lake Erie. Therefore, the effects analysis was based on those hourly temperature change values that occurred between the 99th and 1st percentiles. For the lower Niagara River, where water level fluctuations are less susceptible to environmental factors, the outlier values were included in the analysis. This approach to determine the effects of U.S./Canadian power generation on water temperatures in the upper and lower Niagara River was considered conservative as it is not possible to separate all other factors that contribute to changes in water levels such as small wind effects, boat waves and local environmental conditions. Throughout the remainder of this report, temperature effects in the upper Niagara River based on frequency distribution boxplots are presented as normal values (i.e., those that occur between the 99th and 1st percentiles) in ±ºC/hour, and outlier values (±ºC/hour) are presented only in the figures in Appendix C for illustrative purposes. For the lower Niagara River, the analysis of temperature effects was based on both normal and outlier values in the frequency distribution boxplots.

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Different combinations of these five methods were used to evaluate the effect of U.S./Canadian power generation in each analysis zone. The analytical approach, rationale, and selection of analytical methods used in each analysis zone are described below.

2.3.1.1 Analysis Zone 1: Buckhorn Marsh and Upper Niagara River Tributaries

Seasonal and diurnal patterns, frequency distribution of hourly $\Delta°C_{WT}$, and frequency distribution of hourly ΔWL were used to evaluate the relationship between water temperature and water level fluctuations in Analysis Zone 1. This approach relies on locations in tributaries that are known to be independent of water level fluctuations in the upper Niagara River to provide reference patterns for normal temperature variation.

The following temperature gauge locations were used to identify reference patterns:

- SMC-01 (Big Sixmile Creek), 2003 data
- CC-03 (Cayuga Creek), 2003 data

These locations are upstream of the influence of Niagara River water levels (URS et al. 2005c). There were daily water level fluctuations of small magnitude (~0.2 feet/day) observed at CC-03, however these fluctuations don't show the same daily patterns as observed downstream (URS and Gomez and Sullivan 2005). The fluctuations at CC-03 were likely the result of a SPDES permitted discharge upstream (Redland Quarry). The Redland Quarry, an operating limestone mine in the Cayuga Creek watershed with a reported maximum depth of 140 feet below ground surface (approximately El. 484 feet). It is located approximately 7,500 feet southeast of the Lewiston Reservoir. Groundwater is extracted from sumps in the mine and discharged to a tributary of Cayuga Creek. The extraction and discharge of groundwater at the mine is regulated by SPDES permit #NY0025267. The mine is permitted to discharge a maximum of 432,000 gallons of water per day (300 gallons per minute or 0.67 cfs) to Cayuga Creek (URS et al. 2003). Cayuga Creek has an estimated annual median flow of 10.7 cfs upstream of the Bergholtz Creek confluence (URS et al. 2005c). Temperature data from these locations were used to establish reference patterns of seasonal and diurnal temperature variability, annual distribution of $\Delta°C_{WT}$ values, and the frequency distribution of hourly $\Delta°C_{WT}$ values. Reference and non-reference gauge

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locations in Analysis Zone 1, and analytical methods used in this analysis are listed in Table 2.3.1.1-1. The pattern and magnitude of daily water level fluctuations at GN-Tonawanda (in the Tonawanda Channel) are similar to those at GO-Black_Creek (in the Chippawa Channel). For simplicity, the GN-Tonawanda data were used to examine the effect of water level fluctuations on water temperatures in Big Sixmile Creek because the GN-Tonawanda data were used in the analysis of other upper Niagara River tributaries.

Collectively, the distinct patterns of diurnal temperature variation, annual patterns of $\Delta°C_{WT}$, the frequency distribution of hourly $\Delta°C_{WT}$, and the frequency distribution of hourly ΔWL are used to identify patterns of water temperature changes associated with water level fluctuations. For the purpose of this investigation, locations with patterns of water temperature fluctuation that are routinely dissimilar from patterns present at reference areas (i.e., they have a high frequency of unusual hourly temperature change values) are considered to be affected by water level fluctuations.

2.3.1.2 Analysis Zone 2: Upper Niagara River – Main Channel

Seasonal and diurnal patterns and frequency distribution of hourly $\Delta°C_{WT}$ were used to evaluate the relationship between water temperature and water level fluctuations in Analysis Zone 2, the main channel of the upper Niagara River. The following gauge was identified as a reference location for Niagara River main channel temperature conditions:

- TUNR-03, upper Niagara River at Squaw Island, 2003

This gauge is the furthest upstream on the Niagara River of all temperature sampling locations. TUNR-03 was placed approximately 1.2 miles downstream of the Peace Bridge. While this location may be influenced by water level fluctuations related to U.S./Canadian power generation at times, there is limited potential for temperature effects at this mainstem location for the following reasons:

- TUNR-03 is located near the uppermost extent of the influence of power generation on Niagara River water levels (URS et al. 2005a)

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- Flow velocity in this section of the Niagara River exceeds 8 ft/second (Stantec et al. 2005, URS et al. 2005a), suggesting surface waters at this location are well mixed
- The volume of flow at this location in a 'typical' year ranges from 160,000 to over 250,000 cfs (Stantec et al. 2005)

Based on these factors, temperature conditions at location TUNR-03 are determined predominantly by the temperature of surface waters flowing out of Lake Erie and are considered to be independent of water level fluctuations in the Niagara River. Reference and non-reference locations in analysis Zone 2, and analytical methods used in this analysis are listed in Table 2.3.1.2-1.

2.3.1.3 Analysis Zone 3: Upper Niagara River - Shallow Water Areas off of Main Channel and Immediately Downstream of Tributaries

Seasonal and diurnal patterns and frequency distribution of hourly $\Delta°C_{WT}$ were used to evaluate the relationship between water temperature and water level fluctuations in Analysis Zone 3, the shallow water areas of the upper Niagara River and immediately downstream of tributaries draining to the river. Temperature patterns at location TUNR-03 are used as reference patterns for Analysis Zone 3, with the caveat that this may lead to overestimation of temperature effects at these locations. Temperature effects may be overestimated because these shallow water areas may have different conditions than the main river channel reference gauge. Reference and non-reference gauge locations in Analysis Zone 3, and analytical methods used in this analysis are listed in Table 2.3.1.3-1.

2.3.1.4 Analysis Zone 4: Lower Niagara River– Gorge Between Falls and Tailrace

Seasonal and diurnal patterns, frequency distribution of hourly $\Delta°C_{WT}$, and frequency distribution of hourly ΔWL were used to evaluate the relationship between water temperature and water level fluctuations in Analysis Zone 4, the lower Niagara River between the falls and the RMNPP tailrace. There is no ideal reference location for this analysis zone, therefore, temperature conditions are compared to those in the upper river above the falls to determine if temperature effects are occurring. Reference

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and non-reference gauge locations in Analysis Zone 4, and analytical methods used in this analysis are listed in Table 2.3.1.4-1. The extent of available temperature data in this analysis zone is limited. Therefore, the strength of conclusions based on the lines of evidence applied is relatively weak in comparison to Analysis Zones 2 and 3.

2.3.1.5 Analysis Zone 5: Lower Niagara River– Below Tailrace

Seasonal and diurnal patterns, frequency distribution of hourly $\Delta°C_{WT}$, and frequency distribution of hourly ΔWL were used to evaluate the relationship between water temperature and water level fluctuations in Analysis Zone 5, the lower Niagara River below the tailrace. In addition, water temperatures above and at the tailrace were qualitatively compared with Lewiston Reservoir temperatures. Temperature conditions in this section of the lower river are compared to those in the upper Niagara River above the falls to determine if temperature effects due to water level fluctuations may be occurring. Reference and non-reference gauge locations in this analysis zone, and analytical methods used in this analysis are listed in Table 2.3.1.5-1.

2.3.1.6 Analysis Zone 6: Lewiston Reservoir

Seasonal and diurnal patterns and frequency distribution of hourly $\Delta°C_{WT}$ were used to evaluate the relationship between water temperature and water level fluctuations in Analysis Zone 6, Lewiston Reservoir. The reservoir is subject to regular large changes in water level due to project operations. Temperature conditions in the Lewiston Reservoir are compared to those in its source body, the upper Niagara River. Gauge locations evaluated in Analysis Zone 6 are listed in Table 2.3.1.6.-1.

2.3.2 Focus Species Occurrence by Analysis Zone

The focus species identified in Section 1.1 are not uniformly distributed in the Niagara River and its tributaries, and several species are limited to specific areas within the investigation area. To aid in identifying potential behavior and survival effects, the distribution of focus species within the previously defined analysis zones was identified based on presence/absence and creel surveys conducted as part of

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the Niagara Project FERC relicensing process (Stantec et al. 2005, URS et al. 2002, EI 2001 and 2002, KA 2002). Species documented in an analysis zone where suitable spawning habitat does not occur, spawning has not been documented, or juveniles and adults have not been documented at appropriate times of year to be indicative in spawning activity are marked with an asterisk *. Focus species are distributed by Analysis Zone as follows:

Analysis Zone 1: Buckhorn Marsh and Niagara River Tributaries

- Bluntnose minnow (*Pimephales notatus*)
- Brown bullhead (*Ameiurus nebulosus*)
- Emerald shiner (*Notropis atherinoides*)
- Greater redhorse (*Moxostoma valenciennesi*)*
- Largemouth bass (*Micropterus salmoides*)
- Northern pike (*Esox lucius*)
- Rock bass (*Ambloplites rupestris*)
- Smallmouth bass (*Micropterus dolomieui*)
- White sucker (*Catostomus commersoni*)
- Yellow perch (*Perca flavescens*)

Analysis Zone 2: Upper Niagara River - Main Channel

- Bluntnose minnow
- Brown bullhead
- Emerald shiner
- Greater redhorse
- Lake sturgeon (*Acipenser fulvescens*)
- Lake trout (*Salvelinus namaycush*)

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- Largemouth bass
- Muskellunge (*Esox masquinongy*)
- Northern pike
- Rainbow trout (*Oncorhynchus mykiss*)
- Rainbow smelt (*Osmerus mordax*)
- Rock bass
- Smallmouth bass
- Walleye (*Sander vitreus*)
- White sucker
- Yellow perch

Analysis Zone 3: Upper Niagara River - Shallow Water Areas Off of Main Channel and Immediately downstream of Tributaries

- Bluntnose minnow
- Brown bullhead
- Emerald shiner
- Greater redhorse*
- Largemouth bass
- Muskellunge
- Northern pike
- Rainbow smelt
- Rock bass
- Smallmouth bass
- White sucker

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- Yellow perch

Analysis Zones 4 and 5: Lower Niagara River

- American eel (*Anguilla rostrata*)*
- Bluntnose minnow
- Brown bullhead*
- Chinook salmon (*Oncorhynchus tshawytscha*)
- Emerald shiner
- Greater redhorse
- Lake sturgeon
- Lake trout
- Largemouth bass
- Muskellunge
- Northern pike
- Rainbow smelt
- Rainbow trout
- Rock bass
- Smallmouth bass
- Walleye
- White sucker
- Yellow perch

Analysis Zone 6: Lewiston Reservoir

- Emerald shiner
- Northern pike
- Rock bass

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- Smallmouth bass
- White sucker
- Yellow perch

2.4 Assessment of Potential Behavioral and Survival Effects on Focus Fish Species

The distribution information in Section 2.3.2 identifies the focus species likely to occur in each analysis zone. To determine if a temperature fluctuation at a given location is of sufficient magnitude to cause potential behavioral or survival effects, the magnitude of the temperature fluctuation was compared to literature derived temperature tolerance thresholds for life history stages likely to be present at the time the fluctuations occurred. Four categories of temperature tolerance thresholds are examined for each focus species at four different life history stages:

- Egg/embryo: Cold shock and heat shock
- Larvae/fry: Cold shock, heat shock; lower avoidance, upper avoidance
- Juvenile: Cold shock, heat shock; lower avoidance, upper avoidance
- Adult: Cold shock, heat shock; lower avoidance, upper avoidance

Cold shock and heat shock are survival effects. They refer to positive and negative changes in water temperature sufficient to cause direct mortality, or incapacitation sufficient to greatly increase the likelihood of mortality (i.e., inability to avoid predators, or to avoid being carried into unfavorable habitats). Lower avoidance and upper avoidance describe behavioral tolerance thresholds referring to temperature effects that cause sufficient discomfort to fish such that they avoid the affected area. While avoidance behavior does not cause direct mortality, it can indirectly affect survival. For example, adult fish may abandon nests, leading to loss of egg clutches; some species may delay spawning; or adult and juvenile fish may abandon otherwise suitable habitats and be forced to expend energy competing for new cover, resting and feeding areas. Collectively, these effects can lead to a survival disadvantage (Schneider et al. 2002, Hokanson 1977, McCullough 1999, Wydowski and Whitney 2003, Hubbs and Bailey 1938, Summerfelt 1975, Becker 1983, Coble 1975). Minor rapid temperature fluctuations (i.e., below defined tolerance thresholds) may also cause physiological and behavioral stress on focus species,

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but the extent of these effects are not well documented. Because water level related fluctuations in water temperature tend to occur daily, nest building species may avoid building nests in areas affected by water temperature fluctuations.

Temperature tolerance thresholds for each focus species and life history stage are presented in Tables 2.4-1 through 2.4-4. These thresholds are derived from available literature as cited. For the purpose of this analysis, the following effects thresholds are defined:

- ***No identified behavioral or survival effects***: water level related temperature fluctuations may or may not occur, if they do occur they do not exceed behavioral or survival tolerance thresholds for any focus species in the analysis zone.
- ***Potential behavioral effect:*** Water level related temperature fluctuations occur, and they exceed lower or upper avoidance thresholds at greater than 1 per 100 event frequency during non-spawning and rearing periods.
- ***Potential survival effect:*** Water level related temperature fluctuations occur, and they exceed cold shock or heat shock thresholds at the outlier level of frequency (i.e., below the 1st or above 99th percentile of values).
- ***Likely survival effect:*** Water level related temperature fluctuations occur, and they exceed cold shock or heat shock thresholds at greater than 1 per 100 event frequency during any period.

The exceedence frequency referred to in these effects criteria is considered to be greater than 1 per 100 events if the 'whiskers' of the standard boxplots of $\Delta°C_{WT}$ values exceed any temperature tolerance threshold for any species in the analysis zone. Outlier values, represented by an 'x' on the boxplots, occur less than 1 in 100 times in a normally distributed population of events (Helsel and Hirsch 2002).

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TABLE 2.1-1

GENERAL LOCATION OF TEMPORARY WATER LEVEL AND WATER TEMPERATURE GAUGES IN THE INVESTIGATION AREA, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Description of Location
1	TBSC-01	2003	Burnt Ship Creek, approximately 50 feet from mouth.
	TBSC-02	2003	Burnt Ship Creek, approximately 150 feet from mouth.
	TBSC-03	2003	Burnt Ship Creek, immediately below west weir.
	TM-12	2002	Buckhorn Marsh, above (west of) east weir.
	TBHM-01	2003	Buckhorn Marsh, above (east of) west weir.
	TBHM-02	2002/2003	Buckhorn Marsh, above (west of) east weir.
	TWC-01	2003	Woods Creek, approximately 150 feet upstream from mouth.
	TM-01	2002	Woods Creek, approximately 200 feet upstream from mouth.
	TM-02	2002	Woods Creek, upstream of East River Road bridge.

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TABLE 2.1-1 (CONT.)

GENERAL LOCATION OF TEMPORARY WATER LEVEL AND WATER TEMPERATURE GAUGES IN THE INVESTIGATION AREA, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Description of Location
1	TM-04	2002	Woods Creek, upstream of Baseline Road bridge.
	TWC-02	2003	Woods Creek, Proximal to 2002 gauge TM-04, at the upstream extent of the influence of Niagara River water levels.
	TM-03	2002	Mouth of Gun Creek.
	TGC-01	2003	Mouth of Gun Creek.
	TM-05	2002	Gun Creek, approximately 1000 feet upstream of TM-03.
	GC-02A	2003	Gun Creek, approximately 6,000 feet upstream of mouth.
	TM-06	2002	Spicer Creek, at mouth.
	TM-07	2002	Spicer Creek, approximately 1,500 feet upstream of mouth.
	TM-08	2002	Spicer Creek, within the range of the influence of Niagara River water levels, approximately 3,600 feet upstream of mouth.

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TABLE 2.1-1 (CONT.)

GENERAL LOCATION OF TEMPORARY WATER LEVEL AND WATER TEMPERATURE GAUGES IN THE INVESTIGATION AREA, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Description of Location
1	TSC-01	2003	Spicer Creek, approximately 600 feet upstream of mouth.
	TSC-02	2003	Spicer Creek, approximately 1,200 feet upstream of mouth.
	TM-19	2002	Mouth of Big Sixmile Creek.
	TM-10	2002	Big Sixmile Creek, at upstream end of harbor (1,800 feet upstream from mouth).
	SMC-02	2003	Big Sixmile Creek, at mouth, upstream edge of West River Road bridge.
	TSMC-01	2003	Big Sixmile Creek, proximal to 2002 location TM-10.
	SMC-01	2003	Big Sixmile Creek, approximately 1,900 feet upstream from mouth.
	CC-01	2003	Cayuga Creek, at confluence with Little River.
	CC-02	2003	Cayuga Creek, at confluence with Bergholtz Creek.

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TABLE 2.1-1 (CONT.)

GENERAL LOCATION OF TEMPORARY WATER LEVEL AND WATER TEMPERATURE GAUGES IN THE INVESTIGATION AREA, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Description of Location
1	CC-03	2003	Cayuga Creek, at Southwestern edge of NFIA.
	TTC-01	2003	Tonawanda Creek, approximately 1,500 feet upstream of mouth.
	EC-01	2003	Ellicott Creek, approximately 1,200 feet upstream of mouth.
	EC-02	2003	Ellicott Creek, at Penarrow Drive Bridge.
	EC-03	2003	Ellicott Creek, at Highway 62 Bridge.
	TC-01	2003	Tonawanda Creek, approximately 1,200 feet upstream of East Robinson Road Bridge.
	TFC-01	2003	Fish Creek, upstream of Garlow Road Bridge.
	TFC-02	2003	Fish Creek, upstream of Moyer Road Bridge.
	TGLC-01	2003	Gill Creek, immediately downstream of flow augmentation discharge.

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TABLE 2.1-1 (CONT.)

GENERAL LOCATION OF TEMPORARY WATER LEVEL AND WATER TEMPERATURE GAUGES IN THE INVESTIGATION AREA, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Description of Location
1	TGLC-02	2003	Gill Creek, immediately upstream of flow augmentation discharge.
	TGLC-03	2003	Gill Creek, upstream of Garlow Road Bridge.
2	TM-17	2002	Niagara River, 100 feet upstream of Woods Creek.
	TUNR-01	2003	Niagara River, immediately upstream of Spicer Creek.
	TUNR-02	2003	Niagara River, 1,200 feet upstream of intakes.
2	TUNR-03	2003	Niagara River, Squaw Island at Railroad Bridge.
3	TM-11	2002	Upper Niagara River, mouth of Burnt Ship Creek.
	TM-13	2002	Upper Niagara River, Beaver Island Slough.
	TM-15	2002	Upper Niagara, Strawberry Island shallows (in the Tonawanda Channel between Strawberry and Motor Islands).

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TABLE 2.1-1 (CONT.)

GENERAL LOCATION OF TEMPORARY WATER LEVEL AND WATER TEMPERATURE GAUGES IN THE INVESTIGATION AREA, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Description of Location
3	TM-16	2002	Upper Niagara, Northwest tip of Strawberry Island in shallow water area.
	TM-18	2002	Upper Niagara River, in shallow water bay in Grass Island (Chippawa-Grass Island Pool).
	TM-20	2002	Upper Niagara, shallow water embayment on the north side of Strawberry Island.
	TUNR-04	2003	Upper Niagara River, approximately 50 feet downstream of Woods Creek.
4	TLNR-03	2003	Lower Niagara River, approximately 2,300 feet upstream of the tailrace.
4	LNR-01	2003	Lower Niagara River, approximately 1,700 feet upstream of RMNPP tailrace, downstream of location TLNR-03.
5	TLNR-01	2003	Lower Niagara River, at upstream end of RMNPP tailrace, on the south side near the fishing pier.
	TLNR-04	2003	Lower Niagara River, downstream of TLNR-01, on the north side tailrace.

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TABLE 2.1-1 (CONT.)

GENERAL LOCATION OF TEMPORARY WATER LEVEL AND WATER TEMPERATURE GAUGES IN THE INVESTIGATION AREA, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Description of Location
5	TLNR-05	2003	Lower Niagara River, downstream of TLNR-01, within the middle of RMNPP tailrace.
	TLNR-02	2003	Lower Niagara River, downstream end of the Adam Beck tailrace on the U.S. side of the river.
	LNR-02	2003	Lower Niagara River, approximately 4,500 feet downstream of RMNPP tailrace.
	TM-24	2002	Lower Niagara River, downstream at gorge mouth at edge of Niagara escarpment (Queenston Drift).
	LNR-03	2003	Lower Niagara River, downstream at gorge mouth, approximately 2 miles downstream of the RMNPP tailrace (at Onondaga St.).
	LNR-04	2003	Lower Niagara River, downstream of gorge (Joseph Davis State Park).
	LNR-05	2003	Lower Niagara River, downstream of gorge, one mile upstream of the river mouth at Water Street.
	TM-25	2002	Lower Niagara River, mouth of the Niagara River at Lake Ontario.
6	TLEW-01	2003	Lewiston Reservoir outlet, at the Lewiston Pump Generating Station.

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TABLE 2.3.1.1-1

TEMPERATURE AND WATER LEVEL GAUGE LOCATIONS IN ANALYSIS ZONE 1

Analytical Methods	Year	Temperature Gauge Locations	Water Level Gauge Locations
1, 2	2002	TM-01, TM-02, TM-03, TM-04, TM-05, TM-06, TM-07, TM-08, TM-10, TM-12, TM-19	SD-01, SD-02, SD-03, SD-04, SD-05
1, 2, 3	2003	TWC-01, TWC-02, WC-02, TBHM-01, TBHM-02, TBSC-01, TBSC-02, TBSC-03, TGC-01, CC-01, CC-02, **CC-03**, GC-02A, TSC-01, TSC-02, **SMC-01**, SMC-02, TTC-01, EC-01, EC-02, EC-03, TC-01	WC-01, WC-02, BSC-01, BSC-02, BSC-03, BHM-01, BHM-02, CC-01, CC-02, **CC-03**, GC-01, GC-02A, **SMC-01**, SMC-02, GN-Tonawanda

Notes: Gauge locations highlighted in **bold** are reference locations.

Analytical Methods:

1. Identification of patterns in $\Delta°C_{WT}$ at locations affected by water level fluctuations in the Niagara River in relation to reference locations (independent of water level fluctuations in the Niagara River)
2. Frequency distributions of $\Delta°C_{WT}$ values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River
3. Frequency distributions of ΔWL values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River

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TABLE 2.3.1.2-1

TEMPERATURE AND WATER LEVEL GAUGE LOCATIONS IN ANALYSIS ZONE 2

Analytical Methods	Year	Temperature Gauge Locations	Water Level Gauge Locations
1	2002	TM-17	GN-River_Int
1, 2, 3	2003	TUNR-01, TUNR-02, **TUNR-03**	GN-River_Int, GN-Tonawanda

Notes: Gauge locations highlighted in **bold** are reference locations.

Analytical Methods:

1. Identification of patterns in $\Delta°C_{WT}$ at locations affected by water level fluctuations in the Niagara River in relation to reference locations (independent of water level fluctuations in the Niagara River)
2. Frequency distributions of $\Delta°C_{WT}$ values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River
3. Frequency distributions of ΔWL values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River

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TABLE 2.3.1.3-1

TEMPERATURE AND WATER LEVEL GAUGE LOCATIONS IN ANALYSIS ZONE 3

Analytical Methods	Year	Temperature Gauge Locations	Water Level Gauge Locations
1, 2	2002	TM-11, TM-13, TM-15, TM-16, TM-18, TM-20	SD-06, GN-River_Int
1, 2, 3	2003	TUNR-04	GN-Tonawanda

Notes: Gauge locations highlighted in **bold** are reference locations.

Analytical Methods:

1. Identification of patterns in $\Delta°C_{WT}$ at locations affected by water level fluctuations in the Niagara River in relation to reference locations (independent of water level fluctuations in the Niagara River)
2. Frequency distributions of $\Delta°C_{WT}$ values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River
3. Frequency distributions of ΔWL values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River

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TABLE 2.3.1.4-1

TEMPERATURE AND WATER LEVEL GAUGE LOCATIONS IN ANALYSIS ZONE 4

Analytical Methods	Year	Temperature Gauge Locations	Water Level Gauge Locations
1, 2, 3	2003	TLNR-03, LNR-01, **TUNR-02**	LNR-01

Notes: Gauge locations highlighted in **bold** are reference locations.

Analytical Methods:

1. Identification of patterns in $\Delta°C_{WT}$ at locations affected by water level fluctuations in the Niagara River in relation to reference locations (independent of water level fluctuations in the Niagara River)
2. Frequency distributions of $\Delta°C_{WT}$ values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River
3. Frequency distributions of ΔWL values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River

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TABLE 2.3.1.5-1

TEMPERATURE AND WATER LEVEL GAUGE LOCATIONS IN ANALYSIS ZONE 5

Analytical Methods	Year	Temperature Gauge Locations	Water Level Gauge Locations
1, 2	2002	TM-24, TM-25	SG-01A, SG-01B, SG-01C, SG-02A, SG-03A, SG-04A
1, 2, 3	2003	TLNR-01, TLNR-02, TLNR-04, TLNR-05, LNR-02, LNR-03, LNR-04, LNR-05, **TUNR-02**	LNR-02, LNR-03, LNR-04, LNR-05

Notes: Gauge locations highlighted in **bold** are reference locations.

Analytical Methods:

1. Identification of patterns in $\Delta°C_{WT}$ at locations affected by water level fluctuations in the Niagara River in relation to reference locations (independent of water level fluctuations in the Niagara River)
2. Frequency distributions of $\Delta°C_{WT}$ values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River
3. Frequency distributions of ΔWL values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River

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TABLE 2.3.1.6-1

TEMPERATURE AND WATER LEVEL GAUGE LOCATIONS IN ANALYSIS ZONE 6

Analytical Methods	Year	Temperature Gauge Locations	Water Level Gauge Locations
1, 2	2003	TLEW-01, **TUNR-02**	GN-Reservoir

Notes: Gauge locations highlighted in **bold** are reference locations.

Analytical Methods:

1. Identification of patterns in $\Delta°C_{WT}$ at locations affected by water level fluctuations in the Niagara River in relation to reference locations (independent of water level fluctuations in the Niagara River)
2. Frequency distributions of $\Delta°C_{WT}$ values by hour of day at locations that are affected by and not affected by water level fluctuations in the Niagara River

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TABLE 2.4-1

FOCUS SPECIES TEMPERATURE EFFECTS THRESHOLDS

Species	Delta Threshold C[1,2]				Data Source
	Cold Shock[3]	Heat Shock[4]	Lower Avoidance[5]	Upper Avoidance[6]	
Chinook Salmon					
Eggs (Embryos)	-6@7 to -15@20	-	-	-	Wismer and Christie 1987
Fry (Larvae)	-9.2@10 to -16.6@24	16.5@5 to 1.1@24	<4 (enter gravel)		Wismer and Christie 1987, Raleigh et al. 1986
Juveniles	-	5@17	<4 (enter gravel)	>19.5-22.8	Wismer and Christie 1987, Raleigh et al. 1986
Adults	-	4@18	<3	>21	Wismer and Christie 1987, McCullough 1999
Rainbow Trout					
Eggs (Embryos)	-	-	-	-	-
Fry (Larvae)	-	-	-	-	-
Juveniles	9.5@10, 16.7@20	18.7@5 to 1.7@24.5	-6@12 to -9@24	6@12 to 2@24	Wismer and Christie 1987, McCullough 1999
Adults	-	5@16 to 3@19	-	-	Wismer and Christie 1987
Lake Trout					
Eggs (Embryos)	-	6@8.8	-	-	McCullough 1999
Fry (Larvae)	-		-	-	McCullough 1999
Juveniles	-	8.5@15 to 3.5@20	<1 to <5.6	>11.7 to >18.2	Wismer and Christie 1987

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TABLE 2.4-1 (CONT.)

FOCUS SPECIES TEMPERATURE EFFECTS THRESHOLDS

Species	Delta Threshold C[1,2]				Data Source
	Cold Shock[3]	Heat Shock[4]	Lower Avoidance[5]	Upper Avoidance[6]	
Adults	-	4.5@20	4	14	Wismer and Christies 1987, McCullough 1999
Rainbow Smelt					
Eggs (Embryos)	-	-	-	-	-
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-
Adults	-8.5@17	11.3@10.2 to 13.5@15	-	Increase of 10	Wismer and Christie 1987
Northern Pike					
Eggs (Embryos)	-10	14.5@6.2 to 12.3@11.8	-	-	Wismer and Christie 1987, Hassler 1970
Fry (Larvae)	-15@18	18.5@16	-	-	Wismer and Christie 1987
Juveniles		3.25@30, 7.25@25	-	-	Wismer and Christie 1987
Adults	-16.9@21.8	3@30, 7@25	decrease of 11	-	Wismer and Christie 1987, Inskip 1982, Strand 1986
Muskellunge					
Eggs (Embryos)	-	-	-	-	-
Fry (Larvae)	-	-	-	-	-
Juveniles		7.25@25, 3.25@30			Wismer and Christie 1987

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TABLE 2.4-1 (CONT.)

FOCUS SPECIES TEMPERATURE EFFECTS THRESHOLDS

Species	Delta Threshold C[1,2]				Data Source
	Cold Shock[3]	Heat Shock[4]	Lower Avoidance[5]	Upper Avoidance[6]	
Adults	-	-	-	-	Strand 1986
Emerald Shiner					
Eggs (Embryos)	-12.5	-	-	-	Wismer and Christie 1987
Fry (Larvae)	-13.4@15, -17@25	5.7@25, 18.3@5	-	-	Wismer and Christie 1987
Juveniles	-	12,6@20-25	-	-	Wismer and Christie 1987
Adults	-	-	-14@20	22@20	Wismer and Christie 1987
Bluntnose Minnow					
Eggs (Embryos)	-	-	-	-	-
Fry (Larvae)	-14@15, -17.5@25	19@5, 8.3@25			Carlander 1969
Juveniles	-	-	-	-	-
Adults	-14@15, -17.5@25	19@5, 8.3@25	-6@30, -3@12	9@12, 3@30	Wismer and Christie 1987
Brown Bullhead					
Eggs (Embryos)	-	-	-	-	-
Fry (Larvae)	-	13.2@25	-	-	Wismer and Christie 1987
Juveniles	-	11.9@24	-3.5@3.5, -6@28	11.1@25, 16.5@35	Wismer and Christie 1987
Adults	-33@20, -30.5@36	24.9@5, 13.4@20, 1@40	-	-	Wismer and Christie 1987

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TABLE 2.4-1 (CONT.)

FOCUS SPECIES TEMPERATURE EFFECTS THRESHOLDS

Species	Delta Threshold C[1,2]				Data Source
	Cold Shock[3]	Heat Shock[4]	Lower Avoidance[5]	Upper Avoidance[6]	
American Eel					
Eggs (Embryos)	-	-	-	-	-
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-
Adults	-	-	Decrease of 11.9	33	Wismer and Christie 1987
Rock Bass					
Eggs (Embryos)	-	-	-	-	-
Fry (Larvae)	-	-	-	-	-
Juveniles	-	13.6@23.9, 18@18	-3@18, -6@33	9@18, 2@35	Wismer and Christie 1987
Adults	-	5@30	-	-	Wismer and Christie 1987
Smallmouth Bass					
Eggs (Embryos)	-	12.8@20	-	-	Coble 1975
Fry (Larvae)	-	15@20	-	-	Coble 1975
Juveniles	-13@15, -16@26	19.4@12.8, 2@35	-3@18, -6@33	9@18, 2@33	Wismer and Christie 1987
Adults	-20	2@35	10, Decrease of 11.1		Wismer and Christie 1987, Becker 1983, Coble 1975

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TABLE 2.4-1 (CONT.)

FOCUS SPECIES TEMPERATURE EFFECTS THRESHOLDS

Species	Delta Threshold C[1,2]				Data Source
	Cold Shock[3]	Heat Shock[4]	Lower Avoidance[5]	Upper Avoidance[6]	
Largemouth Bass					
Eggs (Embryos)	-	-	-	-	-
Fry (Larvae)	-	-	-	-	-
Juveniles	-15@20, -19@30	13@20, 5@35	-	-	Wismer and Christie 1987
Adults	-14.5@20, -18.2@30	12.5@20, 6.4@30	-3@12, -3@24, -10	12@12, 11@24	Wismer and Christie 1987, Summerfelt 1975
Yellow Perch					
Eggs (Embryos)	-4.4	17	-	-	Wismer and Christie 1987, Becker 1983
Fry (Larvae)	-	16.4@7.6, 10.8@15.8	-	-	Wismer and Christie 1987
Juveniles	-	-	-3@15, -6@24	5@24, 6@15	Wismer and Christie 1987
Adults	-9.9@11, -21.3@25	16@5, 7.3@25	-	-	Wismer and Christie 1987
Walleye					
Eggs (Embryos)	-8.8@11	20.2@11	-	-	Schneider et al. 2002
Fry (Larvae)	-	-	-	-	-
Juveniles		5.8@25.8, 19@8	-	-	Wismer and Christie 1987
Adults	-17@25	21.7@7.2	-	-	Wismer and Christie 1987, Spotila et al. 1979

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TABLE 2.4-1 (CONT.)

FOCUS SPECIES TEMPERATURE EFFECTS THRESHOLDS

Species	Delta Threshold C[1,2]				Data Source
	Cold Shock[3]	Heat Shock[4]	Lower Avoidance[5]	Upper Avoidance[6]	
Greater Redhorse					
Eggs (Embryos)	-	-	-	-	-
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-
Adults	-	-	-	-	-
White Sucker					
Eggs (Embryos)	-18.3@21.2	10.4@21.1, 20.1@8.9	-	-	McCormick et al. 1977
Fry (Larvae)	-10.4@15.2, -15@21	18@10, 9@21	-	-	Wismer and Christie 1987
Juveniles	-18@20, -19@25	19@5, 4@25	-	-	Wismer and Christie 1987
Adults	-	-	-	12.2@17.2	Wismer and Christie 1987
Lake Sturgeon					
Eggs (Embryos)	>4@14	-	-	-	Wang et al. 1985
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-
Adults	-	-	-1.5 to -3@10-14	-	Kempinger 1988

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Notes:

[1]Acclimation Temperature: Temperature that organism (embryo, larvae, juvenile, or adult) is acclimated to (acclimation temperatures, if available, are preceded by the @ symbol).

[2]Delta Threshold: Change in temperature that produces either avoidance behavior or 50% mortality

[3]Cold Shock: Rapid decrease in temperature documented to cause 50% mortality. Values are given as the negative change of temperature in ºC the fish or embryos were suddenly subjected to (first value) and the acclimation temperature in ºC (example: -10@18). Values for the highest and lowest acclimation temperatures tested are usually given.

[4]Heat Shock: Rapid increase in temperature documented to cause 50% mortality. Values are given as the positive change of temperature in ºC the fish or embryos were suddenly subjected to (first value) and the acclimation temperature in ºC (example: 10@18). Values for the highest and lowest acclimation temperatures tested are usually given.

[5]Lower Avoidance: Rapid decrease in temperature documented to cause avoidance behavior. A single number indicates that lifestage has been documented to avoid water of that absolute temperature.

[6]Upper Avoidance: Rapid increase in temperature documented to cause avoidance behavior. A single number indicates that lifestage has been documented to avoid water of that absolute temperature.

‘ – ‘ indicates no data are available for this parameter.

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TABLE 2.4-2

FOCUS SPECIES LETHAL TEMPERATURE THRESHOLDS

Species	Lower Incipient Lethal Temperature[1,2]	Upper Incipient Lethal Temperature[1,3]	Critical Thermal Maximum[1,4]	Data Source
Chinook Salmon				
Eggs & Spawning Adults	2.5-3	16		McCullough 1999
Fry (Larvae)	0.8@10 to 7.4@24	21.5@5 to 25.1@24	25.1	Wismer and Christie 1987
Juveniles	0.8	22@17, 25.1@20-24	22.8	Wismer and Christie 1987, McCullough 1999, Bjorn and Reiser 1991
Adults	4@18	21-22@19	-	Wismer and Christie 1987, McCullough 1999
Rainbow Trout				
Eggs & Spawning Adults	3	18.5	-	McCullough 1999
Fry (Larvae)	-	-	-	-
Juveniles	0.5@10, 3.3@20	23.7@5, 26.2@24.5	23.9	Wismer and Christie 1987, McCullough 1999, Barnhart 1986
Adults	0	21@16, 22@19	26.3@17	Wismer and Christie 1987, Raleigh et al. 1984, McCullough 1999
Lake Trout				
Eggs & Spawning Adults	-	14.8@8.8	-	McCullough 1999
Fry (Larvae)	-	-	-	-
Juveniles	-	23.5@15-20	-	McCullough 1999

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TABLE 2.4-2 (CONT.)

FOCUS SPECIES LETHAL TEMPERATURE THRESHOLDS

Species	Lower Incipient Lethal Temperature[1,2]	Upper Incipient Lethal Temperature[1,3]	Critical Thermal Maximum[1,4]	Data Source
Adults	-	24.5@20	25.9@17	McCullough 1999
Rainbow Smelt				
Eggs & Spawning Adults	-	-	-	-
Fry (Larvae)	-	-	-	-
Juveniles	-	-	-	-
Adults	8.5@17	21.5@10.2, 28.5@15	22.6@1, 26.4@12.2	Wismer and Christie 1987
Northern Pike				
Eggs & Spawning Adults	4.9@21.8	24.1@11.8, 20.6@6.1	-	Wismer and Christie 1987
Fry (Larvae)	3@18	34.5@16	-	Wismer and Christie 1987
Juveniles	-	33.25@30, 32.25@25	30.8-33.25	Wismer and Christie 1987
Adults	4.9@21.8	33@30, 32@25	-	Wismer and Christie 1987, Inskip 1982
Muskellunge				
Eggs & Spawning Adults	-	-	-	Wismer and Christie 1987, Harrison 1978
Fry (Larvae)	-	-	28.8@7, 34.5@25	Wismer and Christie 1987
Juveniles	24-26.6	-	-	Wismer and Christie 1987
Adults	-	-	32.2	Becker 1983

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TABLE 2.4-2 (CONT.)

FOCUS SPECIES LETHAL TEMPERATURE THRESHOLDS

Species	Lower Incipient Lethal Temperature[1,2]	Upper Incipient Lethal Temperature[1,3]	Critical Thermal Maximum[1,4]	Data Source
Emerald Shiner				
Eggs & Spawning Adults	-	-	-	Wismer and Christie 1987, Goodyear et al. 1982
Fry (Larvae)	1.6@15, 8@25	23.3@5, 30.7@25	34.3	Wismer and Christie 1987
Juveniles	-	32.6@20-25	34	Wismer and Christie 1987
Adults	-	-	37.6	Ross et al. 2001
Bluntnose Minnow				
Eggs & Spawning Adults	-	-	-	-
Fry (Larvae)	1@15, 7.5@25	26@5, 33.3@25		Carlander 1969
Juveniles	-	-	-	-
Adults	1@15, 7.5@25	26@5, 33.3@25	38	Wismer and Christie 1987, Becker 1983
Brown Bullhead				
Eggs & Spawning Adults	-	-	-	-
Fry (Larvae)	-	38.2@25	-	Wismer and Christie 1987
Juveniles	-	35.9@24	-	Wismer and Christie 1987
Adults	0@20, 7@36	29.9@5, 33.4@20, 41@40	37.8@23	Wismer and Christie 1987

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TABLE 2.4-2 (CONT.)

FOCUS SPECIES LETHAL TEMPERATURE THRESHOLDS

Species	Lower Incipient Lethal Temperature[1,2]	Upper Incipient Lethal Temperature[1,3]	Critical Thermal Maximum[1,4]	Data Source
American Eel				
Eggs & Spawning Adults	-	-	-	-
Fry (Larvae)	-	-	-	-
Juveniles	-	-	-	Wismer and Christie 1987
Adults	-	-	-	Wismer and Christie 1987
Rock Bass				
Eggs & Spawning Adults	-	-	-	-
Fry (Larvae)	-	-	-	-
Juveniles	-	37.5@23.9, 36@18	-	Wismer and Christie 1987
Adults	-	35@30	38	Wismer and Christie 1987, Becker 1983
Smallmouth Bass				
Eggs & Spawning Adults	-	32.8@20	-	Coble 1975
Fry (Larvae)	4	35@20	38	Edwards et al. 1983
Juveniles	2@15, 10@26	37@35, 32.2@12.8	36.3@12.8	Wismer and Christie 1987
Adults	-	37@35	-	Wismer and Christie 1987
Largemouth Bass				
Eggs & Spawning Adults	<10	29.1-32.3	36.7@20, 40.1@28	Stuber et al. 1982, Wismer and Christie 1987, Parkos and Wahl 2002

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TABLE 2.4-2 (CONT.)

FOCUS SPECIES LETHAL TEMPERATURE THRESHOLDS

Species	Lower Incipient Lethal Temperature[1,2]	Upper Incipient Lethal Temperature[1,3]	Critical Thermal Maximum[1,4]	Data Source
Fry (Larvae)	-	-	-	-
Juveniles	5@20, 11@30	13@20, 40@35		Wismer and Christies 1987
Adults	5.5@20, 11.8@30	32.5@20, 36.4@30	40.9@32	Wismer and Christie 1987, McCullough 1999
Yellow Perch				
Eggs & Spawning Adults	-	3.7	21	Hokanson 1977
Fry (Larvae)	-	24@7.6, 26.6@15.8	34.8@7.6, 37.6@15.8	Wismer and Christie 1987
Juveniles	-	-	29.2-35	Krieger et al. 1983
Adults	1.1@11, 3.7@25	21@5, 32.3@25	35@22	Wismer and Christie 1987
Walleye				
Eggs & Spawning Adults	2.2@11	31.2@11	-	Schneider et al. 2002
Fry (Larvae)	-	-	-	-
Juveniles	-	31.6@25.8, 27@8	-	Wismer and Christie 1987
Adults	8@25	28.9@7.2	34.3@23.3	Wismer and Christie 1987, Spotila et al. 1979
Greater Redhorse				
Eggs & Spawning Adults	-	-	-	-

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TABLE 2.4-2 (CONT.)

FOCUS SPECIES LETHAL TEMPERATURE THRESHOLDS

Species	Lower Incipient Lethal Temperature[1,2]	Upper Incipient Lethal Temperature[1,3]	Critical Thermal Maximum[1,4]	Data Source
Fry (Larvae)	-	-	-	-
Juveniles	-	-	-	-
Adults	-	-	-	-
White Sucker				
Eggs & Spawning Adults	2.9@21.2	31.5@21.1, 29@8.9	24	Twomey et al. 1984, McCormick et al. 1977
Fry (Larvae)	4.8@15.2, 6@21	28@10, 30@21	32	Wismer and Christie 1987, Twomey et al. 1984
Juveniles	2@20, 6@25	29@25, 26@5	31	Wismer and Christie 1987, Twomey et al. 1984
Adults	1	-	31.6	Twomey et al. 1984
Lake Sturgeon				
Eggs & Spawning Adults	<10@14	-	-	Wang et al. 1985
Fry (Larvae)	-	-	-	-
Juveniles	-	-	-	-
Adults	-	-	-	-

Notes:

[1]Acclimation Temperature: Temperature that organism (embryo, larvae, juvenile, or adult) is acclimated to (acclimation temperatures, if available, are preceded by the @ symbol).

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[2]Lower Incipient Lethal Temperature: The lower temperature value beyond which 50% of the population can no longer survive. Values are given as a lower temperature in ºC the fish or embryos were suddenly subjected to (first value) and the acclimation temperature in ºC (example: 6@18). Values for the highest and lowest acclimation temperatures tested are usually given.

[3]Upper Incipient Lethal Temperature: The upper temperature value beyond which 50% of the population can no longer survive. Values are given as a higher temperature in ºC the fish or embryos were suddenly subjected to (first value) and the acclimation temperature in ºC (example: 32@18). Values for the highest and lowest acclimation temperatures tested are usually given.

[4]Critical Thermal Maximum: The upper temperature value beyond which fish cannot survive.

‘ – ‘ indicates no data are available for this parameter.

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TABLE 2.4-3

FOCUS SPECIES PREFERRED TEMPERATURE RANGES

Species	Temperature Preferences ºC[1]				Data Source
	Staging/ Migration Temperature[2]	Spawning Temperature[3]	Nest Abandonment[4]	Preferred Temperature[5]	
Chinook Salmon					
Eggs & Spawning Adults	10.6-19.4	5.8-12.8 (2.2-16)	-	5.8-12.8 (2.2-18.9)	McCullough 1999
Fry (Larvae)	-	-	-	12-14 (0-24)	Raleigh et al. 1986, Becker 1983
Juveniles	-	-	-	12-18 (0-24)	Raleigh et al. 1986
Adults	-	-	-	2-20	McCullough 1999
Rainbow Trout					
Eggs & Spawning Adults	-	2-15.5	-	7-12 (3-18.5)	Raleigh et al. 1984, McCullough 1999
Fry (Larvae)	-	-	-	13-19 (0-24.5)	Raleigh et al. 1984
Juveniles	-	-	-	7.2-13 (0-29)	Raleigh et al. 1984, Barnhart 1986
Adults	-	-	-	13-21 (0-29)	Raleigh et al. 1984
Lake Trout					
Eggs & Spawning Adults	-	5.5-14.4	-	1.8-10	Wismer and Christie 1987, McCullough 1999
Fry (Larvae)	-	-	-	9-10 (4-18)	Marcus et al. 1984

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TABLE 2.4-3 (CONT.)

FOCUS SPECIES PREFERRED TEMPERATURE RANGES

Species	Temperature Preferences ºC[1]				Data Source
	Staging/ Migration Temperature[2]	Spawning Temperature[3]	Nest Abandonment[4]	Preferred Temperature[5]	
Juveniles	-	-	-	10.8-11.7 (4-18)	Wismer and Christie 1987, McCullough 1999, Marcus et al. 1984
Adults	-	-	-	7-15 (4-18)	McCullough 1999, Marcus et al. 1984
Rainbow Smelt					
Eggs & Spawning Adults	0.50-4.5	2.2-14.5	-	11-17	Wismer and Christie 1987 Goodyear et al. 1982
Fry (Larvae)	-	-	-	6.1-13.3	Becker 1983
Juveniles	-	-	-	6.1-13.3	Becker 1983
Adults	-	-	-	6.1-13.3	Becker 1983
Northern Pike					
Eggs & Spawning Adults	-	4.4-19	-	6.4-17.7	Wismer and Christie 1987
Fry (Larvae)	-	-	-	18-25.6	Wismer and Christie 1987
Juveniles	-	-	-	10-19	Wismer and Christie 1987, Inskip 1982
Adults	-	-	-	14-21	Wismer and Christie 1987, Inskip 1982

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TABLE 2.4-3 (CONT.)

FOCUS SPECIES PREFERRED TEMPERATURE RANGES

Species	Temperature Preferences ºC[1]				Data Source
	Staging/ Migration Temperature[2]	Spawning Temperature[3]	Nest Abandonment[4]	Preferred Temperature[5]	
Muskellunge					
Eggs & Spawning Adults	-	16-18 (8-19)	-	10-18	Wismer and Christie 1987, Harrison 1978
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-
Adults	-	-	-	0.6-25.6	Becker 1983
Emerald Shiner					
Eggs & Spawning Adults	-	20-23.5	-	20-27	Wismer and Christie 1987, Goodyear et al. 1982
Fry (Larvae)	-	-	-	19-29	Wismer and Christie 1987
Juveniles	-	-	-	24-31	Wismer and Christie 1987
Adults	-	-	-	25 (24-31)	Becker 1983
Bluntnose Minnow					
Eggs & Spawning Adults	-	20-26.1	-	19-25	Ross et al. 2001, Scott and Crossman 1979, Becker 1983
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-

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TABLE 2.4-3 (CONT.)

FOCUS SPECIES PREFERRED TEMPERATURE RANGES

Species	Temperature Preferences ºC[1]				Data Source
	Staging/ Migration Temperature[2]	Spawning Temperature[3]	Nest Abandonment[4]	Preferred Temperature[5]	
Adults	-	-	-	23-29.5	Spotila et al. 1979
Brown Bullhead					
Eggs & Spawning Adults	-	20.6-25 (14-29)		20.6-23.3	Wismer and Christie 1987, Blumer 1985, Becker 1983
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-
Adults	-	-	-	20.8-27.3	Becker 1983
American Eel					
Eggs & Spawning Adults	-	-	-	-	-
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	25	Wismer and Christie 1987
Adults	-	-	-	10->32.2 (0-32.2)	Wismer and Christie 1987
Rock Bass					
Eggs & Spawning Adults	12.1-17.7	17.7-31.5	-	20.5-21.1 (17.7-23.5)	Wismer and Christie 1987, Noltie and Keenleyside 1987, Gross and Nowell 1980
Fry (Larvae)	-	-	-	-	-

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TABLE 2.4-3 (CONT.)

FOCUS SPECIES PREFERRED TEMPERATURE RANGES

Species	Temperature Preferences ºC[1]				Data Source
	Staging/ Migration Temperature[2]	Spawning Temperature[3]	Nest Abandonment[4]	Preferred Temperature[5]	
Juveniles	-	-	-	-	-
Adults	-	-	-	24-30.5 (14.7-30.5)	Becker 1983, Wydowski and Whitney 2003
Smallmouth Bass					
Eggs & Spawning Adults	12.8-16	16.1-18.3	15.6	15.6-18.3 (13-25)	Edwards et al. 1983, Wydowski and Whitney 2003, Hubbs and Bailey 1938
Fry (Larvae)	-	-	-	25-29	Edwards et al. 1983
Juveniles	-	-	-	14-31.5	Wismer and Christie 1987
Adults	-	-	-	21-27	Edwards et a. 1983
Largemouth Bass					
Eggs & Spawning Adults	12-15.5	18.9- 22.5 (16.7-29)	19	20-21 (13-26)	Stuber et al. 1982, Summerfelt 1975, Becker 1983
Fry (Larvae)				27-30	Stuber et al. 1982
Juveniles				24-30	Stuber et al. 1982
Adults				24-30	Stuber et al. 1982

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TABLE 2.4-3 (CONT.)

FOCUS SPECIES PREFERRED TEMPERATURE RANGES

Species	Temperature Preferences ºC[1]				Data Source
	Staging/ Migration Temperature[2]	Spawning Temperature[3]	Nest Abandonment[4]	Preferred Temperature[5]	
Yellow Perch					
Eggs & Spawning Adults	6.1-8.9 (6.1-12.8)	9-12 (2-18.6)	-	9-12 (4-20)	Krieger et al. 1983, Hokanson 1977
Fry (Larvae)	-	-	-	3-28	Krieger et al. 1983
Juveniles	-	-	-	-	-
Adults	-	-	-	17.6-25	Krieger et al. 1983
Walleye					
Eggs & Spawning Adults	1.1-17.8	5-12 (2.2-15.6)	-	6-11 (6-15)	McMahon et al. 1984, Goodyear et al. 1982, Schneider et al. 2002, Hokanson 1977
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-
Adults	-	-	-	-	-
Greater Redhorse					
Eggs & Spawning Adults	-	13 - 19	-	-	Healy 2002
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-

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TABLE 2.4-3 (CONT.)

FOCUS SPECIES PREFERRED TEMPERATURE RANGES

Species	Temperature Preferences ºC[1]				Data Source
	Staging/ Migration Temperature[2]	Spawning Temperature[3]	Nest Abandonment[4]	Preferred Temperature[5]	
Adults	-	-	-	-	-
White Sucker					
Eggs & Spawning Adults	4-10	10 - 18	-	12-14 (12-20)	Wismer and Christie 1987, Twomey et al. 1984, Becker 1983
Fry (Larvae)	-	-	-	23-25	Twomey et al. 1984
Juveniles	-	-	-	19-24	Twomey et al. 1984
Adults	-	-	-	19-24	Twomey et al. 1984
Lake Sturgeon					
Eggs & Spawning Adults	-	11-18	-	12-17	Hughes 2002
Fry (Larvae)	-	-	-	-	-
Juveniles	-	-	-	-	-
Adults	-	-	-	-	-

Notes:

[1]Preferred water temperatures with the full range of documented temperatures in parentheses.

[2]Staging/Migration Temperature: Range of water temperatures where a migration to spawning areas, nest building, or other behaviors exhibited prior to spawning most frequently occurs. The water temperature ranges in parenthesis are the full range over which these behaviors have been documented.

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[3]Spawning Temperature: Range of water temperatures where females most frequently release their eggs. The water temperature ranges in parenthesis are the full range over which females have been documented to release their eggs.

[4]Nest Abandonment: Lower water temperature threshold where nest building species have been observed to abandon active nests (nests that contain incubating eggs or fry that the adult fish is guarding from predation or maintaining in some fashion.

[5]Preferred Temperature: Range of water temperature where optimal growth occurs that are preferred by fry, juvenile, or adults when given a thermal gradient to choose from. The range of temperatures given in parenthesis are where optimal growth of fry, juvenile, or adults no longer occurs. For incubating embryos, the range of preferred temperatures are those at which embryos have been documented to hatch with no significant mortalities. The range of temperatures given in parenthesis are those at which a percentage of embryos have been documented to survive.

‘ – ‘ indicates no data are available for this parameter.

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TABLE 2.4-4

FOCUS SPECIES HABITAT PREFERENCES

Species	Spawning Season[1]	Preferred Habitat Type[2]	Preferred Depth (ft)[3]	Preferred Velocities (fps)[4]	Data Source
Chinook Salmon					
Eggs & Spawning Adults	late August to September (late August to mid-November)	mod.-fast riffle, over gravel and cobble	>1	1.5-2.4	Goodyear et al. 1982, Raleigh and Miller 1986, Smith 1985
Fry (Larvae)	n/a[5]	pools and eddies	>0.5	<1.6	Raleigh et al. 1986
Juveniles	n/a	pools and eddies	>0.5	0.3-0.7 (0-3)	Raleigh et al. 1986
Adults (in freshwater)	n/a	Large deep pools	3.9-9.2 (>1)	0.7-3.6 (0.6-5.1)	Raleigh et al. 1986
Rainbow Trout					
Eggs & Spawning Adults	April to May (November to July)	mod.-fast riffle, over gravel and cobble	1-8	1.6-3	Raleigh et al. 1984, Barnhart 1986, Goodyear et. al 1982
Fry (Larvae)	n/a	shallow riffles over gravel and cobble	0.8-1.6	0-0.5	Raleigh et al. 1984
Juveniles	n/a	riffles & runs over gravel and cobble, boulder	>2	0-1	Raleigh et al. 1984
Adults	n/a	riffles and runs over gravel and cobble, boulder	>2	0-1	Raleigh et al. 1984
Lake Trout					
Eggs & Spawning Adults	October to November (September to December)	eddies & runs over boulders, cobble, & gravel	1-120	slow or no current	Marcus et al. 1984, Loftus 1958
Fry (Larvae)	n/a	enter lake soon after hatching	40-175 (1-120)	Lacustrine, pelagic	Marcus et al. 1984, Becker 1983
Juveniles	n/a	lake	40-175	Lacustrine, pelagic	Marcus et al. 1984, Becker 1983
Adults	n/a	lake	40-175	Lacustrine, pelagic	Marcus et al. 1984, Becker 1983
Rainbow Smelt					
Eggs & Spawning Adults	late April to early May (late March to July)	gravel substrates in stream	0.3-4.3	2-2.6	Buckley et al. 1989, Goodyear et al. 1982,
Fry (Larvae)	n/a	drift down to lake soon after hatching	<80	lacustrine, littoral	Buckley et al. 1989, Goodyear et al. 1982, Becker 1983
Juveniles	n/a	midwater offshore regions of lake	<80	lacustrine, littoral	Buckley et al. 1989, Goodyear et al. 1982, Becker 1983
Adults	n/a	midwater offshore regions of lake	<80	Lacustrine, pelagic	Buckley et al. 1989, Goodyear et al. 1982, Wallus 1990
Northern Pike					
Eggs & Spawning Adults	late March to late April (mid-March to June)	calm, shallow water over vegetation	0.5-16	still water	Inskip 1982, Farrell 2001, Goodyear et al. 1982, Wallus 1990

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TABLE 2.4-4 (CONT.)

FOCUS SPECIES HABITAT PREFERENCES

Species	Spawning Season[1]	Preferred Habitat Type[2]	Preferred Depth (ft)[3]	Preferred Velocities (fps)[4]	Data Source
Fry (Larvae)	n/a	calm, shallow water over vegetation	0.3-4	still water	Inskip 1982, Goodyear et al. 1982, Wallus 1990
Juveniles	n/a	calm, shallow water over vegetation	1-16	0-0.3	Inskip 1982
Adults	n/a	calm, shallow water over vegetation	<13 (<60)	0-0.3	Inskip 1982
Muskellunge					
Eggs & Spawning Adults	late March to June	vegetated lotic areas	3-7	0.7	Cook and Solomon 1987, Goodyear et al. 1982, Inskip 1986, Harrison 1978
Fry (Larvae)	n/a	vegetated lotic areas	3-7	0.7	Cook and Solomon 1987, Inskip 1986
Juveniles	n/a	deeper vegetated lotic areas	2-5	>0.3	Cook and Solomon 1987, Inskip 1986, Goodyear et al. 1982
Adults	n/a	deeper vegetated lotic areas	<15 (<50)	>0.3	Cook and Solomon 1987, Becker 1983, Inskip 1986
Emerald Shiner					
Eggs & Spawning Adults	June to July (mid-May to late August)	mid-water	>3	noticeable current	Pflieger 1975, Goodyear et al. 1982
Fry (Larvae)	n/a	pelagic, mid-water to surface in deep rivers	>3	noticeable current	Pflieger 1975, Trautman 1981
Juveniles	n/a	pelagic, mid-water to surface in deep rivers	>3	noticeable current	Pflieger 1975, Trautman 1981
Adults	n/a	pelagic, mid-water to surface in deep rivers	>3	noticeable current	Pflieger 1975, Trautman 1981
Bluntnose Minnow					
Eggs & Spawning Adults	May to July (April to September)	shallow stillwater, sand/gravel in rivers and streams	0.5-3	slow or no current	Ross et al. 2001, Goodyear et al. 1982, Hubbs and Cooper 1936
Fry (Larvae)	n/a	shallow stillwater, sand/gravel in rivers and streams	0.5-3	slow or no current	Goodyear et al. 1982, Hubbs and Cooper 1936
Juveniles	n/a	quiet pools and backwaters of rivers and streams	0.5-13	slow or no current	Pflieger 1975, Becker 1983
Adults	n/a	quiet pools and backwaters of rivers and streams	0.5-13	slow or no current	Pflieger 1975, Becker 1983
Brown Bullhead					
Eggs & Spawning Adults	June to July (May to August)	marshes, bays, coves, creek mouths, nearshore	<4	still water	Goodyear et al. 1982, Becker 1983
Fry (Larvae)	n/a	marshes, bays, coves, creek mouths, nearshore	<1	still water	Goodyear et al. 1982, Scott and Crossman 1979
Juveniles	n/a	shallow warmwater vegetated areas	<40	still water	Scott and Crossman 1979
Adults	n/a	shallow warmwater vegetated areas	<40	still water	Scott and Crossman 1979

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TABLE 2.4-4 (CONT.)

FOCUS SPECIES HABITAT PREFERENCES

Species	Spawning Season[1]	Preferred Habitat Type[2]	Preferred Depth (ft)[3]	Preferred Velocities (fps)[4]	Data Source
American Eel					
Eggs & Spawning Adults	Feb to April	Sargasso Sea	-[6]	-	DFOC 2004
Fry (Larvae)	n/a	Nearshore marine areas	-	-	DFOC 2004
Juveniles	n/a	Estuaries, small to large streams, rivers and lakes	-	-	DFOC 2004
Adults	n/a	Moderate to large streams with continuous flow	-	-	Wallus et al. 1990
Rock Bass					
Eggs & Spawning Adults	late May to June (April to early August)	sand/gravel, sheltered nearshore areas near structure	2-4	slow or no current	Goodyear et al. 1982, Becker 1983, Wydowski and Whitney 2003
Fry (Larvae)	n/a	sand/gravel, sheltered nearshore areas near structure	2-4	slow or no current	Goodyear et al. 1982, Becker 1983, Bovee et al. 1994
Juveniles	n/a	near cover of vegetation, cobble, bed rock, gravel	up to 40	0-0.8	Goodyear et al. 1982, Becker 1983, Bovee et al. 1994
Adults	n/a	near cover of vegetation, cobble, bed rock, gravel	up to 40	0-0.9	Goodyear et al. 1982, Becker 1983, Bovee et al. 1994
Smallmouth Bass					
Eggs & Spawning Adults	May to July (March to mid-August)	cobble or gravel	2-20	0-1.1	Edwards et al. 1983, Goodyear et al. 1982 Hubbs and Bailey 1938, Scott and Crossman 1979
Fry (Larvae)	n/a	slow to moderate current over gravel	0.2-2.4	<0.5	Edwards et al. 1983
Juveniles	n/a	slow to moderate current over boulders, cobble, or gravel	>2.4 (>0.2	0-0.5 (0-2.4)	Edwards et al. 1983
Adults	n/a	slow to moderate current over boulders, cobble, or gravel	>4(>0.8)	0-0.5 (0-2)	Edwards et al. 1983
Largemouth Bass					
Eggs & Spawning Adults	late May to early July (April to August)	slow, gravel pool	0.5-26	0-0.09	Stuber et al. 1982, Goodyear et al. 1982
Fry (Larvae)	n/a	slow pool, 40-80% cover	>3.3 (>0.2)	<0.2	Stuber et al. 1982
Juveniles	n/a	slow river or pool with soft bottom with vegetation	>3.3 (>0.2)	<0.2	Stuber et al. 1982
Adults	n/a	slow river or pool with soft bottom with vegetation	3.3-9.8 (2-43)	<0.2	Stuber et al. 1982, Wydowski and Whitney 2003, Becker 1983
Yellow Perch					
Eggs & Spawning Adults	April to May (March to June)	slow moving, littoral areas over vegetation and brush	1.2-3 (0.5-5.6)	<0.25 (<0.5)	Krieger et al. 1983, Goodyear et al. 1982
Fry (Larvae)	n/a	Near shore and open water	1.1-20	<0.25 (<0.5)	Krieger et al. 1983
Juveniles	n/a	Near shore and open water	1.4-20 (<95)	0-0.15 (<0.4)	Krieger et al. 1983, Carlander 1997

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TABLE 2.4-4 (CONT.)

FOCUS SPECIES HABITAT PREFERENCES

Species	Spawning Season[1]	Preferred Habitat Type[2]	Preferred Depth (ft)[3]	Preferred Velocities (fps)[4]	Data Source
Adults	n/a	Near shore and open water	1.4-20 (<95)	0-0.18 (<0.4)	Krieger et al. 1983, Carlander 1997
Walleye					
Eggs & Spawning Adults	April to May (April to June)	fast-water areas of stream over sand, gravel, and cobble	2.5-5 (1-6.5)	2.5-3 (0-3.6)	McMahon et al. 1984, Goodyear et al. 1982
Fry (Larvae)	n/a	water surface (first 4 days), demersal (<25-40 mm length)	riverine pools and lakes	(<0.25)	McMahon et al. 1984
Juveniles	n/a	riverine pools and littoral habitat in lakes (photosensitive)	riverine pools and lakes	<2	McMahon et al. 1984
Adults	n/a	riverine pools and littoral habitat in lakes (photosensitive)	riverine pools and lakes	<2.4	McMahon et al. 1984
Greater Redhorse					
Eggs & Spawning Adults	April to early July (May to July)	slow, gravel or cobble riffles	0.3-3	1.2 (0.1-3.8)	Healy 2002, Goodyear et al. 1982
Fry (Larvae)	n/a	slow, shallow pool	>0.7 (0.2-3.3)	0.7 (0.3-2.9)	Healy 2002
Juveniles	n/a	slow, medium pool	3.3 (0.2-5)	1.2 (0.2-4.3)	Healy 2002
Adults	n/a	slow, boulder, cobble, & gravel runs	1.5	<0.6	Bunt and Cooke 2002, Healy 2002
White Sucker					
Eggs & Spawning Adults	April to May (April to June)	slow, sand or gravel riffles	0.2-1	1-2	Twomey et al. 1984, Goodyear et al. 1982
Fry (Larvae)	n/a	slow riffle over sand & gravel	>1	<0.3	Twomey et al. 1984
Juveniles	n/a	slow riffle & pool over sand & gravel	3 (>1)	<0.3	Twomey et al. 1984
Adults	n/a	slow pools	3 (>1)	<0.3	Twomey et al. 1984
Lake Sturgeon					
Eggs & Spawning Adults	mid-May to June	deep pool and runs over sand & gravel	2-25	0.3-2.3	Hughes 2002, Threader et al. 1998
Fry (Larvae)	n/a		-	-	Hughes 2002
Juveniles	n/a	deep pool eddies and runs over sand & gravel	6-35	0.6-0.13	Hughes 2002
Adults	n/a	deep pool and runs in main channel over sand & gravel	6-35	0.6-0.13	Hughes 2002

Notes: [1]Spawning Season: The season where mature fish exhibit spawning behavior (migration, staging, nest building, and protection of embryos or larvae/fry (full range of documented spawning season in northern latitudes is in parenthesis). [2]Preferred Habitat Type: The preferred habitat for the release and incubation of eggs, rearing of fry and juveniles, or non-spawning adult fish. [3]Preferred Habitat Depth (ft): The optimum preferred habitat depth in feet (ft) for different life stages of fish (full range of documented depths is in parenthesis) [4]Preferred Habitat Velocities (fps): The optimum preferred habitat velocities in feet/second (fps) for different life stages of fish (full range of documented velocities is in parenthesis) [5]'n/a' not applicable [6]' – ' no data available

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This material is contained in:
Volume 2
Section: Water Temperatures of the Niagara River and its U.S. Tributaries

FIGURE 2.1-1

LOCATIONS OF WATER LEVEL GAUGES AND WATER TEMPERATURE GAUGES IN 2002

[NIP – General Location Maps]

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FIGURE 2.1-2

LOCATIONS OF WATER LEVEL GAUGES AND WATER TEMPERATURE GAUGES IN 2003

[NIP – General Location Maps]

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FIGURE 2.1-3

LOCATIONS OF METEOROLOGICAL DATA COLLECTION SITES IN 2002 AND 2003

[NIP – General Location Maps]

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FIGURE 2.2-1

ANALYSIS ZONE 1: BUCKHORN MARSH AND UPPER NIAGARA TRIBUTARY STREAMS

[NIP – General Location Maps]

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FIGURE 2.2-2

ANALYSIS ZONE 2: UPPER NIAGARA RIVER – MAIN CHANNEL

[NIP – General Location Maps]

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FIGURE 2.2-3

ANALYSIS ZONE 3: UPPER NIAGARA RIVER – SHALLOW WATER AREAS OFF OF MAIN CHANNEL AND IMMEDIATELY DOWNSTREAM OF TRIBUTARIES

[NIP – General Location Maps]

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FIGURE 2.2-4

ANALYSIS ZONE 4: LOWER NIAGARA – GORGE BETWEEN FALLS AND TAILRACE

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FIGURE 2.2-5

ANALYSIS ZONE 5: LOWER NIAGARA – BELOW TAILRACE

[NIP – General Location Maps]

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FIGURE 2.2-6

ANALYSIS ZONE 6: LEWISTON RESERVOIR

[NIP – General Location Maps]

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FIGURE 2.3.1-1

EXAMPLE ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES

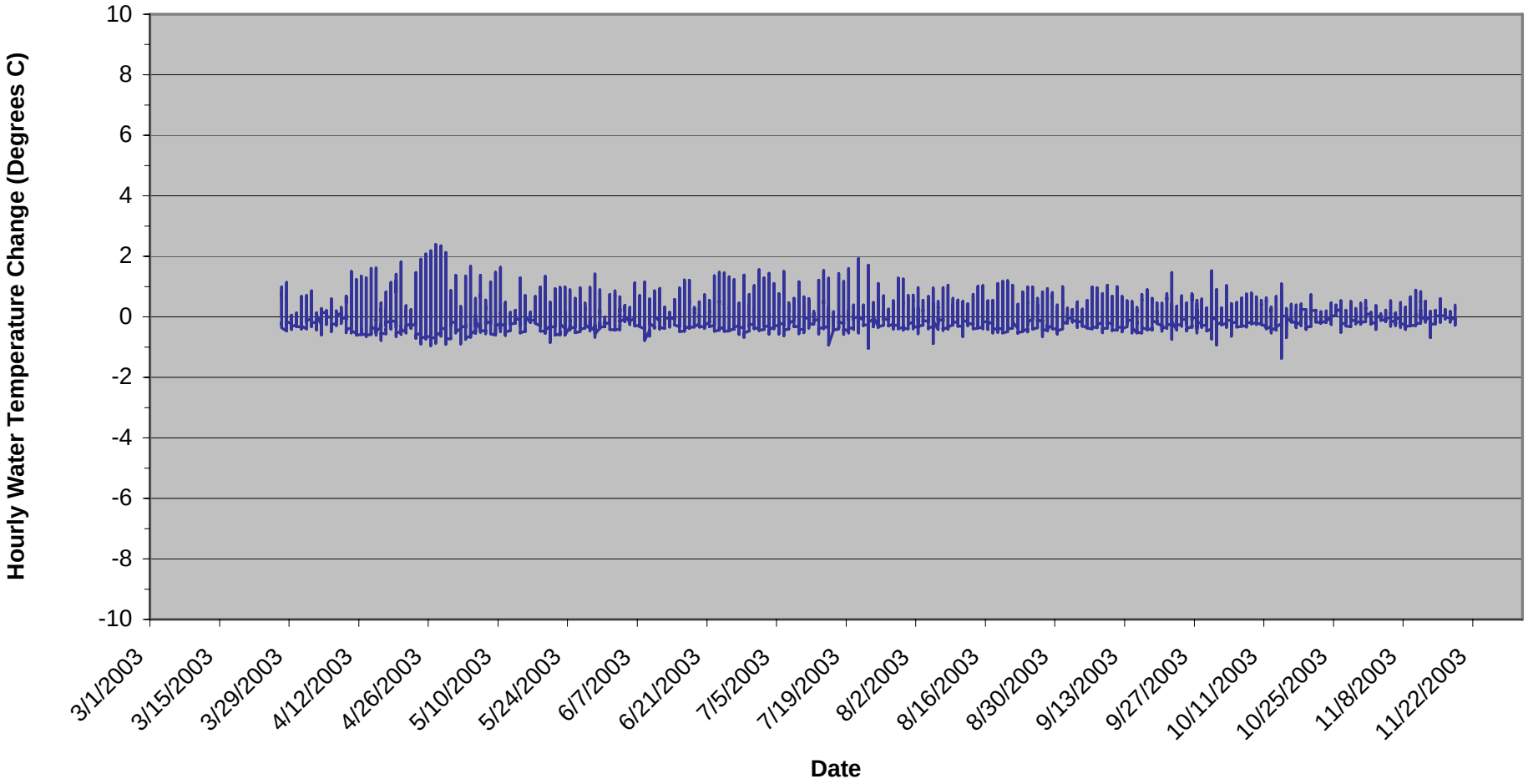

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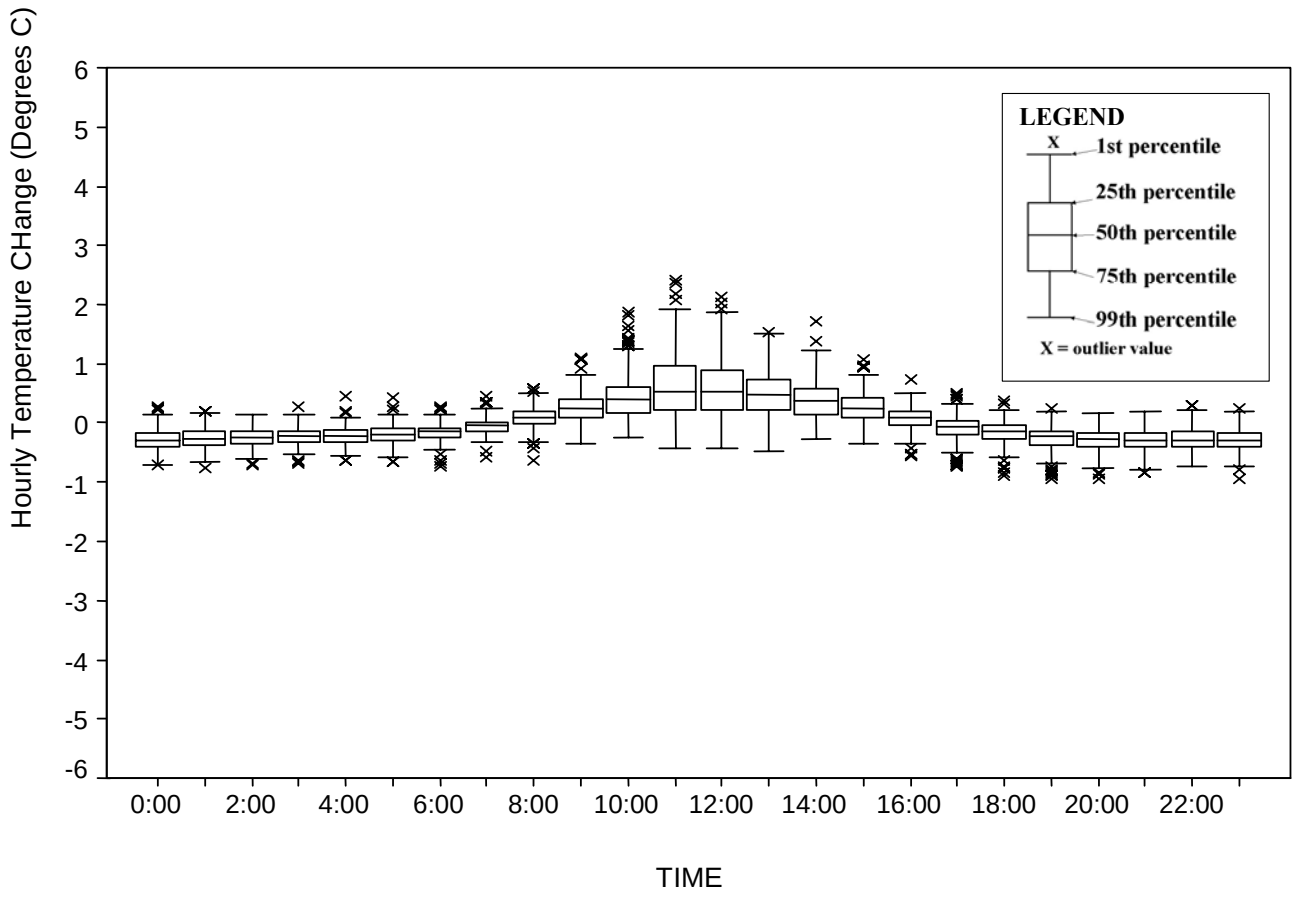
FIGURE 2.3.1-2

EXAMPLE FREQUENCY DISTRIBUTION PLOT OF HOURLY $\Delta°C_{WT}$ VALUES



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3.0 RESULTS

The effect of water level fluctuations on water temperatures could not be determined from the visual assessment; however, it was evident that the timing of water level changes at some locations was consistent with the timing of water temperatures changes at those locations.

The effect of water level fluctuations on water temperatures could not be determined from the correlation analysis. This was likely due to the fact that many of the factors that affect water temperatures are temporally related. Therefore, results from the correlation analysis are not reported further.

As described in Section 2.3, the evaluation of potential water level related temperature effects on focus species in the investigation area is a three-step process: 1) determine if water level fluctuations affect the normal range of seasonal and diurnal temperature fluctuations, 2) determine if the timing of water level fluctuations appear to be correlated with the timing of water temperatures changes at specific times and locations, with effects occurring in the form of rapid, temporary temperature fluctuations, and if such a relationship was identified, 3) determine if identified temperature effects exceed thresholds for behavioral or survival effects on focus species' life history stages at the affected locations and times.

The results of this three -step process are presented in Sections 3.1, 3.2, and 3.3, respectively.

3.1 Seasonal and Diurnal Patterns

Seasonal and diurnal temperature patterns in the investigation area were characterized using data collected at a total of 63 gauge locations in 2002 and 2003. Seasonal and diurnal temperature ranges at all gauge locations are summarized in Table 3.1-1. Water level fluctuations due to U.S./Canadian power generation have no identifiable effect on seasonal or diurnal temperature ranges in the investigation area.

As shown in Table 3.1-1, the observed seasonal range of water temperatures varies within the investigation area, but in general it ranges from near zero to 25 °C in the upper and lower Niagara River

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and zero to 28 °C in tributaries (some gauges were not deployed until April or May, therefore the minimum temperature at some locations simply reflects a deployment at a time of year in which water temperature was greater than 0°C). The average daily water temperatures for March through November 2003 at survey locations in the upper Niagara River and two tributary streams at locations not affected by water level fluctuations are shown in Figure 3.1-1. As shown, the daily average temperature, while variable, increases steadily through spring into mid summer, and then begins to decline into the fall. While daily temperatures may vary considerably, particularly in tributaries, the observed rate of change when viewed from a seasonal perspective is very gradual, approximately 0.2 ºC/day in both the main river and its tributaries. It is instructive to note that the tributary streams are warmer on average than the river in the spring, and cooler in the fall. This is due to the fact that the Niagara River and its source body Lake Erie are massive bodies of water with much greater heat absorption and retention capacity than the relatively small tributary streams, and they respond more slowly to seasonal temperature change.

Diurnal water temperature fluctuations occur in all months when water is not frozen, and all months considered for the purpose of this investigation. Average and maximum diurnal temperature ranges at all locations are shown in Table 3.1-1. Diurnal fluctuations vary around the average daily temperatures determined by seasonal conditions, and are caused by the daily differences in air temperature and exposure to solar radiation. The range of diurnal variation varies by month and location, typically largest in spring and fall. Figure 3.1-2 shows the hourly average temperatures in April and May in the upper Niagara River (immediately upstream of Spicer Creek), and at a location not affected by water level fluctuations in Big Sixmile Creek, an upper Niagara River tributary. As shown, the diurnal temperature variations in the Niagara River (gauge location TUNR-03) do not greatly exceed 2 °C/day. In contrast, diurnal temperature fluctuations in Big Sixmile Creek (gauge location SMC-01) as large as 13 °C/day occur. This degree of diurnal temperature variation is typical in smaller tributaries and is due to diurnal change in air temperature. While the magnitude of diurnal temperature fluctuation can be large, the rate of change is relatively gradual. Temperature changes due to diurnal change in air temperature rarely exceed 2 °C/hour, and are typically less than 1 °C/hour. In the Niagara River proper, the rate of change is even smaller, typically less than 0.5 °C/hour.

Although the water level fluctuations due to U.S./Canadian power generation had no effect on the seasonal and diurnal water temperature ranges, Fish and Gill Creeks, small tributary streams which flow

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adjacent to Lewiston Reservoir, receive water directly or indirectly from Lewiston Reservoir. Both streams receive increased groundwater inflow caused by hydrostatic pressure from the reservoir (URS et al. 2003, URS et al. 2005b). Gill Creek also receives flow augmentation directly from the reservoir from early June through late September.

Diurnal temperatures in Fish Creek are generally comparable to those in Big Sixmile Creek reference location SMC-01. Gauge location TFC-02, located downstream of the reservoir, was consistently 3.5 to 5.0 cooler than at location TFC-01 upstream of the reservoir during early July, and the water temperature at TFC-02 was generally less than 21°C in July and August 2003. This suggests that groundwater discharge to Fish Creek may influence (cool) the water temperatures of Fish Creek.

Gill Creek diurnal temperature ranges in spring and fall months resemble those in Fish Creek, again reflecting a possible influence of groundwater inflow. During summer months, flow augmentation from Lewiston Reservoir dominates temperature conditions downstream of the discharge point (as measured at TGLC-01). The maximum diurnal temperature fluctuation at TGLC-01 during flow augmentation in 2003 was 1.4 °C. In contrast, over the same period the maximum and average diurnal fluctuations immediately upstream at TGLC-03 were 5.4 °C and 2.6 °C, respectively (see Table 3.1-1).

Seasonal temperature ranges in both creeks are also influenced by groundwater influence to an unknown extent and in Gill Creek by flow augmentation. The inflow of groundwater during summer months serves to cool the stream and may lower the summer maximum temperatures below levels that would occur in the absence of this influence.

3.2 Temperature Effects Analysis

The results of the evaluation used to identify temperature effects in the investigation area are presented by analysis zone in the following sections.

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3.2.1 Buckhorn Marsh and Niagara River Tributaries (Analysis Zone 1)

The three methods used to evaluate temperature conditions in Analysis Zone 1 (Figure 2.2-1) were (1) seasonal and diurnal patterns, (2) frequency distribution of hourly $\Delta°C_{WT,}$ and (3) frequency distribution of hourly ΔWL. Figure series 3.2.1-1a, 3.2.1-1b and 3.2.1-1c are used to illustrate how this first method was applied. Figures 3.2.1-1a, 3.2.1-1b and 3.2.1-1c show hourly average water temperatures and water elevations in Big Sixmile Creek at location SMC-01 (approximately 2000 feet upstream of the creek mouth) and in the Niagara River proper (TUNR-02, GN-River_Int), and hourly average air temperature in April, May and June, respectively. Water level readings at SMC-01 demonstrate that this location is independent of water levels in the Niagara River, indicating that this location is a useful reference site for tributary water temperature patterns. Diurnal variations in water temperatures at this location are predominantly influenced by air temperature, and can be as large as 13 °C/day. Figures 3.2.1-2a, 3.2.1-2b and 3.2.1-2c show a similar pattern of response at reference location CC-03 (in Cayuga Creek) in April, May and June, respectively. Water levels measured at this location indicate that it is clearly independent of Niagara River levels. Diurnal temperature fluctuations on the order of 9 °C/day are commonplace at CC-03.

In contrast, Figures 3.2.1-3a, 3.2.1-3b and 3.2.1-3c show hourly average water temperatures and water levels in lower Gun Creek at location GC-01 (at the confluence with the Niagara River), hourly average water levels and temperatures in the Niagara River upstream of Spicer Creek, and hourly average air temperature in April, May and June, respectively. These locations are demonstrably affected by water level fluctuations in the Niagara River. As shown, water temperatures in lower Gun Creek vary with diurnal fluctuations in air temperature, and the range of diurnal temperature fluctuation is similar to those observed in the reference creeks. However, additional fluctuations in temperature also occur that, while within the range of diurnal fluctuation, are independent of air temperature and relatively rapid. Further illustration of these temperature variations is provided in Figure 3.2.1-3d, which examines an eight day period in April 2003 at this location. This figure highlights the potential for rapid water temperature fluctuations that are not consistent with changes in air temperature. These fluctuations are not explained by precipitation events, as no rainfall was recorded at Niagara Falls International Airport (NFIA) during the period from April 15th to April 21st, 2003. (Data for reference locations in Big Sixmile and Cayuga

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Creeks, and at affected locations in Gun Creek for the remaining study period months in 2003 are presented in Appendix B.)

The mechanism for this type of temperature change results from the complex interplay between river water level and tributary outflow. River levels typically are at their lowest daily level in evening hours. As water levels rise in the Chippawa-Grass Island Pool, river water is pushed into tributary mouths causing a change in water temperature. As shown in Figure 3.2.1-3d, even a small rise in river level can result in the inflow of river water and an associated drop in water temperature. A brief leveling of water levels allow for tributary temperatures to equilibrate (rise) as out flowing tributary water replaces the intruding river water. Subsequent rises and leveling of river levels causes similar temperature effects. These effects are most pronounced when the difference between tributary and river temperatures are largest.

Comparison of patterns in $\Delta°C_{WT}$ values clearly distinguishes tributary reference locations from locations affected by water level fluctuations. Figure 3.2.1-4 shows the distribution of $\Delta°C_{WT}$ values at SMC-01 in 2003. The hourly water temperature change at this location throughout the year is typically less than 2 °C/hour positive and a 1 °C/hour negative. This pattern is repeated in upper Cayuga Creek (location CC-03) in 2003 (Figure 3.2.1-5). Values for $\Delta°C_{WT}$ at this location are uniformly less than 2 °C/hour positive and generally less than 1 °C/hour negative. This pattern (i.e., larger hourly rises in temperature than drops) is logical, given that daily gain is controlled by six principal mechanisms, solar energy, longwave radiation, evaporation, convection (air temperature), stream bed conduction, and groundwater inflow. Evaporation, solar energy and longwave radiation are reduced at night, therefore heat loss at night is less rapid on average than heat gain during the day (Betschta 1997, Boyd and Sturdevant 1996). The +2 °C/hour and –1 °C/hour were selected as reference thresholds for determining temperature effects in Analysis Zone 1.

Figures 3.2.1-6 and 3.2.1-7 show $\Delta°C_{WT}$ values at location SMC-02 at the mouth of Big Sixmile Creek, and CC-01 at the mouth of Cayuga Creek, respectively. Hourly water temperature changes at these locations are larger in magnitude than those occurring upstream, regularly exceeding 2 °C/hour and often exceeding 3 °C/hour. Negative temperature changes exceeding 4 °C/hour occur occasionally in

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Cayuga Creek. Water levels at these locations are demonstrably affected by the level of the Niagara River (see Appendix B, Figures B-162 to B-170, and B-180 to B-188, respectively). Of particular interest at each of these locations is the large number of negative changes in water temperature exceeding 3 to 4 °C/hour in the spring. This effect is attributed to the mixing of upper Niagara River water with tributary water at the mouths of Big Sixmile and Cayuga Creeks associated with the daily fluctuations in upper Niagara River water level. The larger hourly changes during spring occur because upper Niagara River water temperatures are cooler than the tributary water temperatures.

Reference locations are further distinguished from affected locations by daily patterns of temperature variability by hour. Frequency distribution plots of $\Delta°C_{WT}$ values by hour of day illustrate these patterns, and provide a clear contrast between locations that are and are not affected by changes in water level. It is important to recall when comparing the annual patterns in $\Delta°C_{WT}$ values to frequency distribution plots that the former show all values, including outliers and rare extremes, while the frequency distribution plots show all normal and outlier values but not the rare extremes.

Figures 3.2.1-8a, 3.2.1-8b, and 3.2.1-8c show the frequency distribution of $\Delta°C_{WT}$ values as standard boxplots by hour of day in April through June, July and August, and September and October, respectively, at reference location SMC-01 in upper Big Sixmile Creek. The figures in this set focus on three distinct periods of interest during the tourist season, distinguished by the differences in average temperature between the river and the tributaries (see Figure 3.2.1-2). In spring and early summer (April, May and June), tributary water temperatures are typically warmer on average than the Niagara River mainstem, in summer (July and August) average river and tributary temperatures are generally comparable, and in fall (September and October) the river is warmer on average than the more rapidly cooling tributaries.

As shown in Figure 3.2.1-8a, $\Delta°C_{WT}$ values during spring and early summer months follow a consistent pattern of warming during the middle hours of the day, and cooling in the evening and early morning hours. The range of $\Delta°C_{WT}$ values is broader during daylight hours, which is attributable to variability in daytime temperatures and solar exposure. A similar pattern occurs in fall (Figure 3.2.1-8c), but with a much narrower range of $\Delta°C_{WT}$ values during midday hours, attributable to cooler days and possibly increased cloud cover during the late summer and early fall. The frequency distribution of

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$\Delta°C_{WT}$ values in July and August is more variable (Figure 3.2.1-8b), which can be attributed to warmer days during summertime.

Similar patterns are evident in upper Cayuga Creek at reference location CC-03. Temperature changes in springtime are more variable in the daytime and smaller and more uniform in nighttime and early morning hours (Figure 3.2.1-9a). Summer (Figure 3.2.1-9b) and fall (Figure 3.2.1-9c) temperatures follow a very similar pattern.

In contrast, $\Delta°C_{WT}$ frequency distribution plots for location SMC-02 at the mouth of Big Sixmile Creek show a markedly different pattern of temperature variability. As shown in Figure 3.2.1-10a, the range of $\Delta°C_{WT}$ values at this location in April, May and June are much broader in comparison to the upstream reference location, and do not follow a pattern consistent with normal diurnal temperature fluctuations. In particular, the broader range of both the boxplots and whiskers indicates that patterns in $\Delta°C_{WT}$ values inconsistent with diurnal variation are commonplace. This is strongly suggestive of an influence on water temperature that occurs throughout the day on a daily basis, and appears not to be related to U.S./Canadian power generation. This pattern is far less evident in the summer and fall (Figures 3.2.1-10b, and 3.2.1-10c), when average upper Niagara River temperatures are more comparable to average tributary temperatures. However, midday temperatures at location SMC-02 in summertime (Figure 3.2.1-10b) are uncharacteristically variable relative to the hours before and after. The SMC-02 gauge was located at the very mouth of Big Sixmile Creek, which is the confluence of Big Sixmile Creek and the upper Niagara River. It is likely that very small changes in water level may affect the location of the mixing zone of the waters of Big Sixmile Creek and the upper Niagara River. It is evident from Figure 3.2.1-10a that the rapid temperature changes occur at all times of the day and night and are similar in magnitude throughout the day and night. In contrast, rapid water level fluctuations at SMC-02 (as measured at the GN_Tonawanda gauge) tend to occur at distinct times in the morning and evening hours only (Figure 3.2.1-13a).

Like location SMC-02 in Big Sixmile Creek, the $\Delta°C_{WT}$ frequency distribution patterns in lower Cayuga Creek at location CC-01 are clearly indicative of a water level influenced effect on temperatures. Figures 3.2.1-11a, 3.2.1-11b, and 3.2.1-11c show the $\Delta°C_{WT}$ frequency distribution plots at this location in April through June, July and August, and September and October, respectively. Temperatures in spring

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show an evident pattern of regular and unusual cooling between 9 and 10pm, and cooling and warming between 6 and 10am in the morning (Figure 3.2.1-11a). The timing of these unusual patterns corresponds with changes in water level in the Chippawa-Grass Island Pool, and the rapid cooling which occurs at night is consistent with the influx of relatively cool water into Cayuga Creek when the pool elevation typically rises in the evening. These patterns are less evident in the summertime (Figure 3.2.1-11b), however a regular pattern of unusual warming at 10pm replaced the springtime cooling pattern. The change in pattern is attributable to the temperature of the Niagara River relative to the tributary streams in late summer, resulting in an influx of relatively warm water into tributaries when water levels rise. This pattern is also evident in the fall (Figure 3.2.1-11c), however the unusual warming pattern has shifted to 8pm. This shift is consistent with changes in Chippawa-Grass Island Pool operation patterns after September 15th to accommodate treaty flow requirements. Treaty requirements specify minimum flows of 100,000 cfs over the falls from 8am to 10pm daily from April 1st to September 15th and from 8am to 8pm from September 16th to October 31st.

Frequency distribution patterns in ΔWL values by hour are clearly supportive of the conclusion of a temperature effect at location CC-01. Figures 3.2.1-12a, 3.2.1-12b and 3.2.1-12c, show the distribution of ΔWL values by hour of day at gauge location GN-River_Int, located approximately 2 miles downstream of CC-01, during the same seasonal periods examined for $\Delta°C_{WT}$. As shown in Figure 3.2.1-12a, there is a clear pattern of larger ΔWL values between 7 and 8 am and 10 and 11pm in April through June. A similar pattern is present in July and August (Figure 3.2.1-12b). In September and October (Figure 3.2.1-12c), the evening pattern in ΔWL values shifts to between 9 and 10 pm, consistent with seasonal changes in treaty flow patterns These patterns in ΔWL comport with the $\Delta°C_{WT}$ values observed at CC-01, and strongly indicate a water level influence effect on temperature. Patterns in ΔWL values by hour affecting Big Sixmile Creek are less clear. Figures 3.2.1-13a, 3.2.1-13b and 3.2.1-13c show the frequency distribution of ΔWL at GN-Tonawanda, a representative location of Niagara River levels affecting Big Sixmile Creek. As shown in all three figures, patterns of water level fluctuations are comparable to those at GN-River_Int, but more muted in magnitude. In comparison, the patterns in $\Delta°C_{WT}$ values at SMC-02 do not comport with ΔWL values as clearly. This disparity is attributed to the fact that gauge SMC-02 was located very close to the mouth of Big Sixmile Creek, and mixing of river and tributary water can occur with very subtle changes in water level. These changes are most pronounced during springtime when the difference between river and tributary temperatures are largest.

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Annual patterns of $\Delta°C_{WT}$ values at remaining locations in Analysis Zone 1 were compared to reference patterns to identify potentially affected locations. Frequency distributions of $\Delta°C_{WT}$ and ΔWL were used to confirm the evident differences in annual $\Delta°C_{WT}$ patterns.. Specifically, locations that are not affected by water level fluctuations show a consistent pattern of relatively small changes in $\Delta°C_{WT}$, with positive changes uniformly larger than negative changes, and the greatest magnitude of $\Delta°C_{WT}$ values occurring in spring and fall months when the natural diurnal variation in water temperature is the greatest. Locations in Analysis Zone 1 where water level related temperature effects were identified are shown in Figure 3.2.1-14. The effect analysis for each gauge location is described in Table 3.2.1-1.

Temperature-affected locations in Analysis Zone 1 are predominantly located at the mouths of tributaries, which are the most exposed to influx and mixing of upper Niagara River water. The largest identified temperature effects occurred in the spring, and were predominantly negative changes. This pattern is consistent with the fact that during spring the river water intruding into tributaries when water levels fluctuate is cooler than the tributaries on average. Notably affected locations include:

- TM-01 (Woods Creek 2002): $\Delta°C_{WT}$ values ranging to –6.5 °C /hour between April 1st and June 30.
- TWC-01 (Woods Creek 2003): $\Delta°C_{WT}$ values ranging to -5.7 °C /hour between April 1st and June 30.
- TGC-01 (Gun Creek 2003): $\Delta°C_{WT}$ values ranging to –4.8 °C /hour between April 1st and June 30.
- TM-03 (Gun Creek 2002): $\Delta°C_{WT}$ values ranging to –4.8 °C /hour between April 1st and June 30.
- CC-01 (Cayuga Creek 2003): $\Delta°C_{WT}$ values ranging to –4.2 °C /hour between April 1st and June 30.
- TTC-01 (Tonawanda Creek 2003): $\Delta°C_{WT}$ values ranging to –2.8 °C /hour between April 1st and June 30.
- TM-19 (Big Sixmile Creek 2002): $\Delta°C_{WT}$ values ranging to –1.8 °C /hour between April 1st and June 30.

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- TBSC-01 (Burnt Ship Creek 2003): $\Delta°C_{WT}$ values ranging to –1.7 °C /hour between April 1st and June 30.

Positive temperature effects were also recorded at several locations in Analysis Zone 1, typically largest at the same locations where the largest negative changes occurred. This pattern is logical, given the fact that the ebb and flood of river water into tributaries would result in the exchange of warmer and cooler water. These changes were uniformly smaller than the negative changes in water temperature observed at the same locations. Positive $\Delta°C_{WT}$ values ranging to +2.3 °C /hour were recorded during spring months at TM-01 and TM-03. It is interesting to note that at 2002 gauge TM-19 located immediately upstream from the placement of SMC-02 in 2003 showed a small range of effects (+1.0 °C /hour.

Small negative and positive temperature anomalies were identified at several upstream locations in tributary streams. Examples include GC-02A (Gun Creek 2003), TM-02 (Woods Creek 2002), TM-04 (Woods Creek 2002), TWC-02 (Woods Creek 2003), TM-08 (Spicer Creek 2002), and CC-02 (Cayuga Creek 2003). Some of these locations are further upstream than locations where no temperature effect was identified, making the cause of this temperature effect unclear. Similar patterns were observed during summer months at reference gauge SMC-01 and CC-03, suggesting that this is a natural temperature pattern rather than an effect from water level fluctuations. The extent of temperature changes at these locations is uniformly small, less than ±2.0 °C /hour. Temperature effects were also identified in lower Tonawanda and Ellicott Creeks. The effect in lower Tonawanda Creek (TTC-01) occurred only in spring, with positive $\Delta°C_{wt}$ values ranging to +2.9 °C /hour and negative values ranging to –2.8 °C /hour. No temperature effects were identified in Buckhorn Marsh, which is largely isolated from water level fluctuations in the upper Niagara River.

3.2.2 Upper Niagara River – Main Channel (Analysis Zone 2)

Location TUNR-03, the upper Niagara River at the Squaw Island railroad bridge, was selected as a reference area for the analysis of temperature effects in the upper Niagara River (see Figure 2.2-2). As noted in Section 2.3.1.2, while this location is within the range of the influence of U.S./Canadian power generation on Niagara River water levels, water level fluctuations in the river are unlikely to influence

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temperature because of the physical conditions present. However, these same physical conditions also may make this location less than fully representative of main channel conditions downstream. Specifically, diurnal temperature fluctuations are more muted at this location, particularly early in the year, due to the turbulence and degree of mixing of the water column caused by strong currents in this area of the upper Niagara River. Hourly average water temperatures during the period of investigation in 2003 at locations TUNR-01, TUNR-02, and TUNR-03 are shown in Figure 3.2.2-1, with hourly water level readings at GN_Frenchman's Creek and GN_Tonawanda, the permanent water level gauges nearest these water temperature gauges, and GO_Ft Erie. Niagara River temperatures over this period range from a low of near 0 ºC in March to a high of 25.5 ºC in mid-August, a normal pattern of seasonal variation in temperature. Figure 3.2.2-2 shows the range of upper Niagara River temperatures at this location in May 2003, along with water levels and hourly air temperature readings. Diurnal temperature variations during this period were very small, typically less than 2 ºC/day.

The pattern of hourly temperature change at this location is instructive. The annual pattern of $\Delta°C_{WT}$ values at TUNR-03 is shown in Figure 3.2.2-3. As shown, the rates of change at this location are consistent with the limited range of diurnal temperature fluctuations. $\Delta°C_{WT}$ values at this location are, with few exceptions, less than 0.5 °C/hour and uniformly less than 1 °C/hour. This pattern of temperature change is expected to be typical at main channel locations in the upper Niagara River. The +1 °C/hour, -0.5 °C/hour $\Delta°C_{WT}$ values were selected as reference thresholds for Analysis Zone 2.

The approach used to assess temperature effects in Analysis Zone 2 is similar to that used in Analysis Zone 1. Specifically, the patterns of seasonal and diurnal temperature fluctuation at the reference location were compared with water temperatures at downstream locations. Annual $\Delta°C_{WT}$ patterns at each location were compared to identify potential temperature effects. The results of this evaluation are shown in Table 3.2.2-1.

As shown in Table 3.2.2-1, no evidence of temperature effects was identified at any of the four temperature gauge locations in Analysis Zone 2. Seasonal and diurnal patterns of temperature fluctuation are comparable at all stations, and consistent with conditions at the reference location. Annual $\Delta°C_{WT}$ patterns at all locations are consistent with the reference location pattern. Notably, with the exception of location TM-17, hourly temperature fluctuations during all times of the year at all locations are uniformly

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less than 0.5 °C/hour. Hourly temperature fluctuations at location TM-17 are slightly larger, between 0.5 and 1.0 °C/hour, but otherwise are consistent with temperature conditions at the reference location. The slightly larger variation in $\Delta°C_{WT}$ at this location is attributed to the fact that this area of the river is shallower than the other locations in this analysis zone, and subject to a greater degree of warming from solar radiation exposure.

3.2.3 Upper Niagara River – Shallow Water Areas off of Main Channel and Immediately Downstream of Tributaries (Analysis Zone 3)

Analysis Zone 3 includes the shallow water areas of the upper Niagara River in the vicinity of Beaver, Motor and Strawberry Islands, as well as shallow water areas downstream of tributaries entering the upper Niagara River (Figure 2.2-3). Because these areas are shallow and the water is moving more slowly than the main channel of the upper Niagara River, these areas may warm or cool relatively quickly compared to that of the main channel of the upper Niagara River. Therefore, they may be more likely to be at different temperatures than the main channel of the Niagara River and thus have the potential to experience rapid temperature changes when upper Niagara River water mixes with the shallow water in these areas. Areas immediately downstream of tributaries are also exposed to the outflow of tributary water that may be at different temperatures from Niagara River water, particularly during spring. The exposure to tributary water is periodic in response to changes in upper Niagara River water level, which cause tributary water impounded by high water levels to flow out of the tributary when river levels drop.

No ideal reference location was identified for evaluation of temperature effects in Analysis Zone 3, because no temperature data was collected at similar locations outside of the range of water level fluctuations due to U.S./Canadian power generation. Therefore, reference thresholds for Analysis Zone 2 (reference location TUNR-03 at Squaw Island) were used to evaluate temperature patterns for this analysis zone, with the caveat that this may lead to overestimation of temperature effects. The approach was similar to that applied in Analysis Zone 2. Specifically, seasonal and diurnal temperature patterns, and annual patterns in $\Delta°C_{WT}$ values were compared to patterns at the reference location. Where possible temperature effects were identified, hourly frequency distribution plots of $\Delta°C_{WT}$ values were compared to hourly frequency distribution plots of ΔWL to determine if the timing of water temperature changes was consistent with rapid water level changes. Where present, frequency distribution patterns of hourly

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$\Delta°C_{WT}$ values were used to determine if these changes are of sufficient magnitude to be considered temperature effects. The results of this analysis are described in Table 3.2.3-1, and locations of gauges where temperature effects occurred are shown graphically in Figure 3.2.3-1.

Annual patterns of $\Delta°C_{WT}$ values are suggestive of temperature effects at some locations in the shallow water areas of the upper Niagara River (Table 3.2.3-1). Data from gauges TM-15 and TM-20, both located on the shallow water bar between Strawberry and Motor Islands (2002), are suggestive of temperature effects. However, the hourly frequency distribution patterns of $\Delta°C_{WT}$ values indicate otherwise. Other shallow water gauge sites (e.g., TM-13, TM-16 and TM-18) do not show annual patterns of $\Delta°C_{WT}$ values that indicate a temperature effect. Collectively, this information suggests that shallow water areas of the upper Niagara River are not prone to temperature effects caused by U.S./Canadian power generation.

In contrast, available gauge data for locations immediately downstream of tributaries do indicate a temperature effect consistent with the timing of water level fluctuations due to U.S./Canadian power generation. Again, these locations are variably exposed to upper Niagara River water and tributary outflows when water levels fluctuate. When the difference between average river and tributary water temperatures is large, the rate of water temperature changes is greatest. For example, gauge TM-11 (2002) recorded temperatures in the shallow water zone of the Chippawa Channel at the mouth of Burnt Ship Creek. Frequency distribution patterns of hourly $\Delta°C_{WT}$ values indicate temperature effects between 5 and 8am and again between 8 and 10pm in spring and summer months. These effects are relatively mild, on the order of –1.1 and +0.4 °C/hour in spring, and –1.0 and +1.0 °C/hour in summer. No temperature effect was evident in the fall.

While effects at the mouth of Burnt Ship Creek may be similar to natural diurnal $\Delta°C_{WT}$ values, data from a similar location showed a more marked temperature effect. Gauge TUNR-04 recorded temperature data immediately downstream of the mouth of Woods Creek in 2003. Frequency distribution patterns of hourly $\Delta°C_{WT}$ values at this location indicated rapid water temperature changes in spring and fall during evening hours consistent with the timing of water level fluctuations due to U.S./Canadian power generation. Temperature effects on the order of –3.2 and +2.5 °C/hour in spring, and –2.0 and

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+2.5 °C/hour in fall were observed. The rate of water temperature change during summer months was smaller, consistent with the fact that temperatures in Woods Creek and the upper Niagara River are generally comparable during this season.

Data from these two gauges suggests that locations in shallow water areas immediately downstream of tributary outlets to the upper Niagara River are subject to temperature effects related to water level fluctuations due to U.S./Canadian power generation, particularly during spring and fall months. The areal extent of the zone of effects downstream of tributary mouths can not be determined from these data. Because the relatively low volume tributary outflows would be expected to mix with and equilibrate to the temperature of upper Niagara River water relatively quickly, the zone of effect is not expected to be large.

3.2.4 Lower Niagara River – Gorge Between Falls and RMNPP Tailrace (Analysis Zone 4)

Analysis Zone 4 includes the main channel of the lower Niagara River between the falls downstream to just upstream of the RMNPP tailrace. This portion of the river flows through the Niagara River Gorge, which is characterized by a fast flowing, turbulent river channel ranging in places to possibly 200 feet in depth. During tourist season, water level fluctuations of 12 ft/day in the lower Niagara River upstream of the tailrace at the Ashland Avenue gauge are common (URS et al. 2005a). Because of the turbulent, high velocity flow in this portion of the river, the surface waters of the river are well mixed and temperatures remain relatively constant. However, some shallow water exposed when river levels drop may warm or cool in response to diurnal air temperature fluctuations, and then experience rapid water temperature fluctuations when inundated by rising river levels.

The approach to the analysis in Analysis Zone 4 is similar to that used in Analysis Zone 2. Because there was no ideal reference location for this portion of the Niagara River, temperature data from gauge locations in Analysis Zone 4 were compared to those from gauge TUNR-02 located at the NYPA intakes in the upper Niagara River. This location is the closest to the falls and the nearest main river temperature sampling point. Annual patterns in $\Delta°C_{WT}$ values from gauge data in Analysis Zone 4 were compared to the location TUNR-02 to identify where potential temperature effects may exist.

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Temperature effects were then confirmed by comparison of frequency distribution patterns of hourly $\Delta°C_{WT}$ and ΔWL values. The results of this analysis are described in Table 3.2.4-1.

As shown in Table 3.2.4-1 and supporting figures, the extent of available temperature data for this analysis zone is somewhat limited temporally. Data were collected at three gauge locations, one in 2002 and two in 2003. A significant portion of the data collected at each of these gauges was removed during the QA/QC process because of defective readings (usually caused by exposure of the gauge to the air during low water levels). The 2002 gauge data from location TM-23 were ultimately not used in the analysis because they were found to be unreliable.

Based on the available data, no temperature effects are evident in this portion of the lower Niagara River despite the large water level fluctuations present. The annual pattern in $\Delta°C_{WT}$ values at location TLNR-03, the furthest upstream gauge, do not indicate a temperature effect. The annual pattern in $\Delta°C_{WT}$ values for summer and fall months at LNR-01, the next downstream gauge, do not indicate a temperature effect. The lack of temperature effect at this location is notable, given that treaty related water level fluctuations are clearly evident. Frequency distribution patterns of ΔWL values show large changes in water level in morning and evening hours. These fluctuations are on the order of ±2 to ±3 feet/hour depending on season. Water level fluctuations at this gauge location (LNR-01) are considered to be representative of the downstream section of this analysis zone.

Although there was no temperature effect in Analysis Zone 4, the water temperatures immediately upstream of the RMNPP tailrace (as measured at TLNR-01, TLNR-03, and LNR-01) are generally lower (approximately 0.5 – 1.7 °C) than the water temperature of the upper Niagara River at TUNR-02 near the NPP intakes from May through September 2003. This is likely due to the cooling effect of water flowing over Niagara Falls and through the high gradient sections of the Niagara River Gorge. As water evaporates, the temperature of the water left behind (i.e., the Niagara River water) decreases (Bartholow 2000).

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3.2.5 Lower Niagara River – Below Tailrace (Analysis Zone 5)

Analysis Zone 5 includes the main channel of the Niagara River from the RMNPP tailrace downstream to the confluence of the river with Lake Ontario. This portion of the river transitions from the relatively narrow, fast flowing channel in the Niagara River Gorge to a wide, slow flowing channel downstream of the Niagara Escarpment and continuing to the confluence. Water levels downstream of the RMNPP tailrace are a function of Lake Ontario level, discharge from RMNPP and Canadian plants, and flow rate over Niagara Falls. A total of 10 gauges collected temperature data in Analysis Zone 5, two in 2002 and eight in 2003.

The approach to the analysis here is similar to that applied in Analysis Zone 4. Temperature data from gauge locations in Analysis Zone 5 were compared to those from location TUNR-02 upstream of the NPP intakes in the upper Niagara River to determine if normal patterns of seasonal and diurnal temperature fluctuations are present. Annual patterns in $\Delta°C_{WT}$ values from gauge data in Analysis Zone 5 were compared to the pattern from location TUNR-02 to identify where potential temperature effects may exist. Temperature effects were then determined by comparison of frequency distribution patterns of hourly $\Delta°C_{WT}$ and ΔWL values. As for Analysis Zone 1, reference thresholds of +1.0 °C/hour and -0.5 °C/hour were used in Analysis Zone 5. The amount of available data varied between gauge locations, with data for several locations being relatively limited. The results of the analysis are presented in Table 3.2.5-1.

As described in Table 3.2.5-1, no temperature effects were identified in Analysis Zone 5. Annual patterns in $\Delta°C_{WT}$ values for gauges TLNR-02 and LNR-02, both located on the U.S. side of the river downstream of the RMNPP and Sir Adam Beck Niagara Generating Station tailraces show no indication of any regular temperature effects. (TLNR-02 and LNR-02 are located approximately 3,200 and 5,500 feet downstream of the tailrace, respectively.) Frequency distribution patterns of hourly $\Delta°C_{WT}$ values for LNR-02 are suggestive of no temperature effect. Data for these two gauge locations are relatively complete for the entire period of data collection in 2003. Annual patterns of $\Delta°C_{WT}$ values from gauge TM-24 (2002) are suggestive of no temperature effect.

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The remaining gauge locations in Analysis Zone 5 are all downstream of the mouth of the Niagara River gorge (approximately 9,000 feet downstream of the RMNPP). The available data for gauges LNR-03, LNR-04 and LNR-05 (2003), and TM-25 (2002) are relatively complete for the periods of analyses in their respective years. Annual patterns in $\Delta°C_{WT}$ values for these gauge locations show no indication of a temperature effect.

The results of the evaluation in Analysis Zone 5 suggest that no temperature effects occur in the main body of the lower Niagara River.

3.2.6 Lewiston Reservoir (Analysis Zone 6)

Analysis Zone 6 is the Lewiston Reservoir (Figure 2.2-6). Water temperatures in the reservoir are strongly influenced by NPP operations, as the upper Niagara River is the sole source of water for the reservoir. Temperature data were collected at one location in the reservoir, gauge TLEW-01, during 2003. The data set collected at this location is relatively complete for the period between April 15th and November 20th. As noted in Section 2.3.1.6, there is no suitable reference area for Analysis Zone 6. Therefore, temperature effects in the reservoir were evaluated by comparing temperature conditions at gauge TLEW-01 to those in its source body, the upper Niagara River at the project intakes (location TUNR-02). Annual patterns of seasonal and diurnal temperature fluctuations were compared between these locations to determine if temperature patterns in the reservoir are clearly different from those in the upper Niagara River, and annual patterns in $\Delta°C_{WT}$ values were evaluated to determine if unusual temperature fluctuation patterns exist.

Lewiston Reservoir was created as a storage reservoir for operational water for the Niagara Power Project. During the tourist season, the reservoir is filled during nighttime hours to store water for daytime power generation when treaty obligations require a larger proportion of the mainstem flow of the Niagara River to be directed over the falls. As a consequence, daily water level fluctuations in the reservoir are large, on the order of 3 to 18 feet/day, and the turnover of reservoir volume is relatively rapid.

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The results of the analysis for Analysis Zone 6 are presented in Table 3.2.6-1. Despite the large water level fluctuations in the reservoir during the tourist season, no temperature effect was evident. The seasonal and diurnal temperature patterns in the reservoir are essentially identical to those in its source body, the upper Niagara River. The annual pattern in $\Delta°C_{WT}$ values (see Appendix C, Figure C-105) shows some indication of anomalous temperature changes, but extreme events are rare and do not exceed ±1.5 °C/hour, and the pattern of $\Delta°C_{WT}$ values is consistent with that of the upper Niagara River reference area (TUNR-02). Based on the available data, there is no evidence of a temperature effect in the Lewiston Reservoir.

It was evident from graphs of the water temperature at TUNR-02 and TLEW-01 that the water temperature of Lewiston Reservoir was generally slightly lower (~1 - 1.5°C lower) than that of the upper Niagara River from late April to mid September 2003 (Appendix B, Figures B-292 – B-300). This may be due to the fact that Lewiston Reservoir is filled at night, when the water temperature of the upper Niagara River (TUNR-02) is generally lower than that during the day.

When considering these results, it is important to note that Lewiston Reservoir temperature conditions are not typical of those in a normal lake environment. Lakes tend to stratify in summer months, with surface layers subject to a higher degree of warming than deeper areas, and have greater diurnal temperature fluctuations. The reservoir, in contrast, has a high turnover rate and does not stratify. Therefore, temperatures tend to resemble those in the upper Niagara River.

3.3 Assessment of Water Level Related Temperature Effects on Focus Species

Rapid changes in water temperatures associated with water level fluctuations in the Niagara River have occurred historically due to natural causes and will continue to occur at susceptible locations, primarily in the lower reaches of tributaries and immediately downstream of tributary mouths. Fish species that utilize these locations have been exposed to these periodic rapid temperature changes throughout their evolutionary and adaptive history. However, a portion of the rapid temperature shifts in water temperature that occur today are considered temperature effects attributable U.S./Canadian power generation.

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Most fish species can tolerate temperature shifts of 15 ºC to 18 ºC provided the end exposure temperature is within the absolute tolerance range of the species (i.e., the Upper and Lower Incipient Lethal Temperatures) (McCullough 1999). Documented effects of rapid changes in water temperature (expressed as ΔT) on eighteen species of fish were presented in Table 2.4-1. Additional summaries of the habitat requirements for each fish species, including the range of temperatures at which spawning occurs in populations at similar latitudes to the investigation area were presented in Tables 2.4-2, 2.4-3, and 2.4-4. Life history information for all focus species is presented in Appendix D.

A combination of methods are used to determine if temperature effects are of sufficient magnitude to potentially affect focus fish species. Where temperature effects were identified, the magnitude of these effects was evaluated against tolerance thresholds for the life history stages of focus fish species likely to be present at the times and locations that the effects occurred.

As described in Section 2.3.2, the distribution of focus fish species within each analysis zone was determined by available habitat, creel, habitat suitability, and presence/absence studies conducted as part of the Niagara Project FERC relicensing process (Stantec et al. 2005, URS et al. 2002, EI 2002, KA 2002). In the following sections, the fish species likely to be present in each analysis zone are grouped by spawning season and spawning temperature ranges. Temperature effects in each analysis zone are compared to tolerance thresholds for these species to determine if behavioral or survival effects potentially occur.

Northern Pike, Yellow Perch, and Walleye

Yellow perch, walleye, and northern pike are spring spawning species that generally spawn soon after ice-out at water temperatures between 2 ºC and 19 ºC, and they typically spawn during the months of April through May and potentially into early June.

Northern pike and yellow perch occur in all six analysis zones, but spawning is probably limited primarily to the upper Niagara River and its U.S. tributaries in Analysis Zones 1 and 2. Yellow perch spawn in protected shoreline areas with slow currents. Yellow perch spawning habitat in the lower

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Niagara River (particularly in Analysis Zone 4) is probably limited, due to the high water velocities, but spawning habitat does occur in areas protected from wind such as the shoreline near Fort Niagara State Park and areas along the shoreline from Youngstown to Lewiston. Walleye are found in the main channels of both the upper and lower Niagara River, and suitable spawning habitat for walleye exists in Analysis Zones 2, 4, and 5, which either do not have temperature effects or do not have temperature effects during the spring spawning period.

During this period, temperature effects (expressed as $\Delta ºC_{WT}$) were found in U.S. tributaries and shallow water areas of the upper Niagara River in Analysis Zones 1 and 3. In Analysis Zone 1, temperature effects reached their maximum negative value of –6.5 $\Delta ºC_{WT}$ at temperature gauge TM-01 (in Woods Creek near its mouth) and maximum positive value of +2.3 $\Delta ºC_{WT}$ at temperature gauge TM-01 and TM-03 (in Gun Creek near its mouth). Mean daily water temperatures varied between approximately 1.5ºC at the beginning of April to about 22ºC at the end of June. In Analysis Zone 3, temperature effects reached their maximum negative value of –2.2 $\Delta ºC_{WT}$ and maximum positive value of +2.5 $\Delta ºC_{WT}$ at temperature gauge TUNR-04 downstream from Woods Creek. Mean daily water temperatures varied between approximately 1.5ºC at the beginning of April to about 22ºC at the end of June.

$\Delta ºC_{WT}$ of these magnitudes are not expected to cause injury to any life history stage of yellow perch, walleye or northern pike. Even though potential rapid $\Delta ºC_{WT}$ is unlikely to be great enough to produce adult avoidance behavior at spawning temperatures, all three species are broadcast spawners that do not provide care for their young, therefore nest abandonment is not a concern. Although cold shocks of -5.5 ºC (i.e., a sudden water temperature decrease of 5.5°C) have created mortalities in some laboratory tests of northern pike embryos, Hokanson et al. (1973) found northern pike embryos resistant to any degree of cold or heat shock within the range of 6 to 19ºC. The identified temperature effects would not cause avoidance behavior in larvae or juveniles. Therefore, the identified temperature effects in Analysis Zones 1 and 3 have no potential for behavioral or survival effects on northern pike, walleye, or yellow perch. Although walleye are found in both the upper and lower Niagara River, suitable spawning habitat for walleye does not occur in the low velocity, soft bottomed habitat of Analysis Zones 1 and 3; suitable spawning habitat only occurs in Analysis Zones 2, 4, and 5, where water temperature effects were not identified or do not occur during the spring spawning period.

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Muskellunge, White Sucker, Greater Redhorse, and Lake Sturgeon

Muskellunge, white sucker, greater redhorse, and lake sturgeon are spring spawning species that generally spawn at temperatures between 8ºC and to 19ºC, which occur during the months of April through June.

Muskellunge occur in Analysis Zones 2, 3, and 5, but suitable spawning and juvenile rearing habitat primarily occurs in shallow water regions of Analysis Zones 2 and 3, with some spawning and juvenile habitat in shallower habitats near the mouth of the lower Niagara River in Analysis Zone 5. There are no documented muskellunge spawning areas in the lower Niagara River, although young-of-the-year muskellunge have been collected from several locations there, all downstream of Lewiston Landing (Analysis Zone 5, NYSDEC 1996) indicating that muskellunge likely spawn in or near these areas. White suckers occur in all analysis zones, while greater redhorse are found in all analysis zones but Lewiston Reservoir (Analysis Zone 6). Both species spawn in shallow riffles and runs with moderate velocity and coarse substrates; these habitats occur in Analysis Zones 3, 4, and 5. Lake sturgeon occur in the mainstem of both the upper and lower Niagara River (Analysis Zones 2, 4 and 5). Spawning by lake sturgeon has been suspected in the lower Niagara River and juvenile and adult lake sturgeon have been documented in the mainstem channels of the upper and lower Niagara River. Actual spawning in the upper Niagara River has not been documented.

Temperature effects during spring (expressed as $\Delta ºC_{WT}$) were found in Analysis Zones 1 and 3. In Analysis Zone 1, temperature effects reached their maximum negative value of –6.5 $\Delta ºC_{WT}$ at temperature gauge TM-01 (in Woods Creek near its mouth) and maximum positive value of +2.3 $\Delta ºC_{WT}$ at temperature gauge TM-01 and TM-03 (in Gun Creek near its mouth). Mean daily water temperatures varied between approximately 1.5ºC at the beginning of April to about 22ºC at the end of June. In Analysis Zone 3, temperature effects reached their maximum negative value of –2.2 $\Delta ºC_{WT}$ and maximum positive value of +2.5 $\Delta ºC_{WT}$ at temperature gauge TUNR-04 downstream from Woods Creek. In Analysis Zones 2 and 5, no temperature effects were identified.

All life stages of these species may occur within the main channel of the river during the remaining months of the year. In addition, although greater redhorse, white suckers, and lake sturgeon

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are found in both the upper and lower Niagara River, suitable spawning habitat for these species does not occur in the low velocity, soft bottomed habitat of Analysis Zones 1 and 3. Even if these species did occur in these analysis zones, the $\Delta ºC_{WT}$ of the magnitude observed are insufficient to elicit behavioral or survival effects to any life stage of these focus species. While temperature effects are unlikely to be great enough to produce adult avoidance behavior at spawning temperatures, all species are broadcast spawners that do not provide care for their young so nest abandonment is not a concern. Recorded mean daily water temperatures and rapid $\Delta ºC_{WT}$ would not cause avoidance behavior in larvae or juveniles. Therefore, the identified temperature effects in Analysis Zones 1 and 3 are not expected to cause behavioral or survival effects on muskellunge, white suckers, greater redhorse, or lake sturgeon.

Smallmouth Bass

Smallmouth bass are spring spawning species that spawn at temperatures between about 16 ºC and 18.3 ºC, which occur during the months of April through June. Smallmouth bass occur in all six analysis zones and spawn in the mainstem channels of the upper (Analysis Zone 2) and lower Niagara River (Analysis Zones 4 and 5). Spawning also likely occurs over coarser substrates in Analysis Zone 3. Although smallmouth bass are common in both the upper and lower Niagara River and probably spawn or rear young in some of the shallow water habitat in Analysis Zone 3, they do not spawn or rear in Buckhorn Marsh and likely do not spawn or rear in the tributary streams of Grand Island in Analysis Zone 1; suitable combinations of depth, water velocity, and coarse substrates generally do not occur in Analysis Zone 1. Surveys of deeper mainland tributaries (Cayuga, Gill, and Tonawanda Creeks) by the NYSDEC (1988) and Kleinschmidt Associates, Inc. (2002) either did not detect smallmouth bass or listed them as rare. Although deeper than Grand Island tributary streams, these streams also have low velocities and soft substrates.

Temperature effects (expressed as $\Delta ºC_{WT}$) at the time and location of smallmouth bass spawning were found in Analysis Zone 3. Temperature effects reached their maximum negative value of –2.2 $\Delta ºC_{WT}$ and maximum positive value of +2.5 $\Delta ºC_{WT}$ at temperature gauge TUNR-04 downstream from Woods Creek. Mean daily water temperatures varied between approximately 1.5ºC at the beginning of April to about 22ºC at the end of June.

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The $\Delta ºC_{WT}$ of this magnitude will not cause injury to any life history stage of smallmouth bass. Observed temperature effects are of insufficient magnitude or duration to cause adult avoidance behavior and potential nest abandonment. Observed temperature effects are also insufficient to cause avoidance behavior in larvae or juveniles. Therefore, the identified temperature effects in Analysis Zone 3 are not expected to cause behavioral or survival effects on smallmouth bass.

Largemouth Bass and Rock Bass

Largemouth bass and rock bass are spring and early summer spawners, that generally spawn at temperatures above 17ºC. Both species can continue to spawn at increasing water temperatures, up to the maximum recorded mean daily temperatures found in this study, with most spawning occurring before the end of June or early July.

Largemouth bass occur in Analysis Zones 1 through 5, but primarily spawn in tributary streams and shallow water areas (Analysis Zones 1 and 3 in the upper Niagara River and shallow shoreline areas of Analysis Zone 5). Rock bass habitat exists in shallower areas of the upper and lower Niagara River (Analysis Zones 2, 3, and 5).

During the spawning period, temperature effects (expressed as $\Delta ºC_{WT}$) were found in Analysis Zones 1 and 3. In Analysis Zone 1, spring (April through June) temperature effects reached their maximum negative value of –6.5 $\Delta ºC_{WT}$ at temperature gauge TM-01 (in Woods Creek near its mouth) and maximum positive value of +2.3 $\Delta ºC_{WT}$ at temperature gauge TM-01 and TM-03 (in Gun Creek near its mouth). Mean daily spring water temperatures varied between approximately 1.5ºC at the beginning of April to about 22ºC at the end of June. Summer (July-August) temperature effects reached their maximum negative value of –1.3 $\Delta ºC_{WT}$ at temperature gauge TGC-01 (in Gun Creek near its mouth). The maximum positive value of +1.9 $\Delta ºC_{WT}$ was reached at temperature gauge TM-08 (in Spicer Creek near its mouth). Mean daily water temperatures varied between approximately 20ºC and 28ºC with the warmest mean daily water temperature occurring near the end of July and beginning of August.

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In Analysis Zone 3, spring temperature effects reached their maximum negative value of –2.2 $\Delta ºC_{WT}$ and maximum positive value of +2.5 $\Delta ºC_{WT}$ at temperature gauge TUNR-04 downstream from Woods Creek. Mean daily water temperatures varied between approximately 1.5ºC at the beginning of April to about 22ºC at the end of June. Summer temperature effects ($\Delta ºC_{WT}$) reached their maximum negative value of –2.0 $\Delta ºC_{WT}$ and maximum positive value of +2.5 $\Delta ºC_{WT}$ at temperature gauge TUNR-04 downstream from Woods Creek. Mean daily water temperatures varied between approximately 20ºC and 28ºC with the warmest mean daily water temperature occurring near the end of July and beginning of August.

In Analysis Zone 5, there were no identified spring temperature effects. Mean daily water temperatures varied between approximately 20ºC and 28ºC with the warmest mean daily water temperature occurring near the end of July and beginning of August.

Spawning habitat of largemouth bass in the upper Niagara River occurs in the low velocity, shallow habitats of Analysis Zones 1 and 3, while spawning habitat of largemouth bass in Analysis Zone 5 of the lower Niagara River occurs in shallower water near shore, primarily near Fort Niagara State Park. Rock bass spawning habitat in the tributary streams of the upper Niagara River in Analysis Zone 1 is limited by a lack of suitable substrates, however suitable spawning habitat (coarse substrate and relatively low water velocities) exists in Analysis Zone 3 (upper Niagara River) and Analysis Zone 5 (lower Niagara River).

Temperature effects of the magnitude observed will not cause injury to any life history stage of largemouth bass or rock bass. These rapid $\Delta ºC_{WT}$ are of insufficient magnitude or duration to cause adult avoidance behavior and potential nest abandonment in either species. Rapid $\Delta ºC_{WT}$ would not cause avoidance behavior in larvae or juveniles. Therefore, the identified temperature effects in Analysis Zones 1 and 3 are not expected to cause behavioral or survival effects on largemouth or rock bass.

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Bluntnose Minnow, Emerald Shiner, and Brown Bullhead

Bluntnose minnows, emerald shiners, and brown bullhead are summer spawners that spawn at temperatures above 20 ºC. All three species will continue to spawn at increasing water temperatures, up to the maximum recorded mean daily temperatures found in this study, generally through the end of July. Bluntnose minnows spawn in May and June and build nests under the surface of various objects such as stones and logs in water of 0.5-3 feet deep. Suitable spawning, egg and larval habitat for bluntnose minnows occurs in areas of little or no velocity in the upper Niagara River (Analysis Zone 3 and to some extent in shallow areas of Analysis Zone 2), in the tributaries of Grand Island and along the shorelines of Cayuga, Ellicott, and Tonawanda Creeks (Analysis Zone 1), and in low velocity areas in the lower Niagara River (primarily near Fort Niagara State Park, Analysis Zone 5). Emerald shiner habitat occurs in all six analysis zones; these fish are broadcast spawners in the pelagic regions of analysis zones 2, 4, 5, and 6, but have also been documented in Analysis Zone 1 (Grand Island tributaries). Brown bullhead spawn in May and June, and build nests in shallow water of less than 4 feet deep. Their nests are usually in substrate of mud, sand, and gravel in areas of little or no velocity. Suitable spawning, egg and larval habitat for brown bullhead occurs in areas of little or no velocity in the upper Niagara River (Analysis Zones 2 and 3), in the tributaries of Grand Island, and along the shorelines of Cayuga, Ellicott, and Tonawanda Creeks (Analysis Zone 1) and in low velocity areas of the lower Niagara River near Fort Niagara State Park (Analysis Zone 5).

Temperature effects during the spawning period (expressed as $\Delta ºC_{WT}$) were found in Analysis Zones 1 and 3. In Analysis Zone 1, summer (July-August) temperature effects reached their maximum negative value of –1.3 $\Delta ºC_{WT}$ at temperature gauge TGC-01 (in Gun Creek near its mouth). The maximum positive value of +1.9 $\Delta ºC_{WT}$ was reached at temperature gauge TM-08 (in Spicer Creek near its mouth). Mean daily water temperatures varied between approximately 20ºC and 28ºC with the warmest mean daily water temperature occurring near the end of July and beginning of August.

In Analysis Zone 3, summer temperature effects ($\Delta ºC_{WT}$) reached their maximum negative value of –2.0 $\Delta ºC_{WT}$ at temperature gauge TUNR-04 downstream from Woods Creek. The maximum positive value of +2.5 $\Delta ºC_{WT}$ was reached at the same location. Mean daily water temperatures varied between

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approximately 20ºC and 28ºC with the warmest mean daily water temperature occurring near the end of July and beginning of August.

Temperature effects of the magnitude observed are not expected to cause injury to any life history stage of bluntnose minnow, emerald shiner, or brown bullhead. The rapid $\Delta ºC_{WT}$ identified is of insufficient magnitude to be great enough to cause avoidance behavior of spawning adults, larvae or juveniles or potential nest abandonment in bluntnose minnows or brown bullheads. The identified rapid $\Delta ºC_{WT}$ would not cause avoidance behavior in larvae or juveniles. Therefore, the identified temperature effects in Analysis Zones 1 and 3 are not expected to cause behavioral or survival effects on bluntnose minnow, emerald shiners, or brown bullhead.

Lake Trout and Chinook Salmon

Lake trout and Chinook salmon are fall spawners. Spawning occurs at about 5.5ºC to 14.5ºC for both species and incubation occurs through the winter months, with the fry emerging in winter or early spring. Lake trout from Lake Ontario enter the lower Niagara River (Analysis Zones 4 and 5) as the water cools off in the fall and continue to occur in the lower Niagara River until warming temperatures force them to move back into Lake Ontario in late spring. Smaller numbers of lake trout migrate from Lake Erie into the main channels of the upper Niagara River (Analysis Zone 2) during the same period. Although river spawning populations of lake trout have been documented in Lake Superior drainages, these fish only enter rivers to spawn during the night and leave before daylight to remain in deeper lake waters during the daytime hours (Loftus 1958). The lake trout stocked into Lake Ontario are deep water spawning Seneca Lake stock fish (Casselman 1995), which have not been documented to spawn in the lower Niagara River. These fish may be entering the river on feeding migrations. Chinook salmon spawn in September and October, at depths of about 1 foot to >20 feet, over gravel to large cobble substrates, in swift (1.4-2.5 fps) water. Water velocity is more important than water depth in the selection of spawning locations. Suitable spawning habitat for Chinook salmon exists downstream of RMNPP tailrace (Stantec et al. 2005) and also upstream of RMNPP. Suitable substrates are common at depths of about 2 feet to >20 feet. Chinook salmon are stocked into the lower Niagara River (Analysis Zones 4 and 5) and other Lake Ontario tributaries but have not been documented to spawn in the lower Niagara River. Chinook salmon are stocked as smolts in the spring and soon migrate out of the river into Lake Ontario before the

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warmer water temperatures of summer (generally by early June). If natural spawning of Chinook salmon occurs in the lower Niagara River, juveniles would continue to rear until about May or June until smolt outmigration to Lake Ontario. The spawning period for Chinook salmon is fall, during or after the months of September and October, and is October – December for lake trout.

No temperature effects were identified in Analysis Zones 2, 4 and 5, thus behavioral or survival effects on lake trout and Chinook salmon are not occurring.

Rainbow Trout and Rainbow Smelt

Rainbow trout (steelhead trout) and rainbow smelt are late winter and spring spawners that generally spawn soon after ice-out at temperatures between 2ºC and 15ºC, which occur during the months of April and May. Rainbow trout fry, if present in the lower Niagara River, would generally migrate downstream to Lake Ontario from April through June. Hatchery steelhead (migratory rainbow trout) are stocked as smolts in the lower Niagara River (Analysis Zones 4 and 5) in the spring, and migrate out to Lake Ontario before the end of June. Naturally spawned steelhead trout normally rear in streams for 1 to 4 years before migrating to the ocean in their native range and in the Great Lakes, where they have been introduced (Barnhart 1986). Steelhead have difficulty extracting oxygen from water at temperatures over 21 ºC regardless of the amount of oxygen present (Barnhart 1986) and would have to migrate to Lake Ontario before temperatures in the lower Niagara River warm up in the summer months. Steelhead have occasionally been observed attempting to spawn in the lower Niagara River in the vicinity of the RMNPP tailrace, and although suitable spawning habitat occurs in the lower Niagara River, successful reproduction has not been confirmed. Rainbow trout stocked into Lake Erie also occur during the cooler months of the year in the main channels of the upper Niagara River (Analysis Zone 2), but spawning and rearing juveniles have never been documented in the upper Niagara River. Rainbow smelt spawn in the lower Niagara River (Analysis Zones 4 and 5) and have been documented to occur in shallow areas near islands located in the main channels of the upper Niagara River (Analysis Zone 3), but spawning has not been documented in the upper Niagara River.

During the spring spawning period, temperature effects were found in Analysis Zone 3. Temperature effects reached their maximum negative value of –2.2 $\Delta ºC_{WT}$ and maximum positive value

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of +2.5 $\Delta ºC_{WT}$ at temperature gauge TUNR-04 downstream from Woods Creek. Mean daily water temperatures varied between approximately 1.5ºC at the beginning of April to about 22ºC at the end of June. The habitat in Analysis Zone 3 is generally comprised of small substrate and therefore generally not suitable for rainbow trout spawning and fry. The habitat in Analysis Zone 3 is suitable for rainbow smelt.

No temperature effects have been documented to occur in the lower Niagara River (Analysis Zones 4 and 5). Temperature effects of the magnitude observed in spring in Analysis Zone 3 are insufficient to cause injury to either species at any life history stage. Rapid $\Delta ºC_{WT}$ would not be expected to cause avoidance behavior in larvae or juveniles. Therefore the identified temperature effects in Analysis Zone 3 would not be expected to cause behavioral or survival effects on rainbow trout or rainbow smelt.

American Eel

American eels are catadromous and spawn in the ocean. Niagara Falls presents a natural barrier to upstream migration, although some American eels move upstream of Lake Ontario through the Welland Canal. All life stages of American eels (juvenile [yellow] and mature [silver] eels) present in the lower Niagara River can easily tolerate the temperatures present throughout the year in the lower Niagara River. In fact, yellow eels and silver eels can tolerate temperatures as high as 32ºC; the maximum water temperatures during 2002 and 2003 were 24.7°C and 25°C in Analysis Zones 4 and 5 respectively.

No temperature effects have been documented to occur in the lower Niagara River (Analysis Zones 4 and 5) so there are no behavioral or survival effects on American eels.

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TABLE 3.1-1

RECORDED MINIMUM AND MAXIMUM TEMPERATURE (°C) AND AVERAGE AND MAXIMUM DAILY TEMPERATURE CHANGE (°C) AT ALL GAUGE LOCATIONS, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Recorded Min	Recorded Max	Maximum Recorded Daily Change			Average Recorded Daily Change		
					April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30	April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30
1	TBSC-01	2003	0.0	25.0	10.6	7.1	6.3	4.9	3.2	2.5
	TBSC-02	2003	0.2	24.1	6.7	4.1	3.9	3.2	2.1	1.7
	TBSC-03	2003	0.3	22.8	3.2	3.3	2.2	1.4	0.9	1.1
	TM-12	2002	4.0	28.0	7.9	5.3	3.8	2.6	2.7	1.8
	TBHM-01	2003	-0.1	24.6	7.3	4.7	4.8	3.1	2.3	2.2
	TBHM-02	2003	0.9	25.6	4.2	3.2	4.0	1.4	1.5	1.8
	TWC-01	2003	0.1	25.1	13.4	5.6	5.9	6.3	3.3	3.0
	TM-01	2002	3.5	26.0	10.6	4.9	4.6	4.9	3.0	2.6
	TM-02	2002	1.4	27.3	6.5	2.6	3.3	2.4	1.1	1.1
	TM-04	2002	0.9	24.6	10.1	3.2	3.7	4.0	1.5	1.6
	TWC-02	2003	-0.2	23.1	8.2	3.4	5.6	3.7	1.5	1.7
	TM-03	2002	2.9	25.4	12.7	5.2	4.8	4.5	2.7	2.4
	TGC-01	2003	-0.1	25.1	11.8	5.8	6.2	5.6	3.1	3.1
	TM-05	2002	2.6	24.4	9.6	4.0	4.5	3.3	1.4	2.1
	GC-02A	2003	2.9	23.4	5.4	3.7	4.1	3.0	1.3	1.8

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TABLE 3.1-1 (CONT.)

RECORDED MINIMUM AND MAXIMUM TEMPERATURE (°C) AND AVERAGE AND MAXIMUM DAILY TEMPERATURE CHANGE (°C) AT ALL GAUGE LOCATIONS, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Recorded Min	Recorded Max	Maximum Recorded Daily Change			Average Recorded Daily Change		
					April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30	April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30
1	TM-06	2002	1.6	25.3	7.9	4.1	7.3	2.9	1.8	3.0
	TM-07	2002	1.8	25.0	9.5	6.3	4.3	4.1	1.9	1.8
	TM-08	2002	1.1	26.6	11.3	8.5	6.9	5.0	4.8	2.7
	TSC-01	2003	0.0	24.5	8.6	5.1	3.9	4.2	1.9	1.9
	TSC-02	2003	0.1	26.7	8.5	8.8	5.3	4.5	4.0	2.1
	TM-19	2002	3.2	26.5	7.0	4.0	3.0	3.4	2.2	1.4
	TM-10	2002	3.2	27.5	9.9	3.1	2.7	2.7	1.7	1.3
	SMC-02	2003	0.7	25.5	9.1	4.6	4.1	5.3	2.4	1.6
	TSMC-01	2003	-0.1	25.4	8.7	5.1	4.5	3.9	2.7	1.8
	SMC-01	2003	0.5	24.4	10.2	6.1	6.4	4.9	3.8	3.0
	CC-01	2003	5.3	25.9	10.2	2.9	3.5	4.8	1.8	1.6
	CC-02	2003	3.6	23.7	5.3	3.8	3.9	2.9	2.0	1.6
	CC-03	2003	3.0	23.9	9.0	6.5	6.4	5.2	4.2	3.1
	TTC-01	2003	7.3	25.4	7.6	1.5	2.5	3.5	0.7	0.7

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TABLE 3.1-1 (CONT.)

RECORDED MINIMUM AND MAXIMUM, TEMPERATURE (°C) AND AVERAGE AND MAXIMUM DAILY TEMPERATURE CHANGE (°C) AT ALL GAUGE LOCATIONS, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Recorded Min	Recorded Max	Maximum Recorded Daily Change			Average Recorded Daily Change		
					April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30	April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30
1	EC-01	2003	4.2	25.6	5.9	3.9	4.5	2.0	1.6	1.8
	EC-02	2003	3.2	25.8	3.8	4.2	3.7	2.0	1.9	1.6
	EC-03	2003	4.1	26.1	5.2	4.2	4.3	2.6	2.4	1.6
	TC-01	2003	7.0	25.5	4.4	2.5	2.2	2.0	0.9	1.0
	TFC-01	2003	0.2	23.3	9.8	9.9	0.0	4.4	7.2	-
	TFC-02	2003	2.0	19.1	10.3	9.4	6.2	5.2	5.7	3.3
	TGLC-01	2003	5.2	24.4	9.2	1.4	8.0	3.2	0.5	1.9
	TGLC-02	2003	0.4	23.0	10.2	12.9	-	5.4	9.7	-
	TGLC-03	2003	4.3	21.0	-	5.4	6.2	-	2.6	1.9
	AVERAGE			**24.9**	**8.4**		**4.5**	**3.7**	**2.6**	**2.0**
	MAX			**28.0**	**13.4**	**8.8**	**8.0**	**6.3**	**9.7**	**3.3**

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TABLE 3.1-1 (CONT.)

RECORDED MINIMUM AND MAXIMUM TEMPERATURE (°C) AND AVERAGE AND MAXIMUM DAILY TEMPERATURE CHANGE (°C) AT ALL GAUGE LOCATIONS, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Recorded Min	Recorded Max	Maximum Recorded Daily Change			Average Recorded Daily Change		
					April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30	April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30
2	TM-17	2002	2.4	25.6	4.0	4.1	3.4	2.3	2.8	1.7
	TUNR-01	2003	0.1	25.2	2.7	1.7	1.9	1.5	1.0	0.8
	TUNR-02	2003	7.0	25.6	2.2	1.7	2.4	1.2	1.0	0.8
	TUNR-03	2003	1.2	25.5	1.9	1.0	2.0	0.9	0.6	0.5
	AVERAGE			**25.5**	**2.7**	**2.1**	**2.4**	**1.5**	**1.3**	**0.9**
	MAX			**25.6**	**4.0**	**4.1**	**3.4**	**2.3**	**2.8**	**1.7**
3	TM-11	2002	1.8	26.2	10.0	5.2	6.4	4.9	2.9	2.1
	TM-13	2002	1.7	26.5	8.2	6.3	12.0	4.3	3.4	3.6
	TM-15	2002	1.7	25.0	6.1	1.0	6.6	2.2	0.7	1.0
	TM-16	2002	2.0	25.4	4.3	1.2	4.0	1.2	0.8	0.7
	TM-18	2002	2.1	25.2	2.2	1.9	1.6	1.1	1.0	1.3
	TM-20	2002	6.9	27.0	7.4	4.8	5.7	3.4	3.0	2.4
	TUNR-04	2003	0.1	25.2	9.3	2.7	5.8	4.0	1.5	2.2
	AVERAGE			**25.8**	**6.8**	**3.3**	**6.0**	**3.0**	**1.9**	**1.9**
	MAX			**27.0**	**10.0**	**6.3**	**12.0**	**4.9**	**3.4**	**3.6**

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TABLE 3.1-1 (CONT.)

RECORDED MINIMUM AND MAXIMUM TEMPERATURE (°C) AND AVERAGE AND MAXIMUM DAILY TEMPERATURE CHANGE (°C) AT ALL GAUGE LOCATIONS, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Recorded Min	Recorded Max	Maximum Recorded Daily Change			Average Recorded Daily Change		
					April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30	April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30
4	TLNR-03	2003	7.7	24.5	1.9	1.7	6.1	1.1	0.8	1.2
	LNR-01	2003	14.9	24.7	1.6	1.5	2.6	1.0	0.8	1.0
	AVERAGE			24.6	2.2	1.6	4.3	1.1	0.8	1.1
	MAX			24.7	2.8	1.7	6.1	1.2	0.8	1.2
5	TLNR-01	2003	2.7	25.3	3.5	1.7	1.2	1.5	0.8	0.6
	TLNR-04	2003	11.9	21.5	-	-	1.1	-	-	0.6
	TLNR-05	2003	8.2	21.5	-	-	2.0	-	-	0.5
	TLNR-02	2003	4.6	25.1	3.1	3.1	1.9	1.1	0.8	0.5
	LNR-02	2003	2.9	25.0	1.7	1.3	1.9	0.9	0.7	0.5
	TM-24	2002	-0.4	25.1	1.9	1.5	1.5[1]	0.9	3.8	5.5
	LNR-03	2003	4.4	24.8	1.5	1.0	1.8	0.8	0.6	0.5
	LNR-04	2003	3.0	24.7	2.5	1.2	2.2	1.0	0.8	0.9
	LNR-05	2003	4.4	24.8	1.3	0.9	1.8	0.6	0.4	0.4

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TABLE 3.1-1 (CONT.)

RECORDED MINIMUM AND MAXIMUM TEMPERATURE (°C) AND AVERAGE AND MAXIMUM DAILY TEMPERATURE CHANGE (°C) AT ALL GAUGE LOCATIONS, 2002 AND 2003

Analysis Zone	Gauge Location ID	Year	Recorded Min	Recorded Max	Maximum Recorded Daily Change			Average Recorded Daily Change		
					April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30	April 1 thru June 30	July 1 thru August 30	Sept. 1 thru Nov. 30
5	TM-25	2002	0.4	25.3	2.0	3.1	4.1	1.1	1.7	2.4
	AVERAGE			**24.3**	**1.7**		**2.0**	**1.0**	**1.2**	**1.2**
	MAX			**25.3**	**3.5**	**3.1**	**4.1**	**1.5**	**3.8**	**5.5**
6	TLEW-01	2003	5.4	25.0	2.6	2.3	1.3	1.2	0.7	0.5

Note: [1] TM-24 was out of water nearly every night during this period; therefore, data for this period were summarized, but not used in the analysis or in the calculation of the average daily change values.

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TABLE 3.2.1-1

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Burnt Ship Creek	2003	TBSC-01	**YES**	4/1 to 6/30 -1.7 +1.7 7/1 to 8/31 -0.8 +1.2	This location is influenced by changes in water level in the Chippawa-Grass Island Pool. Annual patterns and frequency distribution of $\Delta°C_{WT}$ values indicate small temperature effects, predominantly in spring months, consistent with water level changes in the river. Small temperature effects consistent with water level changes are present in the fall, but do not exceed $\Delta°C_{WT}$ reference values.	• B-1 to B-9 • C-1 • C-2a to C-2c • C-3a to C-3c
		TBSC-02, TBSC-03	No	N/A	Influence of water level changes in the Chippawa-Grass Island Pool on locations TBSC-02 and TBSC-03 is limited but does occur. However, annual patterns of $\Delta°C_{WT}$ and frequency distributions of $\Delta°C_{WT}$ by hour at both locations show no evident temperature effect. Lack of effect at TBSC-02 indicates even less potential for temperature effects at TBSC-03.	• B-10 to B-18 • C-4 • C-5a to C-5c • C-6a to C-6c • B-19 to B-27 • C-7
Buckhorn Marsh	2002, 2003	TM-12, TBHM-01, TBHM-02	No	N/A	Water level changes in the Chippawa-Grass Island Pool, Burnt Ship Creek and Woods Creek do not routinely affect water levels in Buckhorn Marsh between the weirs. Annual patterns in $\Delta°C_{WT}$ at 3 temperature gauge locations in 2002 and 2003 do not indicate a temperature effect.	• B-28 to B-54 • C-8 • C-9 • C-10

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Woods Creek	2003	TWC-01	**YES**	4/1 to 6/30 -5.7 +1.3 7/1 to 8/31 -1.0 +0.5	Location TWC-01 (proximal to WL gauge WC-01) is demonstrably influenced by water level changes in the Chippawa-Grass Island Pool. Annual patterns and frequency distribution of $\Delta°C_{WT}$ values at location TWC-01 indicate temperature effects that comport with frequency distribution patterns in ΔWL. Small temperature effects are evident in the fall consistent with water level fluctuations, but they do not exceed reference values	• B-64 to B-72 • C-11 • C-12a to C-12c • C-13a to C-13c
Woods Creek	2002	TM-01	**YES**	4/1 to 6/30 -6.5 +2.3 7/1 to 8/31 -1.0 9/1 to 10/31 -1.0	Location TM-01 is a short distance upstream from WL gauge SD-04, which is demonstrably affected by water level changes in the Chippawa-Grass Island Pool. Annual patterns and frequency distribution of $\Delta°C_{WT}$ values at location TM-01 indicate temperature effects consistent with the frequency distribution of ΔWL values at gauge location SD-04.	• B-55 to B-63 • C-14 • C-15a to C-15c • C-16a to C-16c

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Woods Creek	2002	TM-02	NO*	NA	Location TM-02 is in Woods Creek within the influence of Niagara River water levels . However, temperature effects at this location are limited. No temperature effect is evident in annual patterns of $\Delta°C_{WT}$ values. A minor temperature effect is evident in evening hours based on frequency distribution of hourly $\Delta°C_{WT}$ values, but it does not exceed reference values.	• B-55 to 63 • C-17 • C-18a to C-18c
Woods Creek	2002	TM-04	NO	NA NA	Location TM-04 is in Woods Creek at the upstream extent of the influence of Niagara River water levels . No temperature effect is evident in annual patterns of $\Delta°C_{WT}$ values. A possible temperature effect is evident during evening hours in summer and fall months, based on frequency distributions of hourly $\Delta°C_{WT}$ values, but these effects do not exceed reference values.	• B-55 to B-63 • C-19 • C-20a to C-20c

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Woods Creek	2003	TWC-02	NO*	NA	Proximal to 2002 gauge TM-04, location TWC-02 is in Woods Creek at the upstream extent of the influence of Niagara River water levels . No temperature effect is evident in annual patterns of $\Delta°C_{WT}$ values. A possible temperature effect is evident during evening hours in summer months only, based on frequency distributions of hourly $\Delta°C_{WT}$ values, but these effects do not exceed reference values.	• B-73 to B-81 • C-21 • C-22a to C-22c
Gun Creek	2002	TM-03	**YES**	4/1 to 6/30 -4.8 +2.3 7/1 to 8/31 -1.1 9/1 to 10/31 -0.7	Location TM-03 is at the mouth of Gun Creek, a location demonstrably affected by water level fluctuations in the upper Niagara River (based on WL gauge data in 2003). A temperature effect is evident in annual patterns of $\Delta°C_{WT}$ and frequency distributions of hourly $\Delta°C_{WT}$ values consistent with demonstrated patterns at locations where water level related effects occur.	• B-82 to B-89 • C-23 • C-24a to C-24c

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Gun Creek	2003	TGC-01	**YES**	4/1 to 6/30 -4.8 +1.7 7/1 to 8/31 -1.3 +1.6 9/1 to 10/31 -1.1 +1.8	Location TGC-01 is proximate with WL gauge GC-01, demonstrably affected by water level changes in the upper Niagara River. A temperature effect is evident in annual patterns of $\Delta°C_{WT}$ and frequency distributions of hourly $\Delta°C_{WT}$ values consistent with demonstrated patterns in ΔWL values at proximal gauge location GC-01.	• B-90 to B-98 • C-25 • C-26a to C-26c • C-27a to C-27c
Gun Creek	2002	TM-05	**YES**	9/1 to 10/31 -0.6 +0.9	Location TM-05 is located approximately 1000 feet upstream of TM-03 at the mouth of Gun Creek. This location is within the upstream extent of the influence of Niagara River water levels (Stantec et al. 2005). Annual pattern of $\Delta°C_{WT}$ values indicates a temperature effect in spring, which is evident in frequency distributions of hourly $\Delta°C_{WT}$ values.	• B-82 to B-89 • C-28 • C-29a to C-29c
	2003	GC-02A	No	N/A	Location GC-02A in Gun Creek, is demonstrably within the upstream extent of the influence of Niagara River water levels. However, no temperature effect is evident in annual pattern of $\Delta°C_{WT}$ or frequency distributions of hourly $\Delta°C_{WT}$ values.	• B-99 to B-107 • C-30 • C-31a to C-31c

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Spicer Creek	2002	TM-06	**YES**	9/1 to 10/30 -1.0	Location TM-06 is in Spicer Creek within the upstream extent of the influence of Niagara River water levels . Annual patterns in $\Delta°C_{WT}$ suggest a temperature effect in spring and fall. However, frequency distribution diagrams of hourly $\Delta°C_{WT}$ values indicate anomalous temperature conditions only in fall.	• B-108 to B-116 • C-32 • C-33a to C-33c
		TM-07	No	N/A	Location TM-06 is in Spicer Creek within the upstream extent of the influence of Niagara River water levels . However, annual patterns in $\Delta°C_{WT}$ do not suggest a temperature effect, and frequency distributions of $\Delta°C_{WT}$ show no evident pattern of temperature effects.	• B-117 to B-125 • C-34 • C-35a to C-35c
Spicer Creek	2002	TM-08	**YES**	7/1 to 8/31 +1.9	Location TM-08 is in Spicer Creek within the upstream extent of the influence of Niagara River water levels. Annual patterns of $\Delta°C_{WT}$ show an unusual warming effect prevalent during summer months. Frequency distribution patterns of hourly $\Delta°C_{WT}$ values indicate a temperature effect during summer between 8 and 9am.	• B-126 to B-134 • C-36 • C-37a to C-37c

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Spicer Creek	2003	TSC-01	No	N/A	Location TSC-01 is within the upstream extent of the influence of Niagara River water levels. However, annual patterns and frequency distributions of $\Delta°C_{WT}$ values show no evidence of temperature effect when compared with frequency distributions of ΔWL values at proximal locations in the Niagara River, and $\Delta°C_{WT}$ values in reference locations.	• B-135 to B-143 • C-38 • C-39a to C-39c • C-40a to C-40c
		TSC-02	No	N/A	Location TSC-01 is within the upstream extent of the influence of Niagara River water levels in summer months. Annual patterns of $\Delta°C_{WT}$ show an unusual warming effect prevalent during summer months. However, frequency distribution patterns of hourly $\Delta°C_{WT}$ values do not show unusual warming patterns.	• B-144 to B-152 • C-41 • C-42a to C-42c
Big Sixmile Creek	2002	TM-19	**YES**	4/1 to 6/30 -1.8	Location TM-19 is at the mouth of Big Sixmile Creek and is within the upstream extent of the influence of Niagara River water levels. Annual patterns in $\Delta°C_{WT}$ suggest a temperature effect, which is consistent with the frequency distribution diagrams of hourly $\Delta°C_{WT}$ values for spring and summer months.	• B-153 to B-161 • C-43 • C-44a to C-44c
				7/1 to 8/31 -1.0		

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Big Sixmile Creek	2002	TM-10	No	N/A	Location TM-10 is proximal to 2003 location SMC-01, which is not affected by water level fluctuations. Annual patterns in $\Delta°C_{WT}$ values suggest infrequent anomalous temperature events during spring months. However, frequency distribution patterns in $\Delta°C_{WT}$ values do not indicate a consistent pattern of temperature changes attributable to water level fluctuations.	• B-153 to B-161 • C-45 • C-46a to C-46c
Big Sixmile Creek	2003	SMC-02	**YES**	4/1 to 6/30 -3.9 +4.8	This location is demonstrably affected by water level fluctuations in the upper Niagara River. Annual patterns and frequency distribution patterns in $\Delta°C_{WT}$ values strongly indicate a temperature effect at this location in spring. An observed summer temperature shift was too small to be considered a temperature effect. No identifiable effect is present in the fall. Anomalous patterns in water temperature fluctuation occur during every hourly period during spring. Comparison of frequency distribution patterns between $\Delta°C_{WT}$ at SMC-02 and ΔWL at gauge GN-Tonawanda suggests that this location is highly susceptible to temperature effects from water level fluctuations.	• B-162 to B-170 • C-47 • C-48a to C-48c • C-40a to C-40c

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Big Sixmile Creek		TSMC-01	No	N/A	Location TSMC-01 is proximal to 2002 location TM-10 and is close to 2003 locations SMC-01, and shows similar annual patterns in $\Delta°C_{WT}$ values.	• B-171 to B-179 • C-49
Big Sixmile Creek	2003	SMC-01	No	N/A	Location SMC-01 is a temperature reference location and was upstream of all water level fluctuations. Conditions at this location are described in Section 3.2.1.	• B-171 to 179 • C-50 • C-51a to C-52c
Cayuga Creek	2003	CC-01	**YES**	4/1 to 6/30 -4.0 +2.1 7/1 to 8/30 -1.0 9/1 to 10/31 +2.0	Location CC-01 is demonstrably affected by water level fluctuations in the Chippawa-Grass Island Pool. Annual patterns and frequency distribution patterns in $\Delta°C_{WT}$ values strongly indicate a temperature effect at this location, and the timing of these fluctuations is consistent with water level changes in the Chippawa-Grass Island Pool.	• B-180 to B-188 • C-52 • C-53a to C-53c • C-54a to C-54c

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Cayuga Creek	2003	CC-02	**YES***	7/1 to 8/31 -1.0	Location CC-02 is demonstrably affected by water level fluctuations in the Chippawa-Grass Island Pool. Annual patterns in $\Delta°C_{WT}$ values do not strongly indicate a temperature effect. However, frequency distribution patterns in $\Delta°C_{WT}$ values indicate a minor a cooling effect in summer (at about 8:00 am) consistent with the timing of water level changes. It is not clear if water from the upper Niagara River is mixing with Cayuga Creek water at CC-02.	• B-189 to B-197 • C-55 • C-56a to C-56c
		CC-03	No	N/A	Location CC-01 is a temperature reference location and is upstream of water level fluctuations. Conditions at this location are described in Section 3.2.1.	• B-189 to B-197 • C-57 • C-58a to C-58c

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Tonawanda/ Ellicott Creek	2003	TTC-01	**YES**	4/1 to 6/30 -2.8 +1.3	Location TTC-01 is within the upstream extent of the influence of Niagara River water levels and unusual patterns of temperature variability are evident during spring months. Annual patterns and hourly frequency distributions of $\Delta°C_{WT}$ values strongly indicate a temperature effect during spring months. No effect is evident during summer and fall. The timing of this temperature effect is consistent with water level fluctuations in the Niagara River at GN-Tonawanda.	• B-207 to B-215 • C-59 • C-60a to C-60c • C-40a to C-40c
		EC-01	**YES**	9/1 to 10/31 -0.7	Location EC-01 is within the upstream extent of the influence of Niagara River water levels. Annual patterns in $\Delta°C_{WT}$ values suggest a temperature effect during early summer and fall. However, frequency distributions in $\Delta°C_{WT}$ values only indicate a temperature effect during fall.	• B-198 to B-206 • C-61 • C-62a to C-62c

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Tonawanda/ Ellicott Creek	2003	EC-02 EC-03 TC-01	No	N/A	Locations EC-02 and EC-03 are within the upstream extent of the influence of Niagara River water levels. Location TC-01 is upstream of the extent of the influence of Niagara River water levels. Annual patterns in $\Delta°C_{WT}$ values do not indicate a temperature effect. Frequency distribution patterns in $\Delta°C_{WT}$ at EC-02 confirm the lack of temperature effect. The position of EC-03 and TC-01 upstream of this unaffected location indicate temperature effects from Niagara River fluctuations are unlikely to occur.	• B-207 to B-215 • C-63 • C-64a to C-64c • C-65 • C-66
Fish Creek	2003	TFC-01 TFC-02	**Yes**	N/A	Fish Creek is not affected by water level fluctuations in the Niagara River. However, hydrostatic pressure from Lewiston Reservoir influences groundwater inflow to the stream. Seasonal temperature patterns and annual patterns in $\Delta°C_{WT}$ values are not consistent with a temperature effect. However, diurnal temperature fluctuations in Fish Creek are relatively moderate compared to reference areas, indicating an effect of groundwater influx.	• B-216 to B-224 • C-67 • C-68

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TABLE 3.2.1-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 1, BUCKHORN MARSH AND UPPER NIAGARA RIVER TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Gill Creek	2003	TGLC-01 TGLC-03	**YES**	N/A	Gill Creek, where temperature data were collected, is not affected by water level fluctuations in the Niagara River. Groundwater inflow caused by hydrostatic pressure from Lewiston Reservoir, and flow augmentation from the reservoir affect temperatures in the creek. Seasonal and diurnal temperature patterns, and annual patterns in $\Delta°C_{WT}$ values indicate that flow augmentation tends to mute diurnal temperature fluctuations during summer, therefore the effect is to stabilize temperatures during warm weather months, consistent with observed temperatures in Lewiston Reservoir.	• B-224 to B-233 • C-69 • C-71
Gill Creek	2003	TGLC-02	No	N/A	This location is upstream of the point where flow augmentation occurs. Seasonal and diurnal temperature patterns, and annual patterns in $\Delta°C_{WT}$ values are not consistent with a temperature effect.	• B-224 to B-233 • C-70

Notes: [a] **YES*** indicates a potential temperature effect has been identified, but results are equivocal due to small size of data set. No* indicates an equivocal finding of no effect due to small size of data set.
[b] Extent of temperature effects expressed as an hourly change in water temperature ($\Delta°C_{WT}$).

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TABLE 3.2.2-1

ANALYSIS RESULTS, ANALYSIS ZONE 2, UPPER NIAGARA RIVER – MAIN CHANNEL

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Niagara River, upstream of Woods Creek	2002	TM-17	No	N/A	This location is influenced by changes in water level in the Chippawa-Grass Island Pool. However, temperature patterns indicate normal diurnal temperature fluctuations. Annual distribution of $\Delta°C_{WT}$ values indicate no evident temperature effects during any season.	• B-241 to B-247 • C-72
Niagara River, upstream of Spicer Creek	2003	TUNR-01	No	N/A	Location TUNR-01 is within the upstream extent of the influence of water level fluctuations in the Chippawa-Grass Island Pool. However, temperature patterns indicate normal diurnal temperature fluctuations. Annual distribution of $\Delta°C_{WT}$ values indicate no evident temperature effects during any season.	• B-248 to B-256 • C-73

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TABLE 3.2.2-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 2, UPPER NIAGARA RIVER – MAIN CHANNEL

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Niagara River, upstream of intakes		TUNR-02	No	N/A	Location TUNR-02 is influenced by water level fluctuations in the Chippawa-Grass Island Pool. However, temperature patterns indicate normal diurnal temperature fluctuations. Annual distribution of $\Delta°C_{WT}$ values indicate no evident temperature effects during any season.	• B-257 to B-265 • C-74
Niagara River, Squaw Island	2003	TUNR-03	No	N/A	Location TUNR-03 is a reference location for temperature conditions in the upper Niagara River. Conditions at this location are described in Section 3.2.2.	• B-248 to B-256 • C-75

Notes:

[a] **YES*** indicates a potential temperature effect has been identified, but results are equivocal due to small size of data set. No* indicates an equivocal finding of no effect due to small size of data set.

[b] Extent of temperature effects expressed as an hourly change in water temperature ($\Delta°C_{WT}$).

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TABLE 3.2.3-1

ANALYSIS RESULTS, ANALYSIS ZONE 3, UPPER NIAGARA RIVER – SHALLOW WATER AREAS OFF OF MAIN CHANNEL AND IMMEDIATELY DOWNSTREAM OF TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Upper Niagara River, mouth of Burnt Ship Creek	2002	TM-11	**YES***	4/1 to 6/30 -1.1 7/1 to 8/31 -1.0 +1.0	TM-11 is at the mouth of Burnt Ship Creek and within the upstream extent of the influence of water level fluctuations in the Chippawa-Grass Island Pool. Annual patterns of $\Delta°C_{WT}$ values indicate a temperature effect in spring and late summer. Frequency distributions of $\Delta°C_{WT}$ values confirm a temperature effect in spring and summer.	• B-28 to B-36 • C-76 • C-77a to C-77c
Upper Niagara River, Beaver Island Slough		TM-13	No	N/A	TM-13 is located in the Beaver Island Slough and is relatively isolated from the upper Niagara River. Annual patterns of $\Delta°C_{WT}$ values are consistent with diurnal temperature variation and show no influence from water level fluctuations in the Chippawa-Grass Island Pool.	• B-234 to B-240 • C-78
Upper Niagara, Strawberry Island		TM-15	No	N/A	TM-15 is located in the Tonawanda Channel between Strawberry and Motor Islands. Annual patterns of $\Delta°C_{WT}$ values are suggestive of a temperature effect. However, frequency distributions of $\Delta°C_{WT}$ values show no indication of a temperature effect consistent with water level fluctuations during spring months.	• B-234 to B-240 • C-79 • C-80a to C-80

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TABLE 3.2.3-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 3, UPPER NIAGARA RIVER – SHALLOW WATER AREAS OFF OF MAIN CHANNEL AND IMMEDIATELY DOWNSTREAM OF TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Upper Niagara, Strawberry Island	2002	TM-16	No	N/A	TM-16 is located at the Northwest tip of Strawberry Island in a shallow water zone. The annual pattern of $\Delta°C_{WT}$ values shows no indication of a water level related temperature effect, with the exception of rare anomalies most likely due to natural events .	• B-234 to B-240 • C-81
Upper Niagara River, Grass Island		TM-18	No	N/A	TM-18 is located in a shallow water bay in Grass Island and is subject to water level fluctuations in the Chippawa-Grass Island Pool. The annual pattern of $\Delta°C_{WT}$ values shows no indication of a water level related temperature effect, with the exception of rare anomalies in fall.	• B-241 to B-247 • C-83

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TABLE 3.2.3-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 3, UPPER NIAGARA RIVER – SHALLOW WATER AREAS OFF OF MAIN CHANNEL AND IMMEDIATELY DOWNSTREAM OF TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Upper Niagara, Strawberry Island	2002	TM-20	**YES***	4/1 to 06/30 -0.9 +1.5	TM-20 is located in a shallow water embayment on the north side of Strawberry Island. The annual pattern in $\Delta°C_{WT}$ values indicates a water level related temperature effect may be present at this location. However, frequency distribution patterns of $\Delta°C_{WT}$ values show no clear indication of a temperature effect related to water level changes. This suggests that the identified temperature effect at this shallow water location is in fact due to a greater range of normal diurnal temperature fluctuation than other areas in the upper Niagara River mainstem.	• B-234 to B-240 • C-84 • C-85a to C-85c
				7/1 to 08/30 -0.9 +0.9		
				9/1 to 10/31 -0.9 +1.0		

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TABLE 3.2.3-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 3, UPPER NIAGARA RIVER – SHALLOW WATER AREAS OFF OF MAIN CHANNEL AND IMMEDIATELY DOWNSTREAM OF TRIBUTARIES

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Upper Niagara River, downstream of Woods Creek	2003	TUNR-04	**YES**	4/1 to 6/30 -3.2 +2.5	TUNR-04 is located immediately downstream of Woods Creek, and is variably exposed to creek outflow. The annual pattern in $\Delta°C_{WT}$ values strongly indicates a water level related temperature effect at this location. This is confirmed by frequency distribution patterns of $\Delta°C_{WT}$ values, which show a strong temperature effect in spring between 9 and 11pm, and in fall between 7 and 10pm. A more muted temperature effect is evident between 9 and 10pm in summer months. This is consistent with the tendency for tributary temperatures to be similar to river temperatures during summer months, indicating no temperature effects even though water level fluctuations occur.	• B-266 to B-274 • C-86 • C-87a to C-87c
				7/1 to 8/31 -0.9		
				9/1 to 10/31 -2.0 +2.5		

Notes:

[a] **YES*** indicates a potential temperature effect has been identified, but results are equivocal due to small size of data set. No* indicates an equivocal finding of no effect due to small size of data set.

[b] Extent of temperature effects expressed as an hourly change in water temperature ($\Delta°C_{WT}$).

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TABLE 3.2.4-1

ANALYSIS RESULTS, ANALYSIS ZONE 4, LOWER NIAGARA RIVER – GORGE BETWEEN FALLS AND RMNPP TAILRACE

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Lower Niagara River, above tailrace	2003	TLNR-03	No	N/A	TLNR-03 is located upstream of the RMNPP tailrace. Temperatures in this portion of the river are determined primarily by water temperatures upstream of the falls, and the high velocity of water ensures well mixed conditions. Seasonal and diurnal patterns of temperature fluctuation at this location are consistent with the upper Niagara River. Data at this location are limited to the period between late spring and early fall, with scattered data during summer months. The annual $\Delta°C_{WT}$ pattern for available data is consistent with patterns in the upper Niagara River. Frequency distribution patterns of $\Delta°C_{WT}$ values show no indication of a temperature effect at this location. In addition, there is no evidence of a temperature effect at gauge LNR-01 located immediately downstream during the same time period.	• B-284 to B-291 • C-88 • C-89

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TABLE 3.2.4-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 4, LOWER NIAGARA RIVER – GORGE BETWEEN FALLS AND RMNPP TAILRACE

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Lower Niagara River, above tailrace	2003	LNR-01	No*	N/A	LNR-01 is located downstream of location TLNR-03 approximately 1000 feet upstream of the RNMPP tailrace. Water temperatures in this portion of the river are determined primarily by water temperatures upstream of the falls, and the high velocity of water ensures well mixed conditions. Seasonal and diurnal patterns of temperature fluctuations at this location are consistent with the upper Niagara River. Data at this location are limited to the period between late spring and early fall. The annual $\Delta°C_{WT}$ pattern in available data is otherwise consistent with patterns in the upper Niagara River..	• B-284 to B-291 • C-90 • C-91a to C-91c

Notes:

[a] **YES*** indicates a potential temperature effect has been identified, but results are equivocal due to small size of data set. No* indicates an equivocal finding of no effect due to small size of data set.

[b] Extent of temperature effects expressed as an hourly change in water temperature ($\Delta°C_{WT}$).

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TABLE 3.2.5-1

ANALYSIS RESULTS, ANALYSIS ZONE 5, LOWER NIAGARA RIVER – BELOW TAILRACE

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Lower Niagara River, at tailrace	2003	TLNR-01	No	N/A	TLNR-01 is located within the RMNPP tailrace, on the south side near the fishing pier. Data at this location are limited to summer months in 2003. Annual patterns in $\Delta°C_{WT}$ values indicate no temperature effect at this location. Frequency distributions of hourly $\Delta°C_{WT}$ values also show a no temperature effect. Data were not available for fall months, and data for spring were limited to several days in May and most of June.	• B-284 to B-291 • C-92 • C-93
Lower Niagara River, at tailrace		TLNR-04	No	N/A	TLNR-04 is located downstream of TLNR-01 within the RMNPP tailrace on the north side. Data at this location are limited to fall months in 2003. Annual patterns in $\Delta°C_{WT}$ values for this period show no indication of a temperature effect at this location.	• B-284to B-291 • C-94
Lower Niagara River, at tailrace	2003	TLNR-05	No*	N/A	TLNR-05 is located downstream of TLNR-01 within the middle of the Niagara project tailrace. Data at location are limited to fall months in 2003. Patterns of annual and diurnal temperature variability at this location are consistent with those in the upper Niagara River. The annual pattern in $\Delta°C_{WT}$ values for this period shows no indication of a temperature effect at this location.	• B-284 to B-291 • C-95

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TABLE 3.2.5-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 5, LOWER NIAGARA RIVER – BELOW TAILRACE

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Lower Niagara River, at Adam Beck tailrace	2003	TLNR-02	No*	N/A	TLNR-02 is located on the U.S. side of the river, downstream of the Sir Adam Beck tailrace. Data at this location are scattered during spring, summer and fall months in 2003. Patterns of annual and diurnal temperature variability at this location are consistent with those in the upper Niagara River. The annual pattern in $\Delta°C_{WT}$ values for this period shows one rare temperature anomaly, but otherwise indicates no temperature effect at this location.	• B-284 to B-291 • C-96
Lower Niagara River, downstream of Adam Beck tailrace	2003	LNR-02	No*	N/A	LNR-02 is located in the lower end of the Niagara River Gorge downstream of the Sir Adam Beck and RMNPP tailraces. Patterns of annual and diurnal temperature variability at this location are consistent with those in the upper Niagara River. The annual pattern in $\Delta°C_{WT}$ values for this period shows no indication of a project related temperature effect.	• B-301 to B-308 • C-97 • C-98a to C-98c
Lower Niagara River, downstream at gorge mouth	2002	TM-24	No	N/A	TM-24 is located at the mouth of the Niagara River Gorge. Patterns of annual and diurnal temperature variability at this location are consistent with those in the upper Niagara River. Frequency distribution patterns of $\Delta°C_{WT}$ values indicate no temperature effect .	• B-275 to B-283 • C-99 • C-100a to C-100c

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TABLE 3.2.5-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 5, LOWER NIAGARA RIVER – BELOW TAILRACE

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Lower Niagara River downstream of gorge	2003	LNR-03	No	N/A	LNR-03 is located downstream of the mouth of the Niagara River Gorge approximately 2 miles downstream of the RMNPP tailrace. Patterns of annual and diurnal temperature variability at this location are consistent with those in the upper Niagara River. The annual pattern in $\Delta°C_{WT}$ values for this period shows no indication of a temperature effect.	• B-301 to B-308 • C-101
Lower Niagara River downstream of gorge		LNR-04	No	N/A	LNR-04 is located approximately midway between the mouth of the Niagara River Gorge and Lake Ontario. Patterns of annual and diurnal temperature variability at this location are consistent with those in the upper Niagara River. The annual pattern in $\Delta°C_{WT}$ values for this period show no indication of a temperature effect.	• B-301 to B-308 • C-102
Lower Niagara River downstream of gorge		LNR-05	No	N/A	LNR-05 is located approximately one mile upstream of the river mouth. Patterns of annual and diurnal temperature variability at this location are consistent with those in the upper Niagara River. The annual pattern in $\Delta°C_{WT}$ values for this period show no indication of a temperature effect.	• B-301 to B-308 • C-103

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TABLE 3.2.5-1 (CONT.)

ANALYSIS RESULTS, ANALYSIS ZONE 5, LOWER NIAGARA RIVER – BELOW TAILRACE

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Lower Niagara River at Lake Ontario	2002	TM-25	No	N/A	TM-25 is located at the mouth of the Niagara river at Lake Ontario. Patterns of annual and diurnal temperature variability at this location are consistent with those in the upper Niagara River. The annual pattern in $\Delta°C_{WT}$ values for this period show no indication of a temperature effect. Some temperature anomalies occur during November, after the close of the tourist season. These anomalies are attributed to wave action during fall storms on Lake Ontario.	• B-275 to B-283 • C-104

Notes:

[a] **YES*** indicates a potential temperature effect has been identified, but results are equivocal due to small size of data set. No* indicates an equivocal finding of no effect due to small size of data set.

[b] Extent of temperature effects expressed as an hourly change in water temperature ($\Delta°C_{WT}$).

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TABLE 3.2.6-1

ANALYSIS RESULTS, ANALYSIS ZONE 6, LEWISTON RESERVOIR

Area	Data Year	Temperature Gauge(s) #	Effect Identified?[a]	Extent of Effect ($\Delta°C_{WT}$)[b]	Comments	Supporting Figures (Appendices B and C)
Lewiston Reservoir	2003	TLEW-01	No	N/A	TLEW-01 is located at the outlet of Lewiston Reservoir at the Lewiston Pump Generating Plant. Annual and diurnal patterns of temperature variability in the reservoir are consistent with temperatures in its source body, the upper Niagara River. The annual pattern of $\Delta°C_{WT}$ values shows no large rapid temperature variations at any time of the data period, suggesting that temperatures are primarily controlled by the input source. The water temperature in the reservoir is generally slightly lower than that of the upper Niagara River near the NPP intakes in spring and early summer. This is due to the fact that water is pumped into the reservoir during the night, when the average water temperature is lower than during the daytime.	• B-292 to B-300 • C-105

Notes:

[a] **YES*** indicates a potential temperature effect has been identified, but results are equivocal due to small size of data set. No* indicates an equivocal finding of no effect due to small size of data set.

[b] Extent of temperature effects expressed as an hourly change in water temperature ($\Delta°C_{WT}$).

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FIGURE 3.1-1

SEASONAL TEMPERATURE FLUCTUATIONS AT SELECTED GAUGE LOCATIONS IN THE UPPER NIAGARA RIVER (TUNR-01) AND TRIBUTARY STREAMS (SMC-01, TWC-02), MARCH-NOVEMBER 2003 (SHOWN AS DAILY AVERAGE TEMPERATURES)

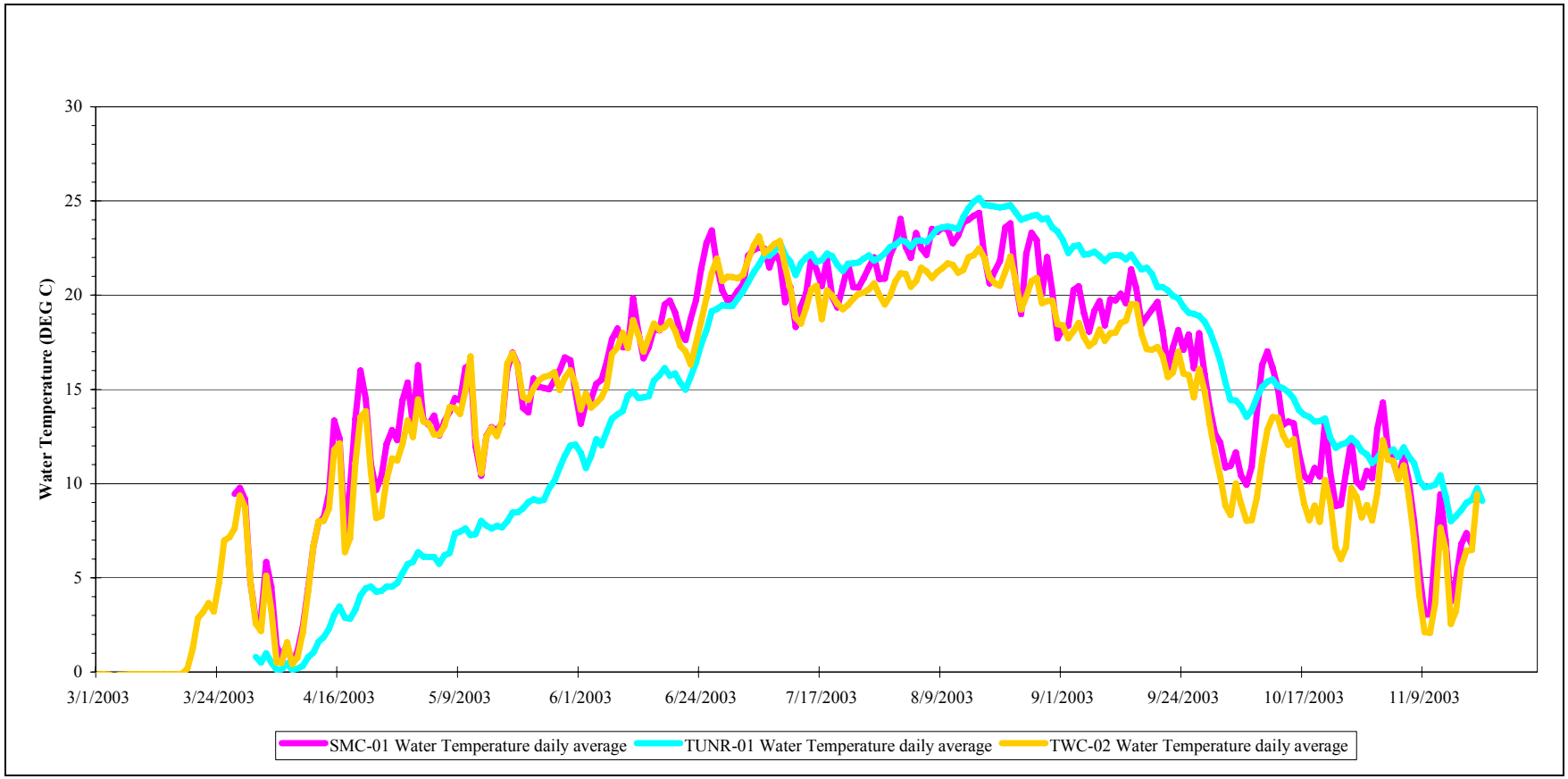

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FIGURE 3.1-2

DIURNAL TEMPERATURE FLUCTUATIONS AT SELECTED GAUGE LOCATIONS IN THE UPPER NIAGARA RIVER (TUNR-01) AND BIG SIXMILE CREEK (SMC-01), APRIL-MAY 2003 (SHOWN AS HOURLY AVERAGE TEMPERATURES)

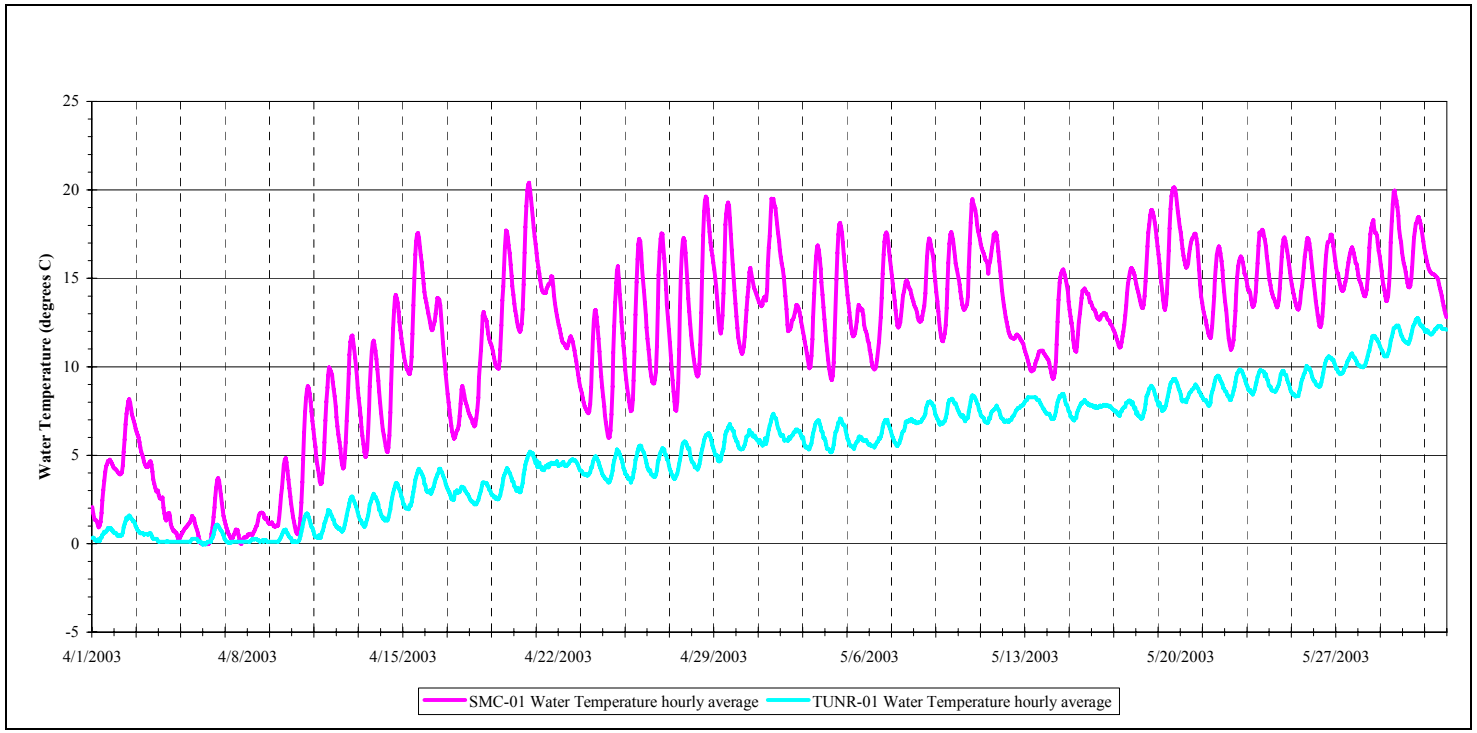

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FIGURE 3.2.1-1A

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN BIG SIXMILE CREEK AT LOCATION SMC-01, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE IN APRIL 2003

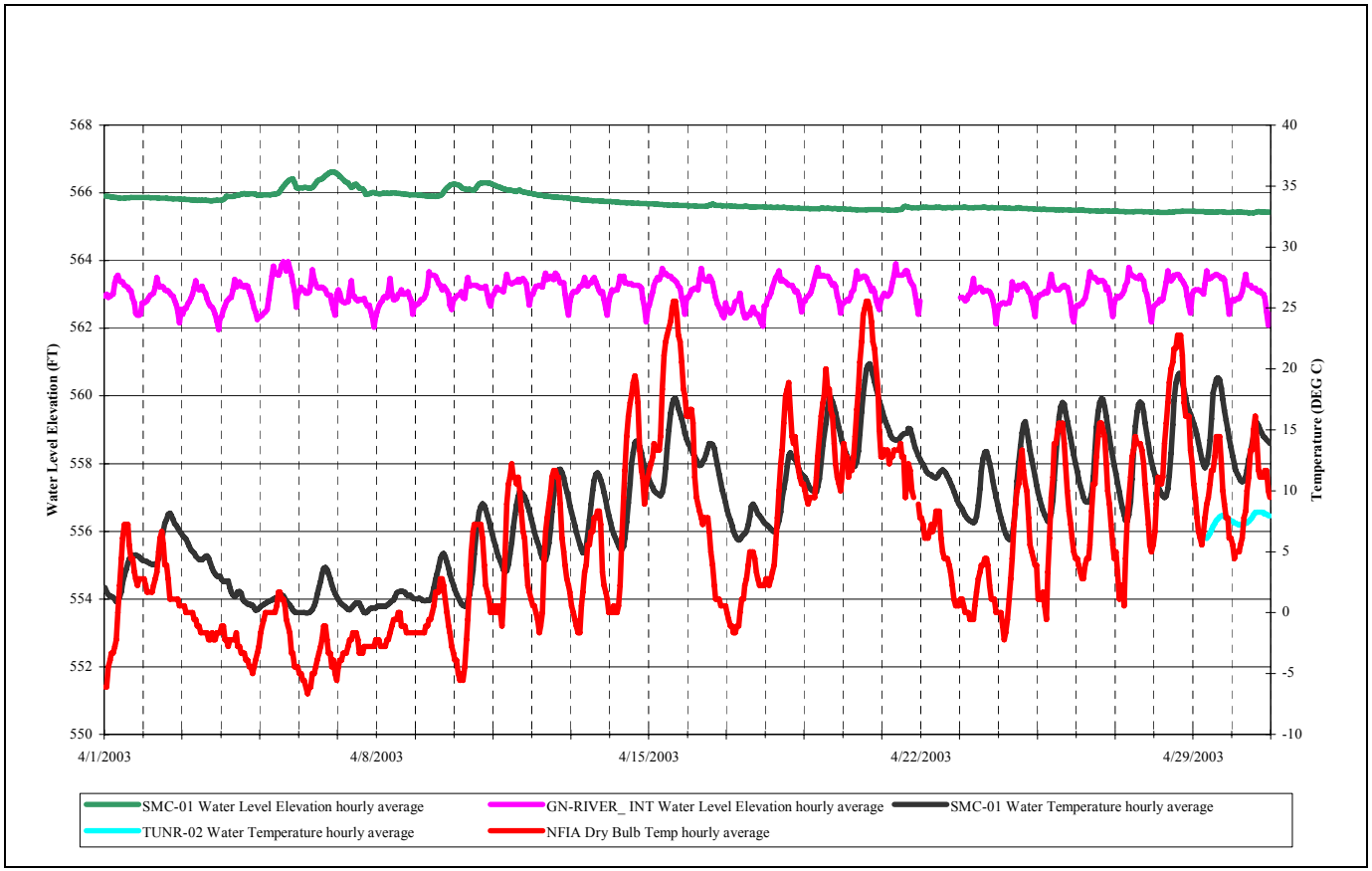

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FIGURE 3.2.1-1B

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN BIG SIXMILE CREEK AT LOCATION SMC-01, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE IN MAY 2003

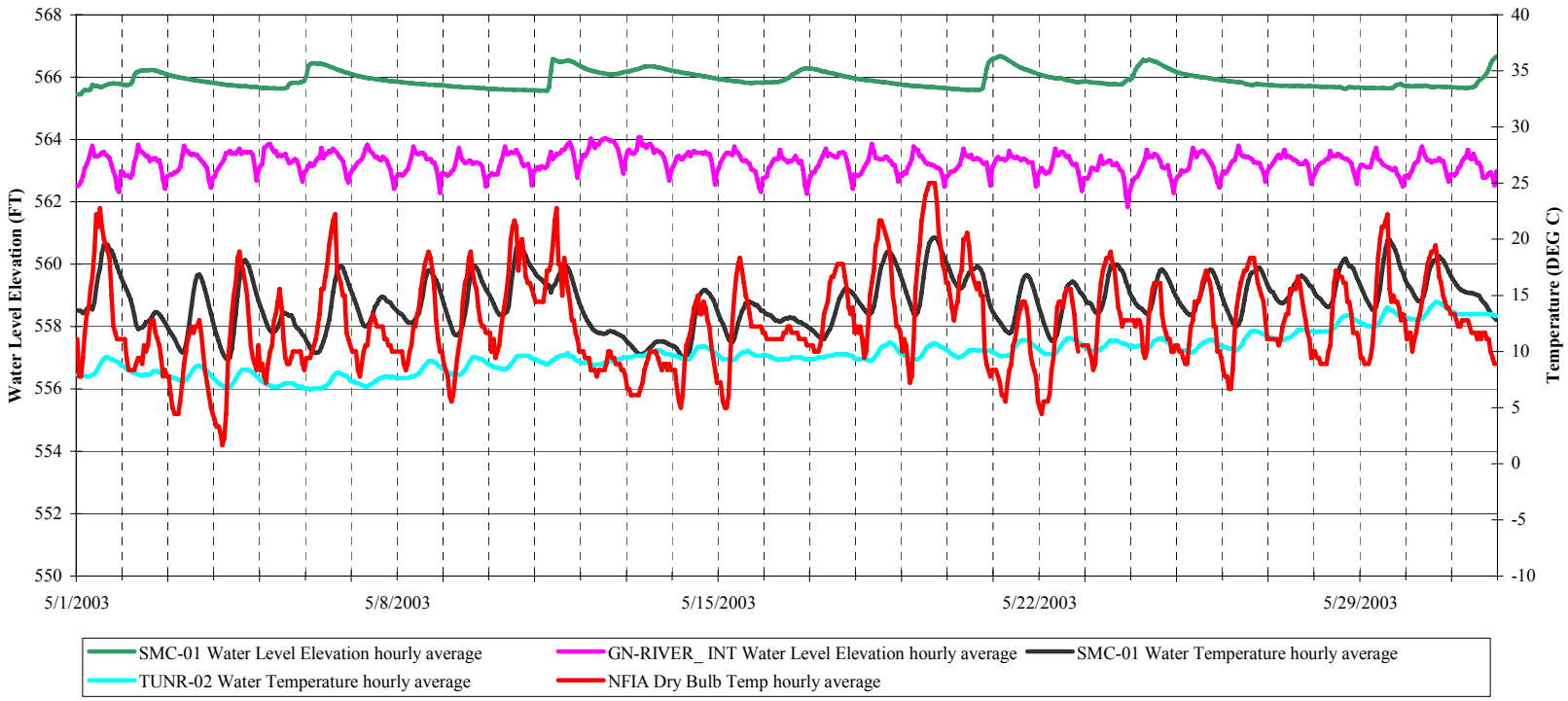

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FIGURE 3.2.1-1C

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN BIG SIXMILE CREEK AT LOCATION SMC-01, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE IN JUNE 2003

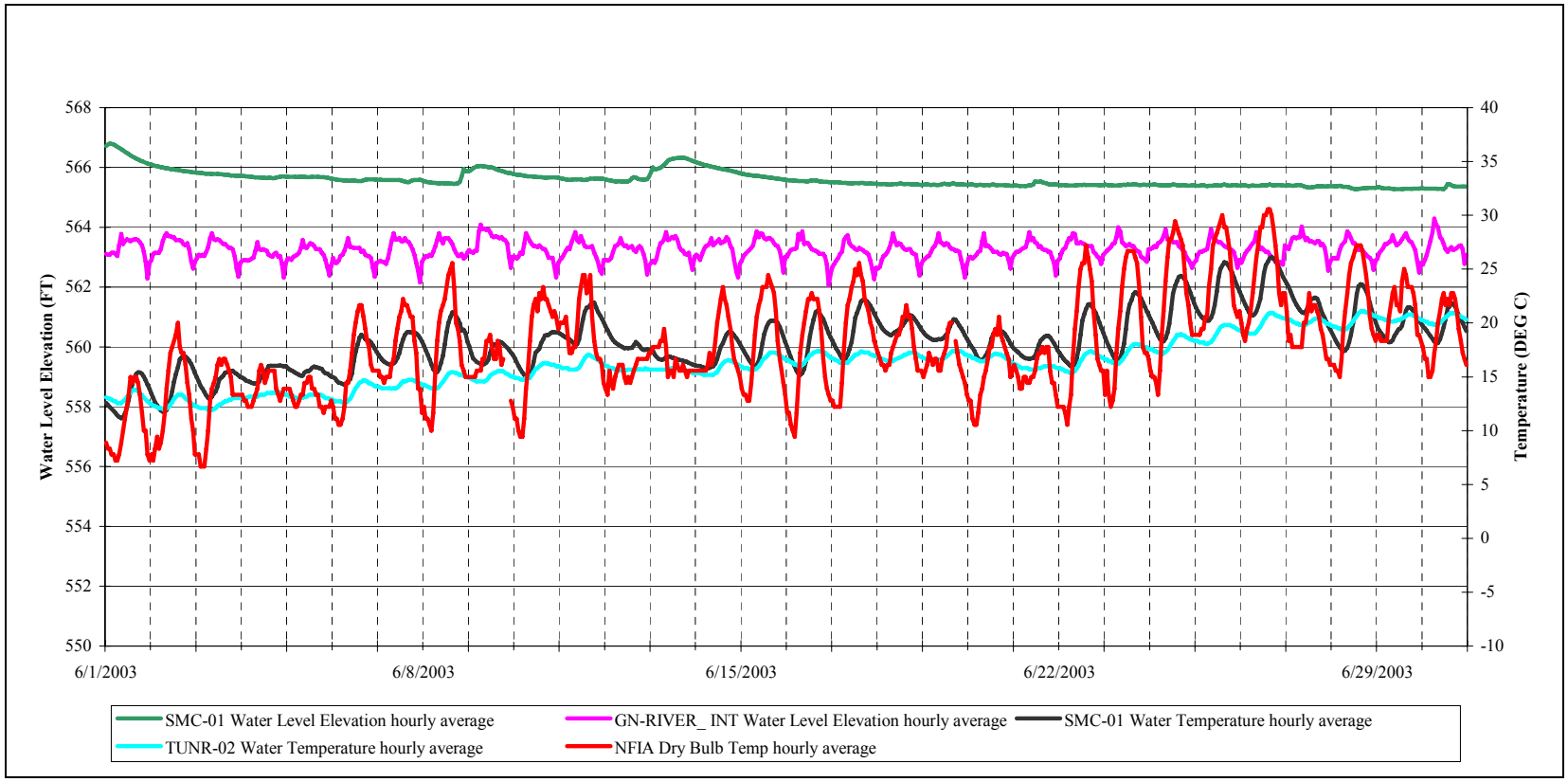

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FIGURE 3.2.1-2A

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN CAYUGA CREEK AT LOCATION CC-03, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE IN APRIL 2003

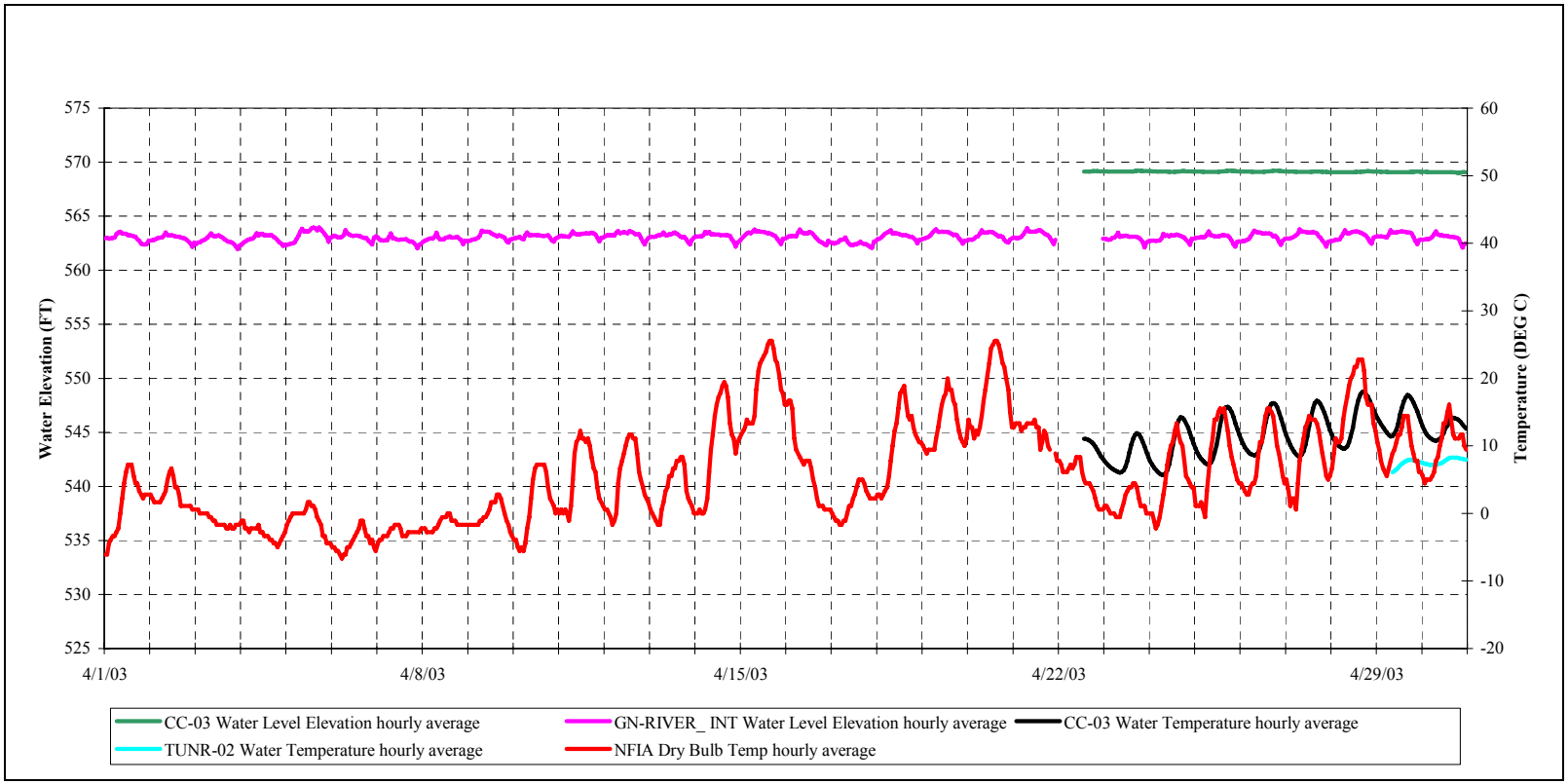

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FIGURE 3.2.1-2B

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN CAYUGA CREEK AT LOCATION CC-03, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE IN MAY 2003

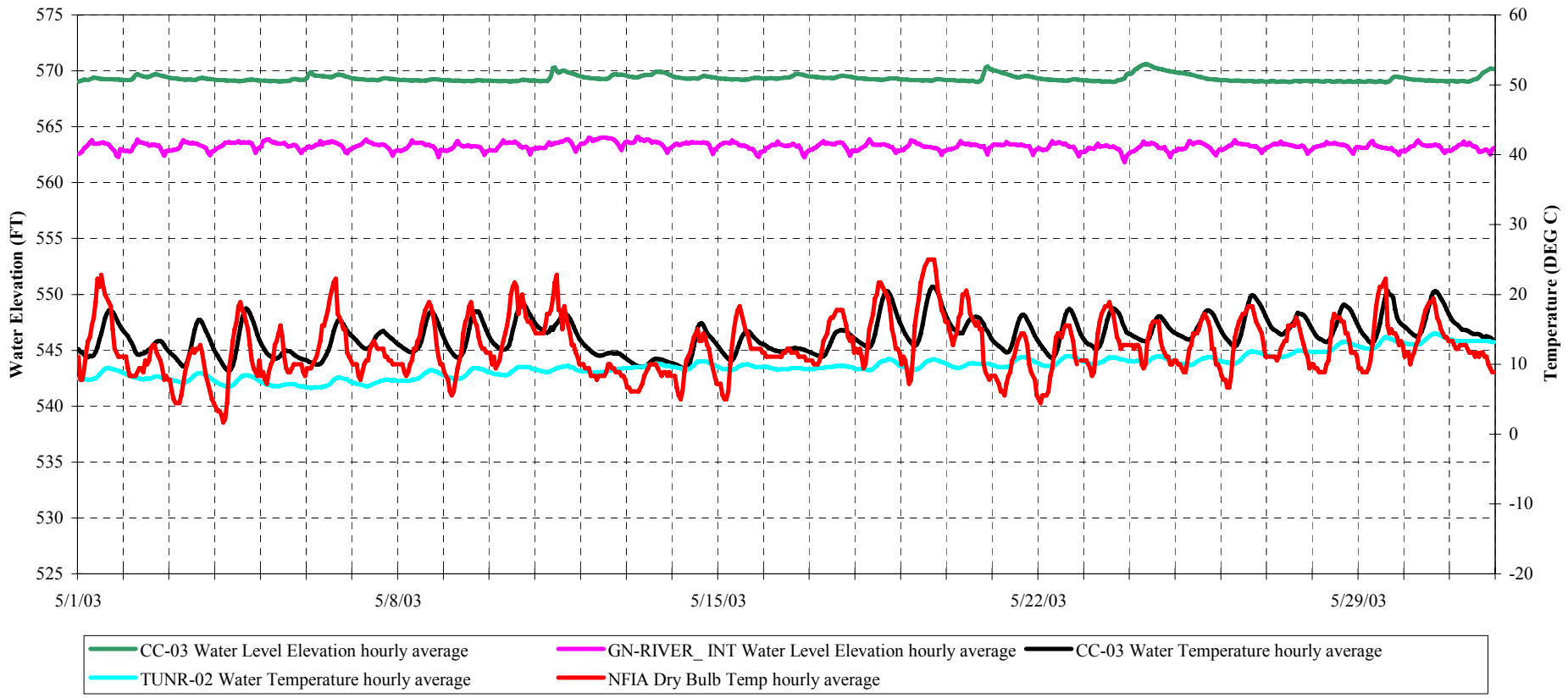

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FIGURE 3.2.1-2C

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN CAYUGA CREEK AT LOCATION CC-03, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE IN JUNE 2003

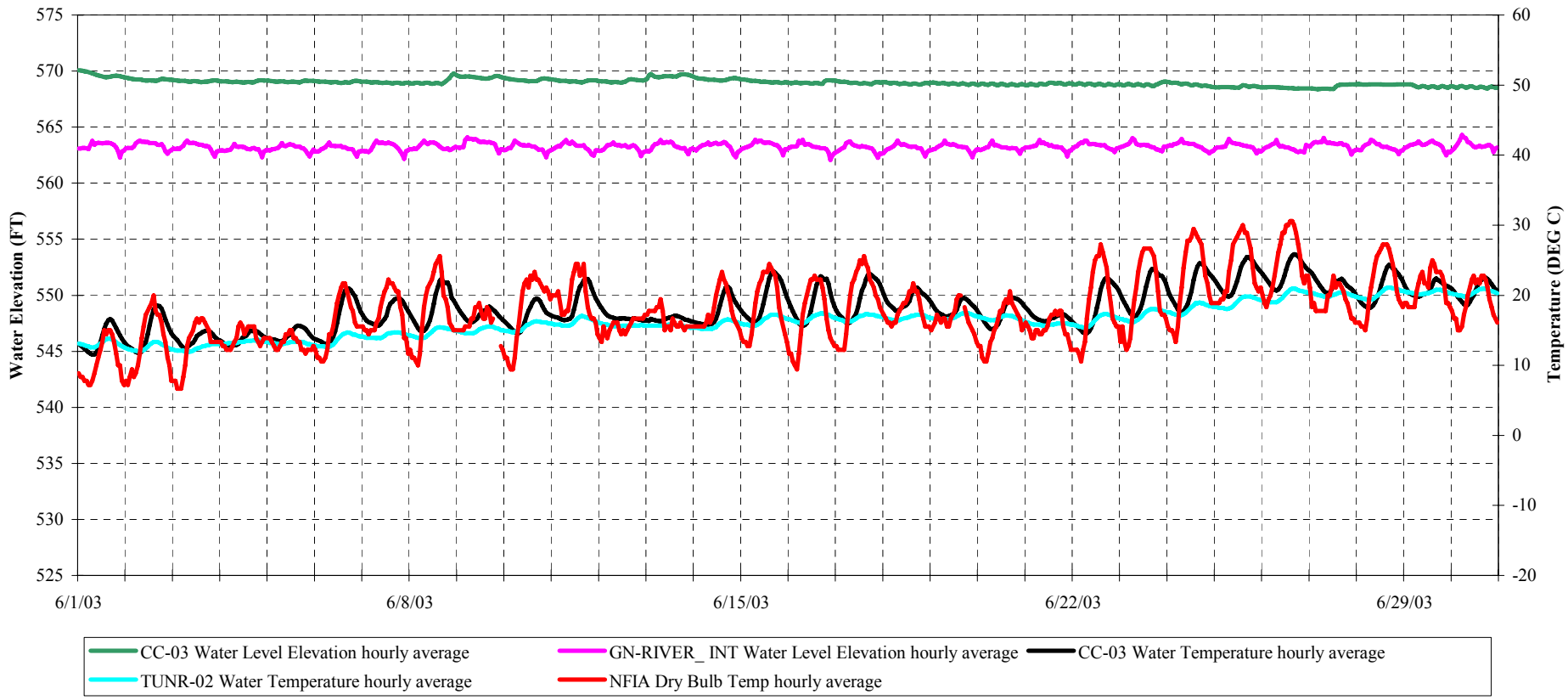

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FIGURE 3.2.1-3A

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN LOWER GUN CREEK AT LOCATION GC-01, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE IN APRIL 2003

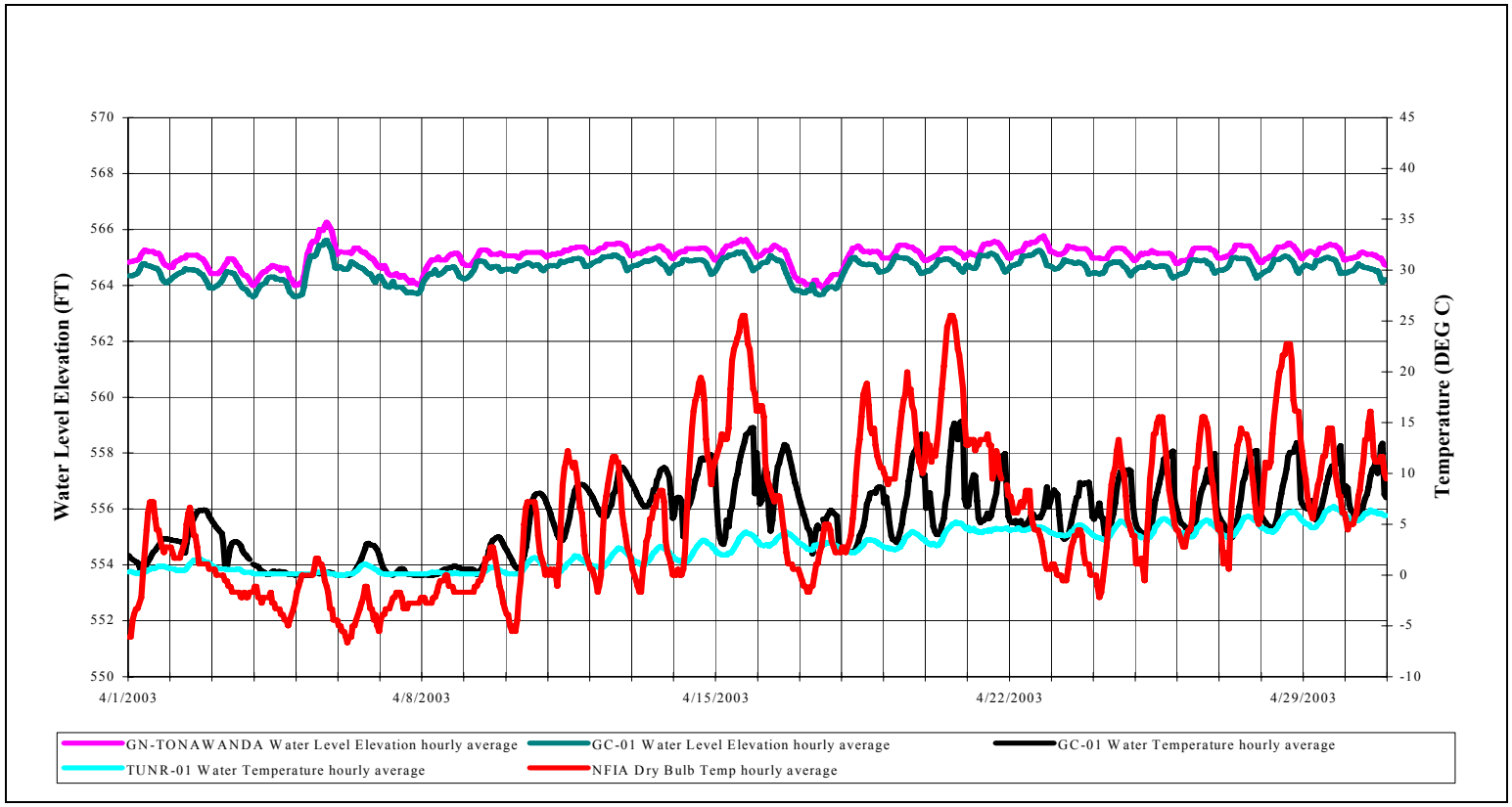

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FIGURE 3.2.1-3B

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN LOWER GUN CREEK AT LOCATION GC-01, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE IN MAY 2003

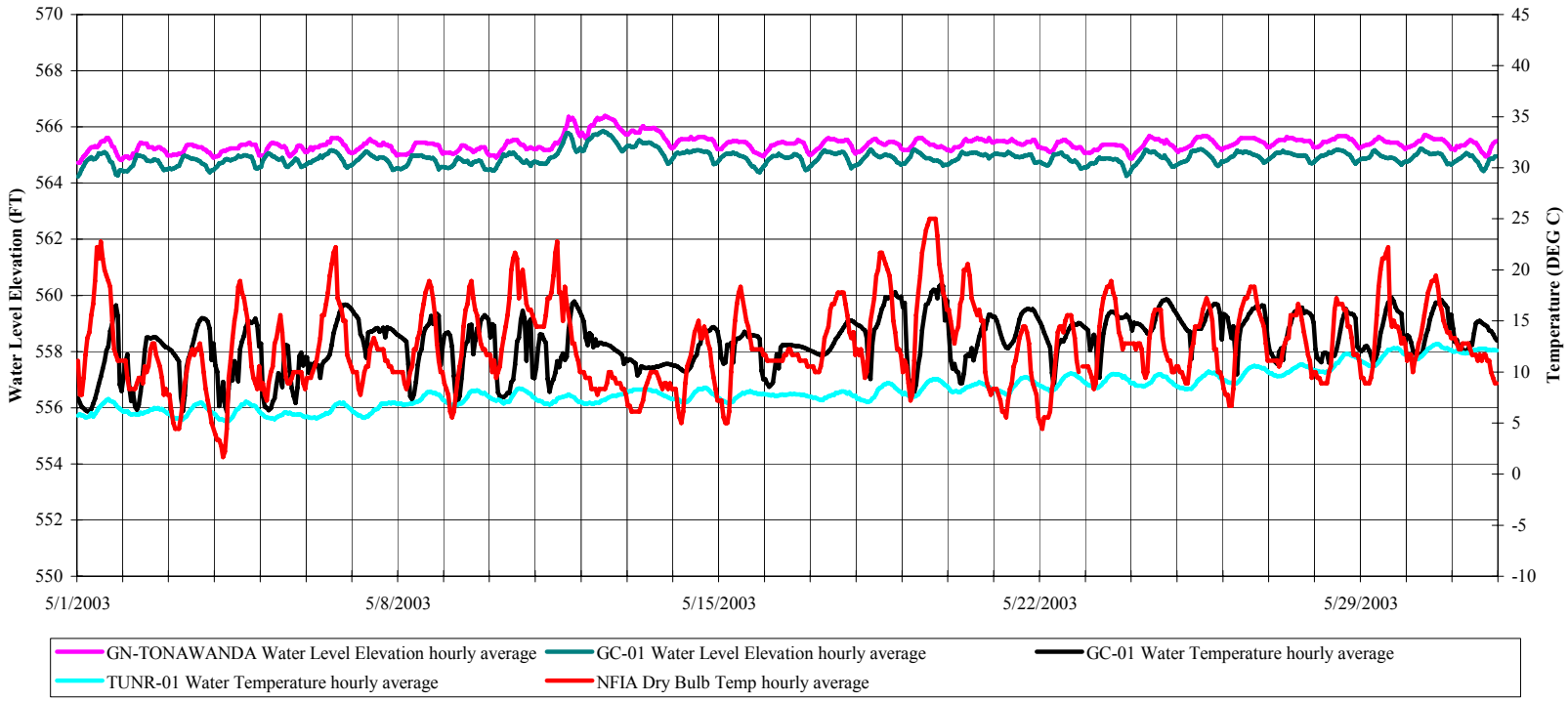

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FIGURE 3.2.1-3C

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN LOWER GUN CREEK AT LOCATION GC-01, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE IN JUNE 2003

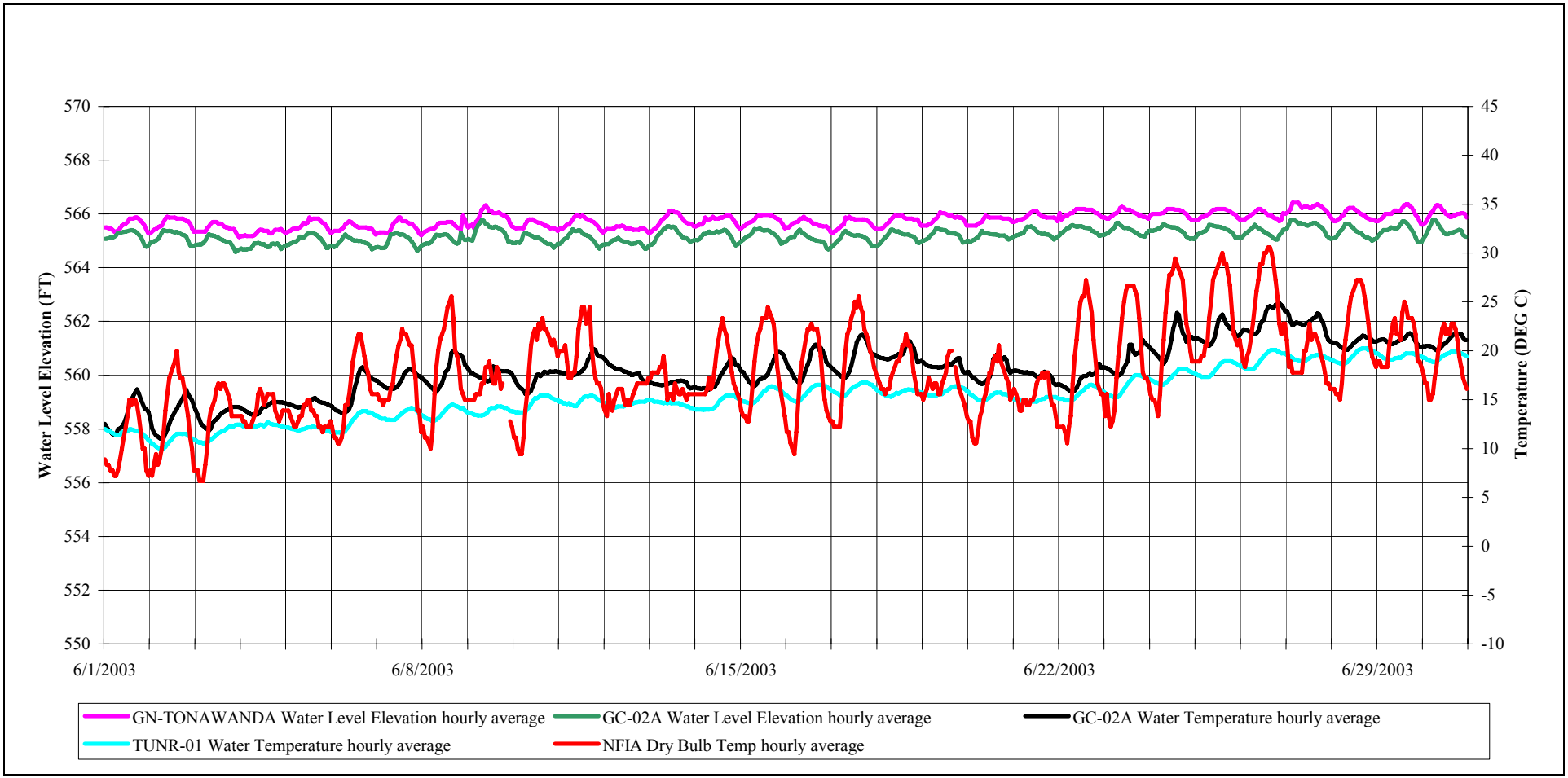

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FIGURE 3.2.1-3D

HOURLY AVERAGE WATER TEMPERATURES AND WATER ELEVATIONS IN LOWER GUN CREEK AT LOCATION GC-01, NIAGARA RIVER, AND HOURLY AVERAGE AIR TEMPERATURE, APRIL 15 TO 21, 2003

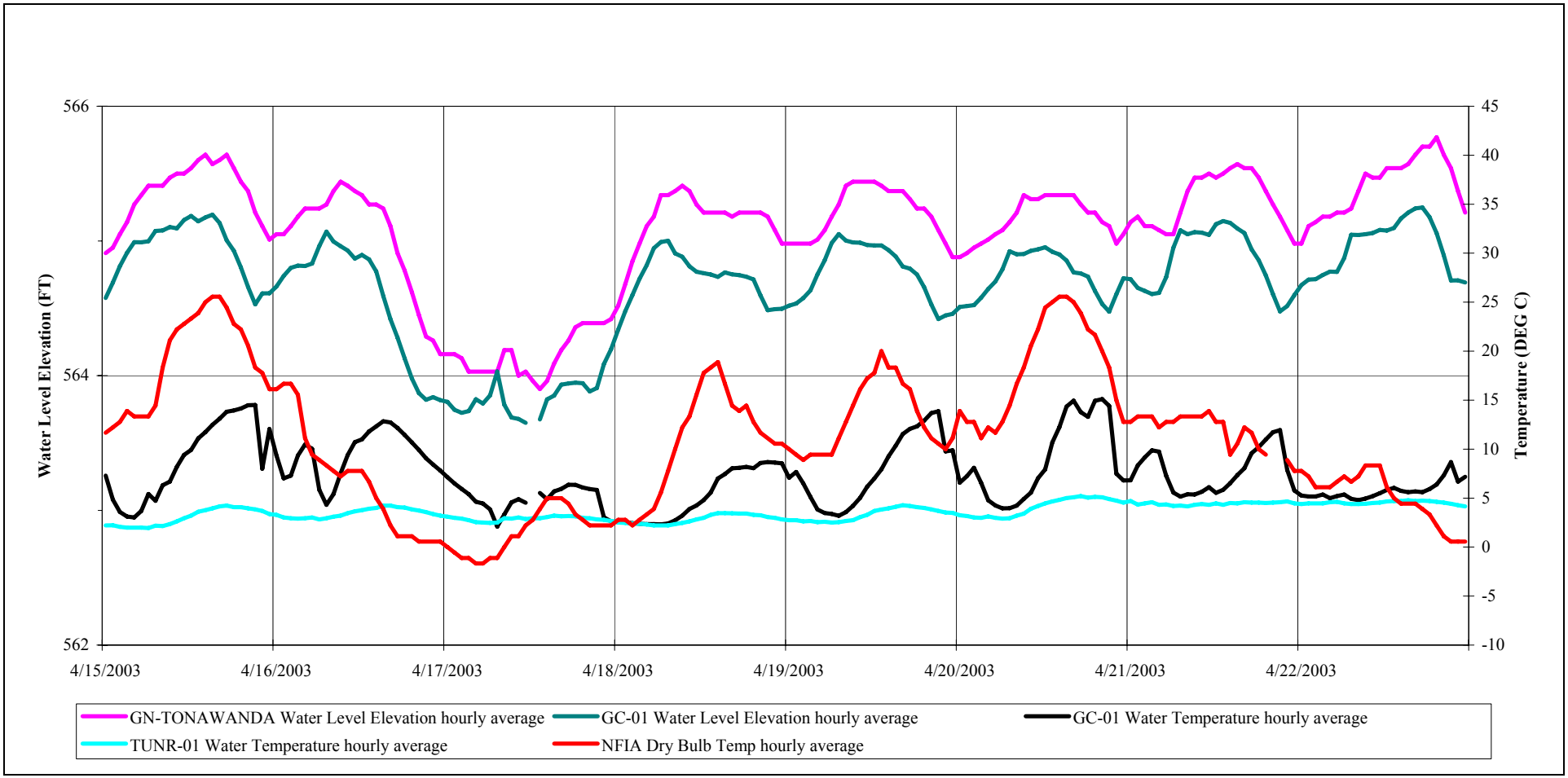

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FIGURE 3.2.1-4

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES AT GAUGE SMC-01 IN BIG SIXMILE CREEK, 2003

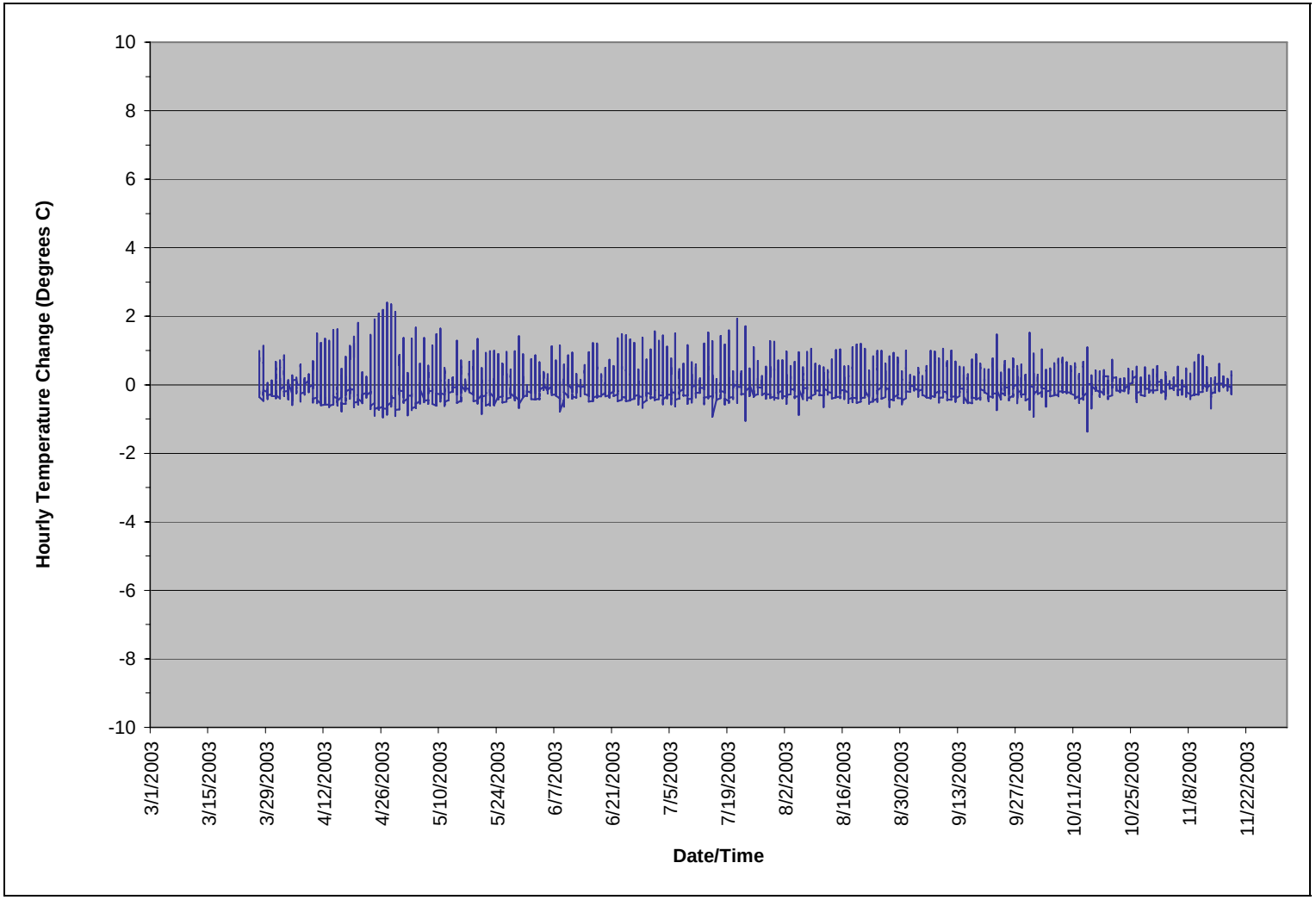

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FIGURE 3.2.1-5

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES AT GAUGE CC-03 IN CAYUGA CREEK, 2003

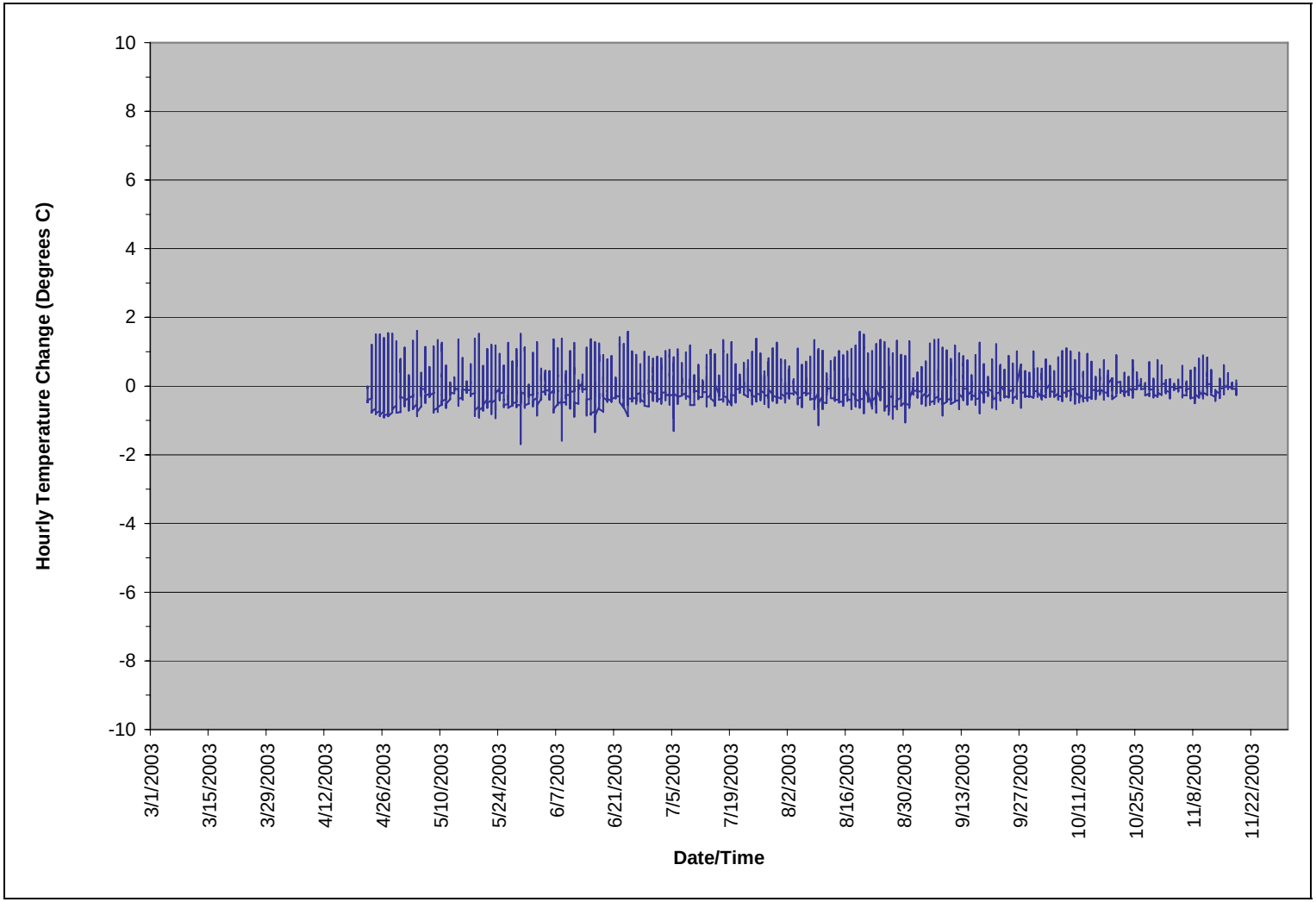

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FIGURE 3.2.1-6

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES AT GAUGE SMC-02 IN BIG SIXMILE CREEK, 2003

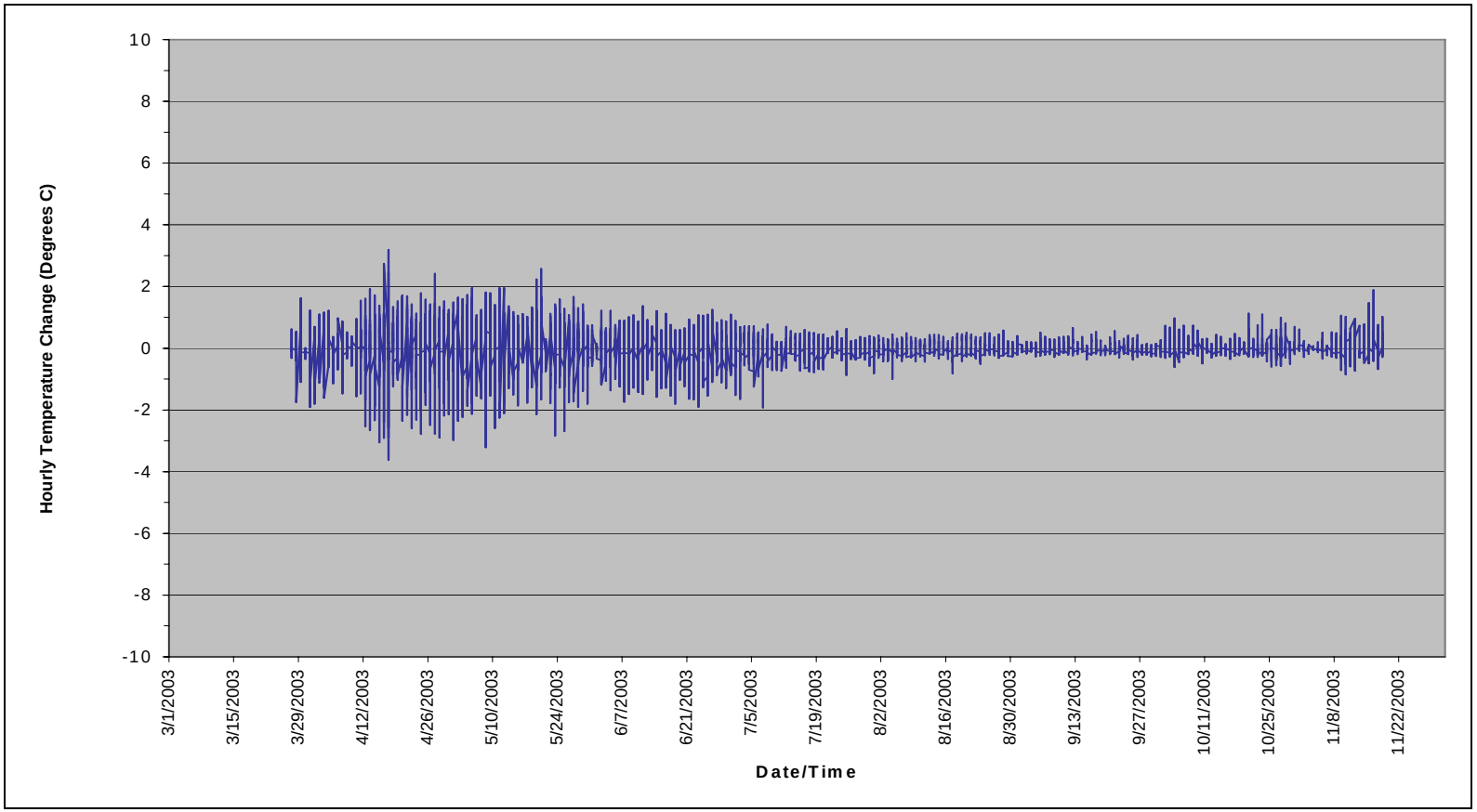

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FIGURE 3.2.1-7

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES AT GAUGE CC-01 IN CAYUGA CREEK, 2003

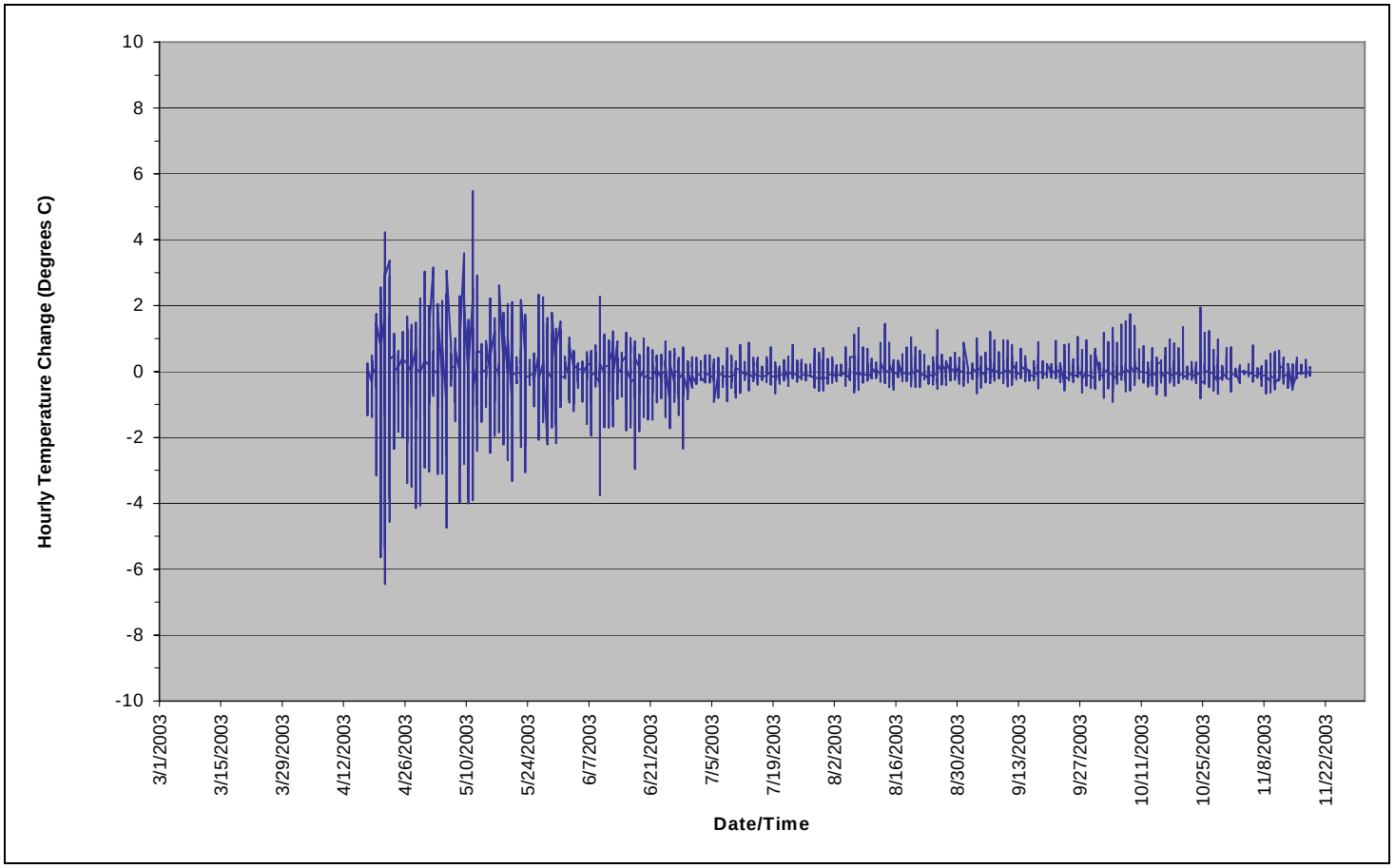

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FIGURE 3.2.1-8A

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE SMC-01 IN BIG SIXMILE CREEK, APRIL 1 TO JUNE 30, 2003

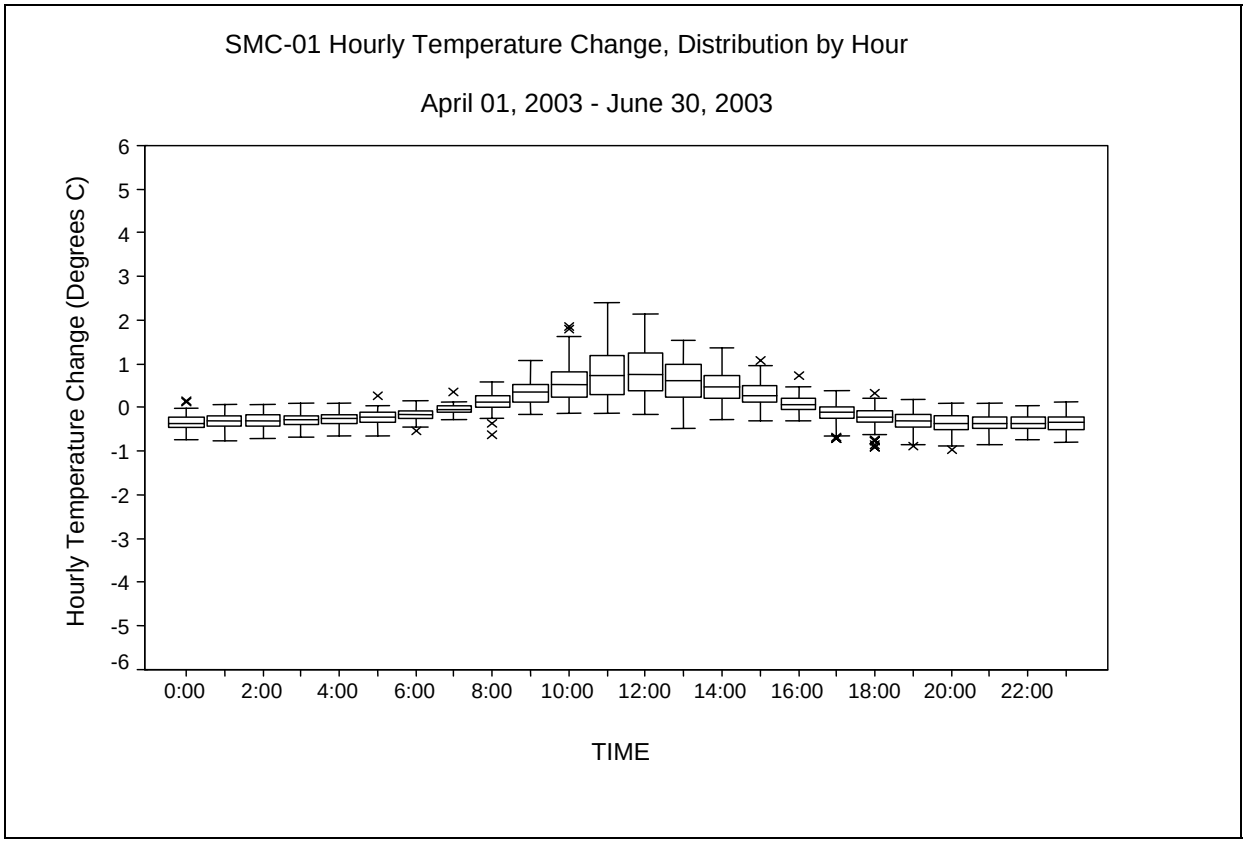

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FIGURE 3.2.1-8B

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE SMC-01 IN BIG SIXMILE CREEK, JULY 1 TO AUGUST 31, 2003

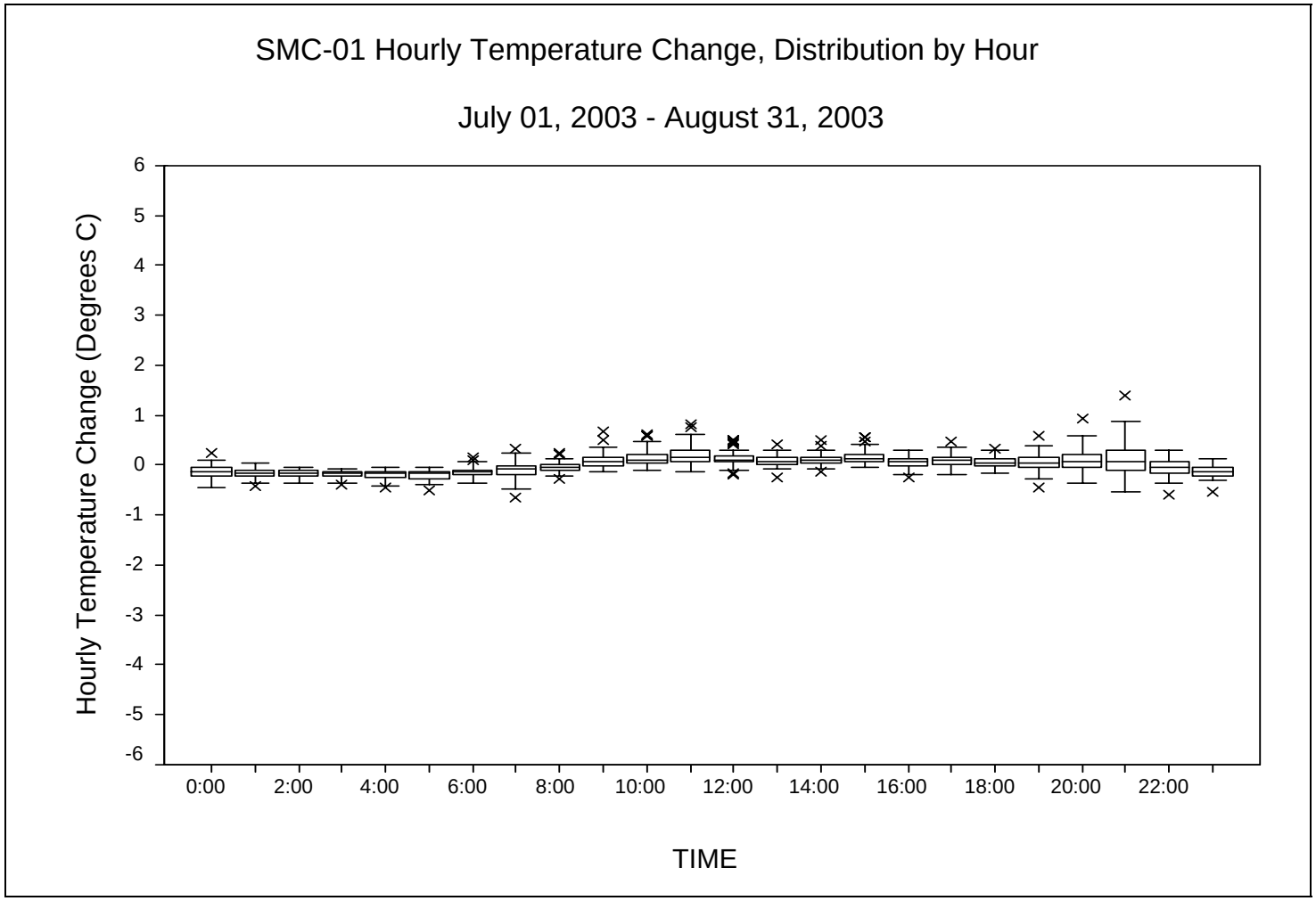

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FIGURE 3.2.1-8C

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE SMC-01 IN BIG SIXMILE CREEK, SEPTEMBER 1 TO OCTOBER 31, 2003

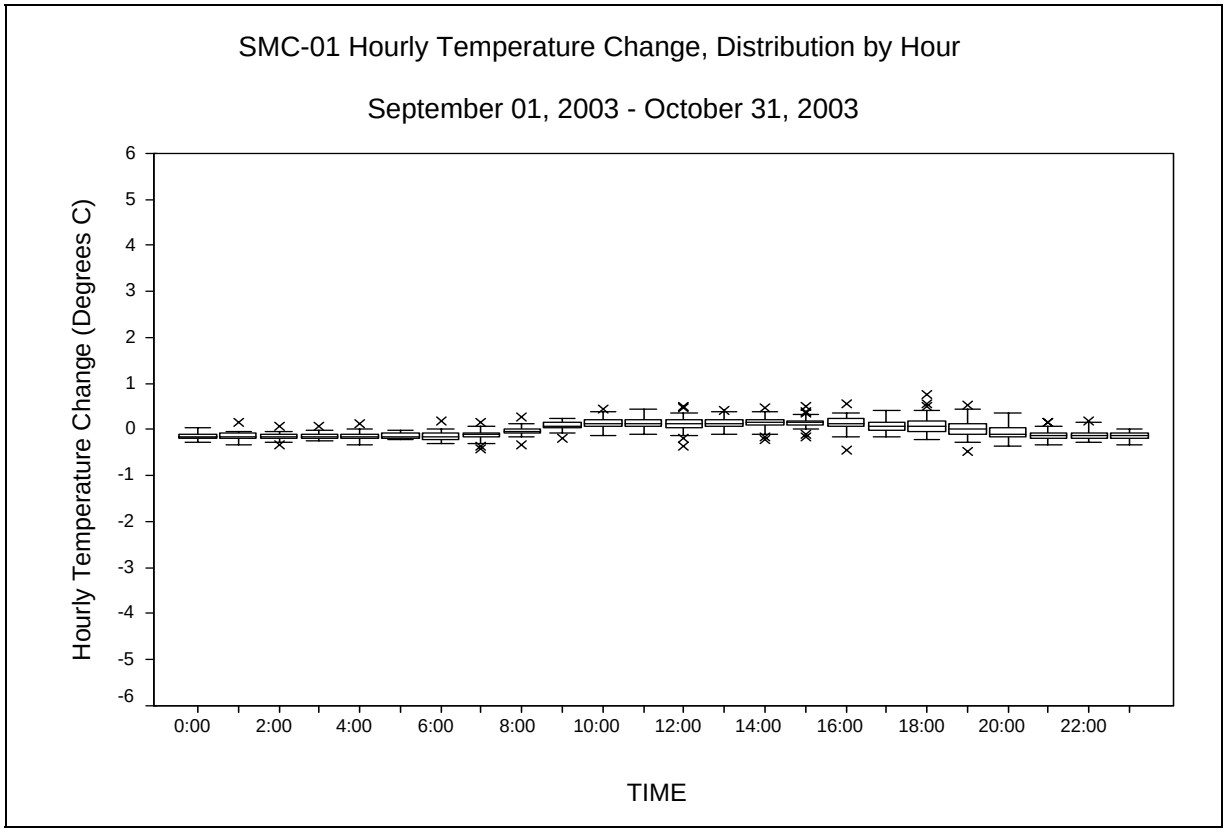

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FIGURE 3.2.1-9A

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE CC-03 IN CAYUGA CREEK, APRIL 1 TO JUNE 30, 2003

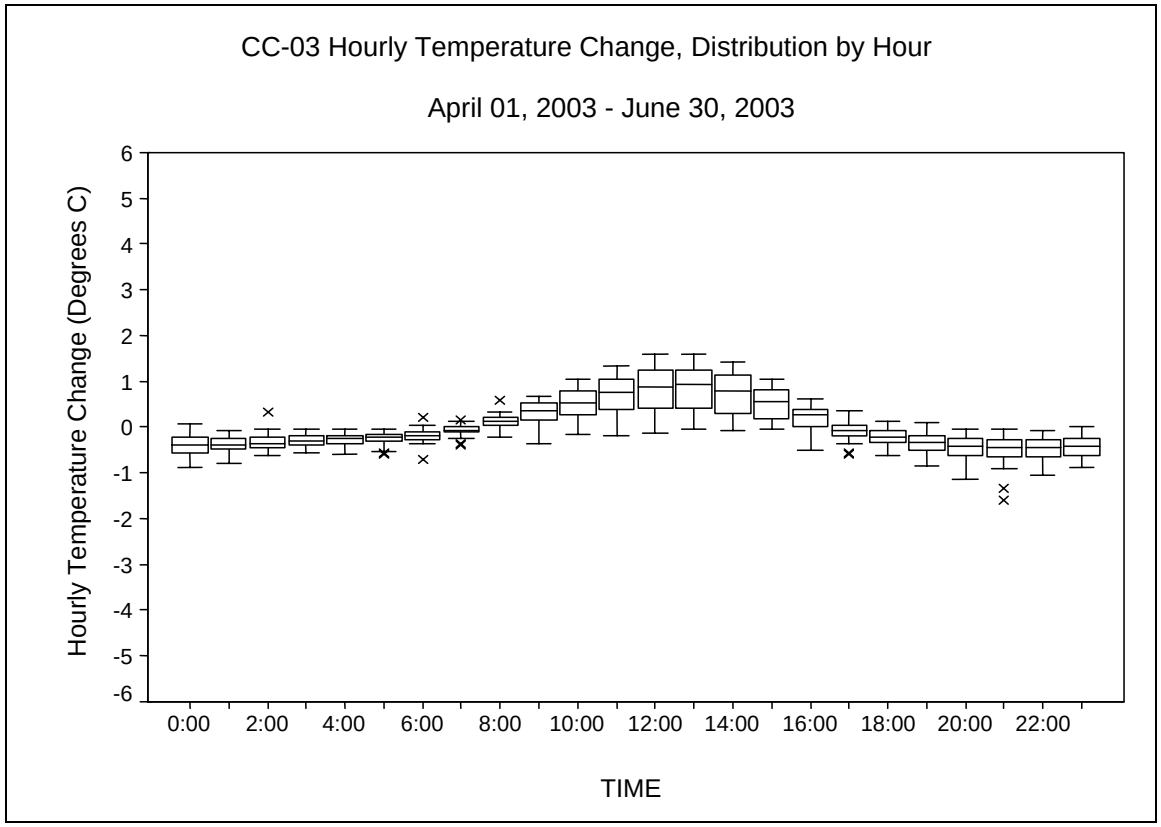

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FIGURE 3.2.1-9B

FREQUENCY DISTRIBUTION BOXPOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE CC-03 IN CAYUGA CREEK, JULY 1 TO AUGUST 31, 2003

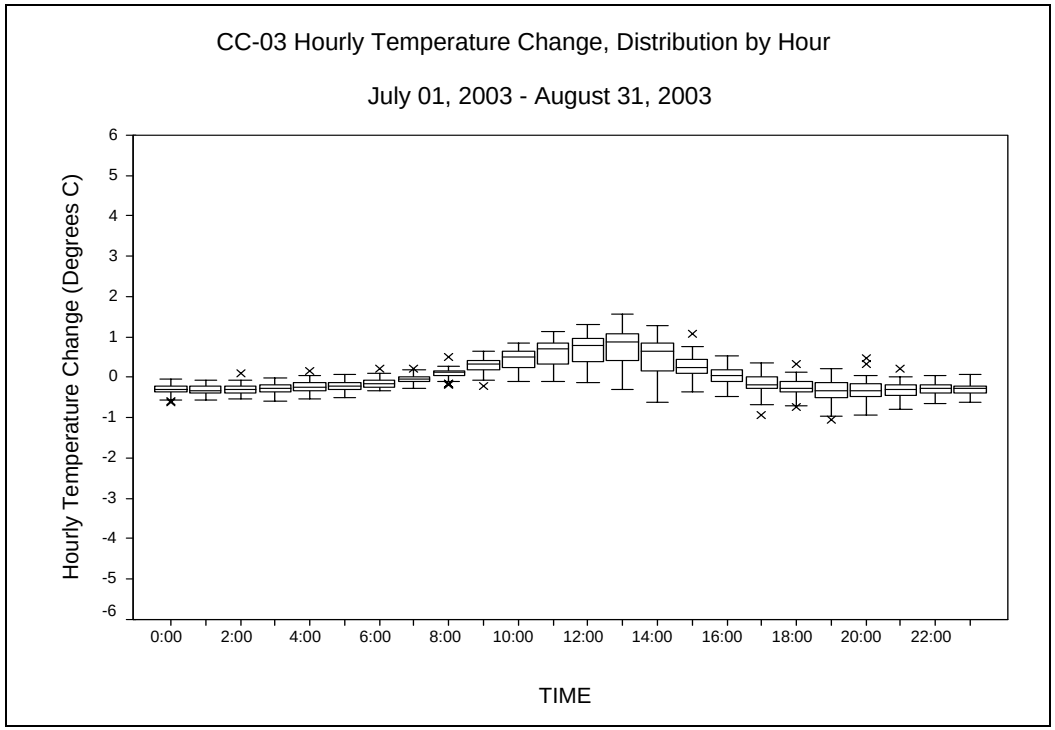

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FIGURE 3.2.1-9C

FREQUENCY DISTRIBUTION BOXPOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE CC-03 IN CAYUGA CREEK, SEPTEMBER 1 TO OCTOBER 31, 2003

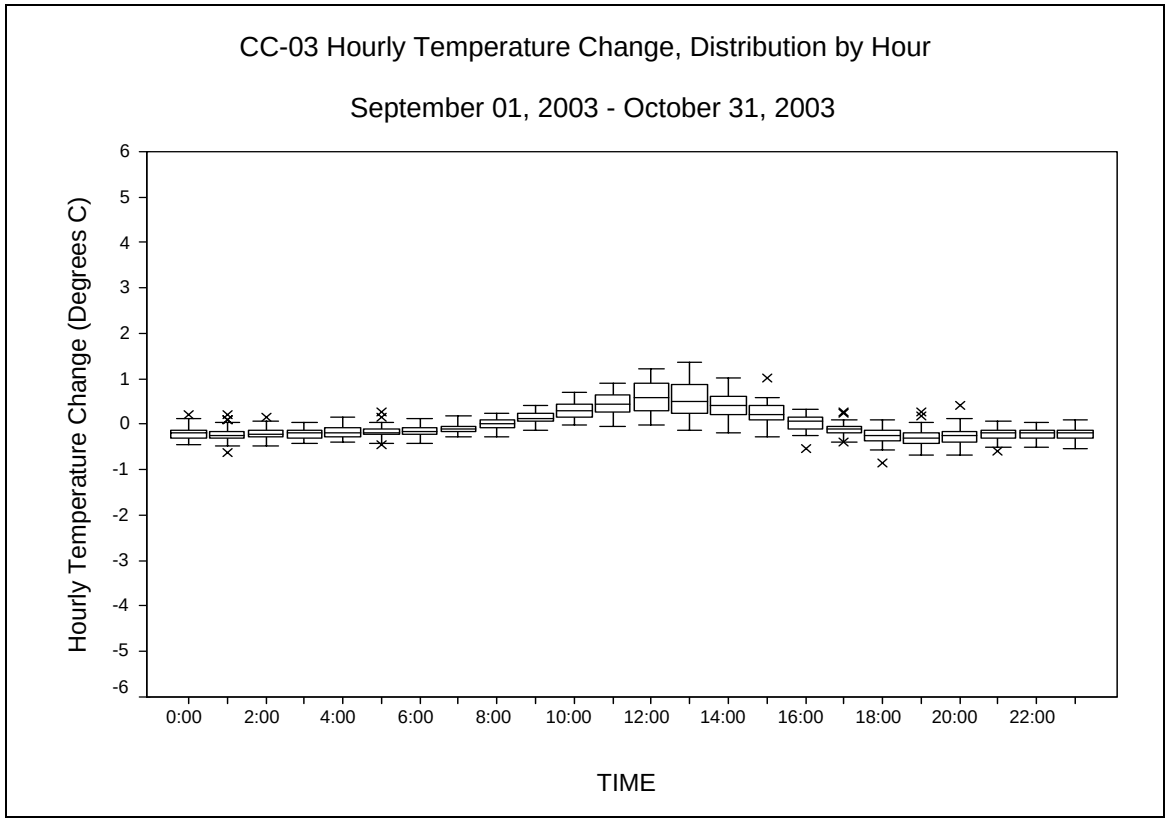

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FIGURE 3.2.1-10A

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE SMC-02 IN BIG SIXMILE CREEK, APRIL 1 TO JUNE 30, 2003

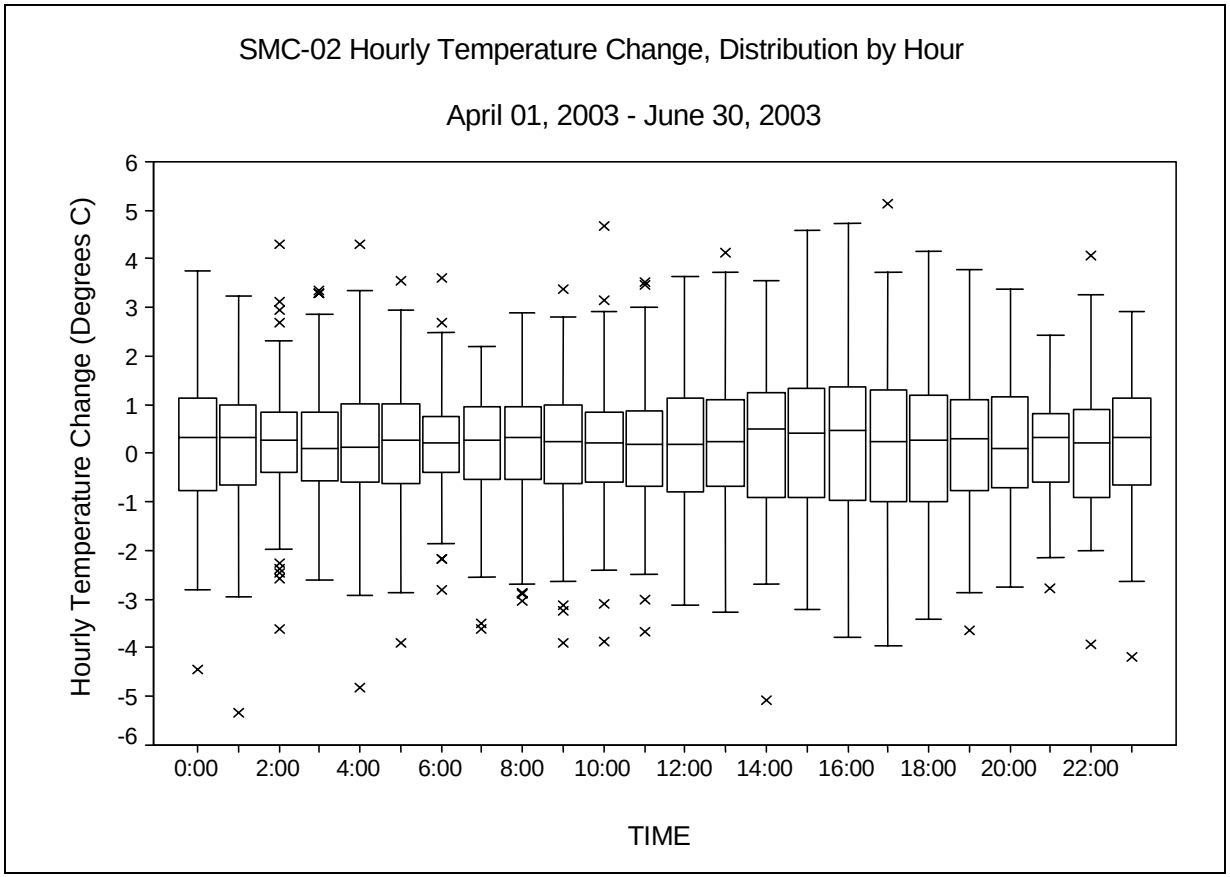

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FIGURE 3.2.1-10B

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE SMC-02 IN BIG SIXMILE CREEK, JULY 1 TO AUGUST 31, 2003

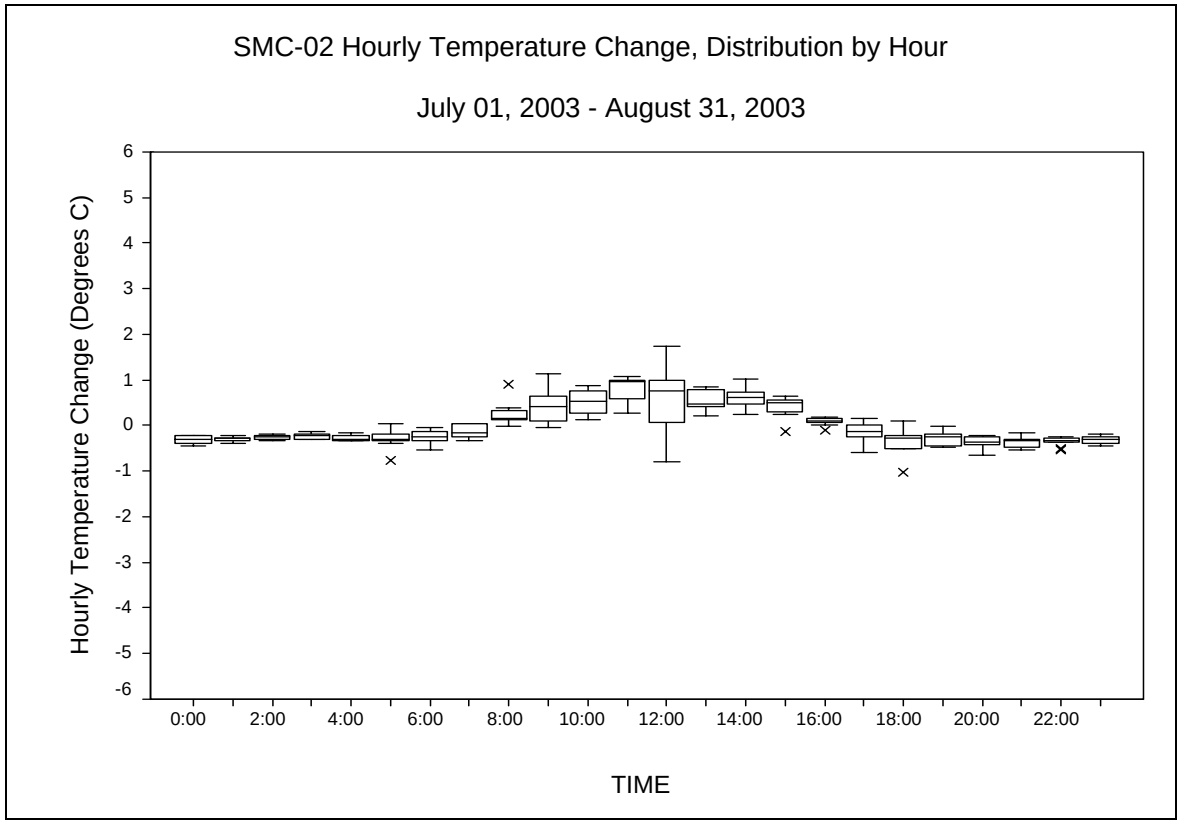

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FIGURE 3.2.1-10C

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE SMC-02 IN BIG SIXMILE CREEK, SEPTEMBER 1 TO OCTOBER 31, 2003

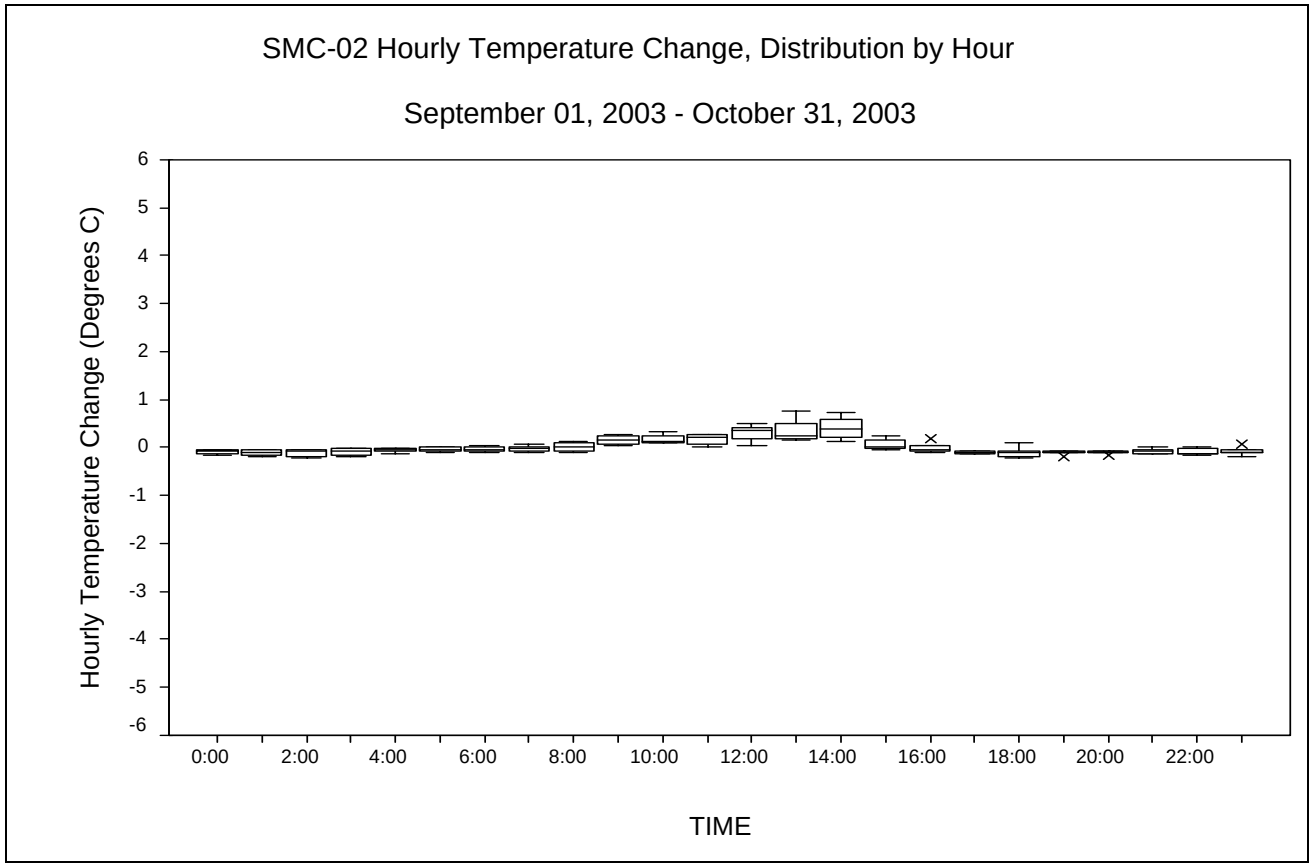

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FIGURE 3.2.1-11A

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE CC-01 IN CAYUGA CREEK, APRIL 1 TO JUNE 30, 2003

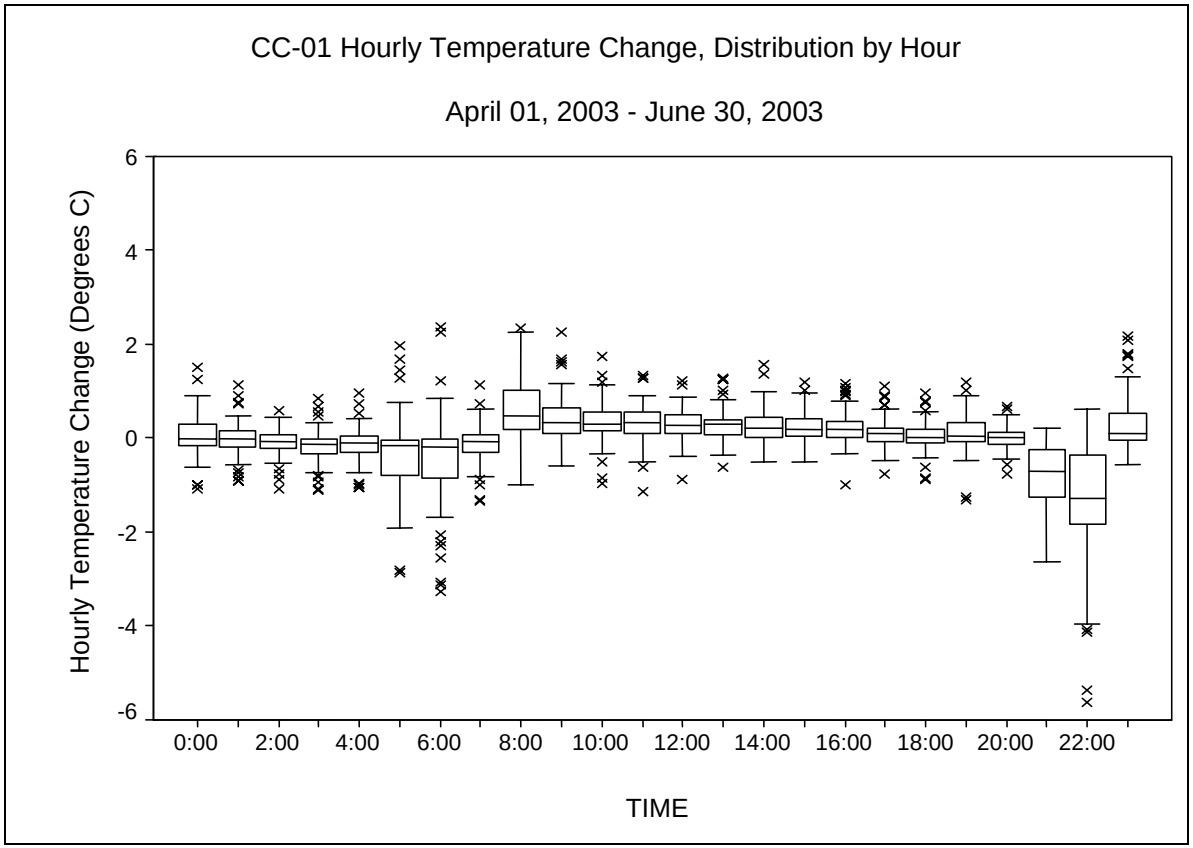

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FIGURE 3.2.1-11B

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE CC-01 IN CAYUGA CREEK, JULY 1 TO AUGUST 31, 2003

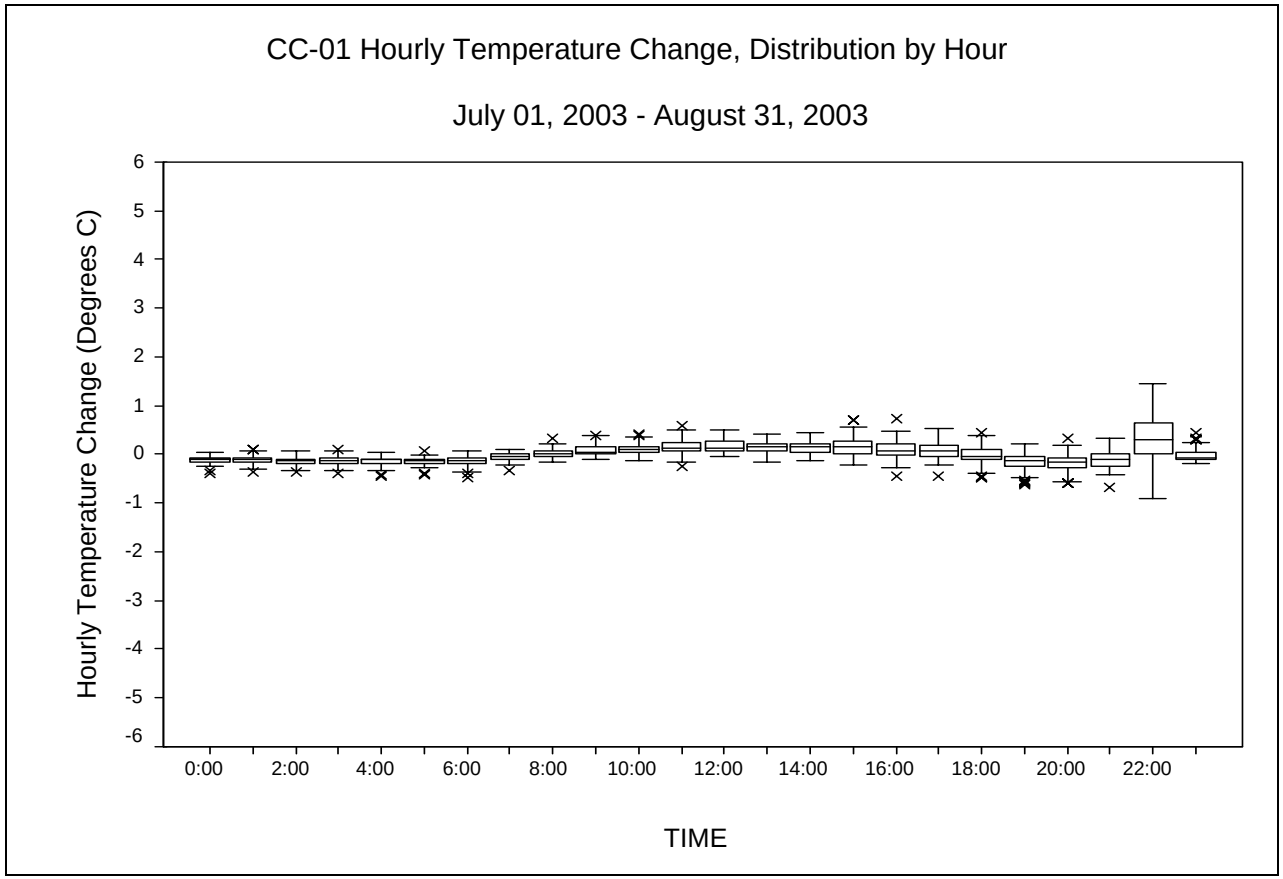

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FIGURE 3.2.1-11C

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY $\Delta°C_{WT}$ VALUES AT GAUGE CC-01 IN CAYUGA CREEK, SEPTEMBER 1 TO OCTOBER 31, 2003

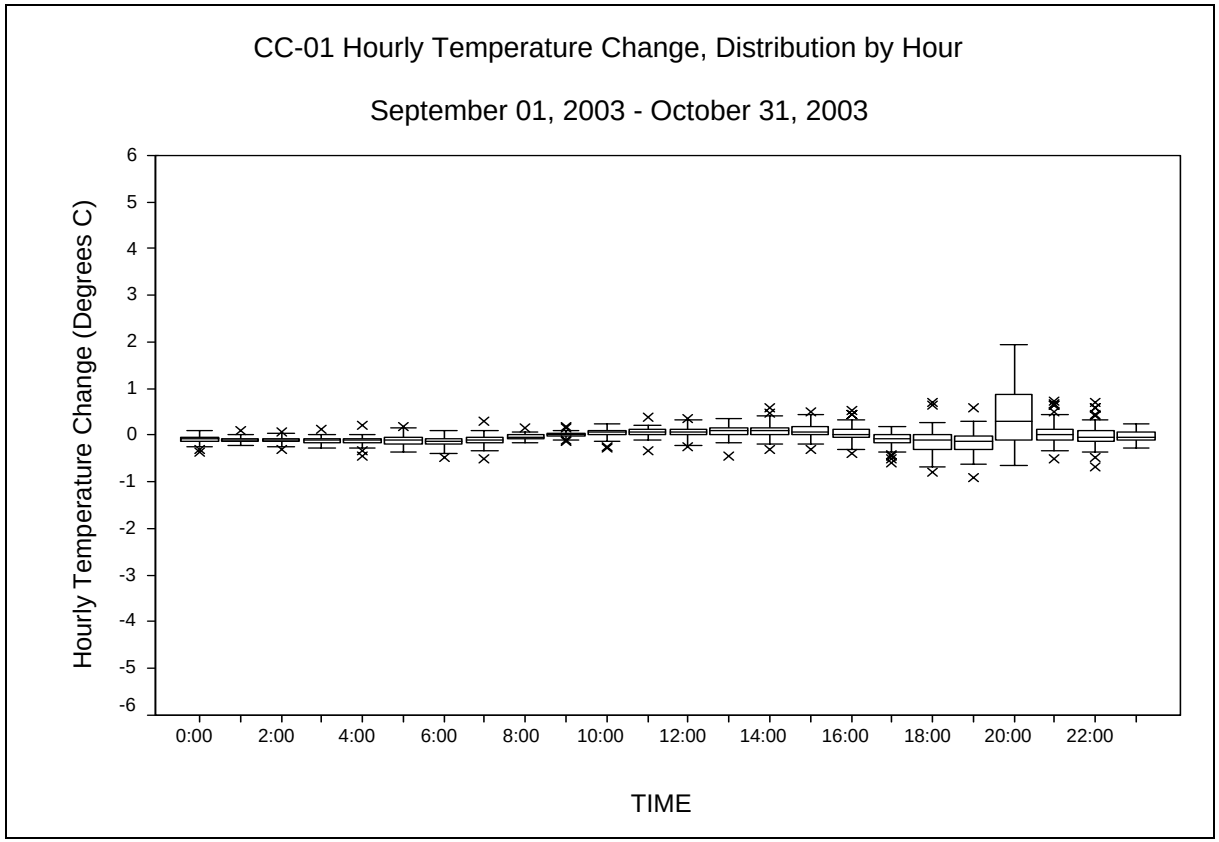

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FIGURE 3.2.1-12A

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY ΔWL VALUES AT GAUGE GN-RIVER_INT IN THE UPPER NIAGARA RIVER, APRIL 1 TO JUNE 30, 2003

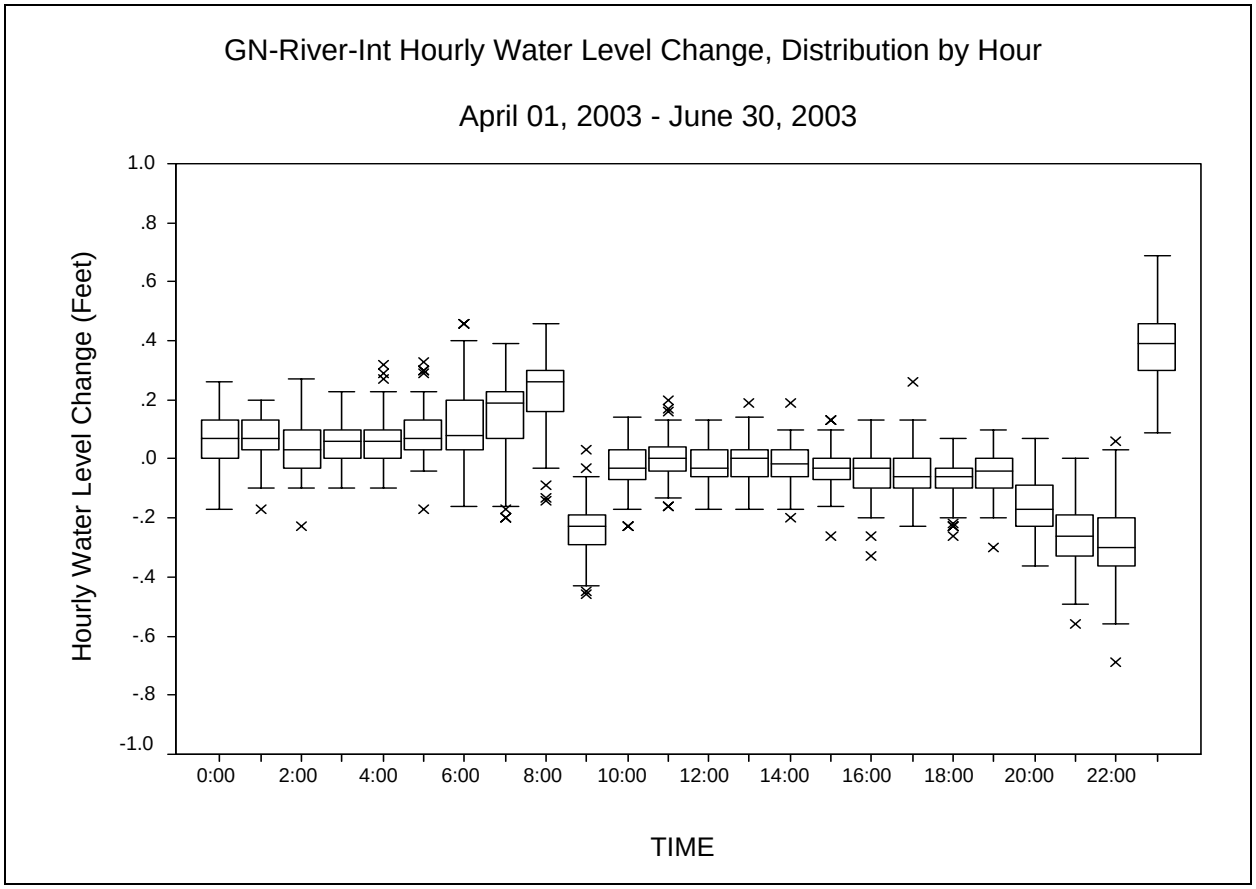

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FIGURE 3.2.1-12B

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY ΔWL VALUES AT GAUGE GN-RIVER_INT IN THE UPPER NIAGARA RIVER, JULY 1 TO AUGUST 31, 2003

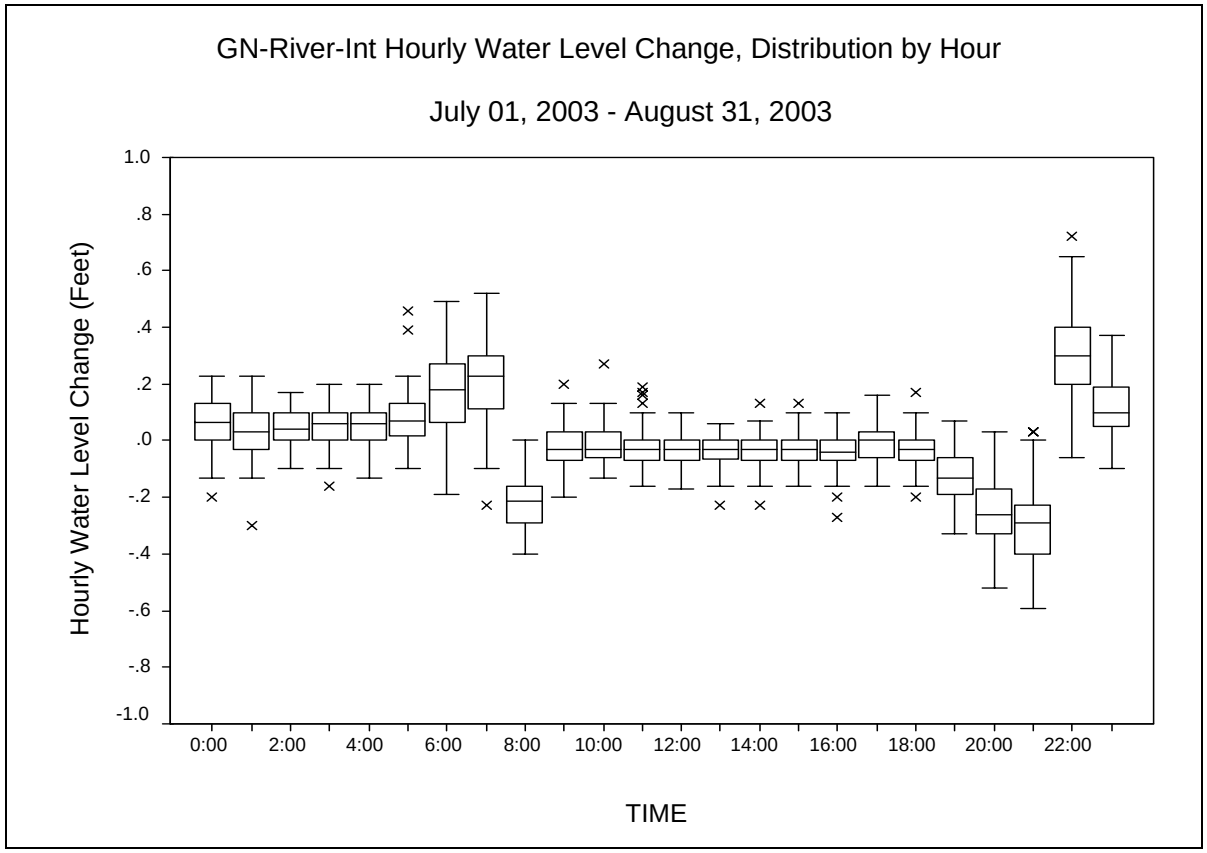

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FIGURE 3.2.1-12C

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY ΔWL VALUES AT GAUGE GN-RIVER_INT IN THE UPPER NIAGARA RIVER, SEPTEMBER 1 TO OCTOBER 31, 2003

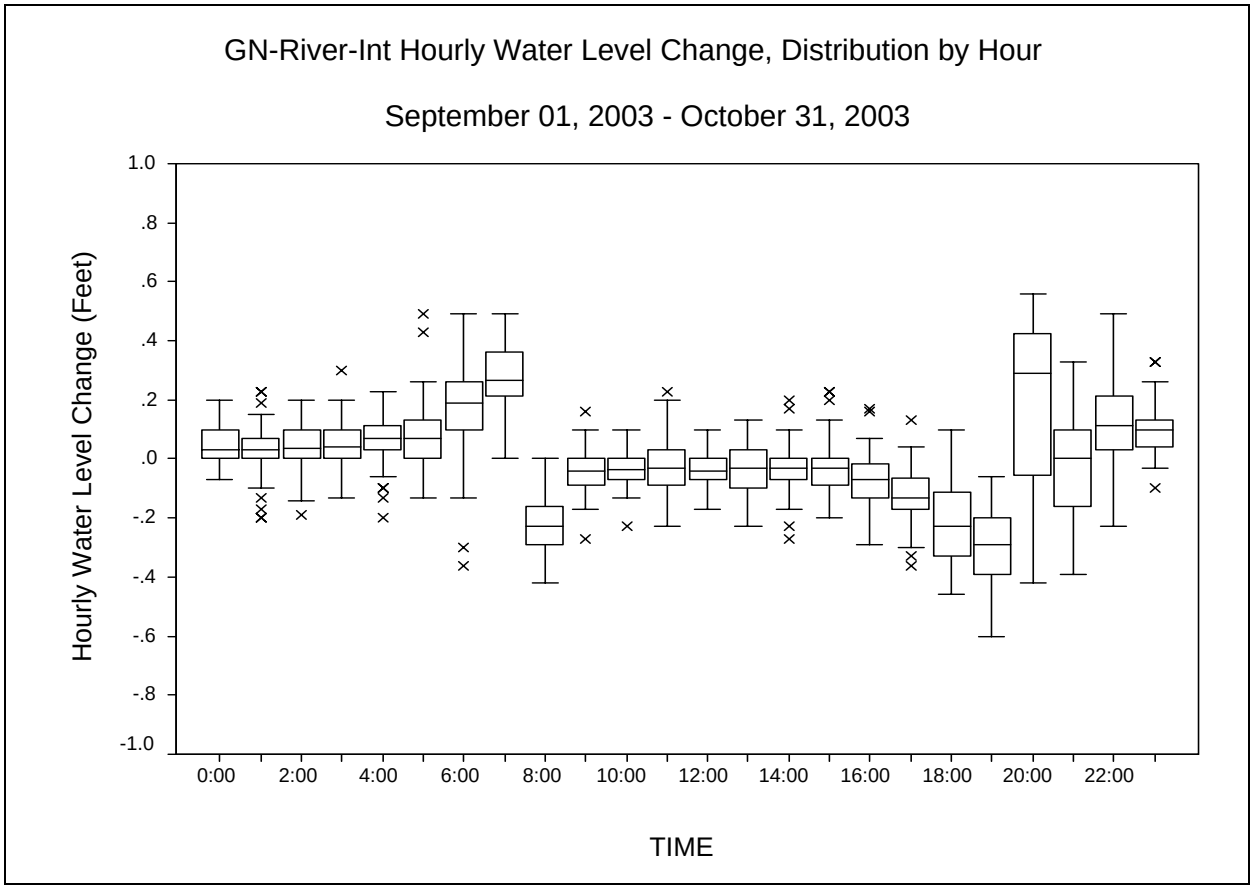

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FIGURE 3.2.1-13A

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY ΔWL VALUES AT GAUGE GN-TONAWANDA IN THE UPPER NIAGARA RIVER, APRIL 1 TO JUNE 30, 2003

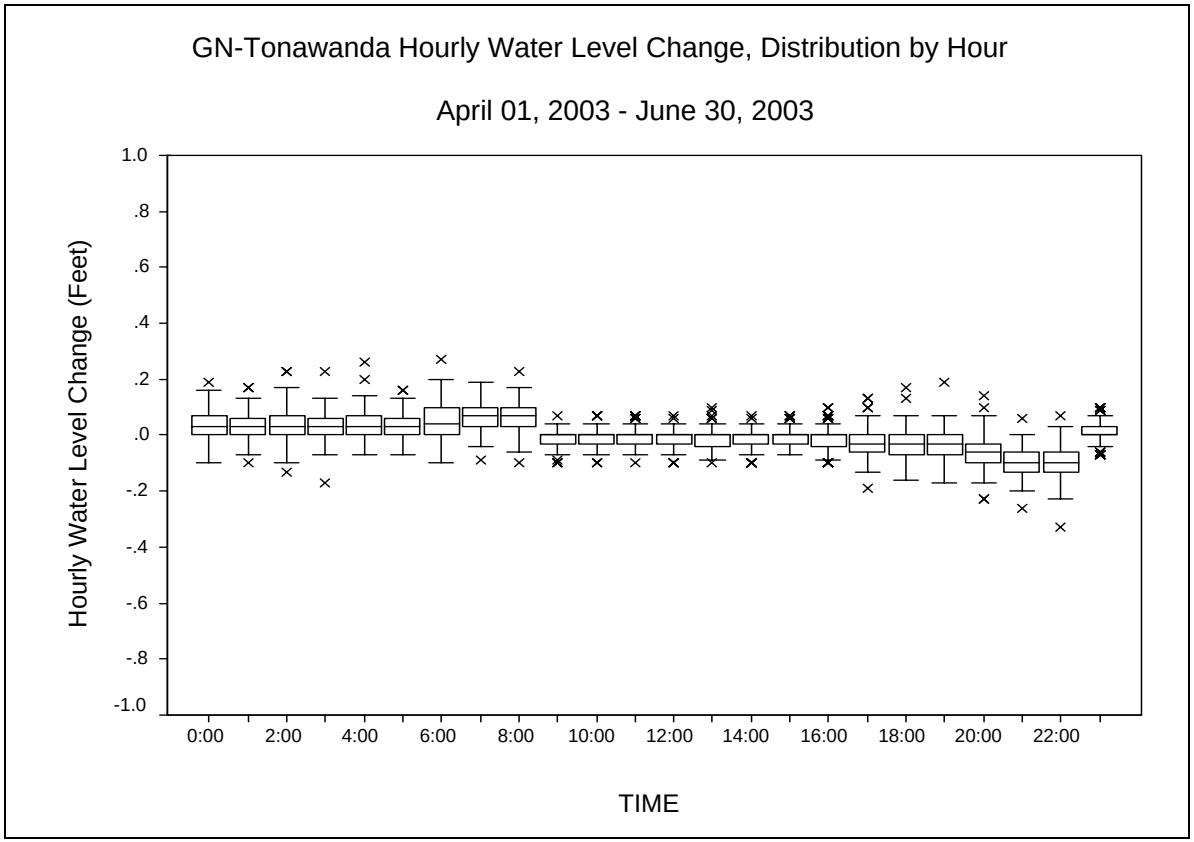

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FIGURE 3.2.1-13B

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY ΔWL VALUES AT GAUGE GN-TONAWANDA IN THE UPPER NIAGARA RIVER, JULY 1 TO AUGUST 31, 2003

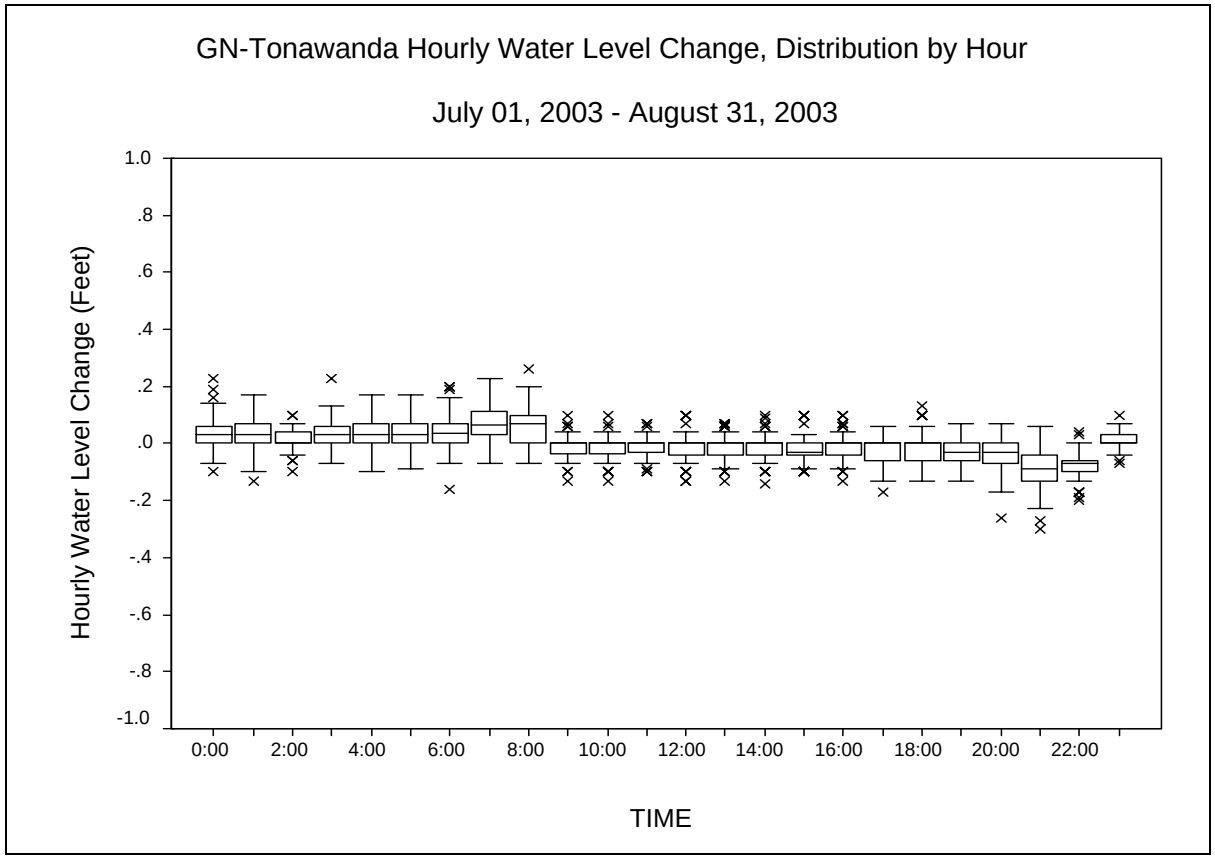

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FIGURE 3.2.1-13C

FREQUENCY DISTRIBUTION BOXPLOTS OF HOURLY ΔWL VALUES AT GAUGE GN-TONAWANDA IN THE UPPER NIAGARA RIVER, SEPTEMBER 1 TO OCTOBER 31, 2003

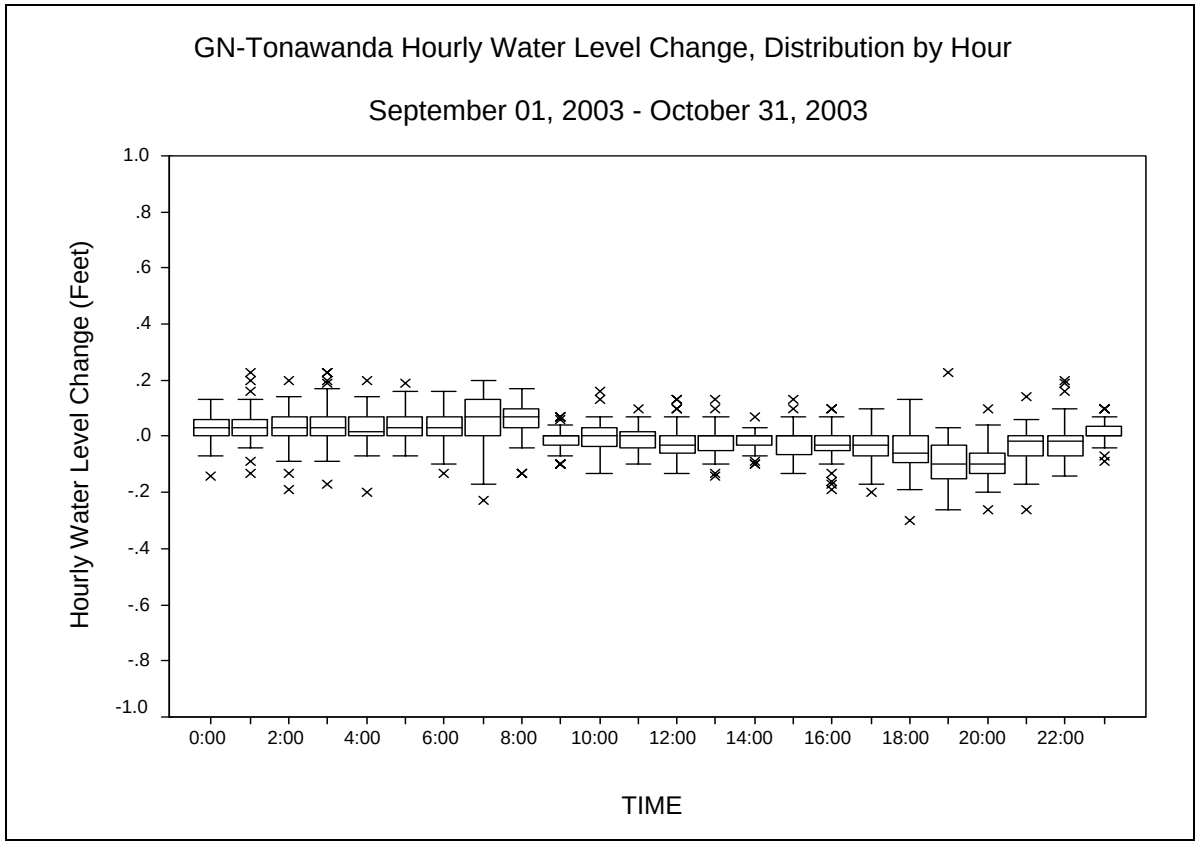

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FIGURE 3.2.1-14

GAUGE LOCATIONS IN ANALYSIS ZONE 1 WHERE TEMPERATURE EFFECTS ARE IDENTIFIED

[NIP – General Location Maps]

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FIGURE 3.2.2-1

SEASONAL WATER LEVELS AND WATER TEMPERATURES FOR ANALYSIS ZONE 2 GAUGES IN THE UPPER NIAGARA RIVER, 2003

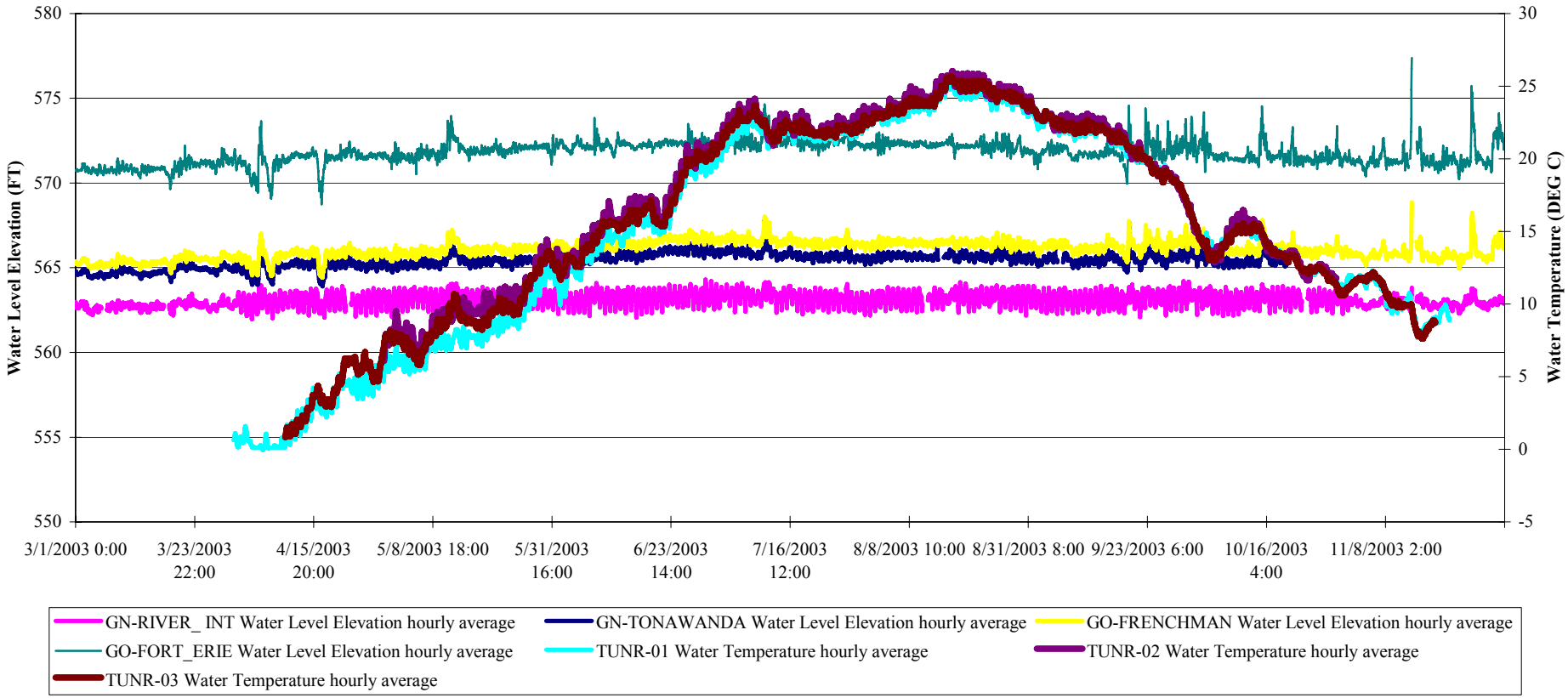

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FIGURE 3.2.2-2

HOURLY AVERAGE WATER TEMPERATURES AT ANALYSIS ZONE 2 REFERENCE LOCATION TUNR-03, MAY 2003

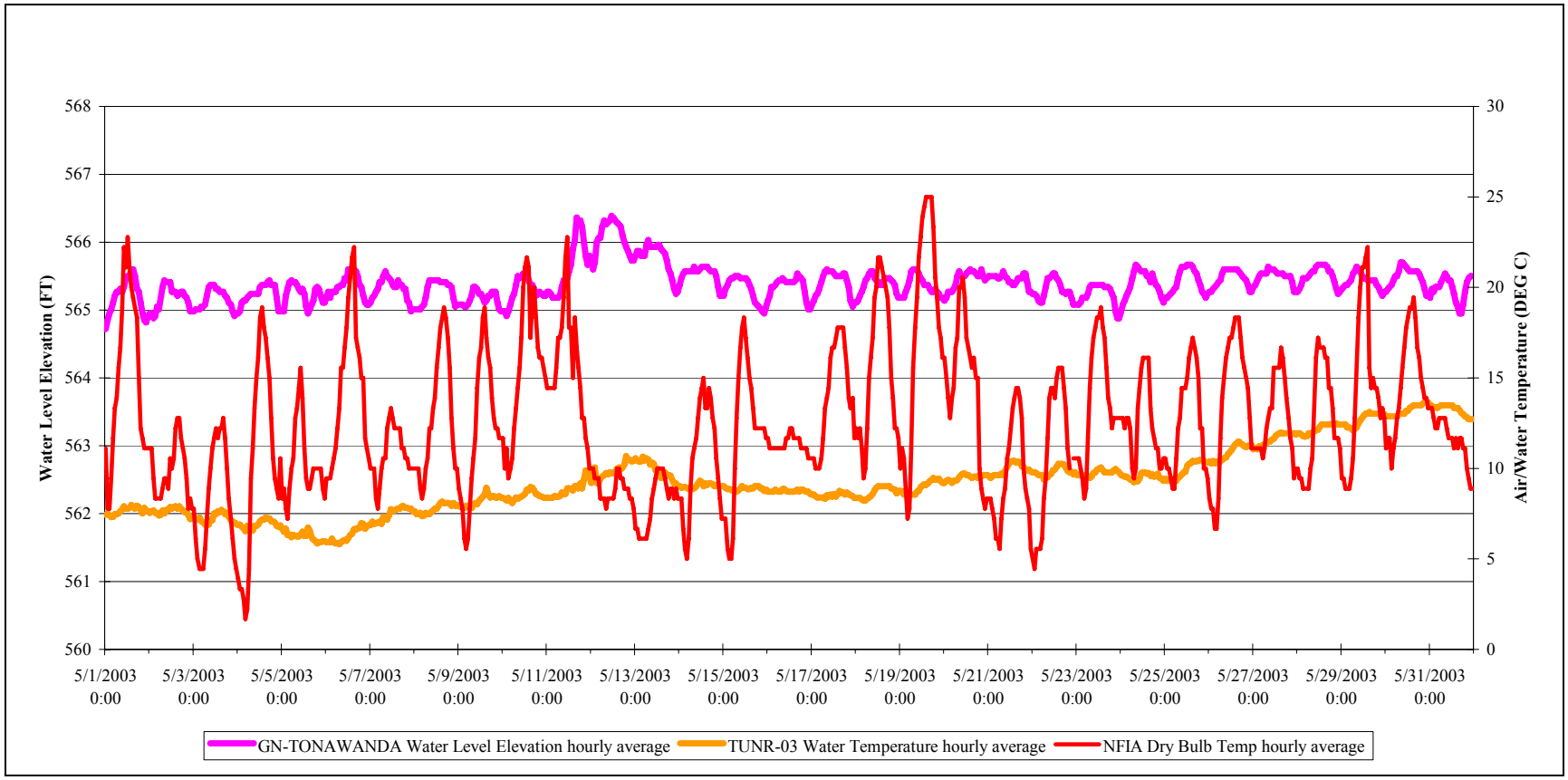

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FIGURE 3.2.2-3

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES AT GAUGE TUNR-03 IN THE UPPER NIAGARA RIVER, 2003

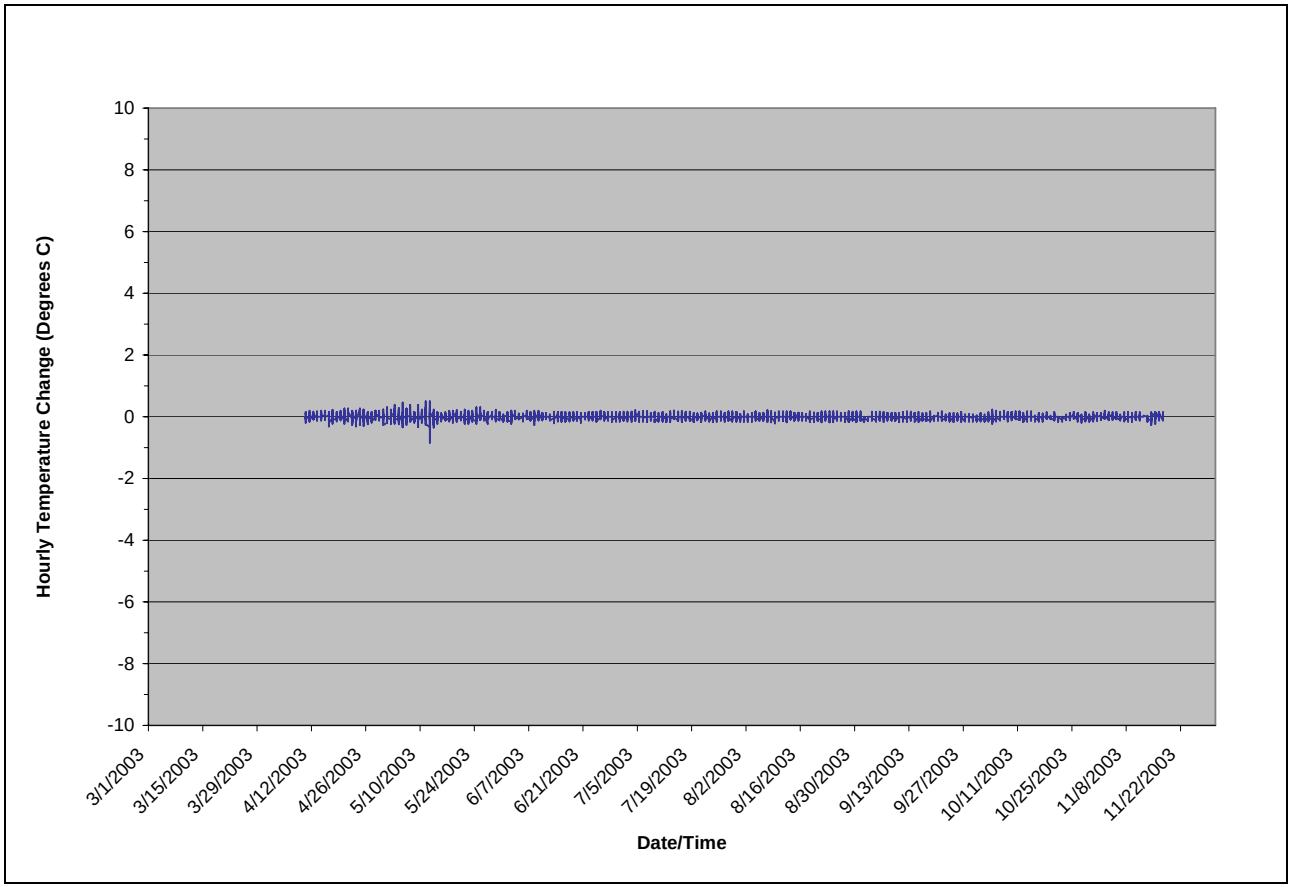

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FIGURE 3.2.3-1

GAUGE LOCATIONS IN ANALYSIS ZONE 3 WHERE TEMPERATURE EFFECTS ARE IDENTIFIED

[NIP – General Location Maps]

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4.0 DISCUSSION

Water temperature conditions in the Niagara River and its tributaries are influenced by a complex interaction of natural and man-made factors. Under natural conditions, water temperatures in the study area would have varied following seasonal and diurnal temperature patterns driven by meteorological conditions. In addition, occasional storm or wind events on Lake Erie cause rapid changes in Niagara River levels, which would in turn result in temperature fluctuations in some areas.

The influence of U.S./Canadian power generation on water levels (and thereby water temperatures) are superimposed on these natural patterns and interact in complex ways. U.S./Canadian power generation influences water level in the upper Niagara River and its U.S. tributaries. Between the falls and the RMNPP tailrace, treaty flow requirements are the sole manmade source of water level fluctuations. Below the tailrace, both hydropower operations and treaty flow requirements again influence water levels. In contrast, Lewiston Reservoir is an entirely artificial water body with conditions determined entirely by NPP project operations.

Seasonal and diurnal patterns of temperature variability in the Niagara River and its tributaries do not appear to be affected by U.S./Canadian power generation. The seasonal range in water temperatures throughout the study area ranges from approximately zero to 25°C between winter and summer, with maximum temperatures reaching slightly higher (28.5°C) in tributary streams. Tributaries are prone to freezing in winter months. Diurnal temperature fluctuations in the main channel of the Niagara River range from 2 to 3°C/day, but can be larger in shallow water areas. Diurnal fluctuations in tributaries are as large as 13°C/day, but are typically on the order of 6 to 8°C/day.

NPP operations indirectly affect seasonal and diurnal temperature ranges in two tributaries, Fish Creek and Gill Creek, however these effects are not due to water level fluctuations. In both creeks, groundwater discharge due to hydrostatic pressure caused by the Lewiston Reservoir results in increased stream flows and moderation of summer water temperatures in reaches adjacent to and downstream of the reservoir. Gill Creek also receives flow augmentation directly from the reservoir in summer months, which minimizes diurnal temperature fluctuations.

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Rapid changes in water temperatures occur at several locations in the study area that are caused by the mixing of water bodies at different temperatures. Such mixing events can be caused by heavy precipitation, and by water level fluctuations caused U.S./Canadian power generation and natural causes. Temperature changes caused by water level fluctuations attributable to U.S./Canadian power generation exceeding reference thresholds are considered temperature effects. Reference thresholds for Analysis Zone 1 are $\Delta°C_{WT}$ values of +2 °C/hour and –1 °C/hour. Thresholds in remaining analysis zones are +1 C/hour and –0.5 °C/hour.

Temperature effects were identified at 18 of 63 gauge locations in the investigation area in 2002 and 2003. The majority of these (16) were located at or near the mouths of tributaries in the upper Niagara River (Analysis Zone 1). Other affected locations included gauges in the Niagara River immediately downstream of tributary mouths (Analysis Zone 3). The majority of these effects were mild (< ±2.0°C/hour), but some, predominantly at tributary mouths, were more pronounced (-6.5 to + 5.2°C/hour). Larger temperature anomalies occurred at some locations, but at too low a frequency to be associated with water level fluctuations due to U.S./Canadian power generation and are not considered temperature effects. These rare extreme events occurred at a comparable frequency to large natural changes in Niagara River level, and are most likely due to water level fluctuations associated with these natural causes. These natural conditions must be considered when interpreting the magnitude and extent of identified temperature effects. Moreover, the natural ability of focus species to compensate for such temperature fluctuations must be considered when evaluating the potential for behavioral or survival effects.

Fish species native or introduced to the Niagara River and/or its tributaries have evolved and adapted to the natural range of seasonal and diurnal temperature fluctuations that occur in these habitats. Fish compensate for temperature variations using a variety of physiological and behavioral mechanisms. For example, a species may adapt physiologically to changes in temperature by altering metabolism to account for seasonal changes in energy requirements (Nielsen and Pigott 1995, McCullough 1999, Hokanson 1977). Over the long term, this may involve changing cellular protein and enzyme structure to function at different temperature ranges when introduced to new habitats with different temperature regimes (Nielsen and Pigott 1995). Fish also adapt behaviorally to changes in temperature, moving between habitats to seek out favorable conditions, and timing spawning to coincide with temperatures that

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are most favorable to egg incubation and juvenile rearing (McCullough 1999, Hokanson 1977, Schneider et al. 2002, Spotila et al. 1979). Stressed eggs may produce stressed fry that will not perform well after swim-up. In some species of fish, there is evidence that reduced fitness may appear at a later stage (Schneider et al. 2002).

Fish species occurring in the investigation area use a combination of these mechanisms to adapt to the broad range of diurnal and seasonal water temperatures that occur here. However, the effectiveness of these adaptive mechanisms is limited by the rate at which temperature changes occur (McCullough 1999, Hokanson 1977, Schneider et al. 2002). Specifically, rapid changes in temperature exceeding a given threshold may cause a species to attempt to move to more favorable conditions (i.e., an avoidance response). If temperature effects are large enough, they may exceed thresholds for heat shock or cold shock leading to death or significant injury, or cause stress likely to lead to death. For example, while a fish stunned but not killed by cold shock may recover, it may be unable to swim or control its buoyancy for a period, and this can have survival consequences. Temperature shocked fish can temporarily lose their equilibrium and maneuverability, experiencing increased levels of predation (McCullough 1999). Cold shock experiments on rainbow trout found that from an instantaneous thermal decrease of 16.5ºC (exposure to 3.5ºC water from an acclimation temperature of 20ºC), caused complete loss of equilibrium and a 50% mortality occurred over a 4 day period. This means that even though 50% of the test fish survived, the cold shock caused incapacitation significant enough to lead indirectly to death by predation (McCullough 1999).

While the range of water temperatures occurring in the investigation area is broad, the rates of temperature change are slow relative to thresholds rates that cause adverse effects. Even diurnal temperature fluctuations as large as 13 °C/day typically occur at rates rarely larger than 2 °C/hour, and often less than 1 °C/hour. Rapid changes in water temperature that are within the range of diurnal fluctuation, but which exceed typical natural rates of change can cause behavioral and survival effects for several species. These adverse effects include avoidance behavior, physiological stress, and potentially mortality. Eggs and larvae, which are less mobile than juveniles and adults, may be particularly vulnerable to rapid temperature changes (Wismer and Christie 1987, Hokanson 1977, Schneider et al. 2002, McCullough 1999). However, these rapid changes have to be relatively large to cause these kinds of effects. A change of temperature during the incubation of walleye embryos of ±19ºC over a 2-hour

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period causes neither "excessive mortality nor any immediate adverse effect." Walleye fry tolerate temperature changes of 1.5ºC/minute, a relatively high rate compared with changes likely to occur in natural spawning areas (Schneider et al. 2002). Most fish species can tolerate temperature shifts of 15ºC to 18ºC provided the exposure temperature is within the tolerance range (Upper and Lower Incipient Lethal Temperatures) of the species (McCullough 1999).

When a temperature effect causes a fish species to avoid an affected habitat, but is not large enough to cause survival effects, this is considered a behavioral effect. Consequences of behavioral effects include displacement of fry and juveniles to sub-optimal habitats where they experience increased predation and competition. Displaced fish can also experience sub-optimal growth rates (McCullough 1999). Nesting adult male fish protecting, cleaning, and aerating their eggs and fry, such as largemouth and smallmouth bass, may abandon their nests when temperatures suddenly drop (Wydowski and Whitney 2003, Hubbs and Bailey 1938, Summerfelt 1975). Adults generally do not return to their original nest, but instead create new nests (Hubbs and Bailey 1938, Summerfelt 1975). The eggs and fry present in abandoned early season nests are generally lost to predation (Wydowski and Whitney 2003, Hubbs and Bailey 1938, Summerfelt 1975). This generally requires a drop of average mean daily temperature of about 10-11ºC for an extended period of time (Becker 1983, Coble 1975). These conditions are usually caused by storm-related high flow events or weather fronts. Rapid changes in temperature related to anthropogenic changes in water temperature in the Niagara River are highly unlikely to exceed the average diurnal changes in temperature, reach or exceed 10ºC, or last for an extended period of time.

Large rapid changes in water level in the Niagara River due to natural causes occur regularly, if infrequently, on an annual basis (URS et al. 2005a). As a consequence, rapid changes in water temperature caused by mixing effects that are attributable to natural causes have occurred historically and will continue to occur at susceptible locations. Fish species that utilize these locations would have been exposed to these periodic rapid temperature changes throughout their evolutionary and adaptive history in this environment.

Water level fluctuations due to U.S./Canadian power generation increase the frequency of rapid temperature fluctuations at some locations that are large enough to be considered temperature effects.

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The magnitude of observed temperature effects is not large enough to cause behavioral or survival effects on any focus species at any location. Moreover, the locations with the greatest identified temperature effects are those areas most likely to have experienced natural rapid temperature fluctuations historically. Focus fish species would be expected to have adjusted their habitat preferences in accordance with these natural conditions.

No temperature effects were identified in Lewiston Reservoir (Analysis Zone 6). However, temperature patterns present in the reservoir are unusual in comparison to natural lake systems. Large lakes tend to stratify in summer months, leading to greater diurnal temperature fluctuations and warmer overall temperatures in shallow and surface waters. Lewiston Reservoir does not stratify during summer months because of its rapid turnover rate. Temperatures in this entirely artificial water body mimic those in its source body, the upper Niagara River, and the conditions present will not result in behavioral or survival effects on focus species. The water temperature of Lewiston Reservoir is generally slightly cooler than the upper Niagara River near the NPP intakes from late April to mid September 2003. This is due to the fact that water is pumped into the reservoir during the night, when average water temperatures are lower than during the daytime.

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5.0 CONCLUSIONS

The objectives of this study were to: 1) determine if water level fluctuations in the Niagara River affect water temperatures in the Niagara River, U.S. tributaries of the Niagara River, and Lewiston Reservoir, and, if so, 2) describe the nature and extent of the effects and their potential influence on the behavior and survival of fish.

The findings of this investigation lead to the following conclusions:

- The normal seasonal and diurnal temperature patterns in the Niagara River and its tributaries, as measured at 63 temperature gauge locations, were unaffected by water level fluctuations related to U.S./Canadian power generation. The seasonal water temperatures in the investigation area ranged from approximately zero to 25°C, with some tributaries reaching higher temperatures (28.5°C). Diurnal temperatures in the main channel of the Niagara River fluctuated by as much as 2 to 3°C/day, more in shallow slackwater areas. Diurnal temperatures in tributaries fluctuated by as much as 13°C/day, but more typically 6 to 8°C/day.
- Groundwater flow caused by the hydrostatic pressure of Lewiston Reservoir affects seasonal and diurnal temperature ranges in portions of Fish and Gill Creeks. Portions of the creeks receiving groundwater inflow are as much as 5°C cooler than upstream areas during summer months. Gill Creek also receives flow augmentation from Lewiston Reservoir from late spring through early fall. This greatly reduced diurnal temperature fluctuations below the discharge in 2003.
- Water temperature effects due to U.S./Canadian power generation, expressed as positive or negative hourly changes in water temperature ($\Delta\ ^{\circ}C_{WT}$) in excess of reference thresholds, were identified at 18 of 63 temperature gauge locations.

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- Water temperature effects due to U.S./Canadian power generation were identified at 16 of 39 locations in Niagara River tributaries (Analysis Zone 1), predominantly in mixing zones near tributary mouths. Effects were most pronounced in spring and fall months, when the difference between average tributary temperatures and average river temperatures was larger. Effects ranged as large as –6.5 and +4.8˚C/hour.
- Temperature effects were observed in shallow water areas of the upper Niagara River (Analysis Zone 3) at two of seven gauge locations, both in mixing zones at or immediately downstream of tributary mouths. Effects ranged as large as –3.2 to +2.5˚C/hour.
- All temperature effects observed in Analysis Zones 1 and 3 are historically within the likely range of temperature fluctuations caused by natural fluctuations in water level in the Niagara River.
- No temperature effects were observed in the lower Niagara River at, and downstream of, the RMNPP tailrace (Analysis Zone 5).
- No temperature effects were identified in Analysis Zones 2 or 4, the main channel of the upper Niagara River and the lower Niagara River between the falls and the RMNPP tailrace, respectively.
- No temperature effects were identified in Lewiston Reservoir (Analysis Zone 6), and temperature conditions are consistent with those in its source body, the upper Niagara River. The reservoir does not thermally stratify during summer months, or develop the diurnal temperature fluctuations expected in shallow waters. This is attributed to the rapid turnover rate of the related project operations. The water temperature of Lewiston Reservoir is generally slightly cooler than the upper Niagara River near the NPP intakes in the spring. This is due to the fact that water is pumped into the reservoir during the night, when average water temperatures are lower than during the daytime.

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- At all locations where temperature effects were identified, the effects were of insufficient magnitude to affect the behavior and survival of any life history stage of any focus species likely to be present.

Water level fluctuations in the upper and lower Niagara River and its tributaries are caused by natural events (wind and storms on Lake Erie, ice flow, etc.), treaty flow requirements, and U.S./Canadian power generation. As noted, none of the identified temperature effects were of sufficient magnitude to cause potential behavioral or survival effects on any life history stage of focus fish species. Based on these findings, U.S./Canadian power generation is not believed to result in any temperature effects causing potential behavioral or survival effects on focus species in the investigation area.

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APPENDIX A – TEMPORARY WATER LEVEL AND TEMPERATURE GAUGE SPECIFICATIONS, AND DATA QUALITY CONTROL AND QUALITY ASSURANCE

Specifications for the temporary temperature and water level gauges used to gather data for this analysis are presented in Table A-1. With some exceptions, temporary gauges were generally installed in March or April and removed by mid-November (unless otherwise noted, all elevations are given in United States Lake Survey Datum 1935). Water level gauges were placed in protective PVC housings attached vertically to support stakes driven into the sediment, or to other fixed structures (e.g., boat docks). Temperature gauges were placed in protective PVC housings which were attached to similar supports using steel chain or cable. Data retrieval was usually performed once every one to two weeks at each station. During each site visit, the gauges were inspected, checks were performed to ensure gauges operating properly, and appropriate corrective actions taken as needed.

The calibration of both water level and temperature gauges were checked as per manufacturer's recommendations before and after deployment, and during deployment as needed. Calibration checks on the temperature meters using ice/water baths were done prior to and after deployment. All water level and temperature data were reviewed in order to identify erroneous or suspect data. Once this process was completed and the data set was verified, data were sorted using hourly water level and temperature averages for analyses. Graphs of hourly water levels and temperature for gauges in the same locale were plotted and reviewed to identify trends caused by natural conditions (e.g., precipitation) and by manmade regulation (e.g., Chippawa-Grass Island Pool regulation).

Data collected from the temporary continuous water level gauges were referenced to real elevation data collected by field surveys (points usually at the top of the PVC installation housings previously described). Surveys were conducted once near the beginning of the sampling season and once at the end of the sampling season at each location. Ending survey data matched beginning survey data, indicating the temporary installations remained at a constant elevation throughout the sampling period. Field procedures to ensure quality of data were undertaken at each site during data retrieval, which generally occurred every one to two weeks. The primary procedure used to verify that the gauges were accurately recording data included measuring depth to water from the top of the PVC housing using an electronic water level indicator, and taking a simultaneous measurement of the depth of the water column above the gauge. The latter measurement was taken with the gauge itself. Because the distance between

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the top of the PVC and the gauge remains constant, the sum of the two field measurements should also remain constant, since this sum is, in theory, equivalent to the distance between the top of the PVC and the gauge. Corrective actions (i.e., data gauge maintenance, repair or replacement) were taken when field measurements indicated that the gauge may not have been accurately recording data. The instrument was generally considered to be operating properly if the measurements did not vary by more than 0.10 feet from one data retrieval to the next. Water temperature data was also verified during data retrieval with an independent meter.

Desktop review of the continuous water level and temperature data was undertaken to ensure accuracy of the data. Data was examined to identify any erroneous patterns from week to week, or in relation to other data collected nearby.

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TABLE A-1

FIELD EQUIPMENT SPECIFICATIONS

Parameter	Equipment	Range	Resolution	Accuracy
Temperature, discrete	YSI 550A	-5 to 45 °C	0.1 °C	± 0.3 °C
Water level, continuous	In-Situ miniTROLL, Pro	0-21 meters	1 mm	± 1% of reading
Temperature, continuous	In-Situ miniTROLL, Pro	-5 to 50 °C	0.001 °C	± 0.25 °C
Temperature, continuous	Onset Optic StowAway	-5 to 37 °C	0.16 °C	± 0.2 °C

Note: Water temperature at each sampling site was recorded continuously with the In-Situ miniTROLL, the Onset Optic StowAway, or both.

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APPENDIX B – WATER TEMPERATURE, WATER LEVEL, AND METEOROLOGICAL DATA COLLECTED IN THE INVESTIGATION AREA

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FIGURE B-1: BURNT SHIP CREEK (TBSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

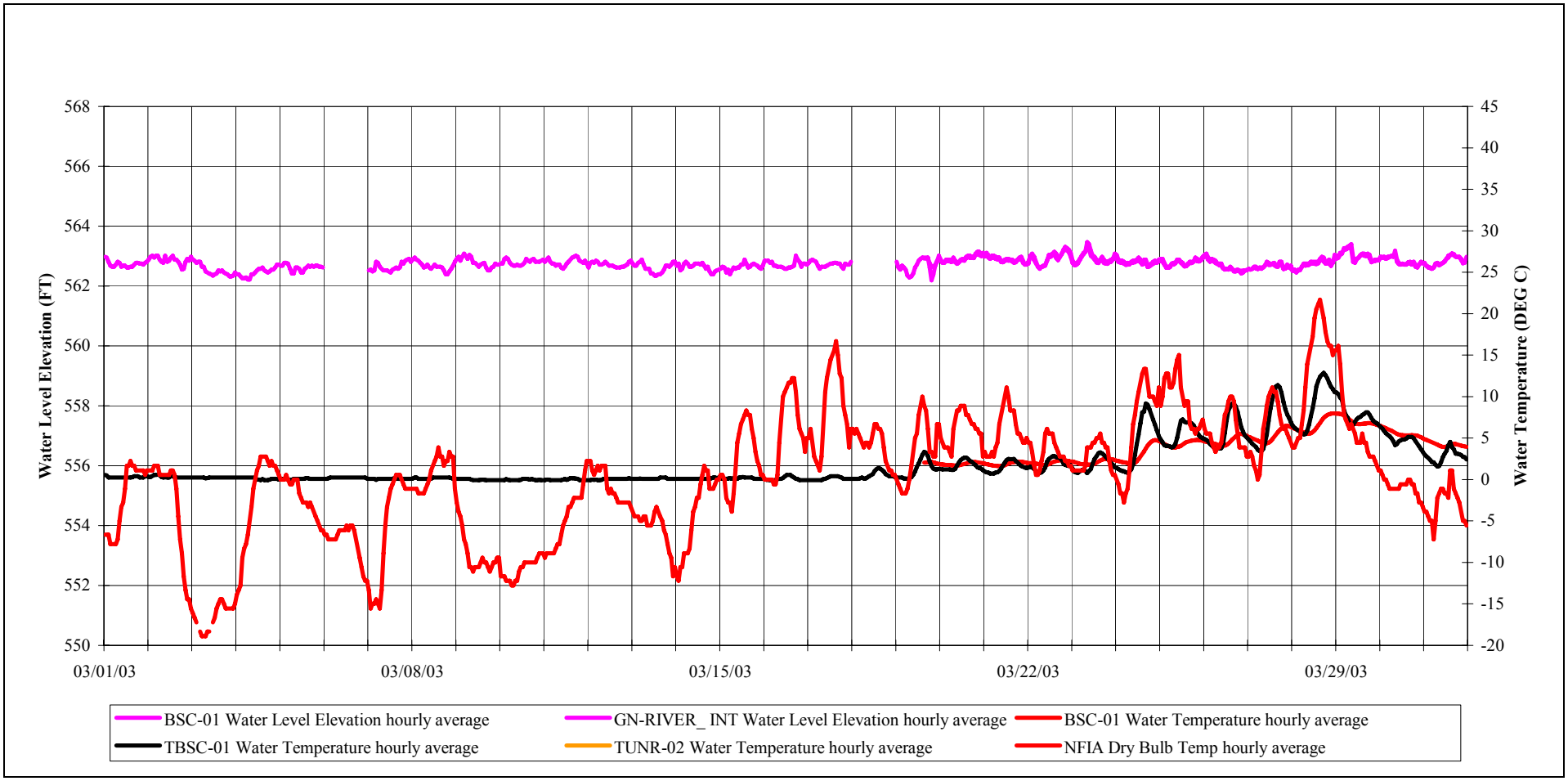

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FIGURE B-2: BURNT SHIP CREEK (TBSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

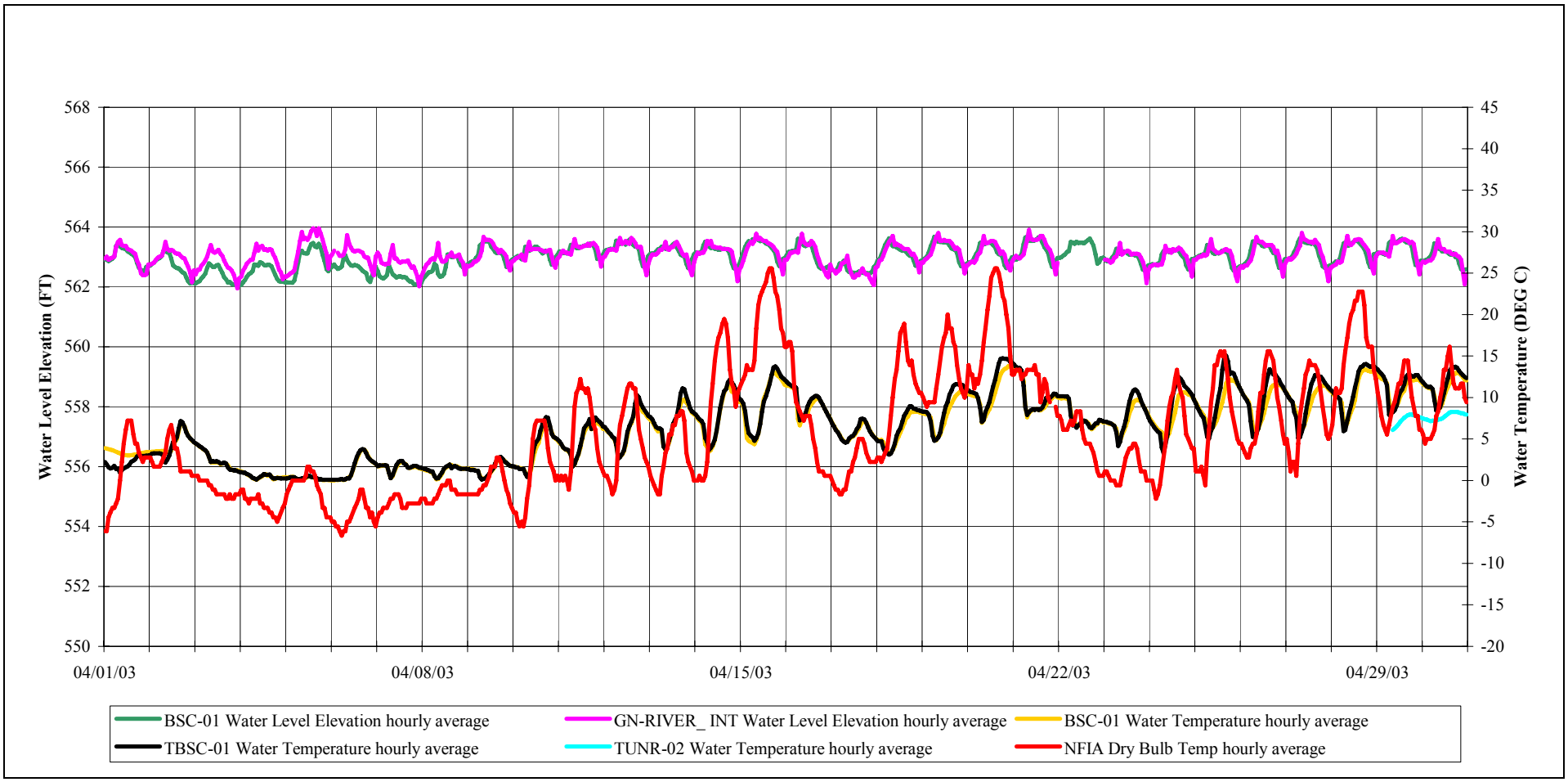

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FIGURE B-3: BURNT SHIP CREEK (TBSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

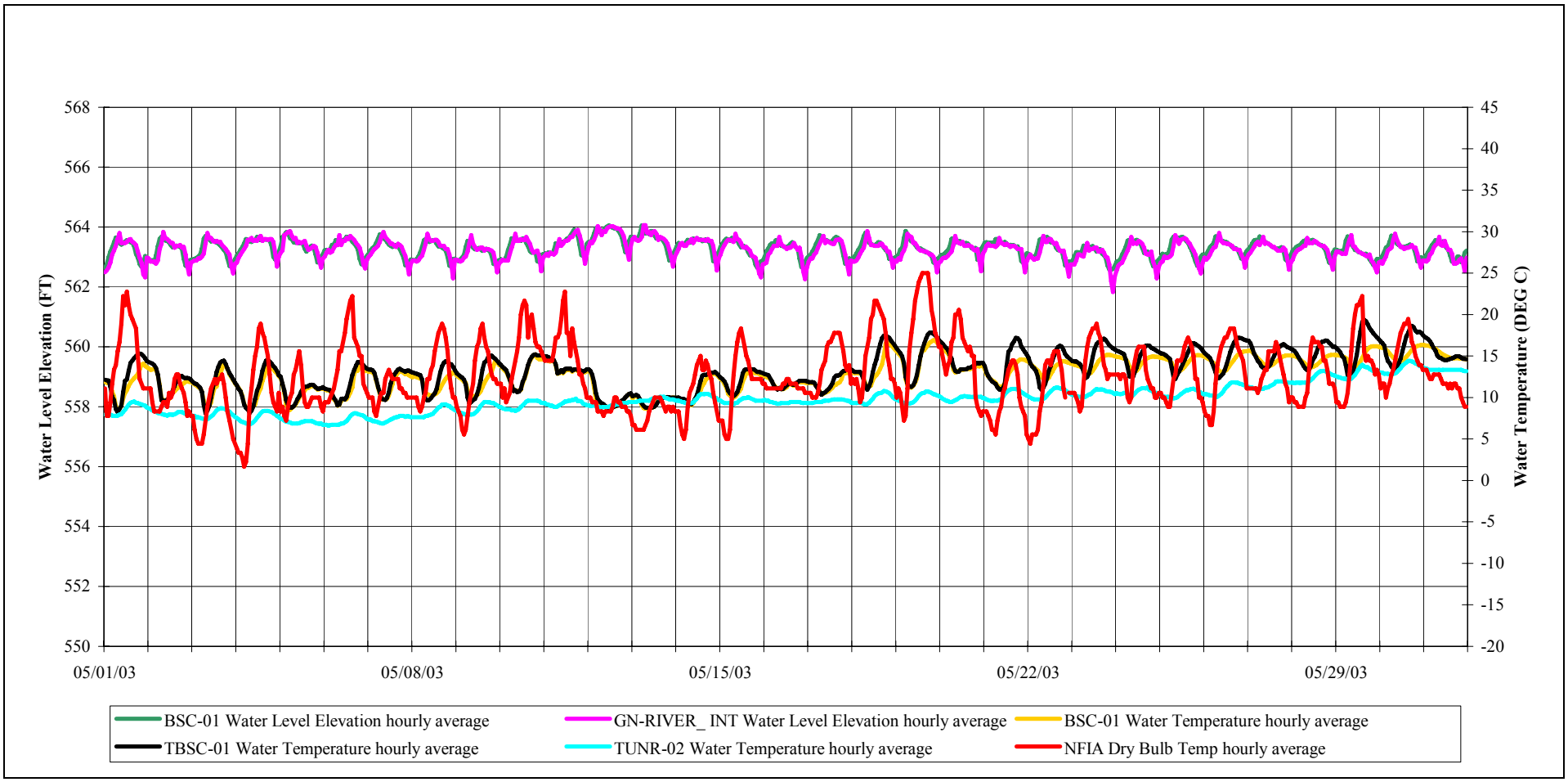

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FIGURE B-4: BURNT SHIP CREEK (TBSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

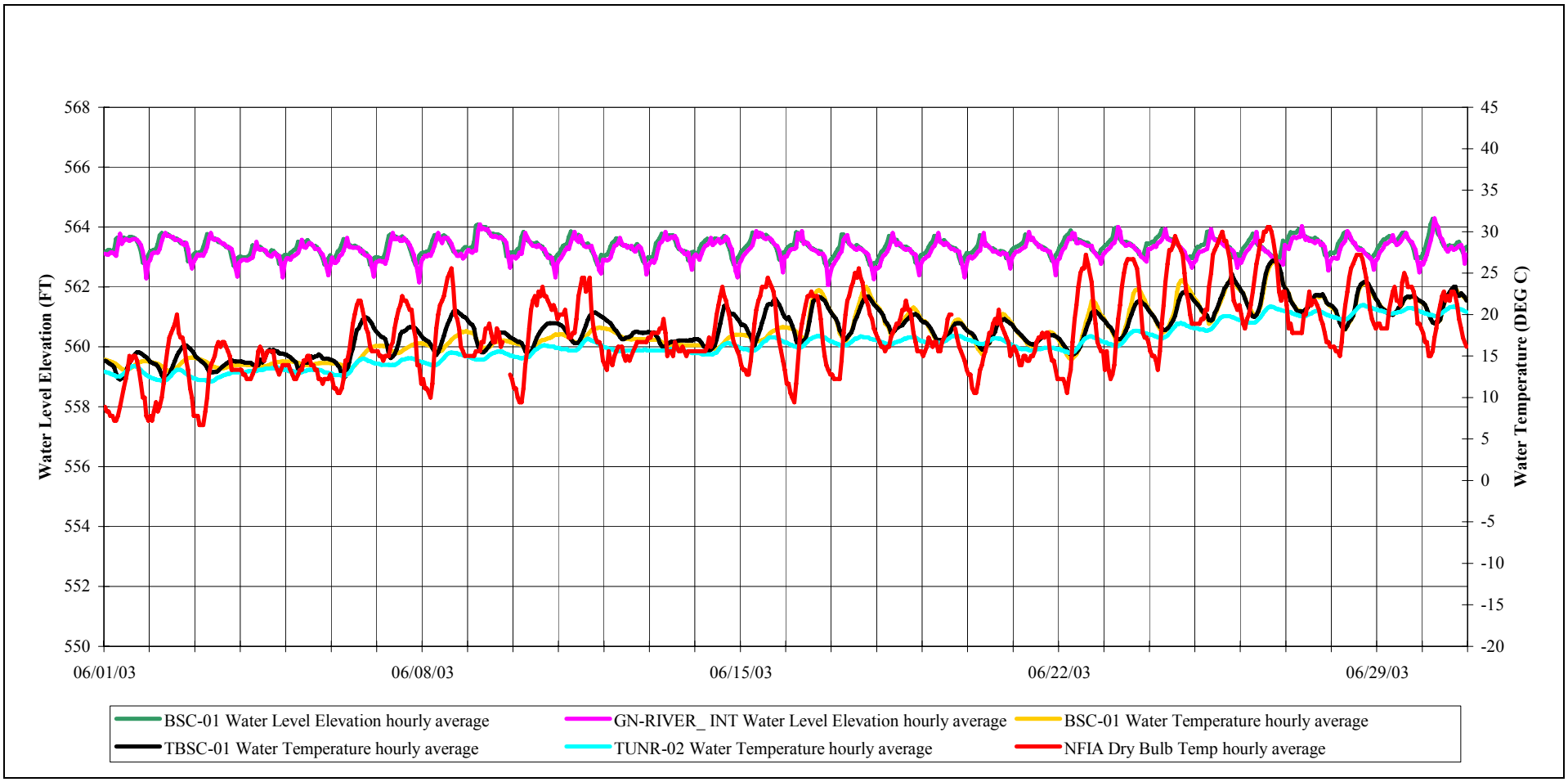

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FIGURE B-5: BURNT SHIP CREEK (TBSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

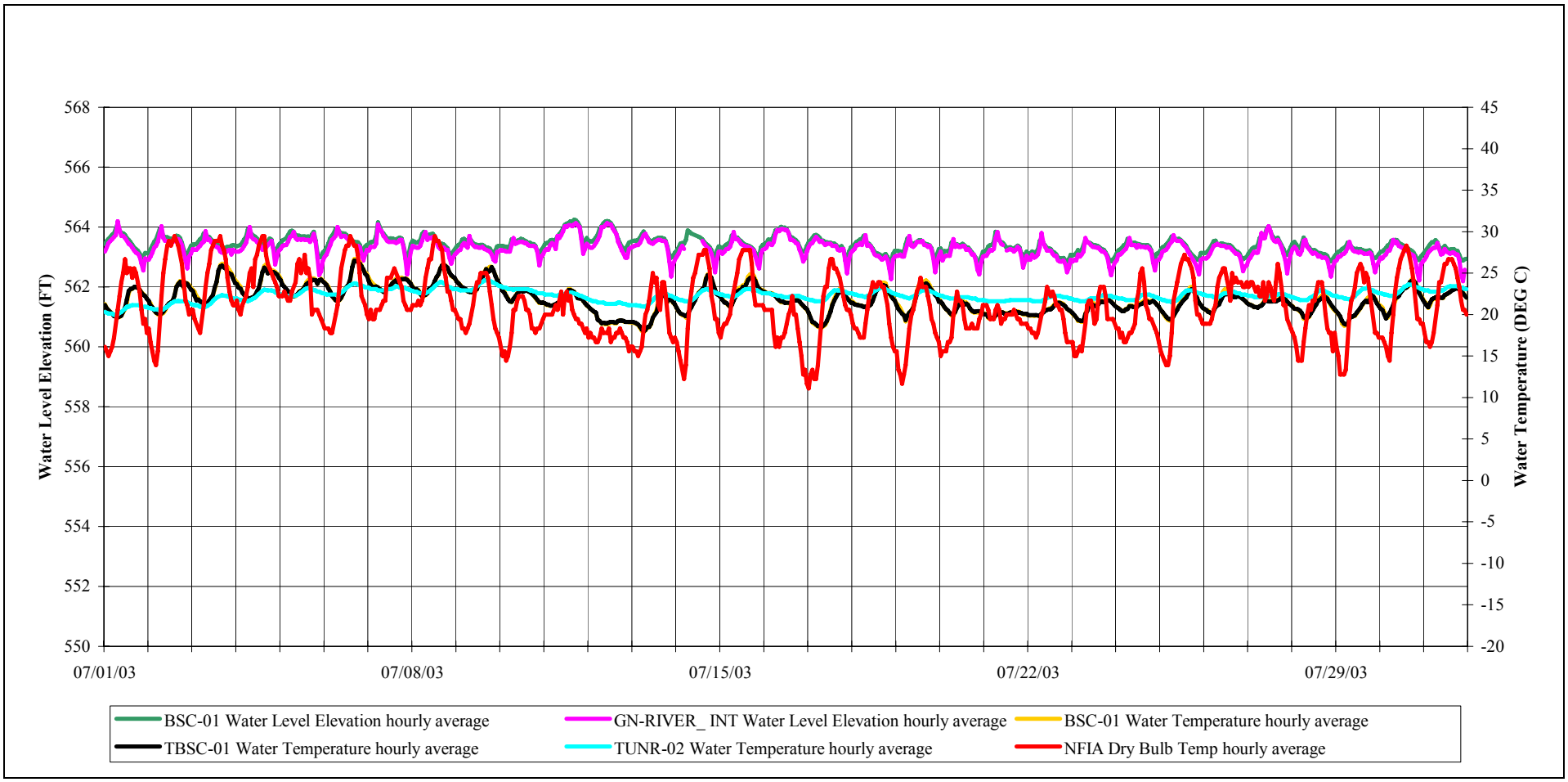

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FIGURE B-6: BURNT SHIP CREEK (TBSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

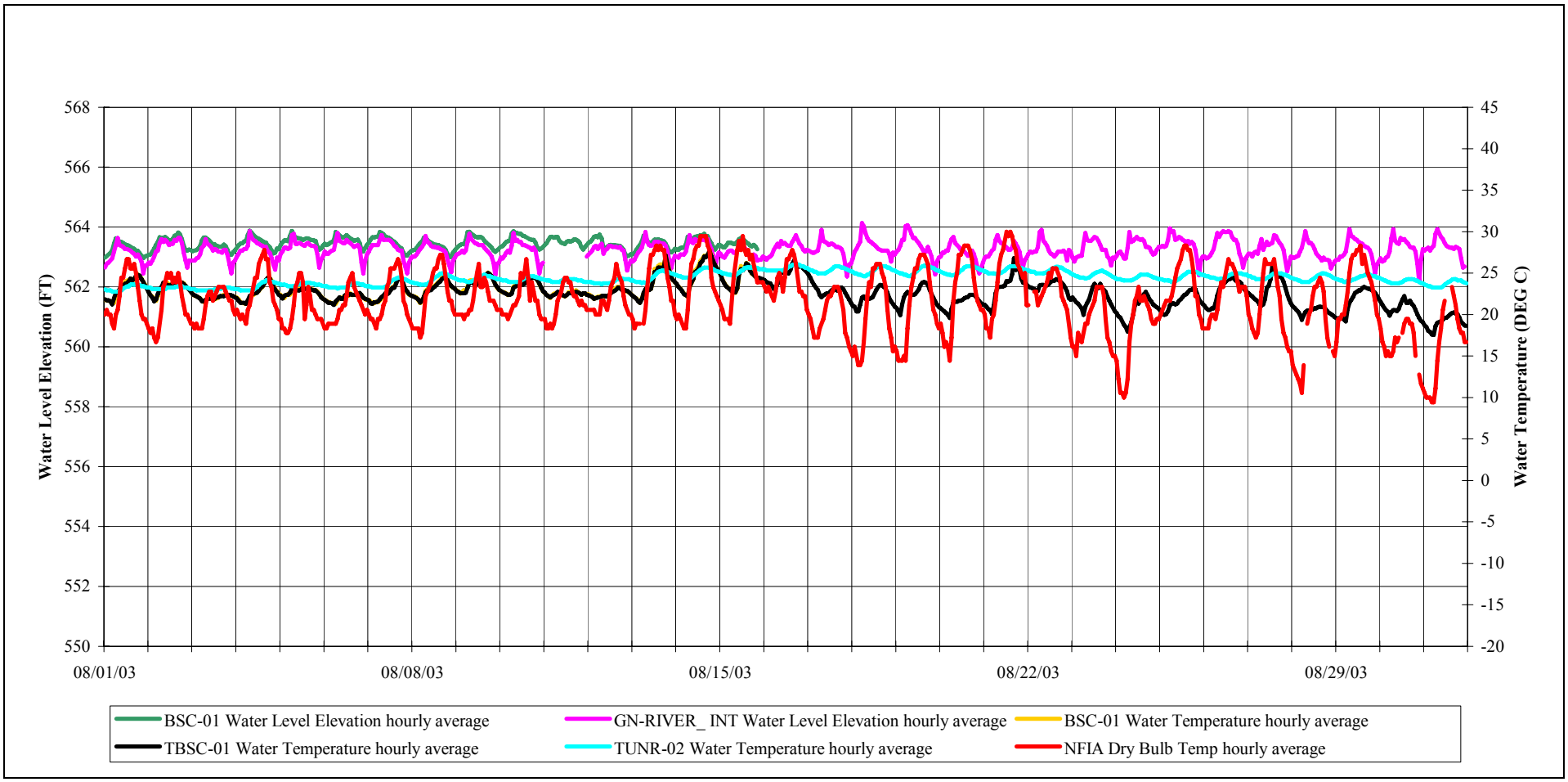

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FIGURE B-7: BURNT SHIP CREEK (TBSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

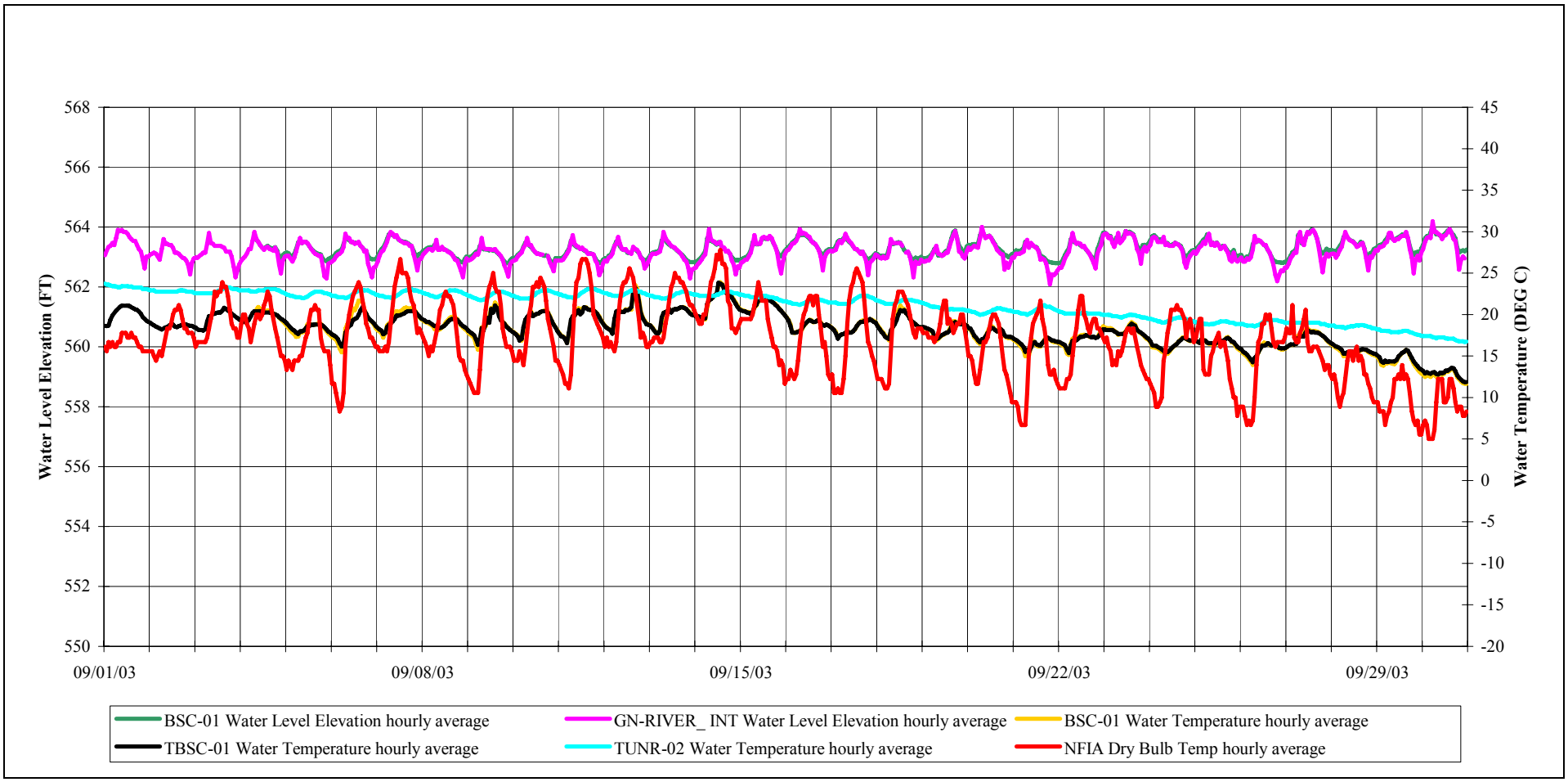

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FIGURE B-8: BURNT SHIP CREEK (TBSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

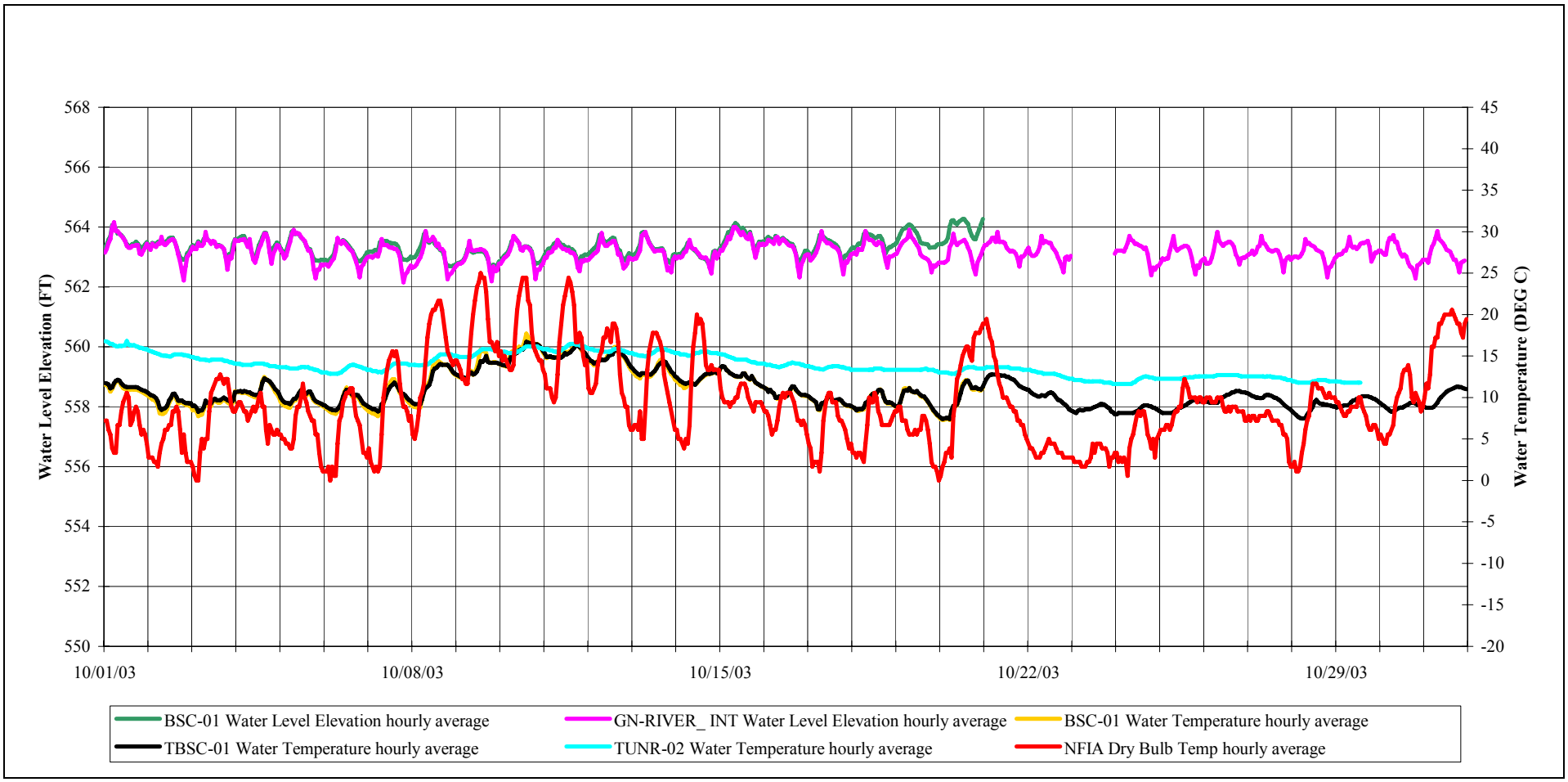

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FIGURE B-9: BURNT SHIP CREEK (TBSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

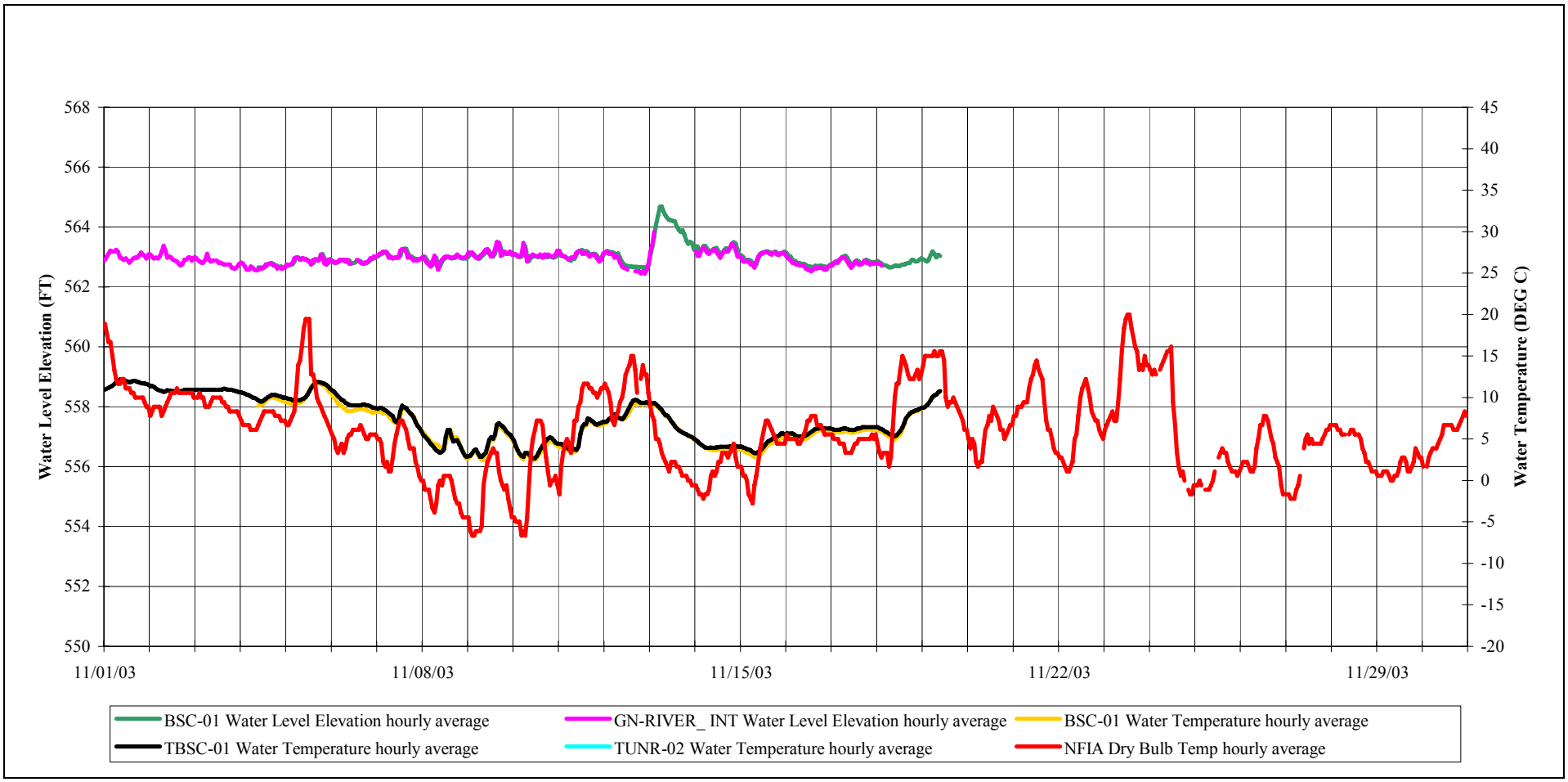

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FIGURE B-10: BURNT SHIP CREEK (TBSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

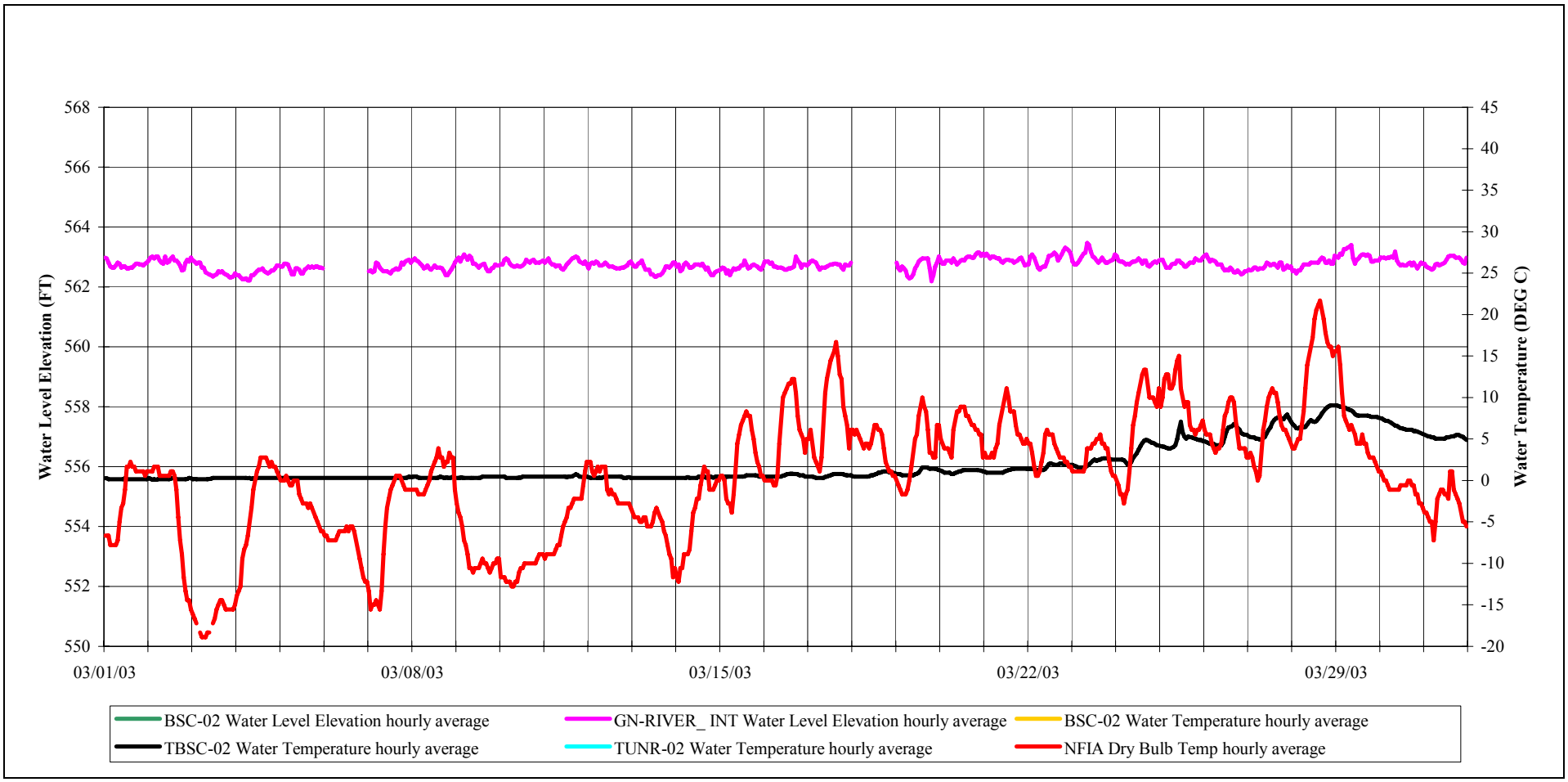

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FIGURE B-11: BURNT SHIP CREEK (TBSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

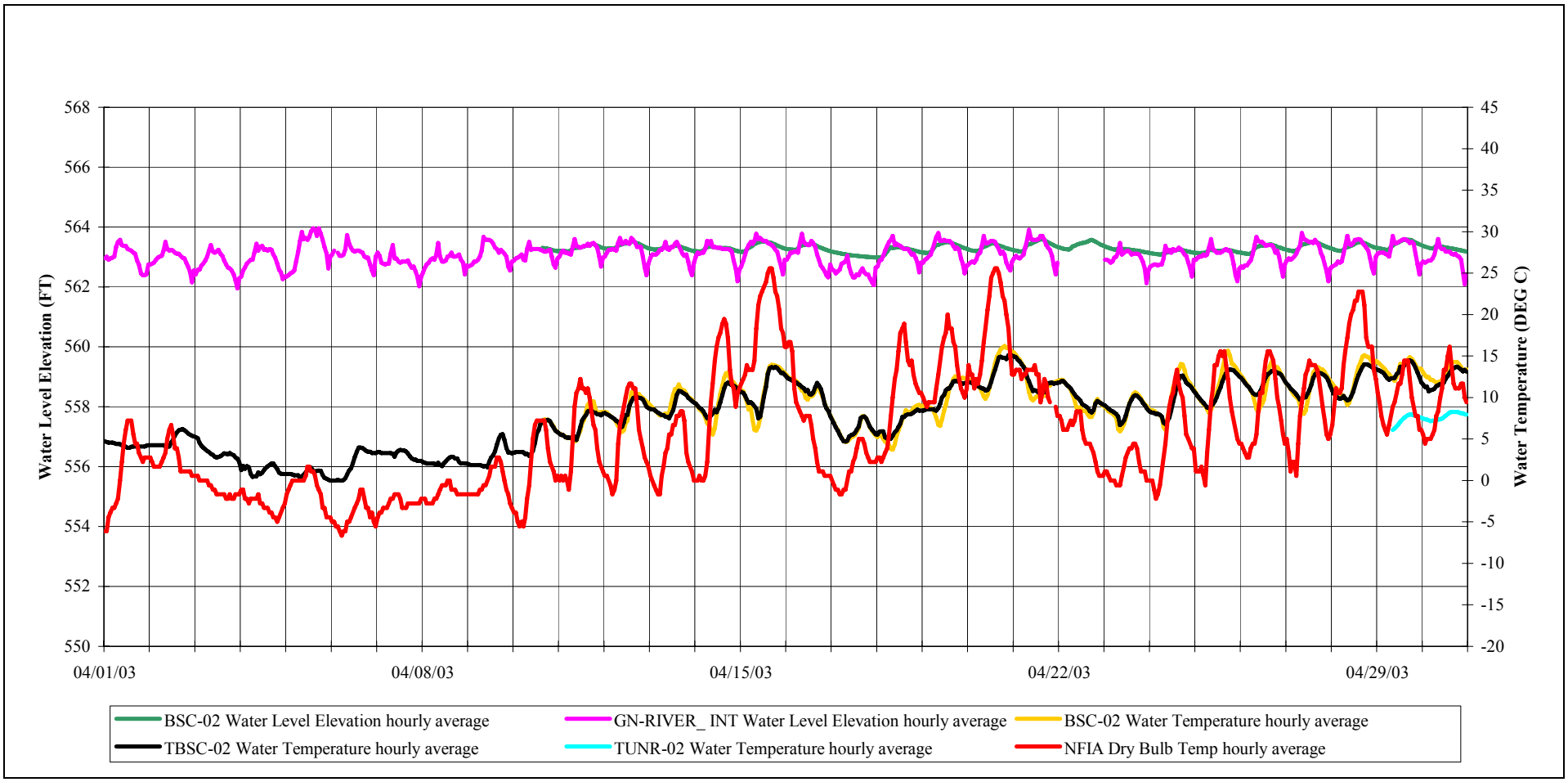

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FIGURE B-12: BURNT SHIP CREEK (TBSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

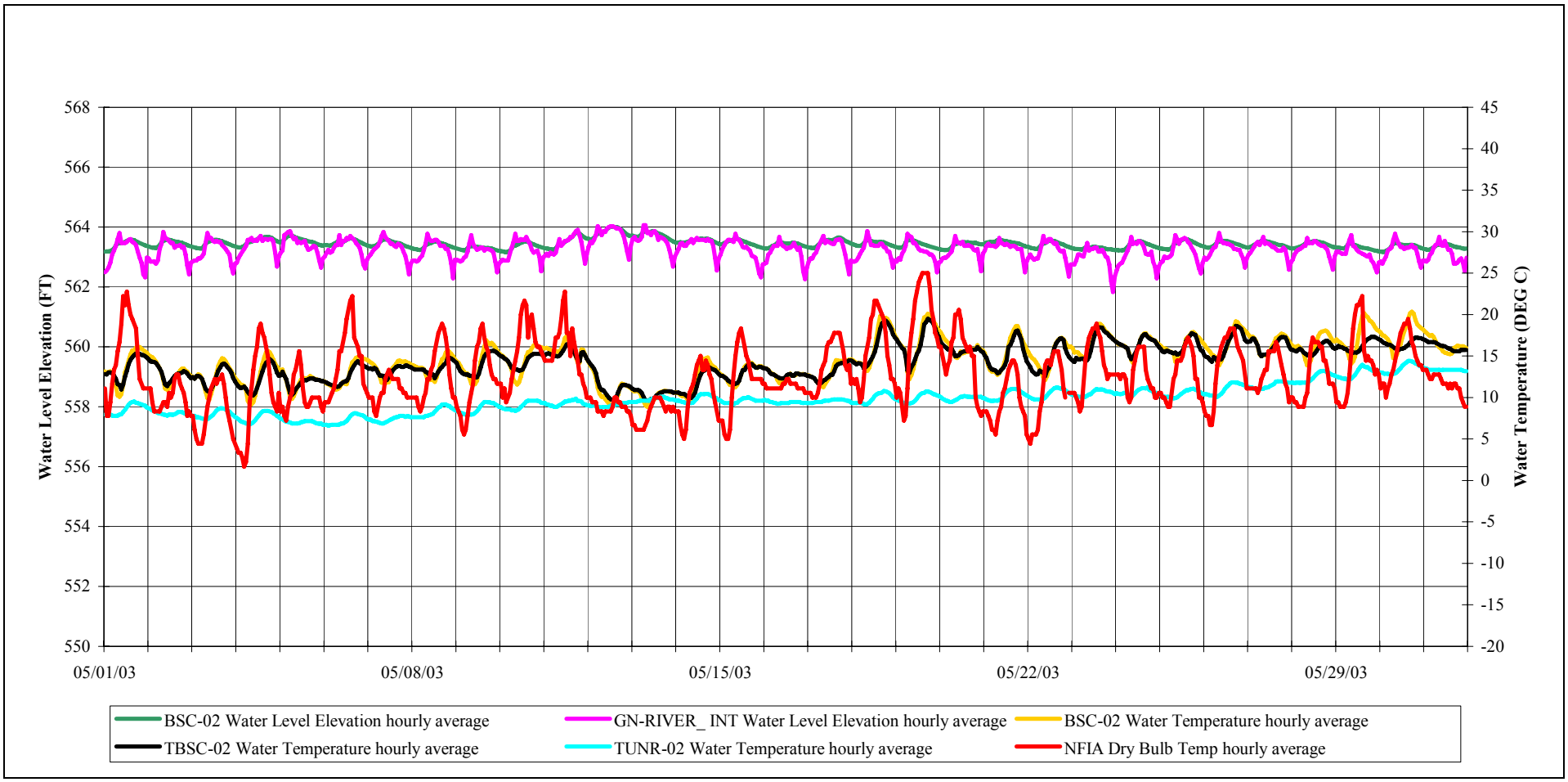

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FIGURE B-13: BURNT SHIP CREEK (TBSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

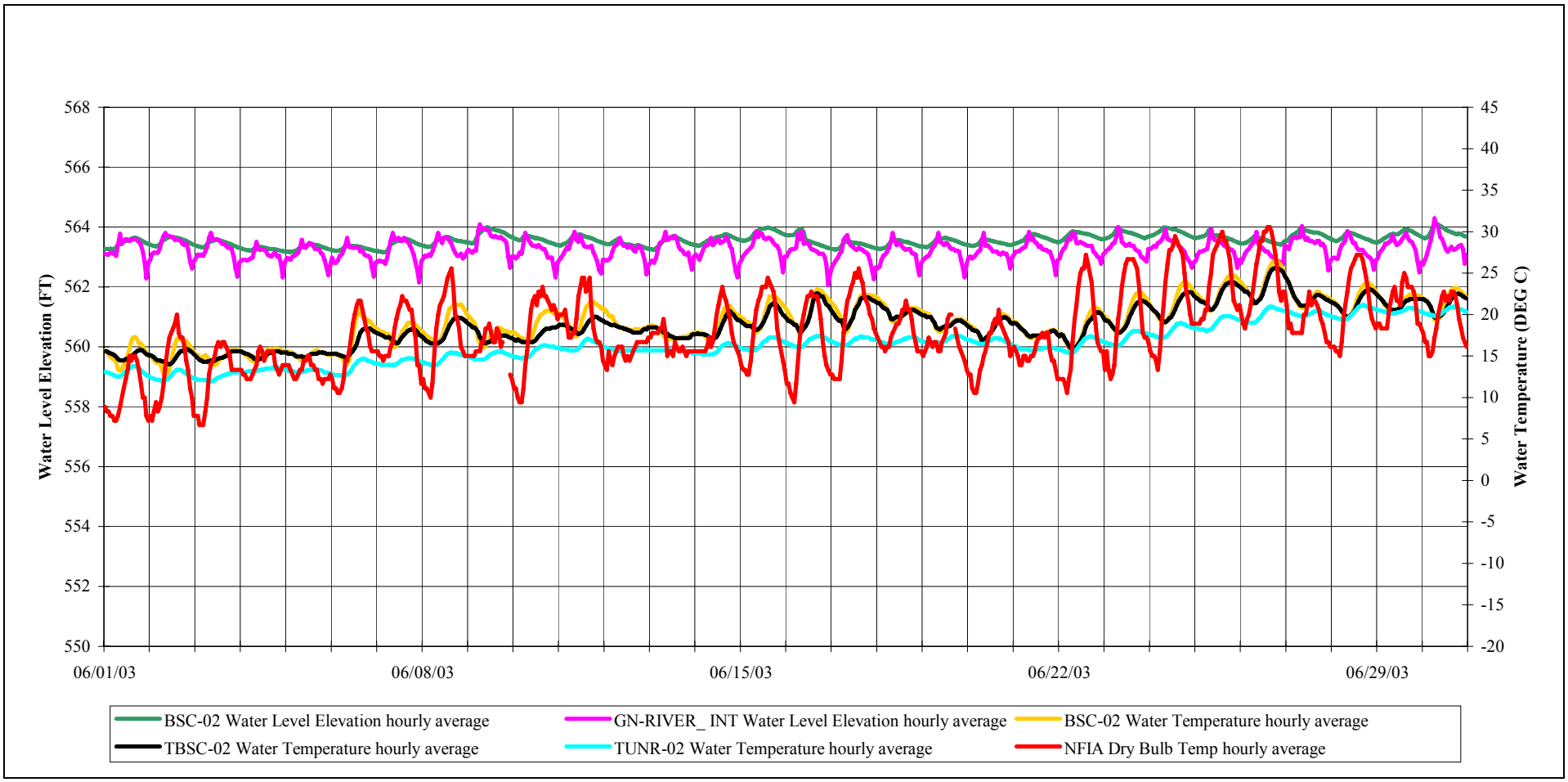

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FIGURE B-14: BURNT SHIP CREEK (TBSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

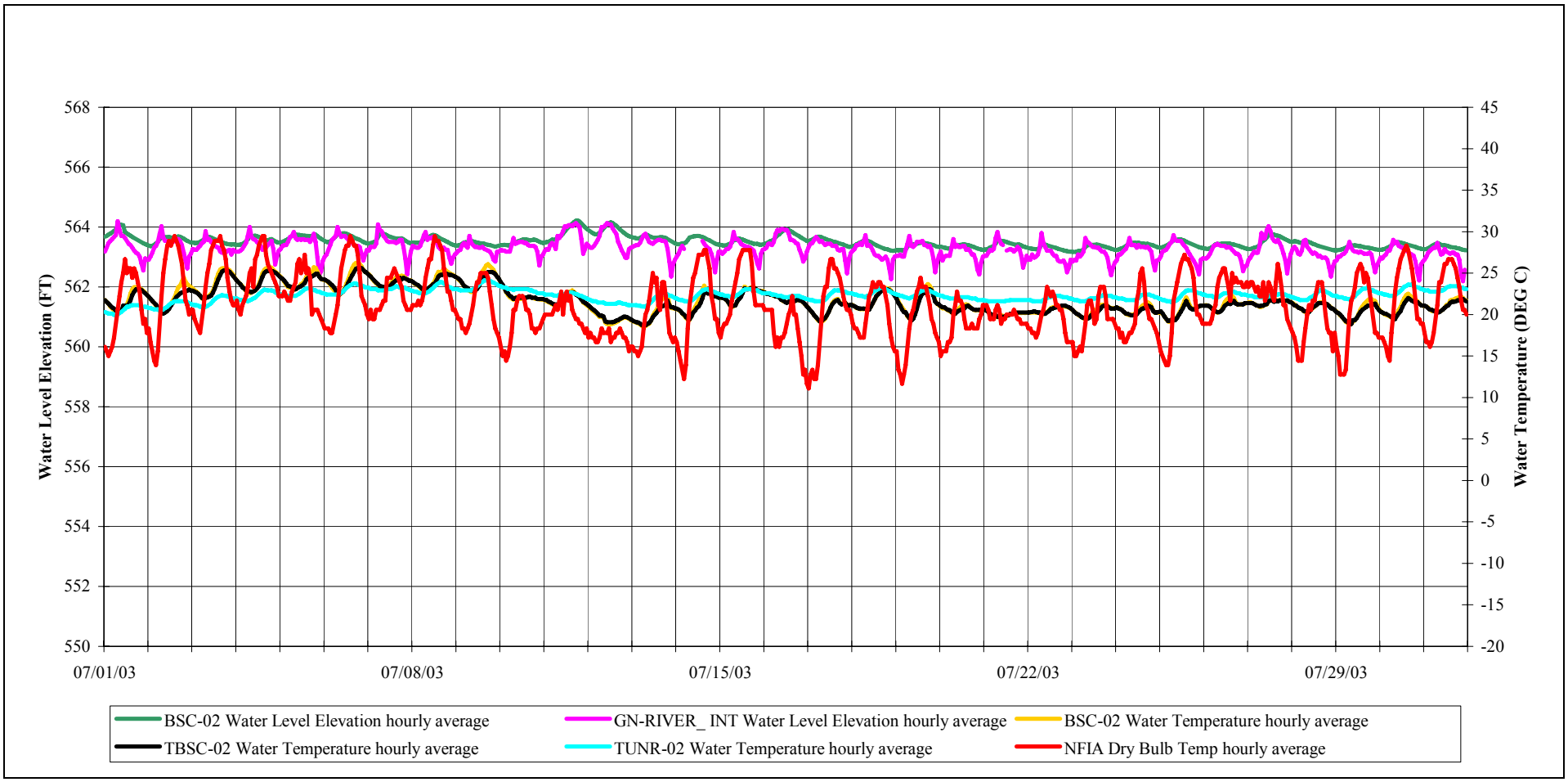

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FIGURE B-15: BURNT SHIP CREEK (TBSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

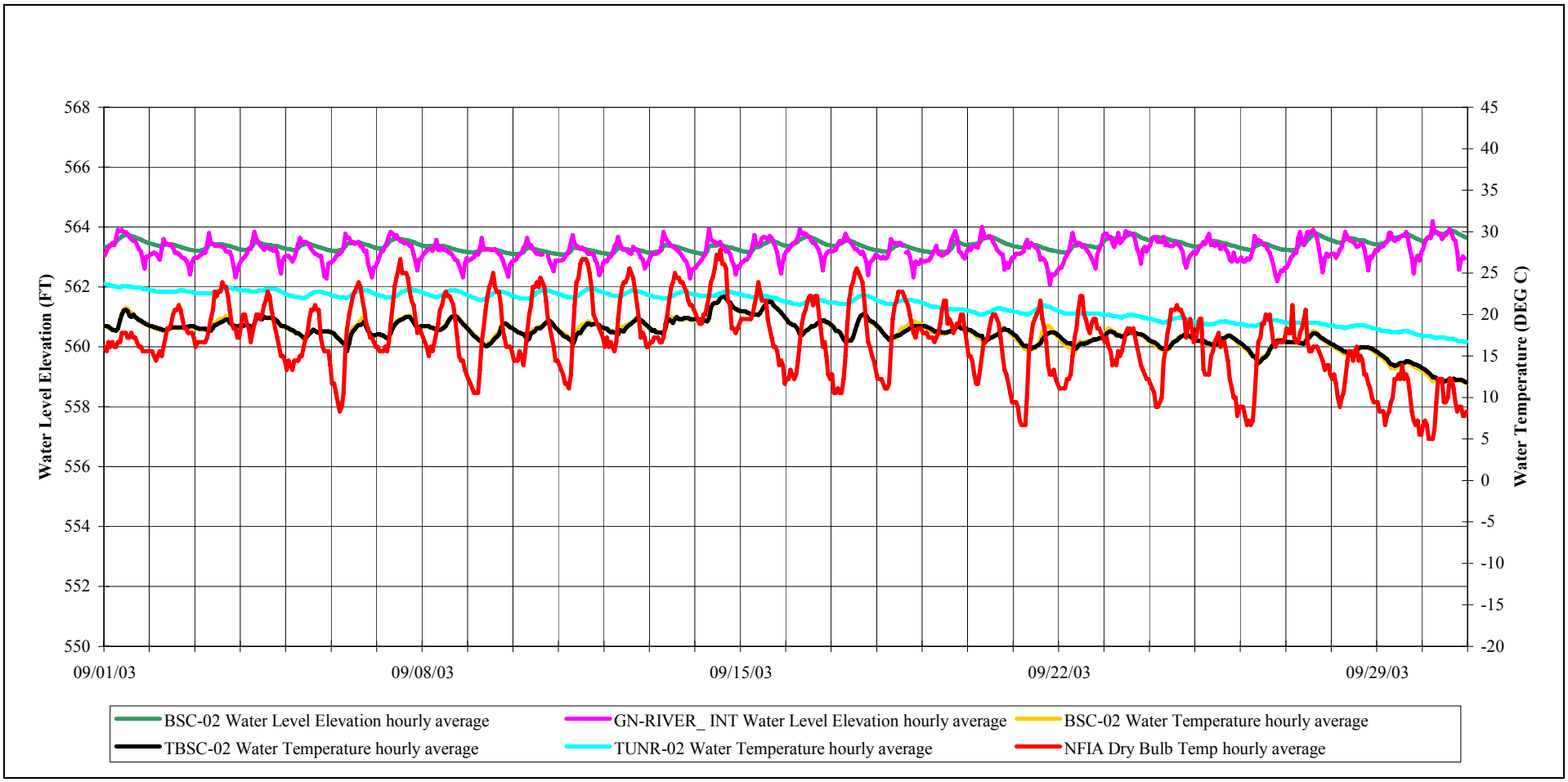

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FIGURE B-16: BURNT SHIP CREEK (TBSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

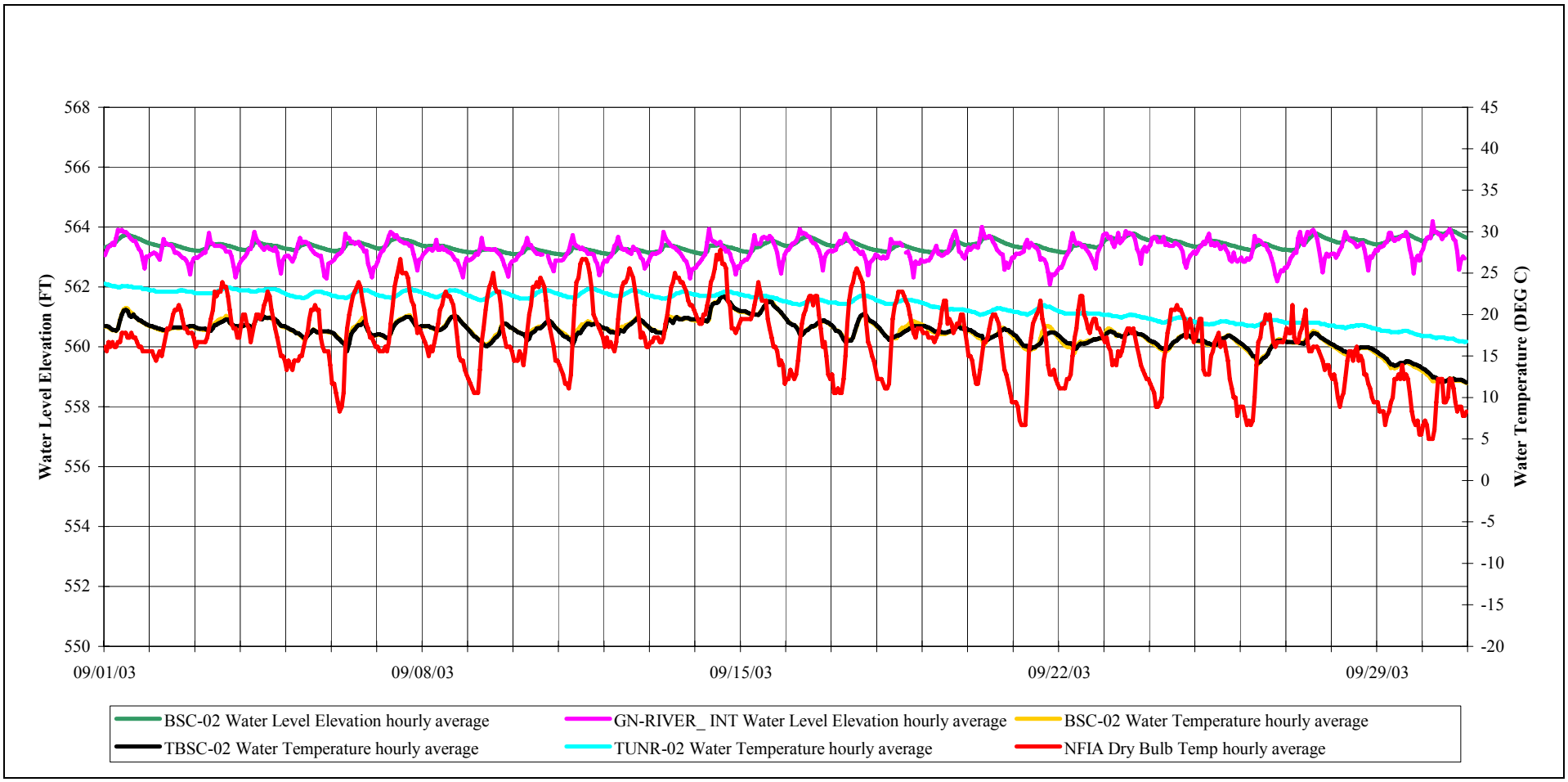

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FIGURE B-17: BURNT SHIP CREEK (TBSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

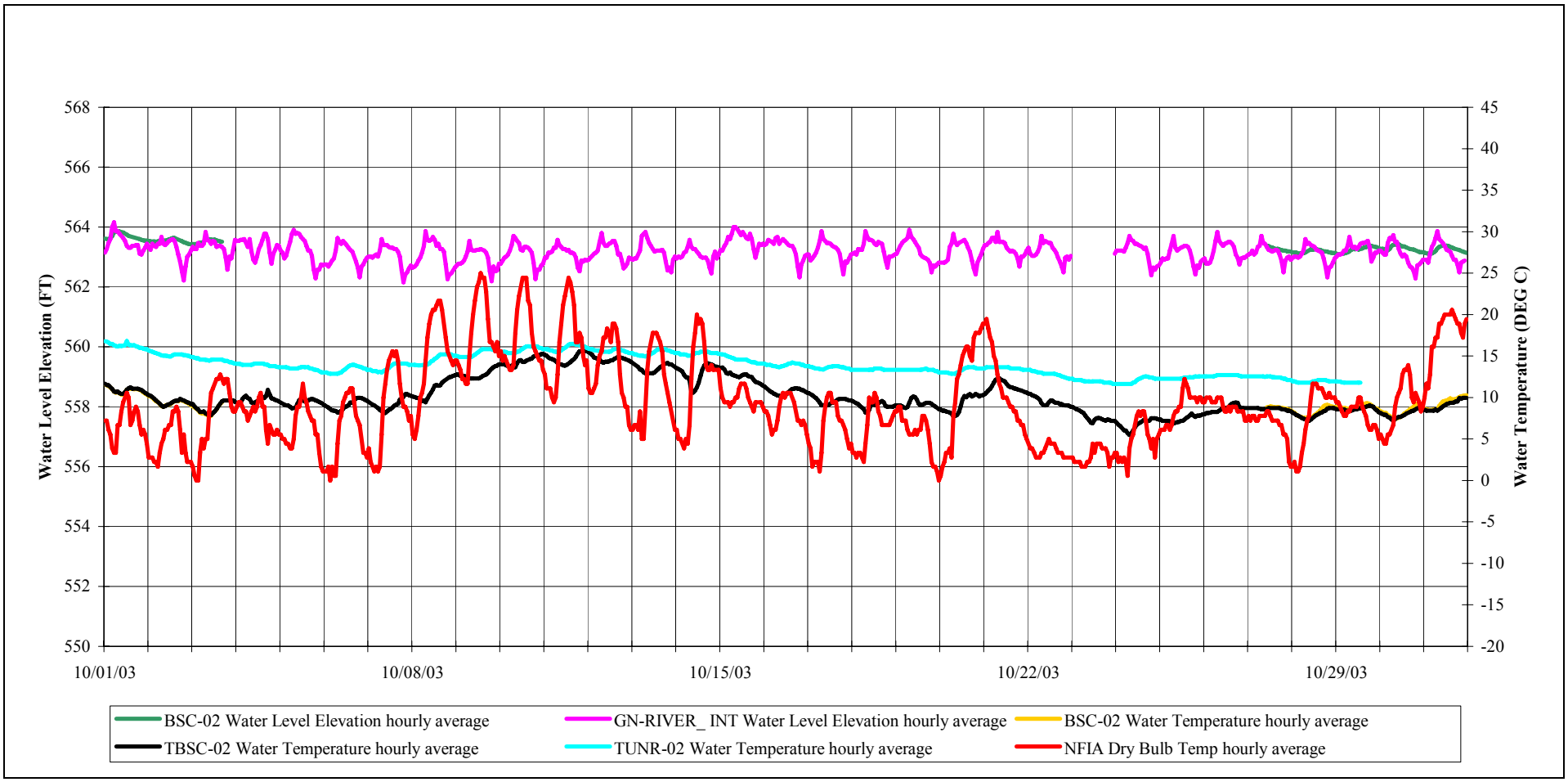

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FIGURE B-18: BURNT SHIP CREEK (TBSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

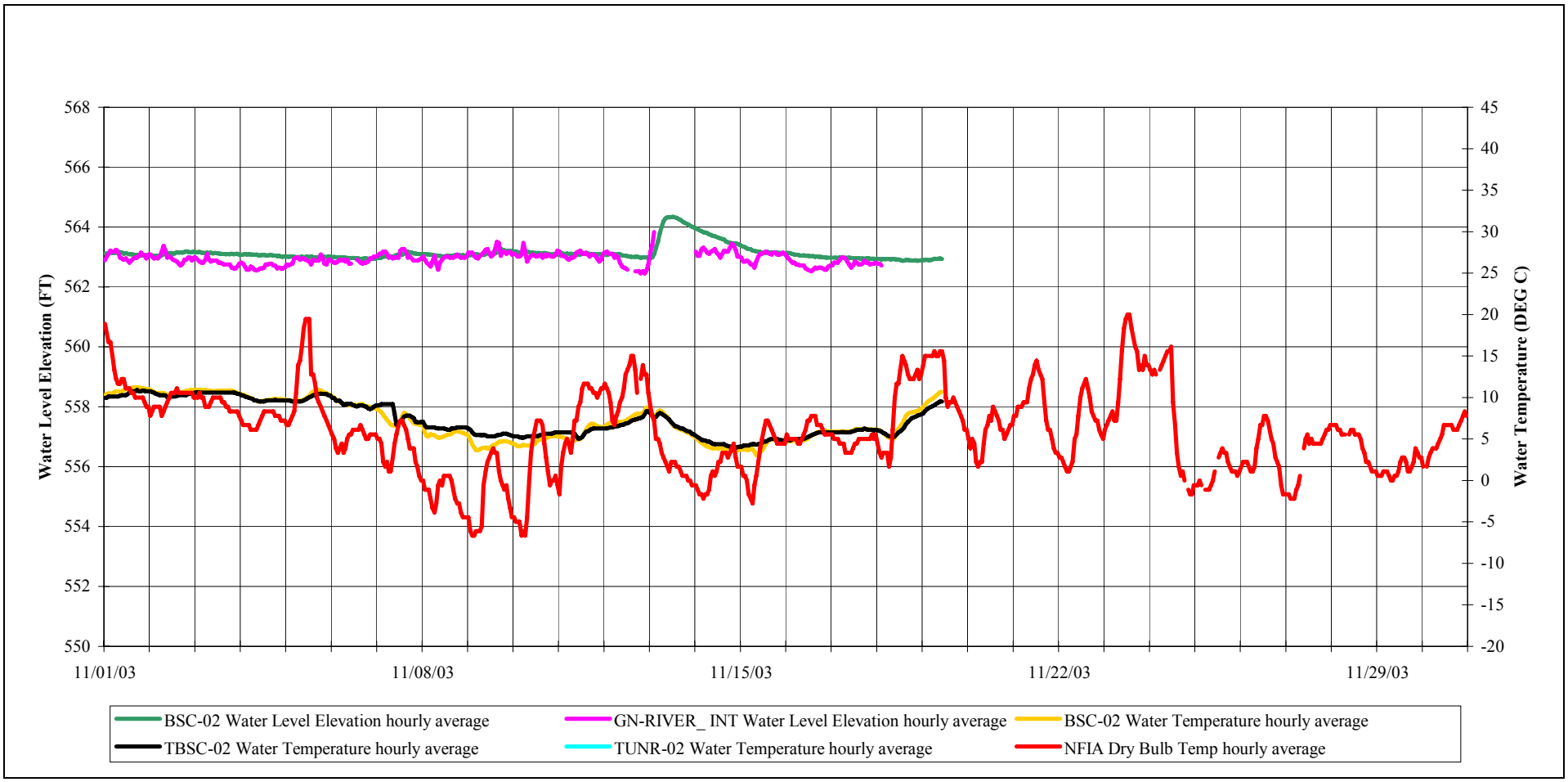

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FIGURE B-19: BURNT SHIP CREEK (TBSC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

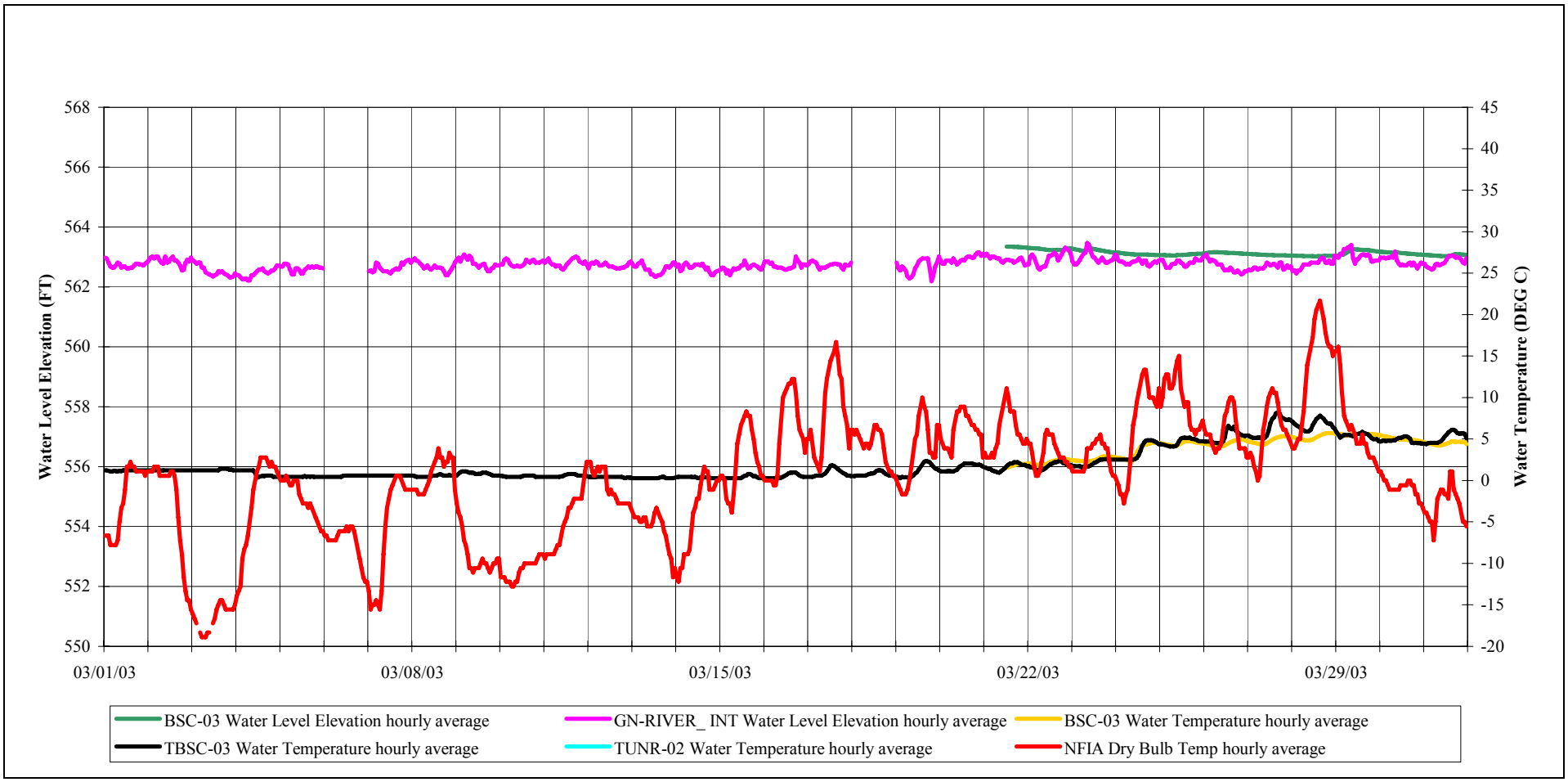

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FIGURE B-20: BURNT SHIP CREEK (TBSC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

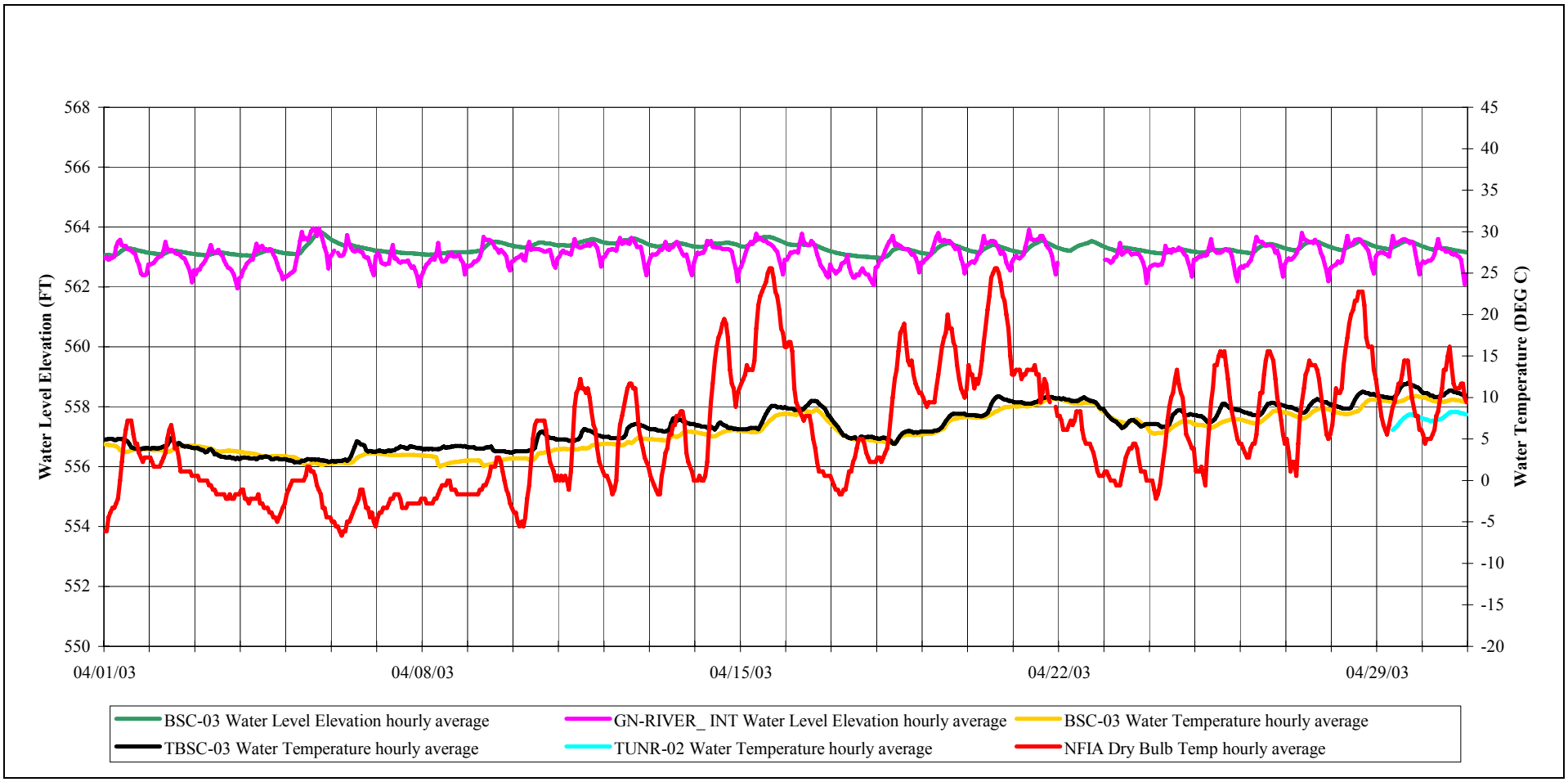

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FIGURE B-21: BURNT SHIP CREEK (TBSC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

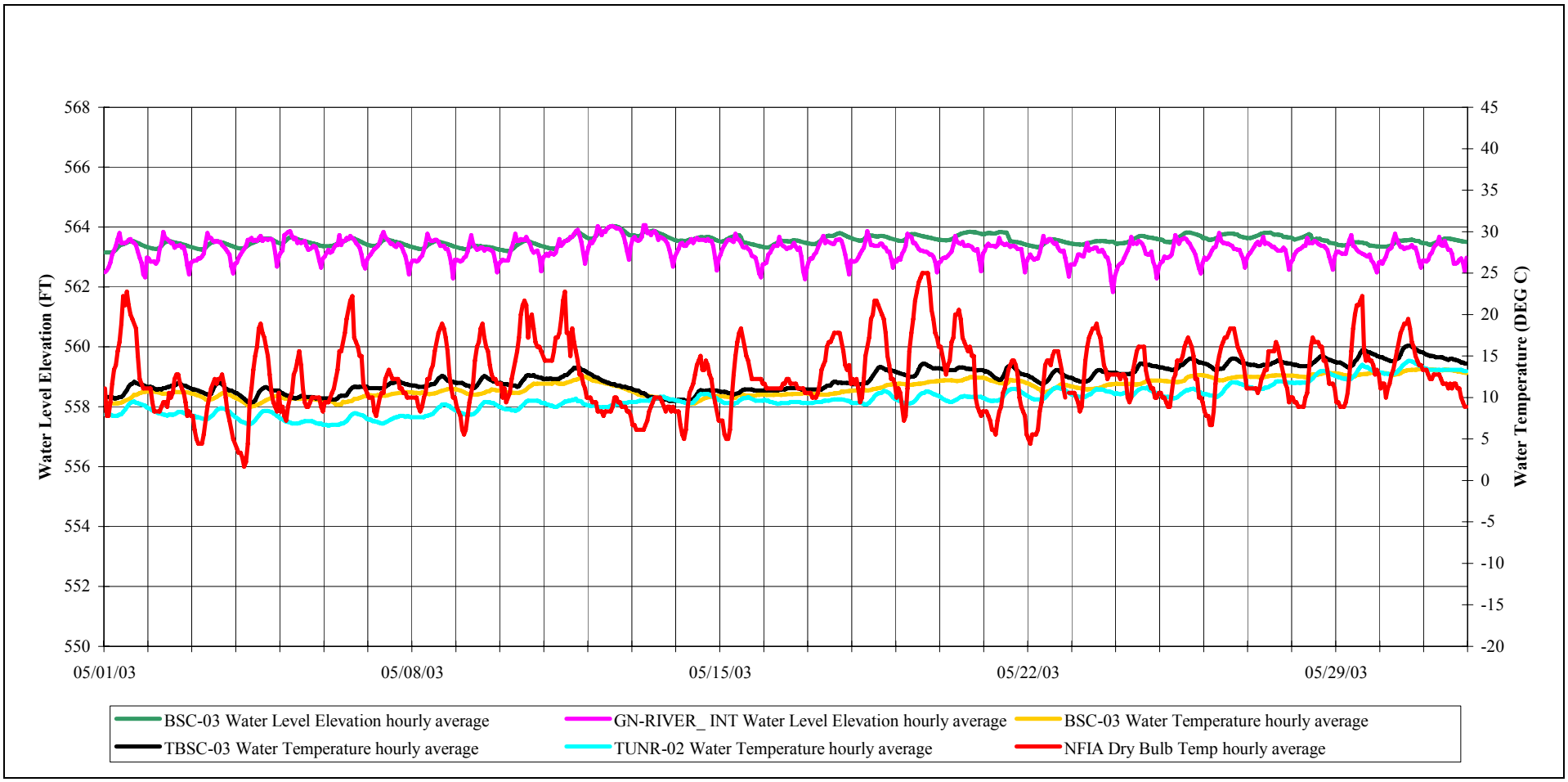

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FIGURE B-22: BURNT SHIP CREEK (TBSC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

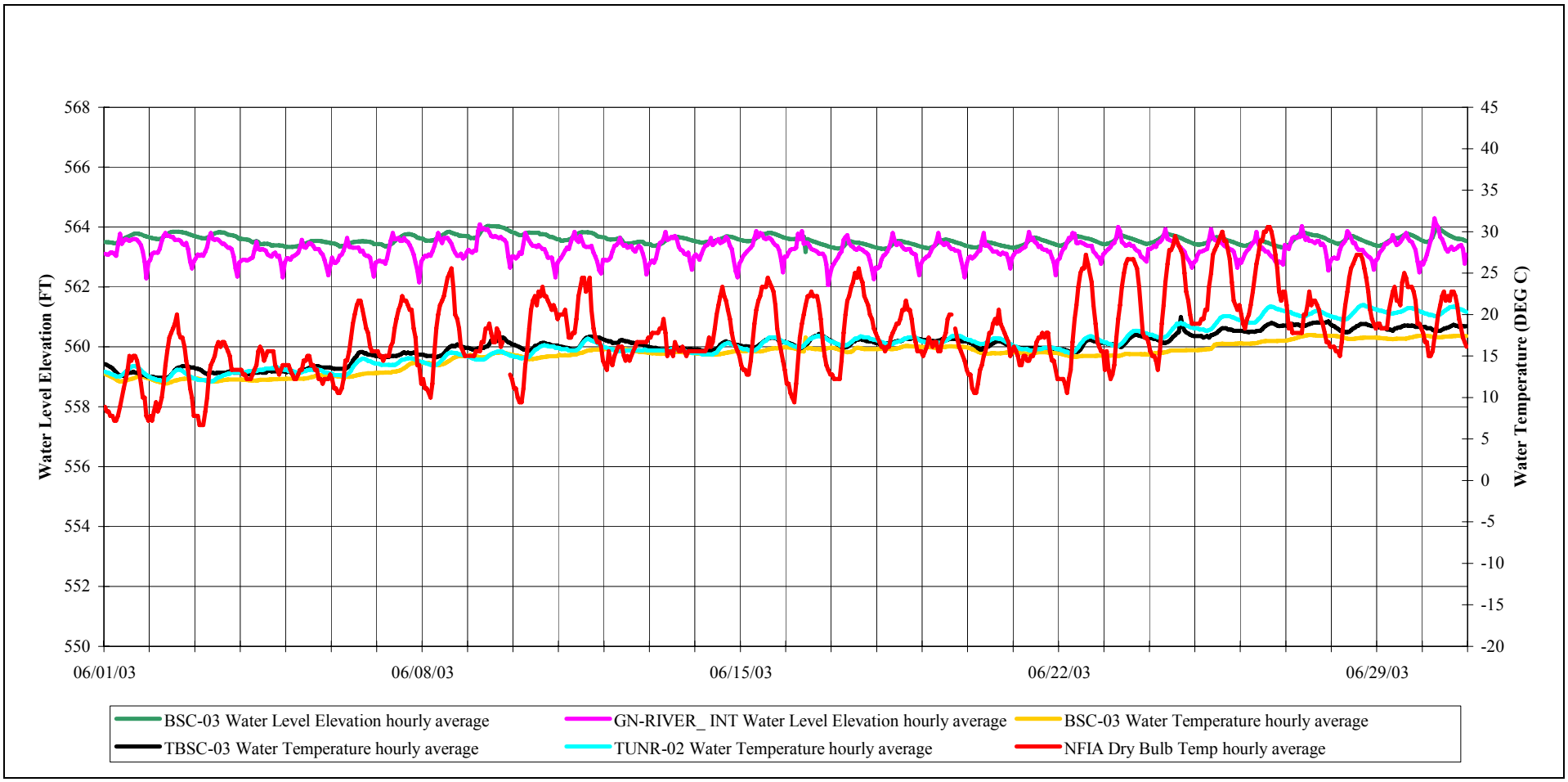

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FIGURE B-23: BURNT SHIP CREEK (TBSC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

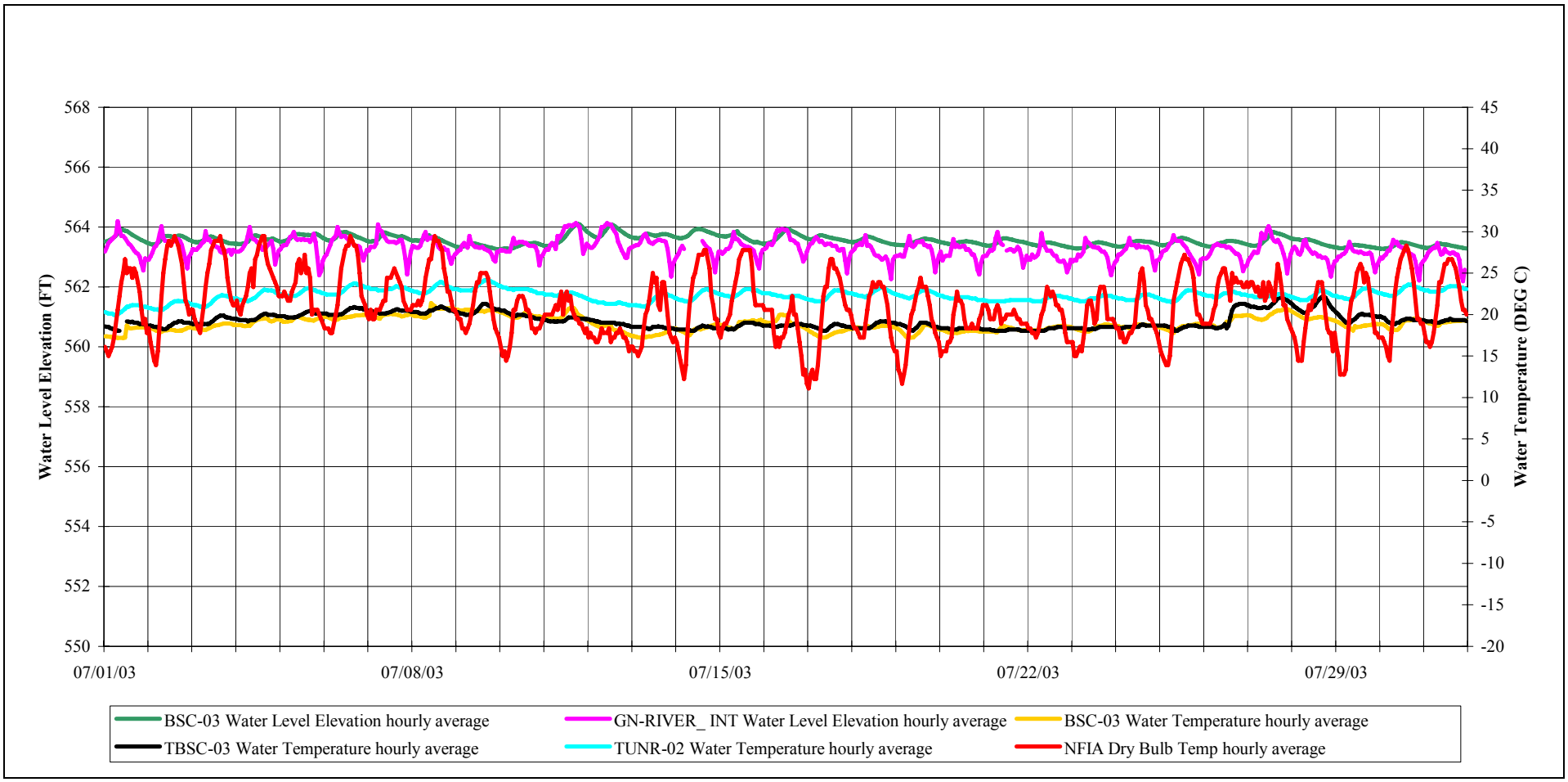

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FIGURE B-24: BURNT SHIP CREEK (TBSC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

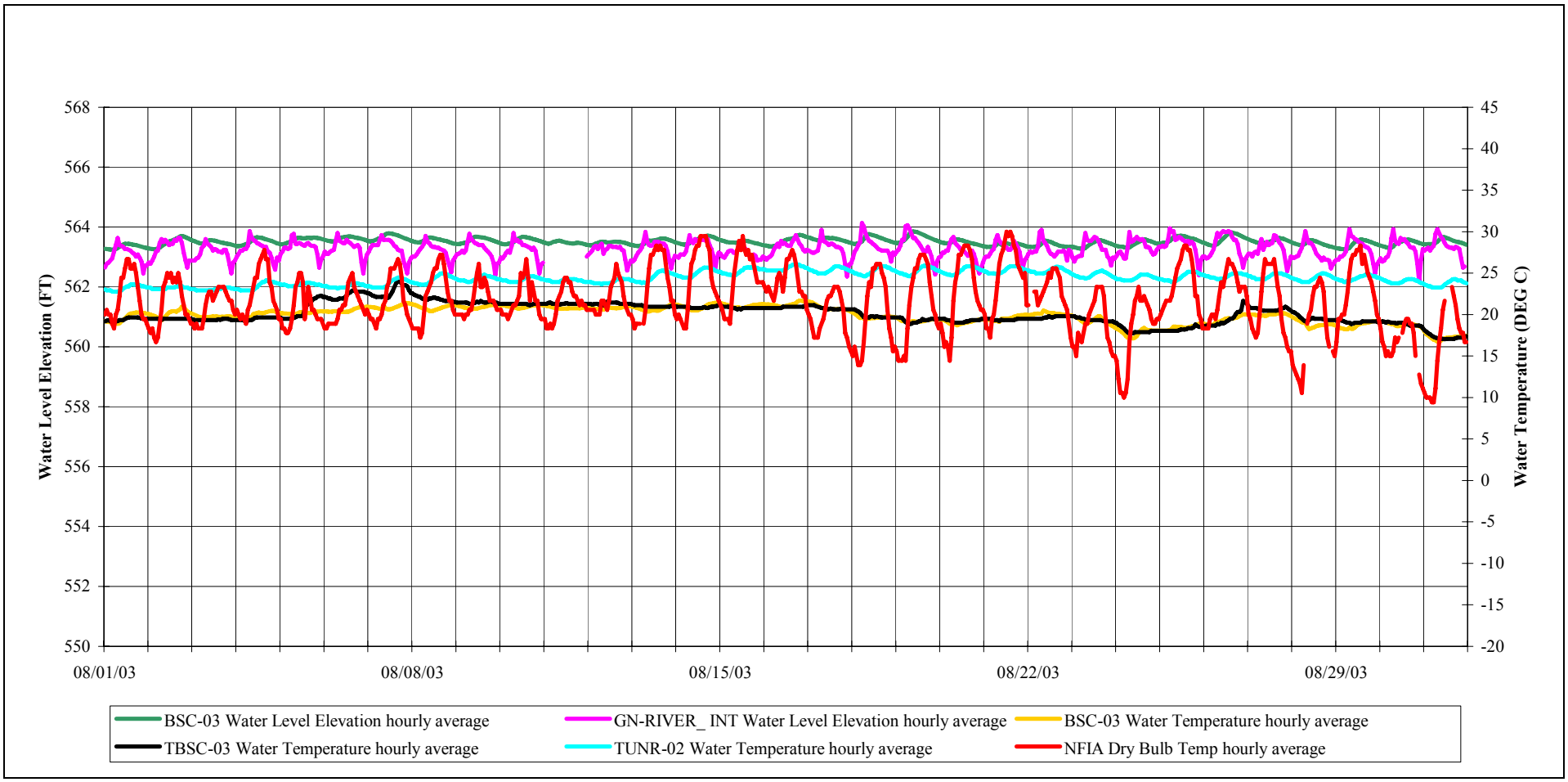

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FIGURE B-25: BURNT SHIP CREEK (TBSC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

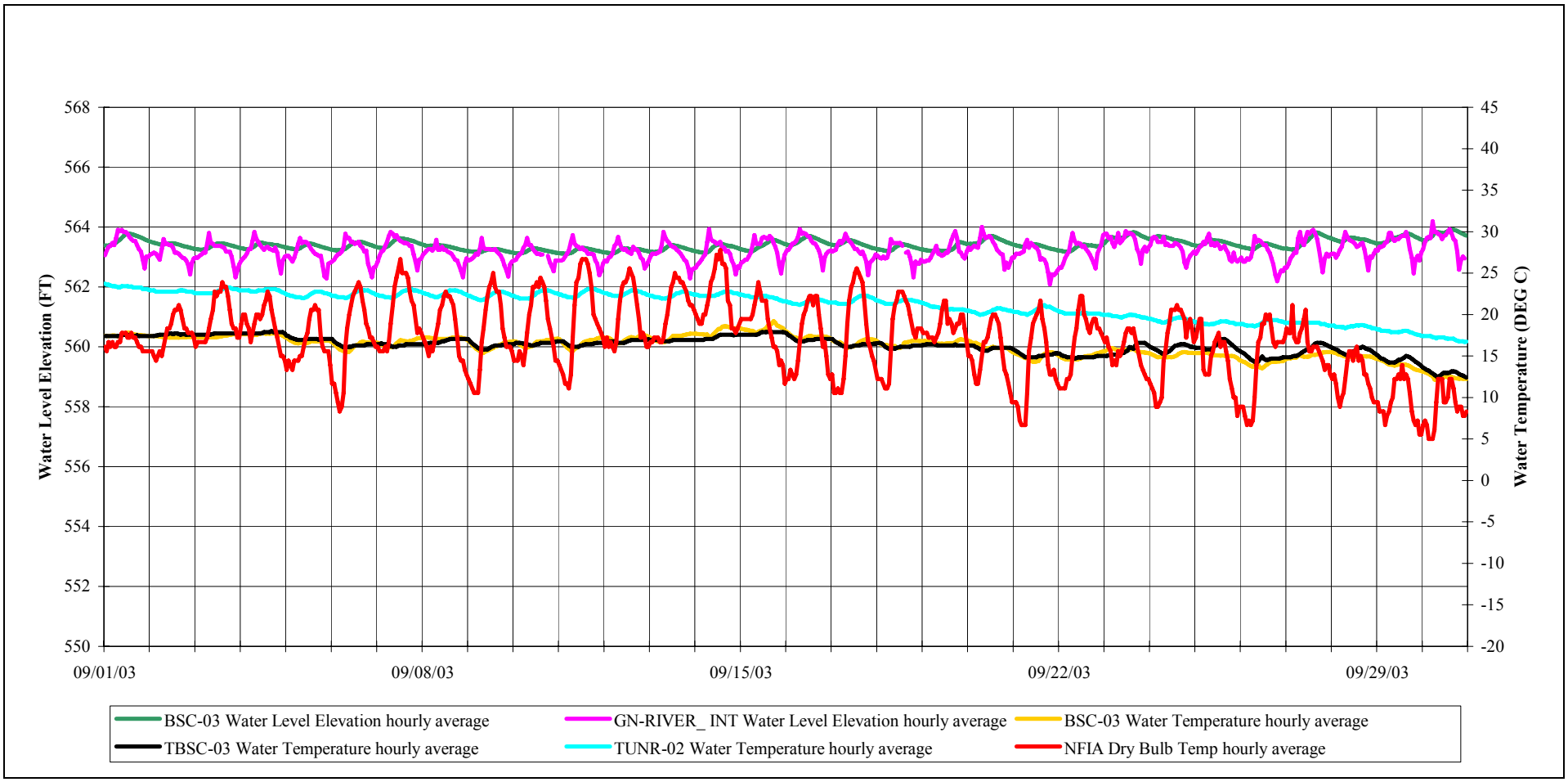

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FIGURE B-26: BURNT SHIP CREEK (TBSC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

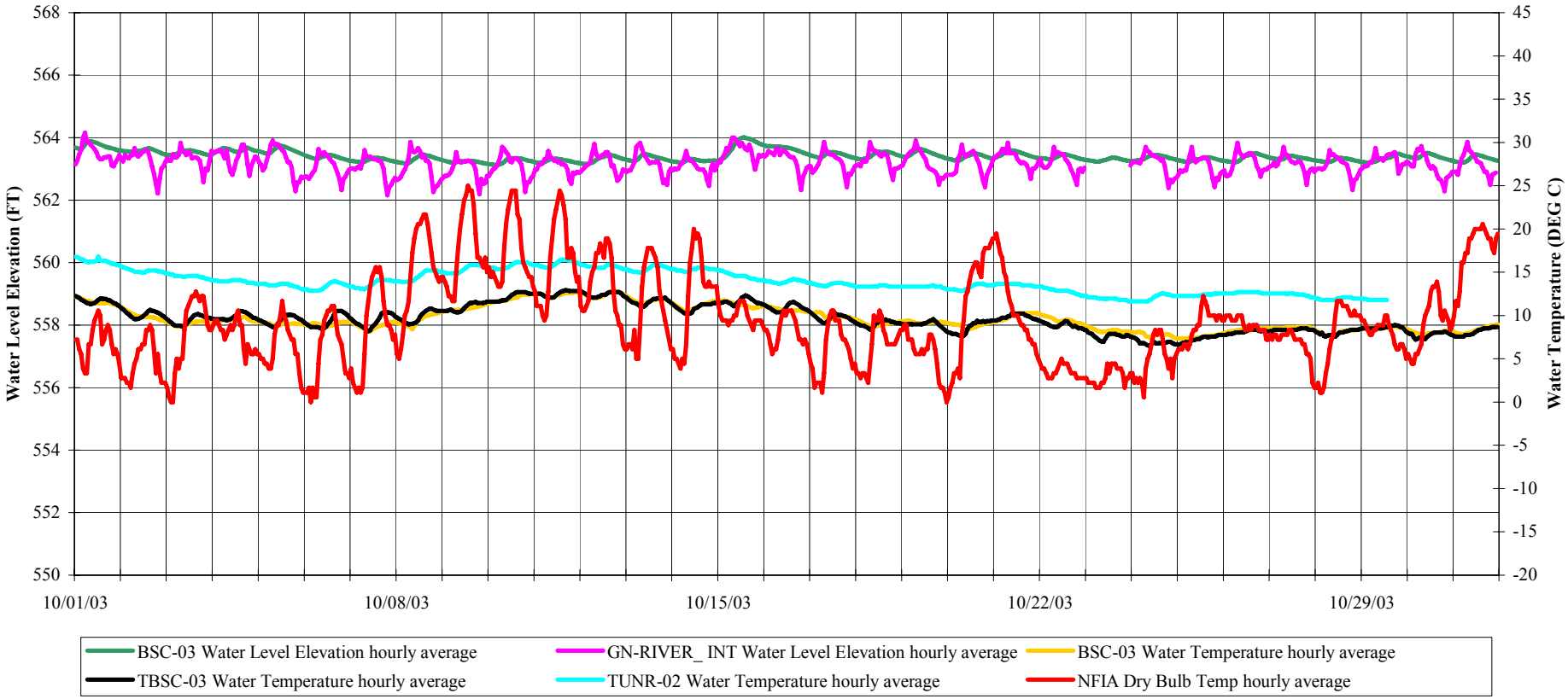

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FIGURE B-27: BURNT SHIP CREEK (TBSC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

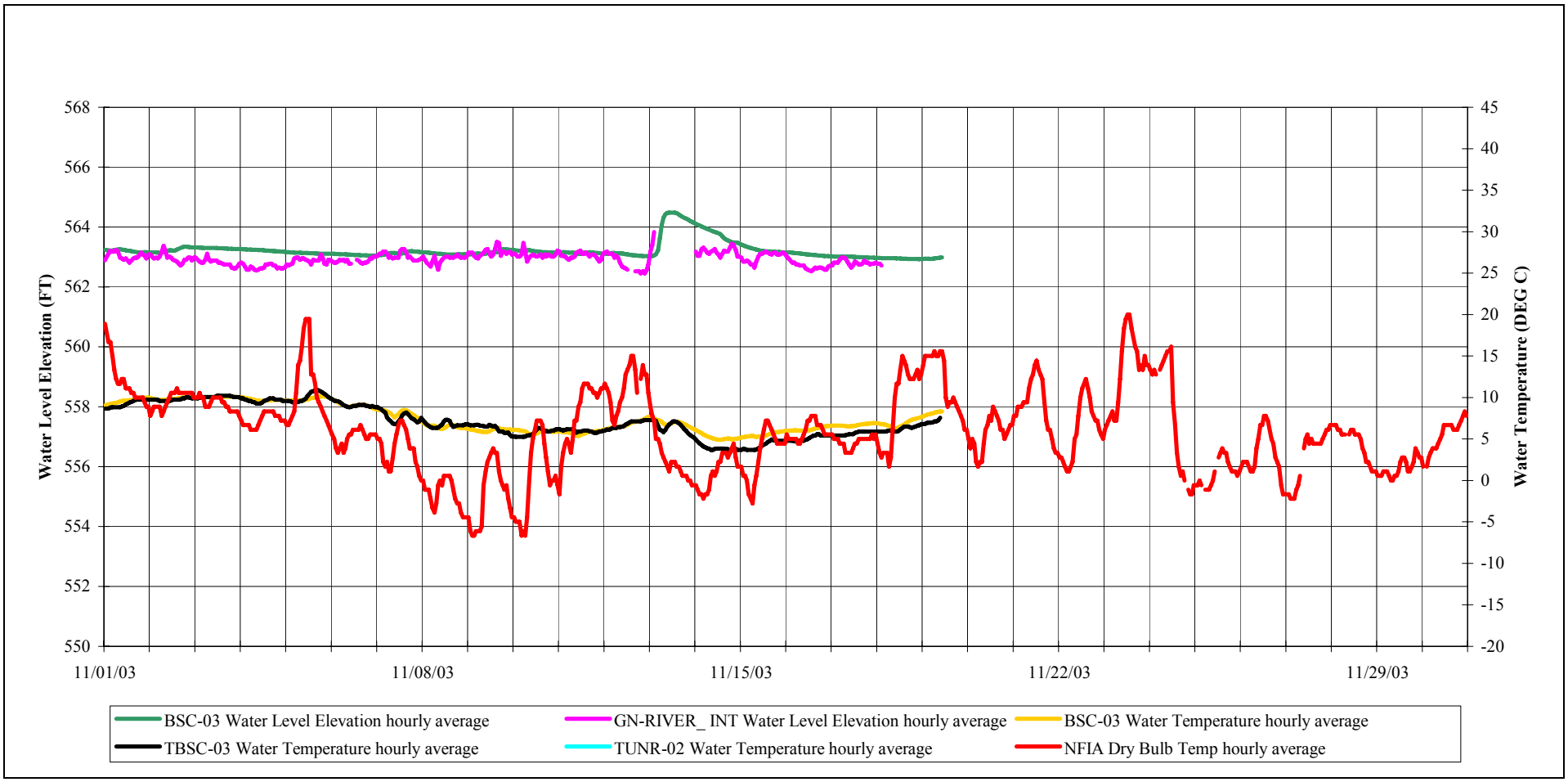

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FIGURE B-28: BUCKHORN MARSH-WEST

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2002

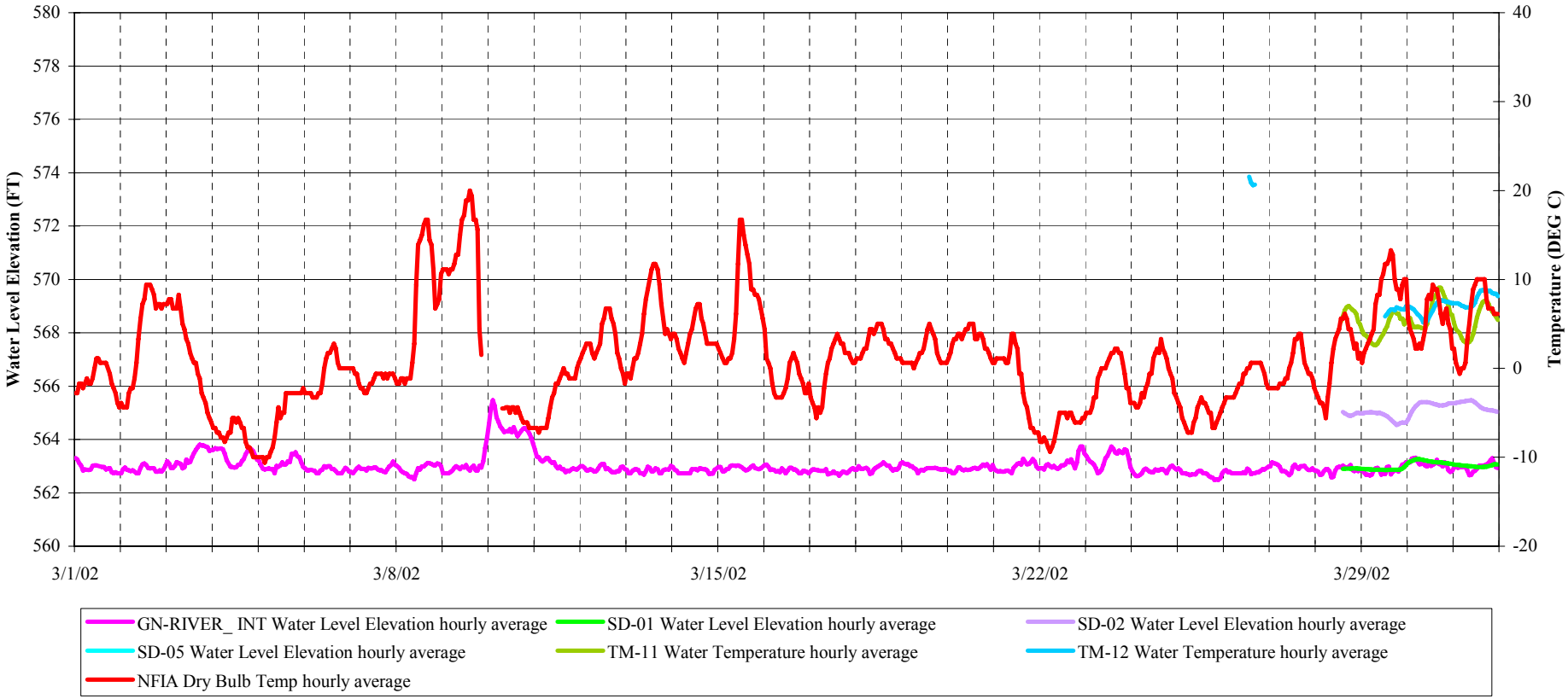

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FIGURE B-29: BUCKHORN MARSH-WEST

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

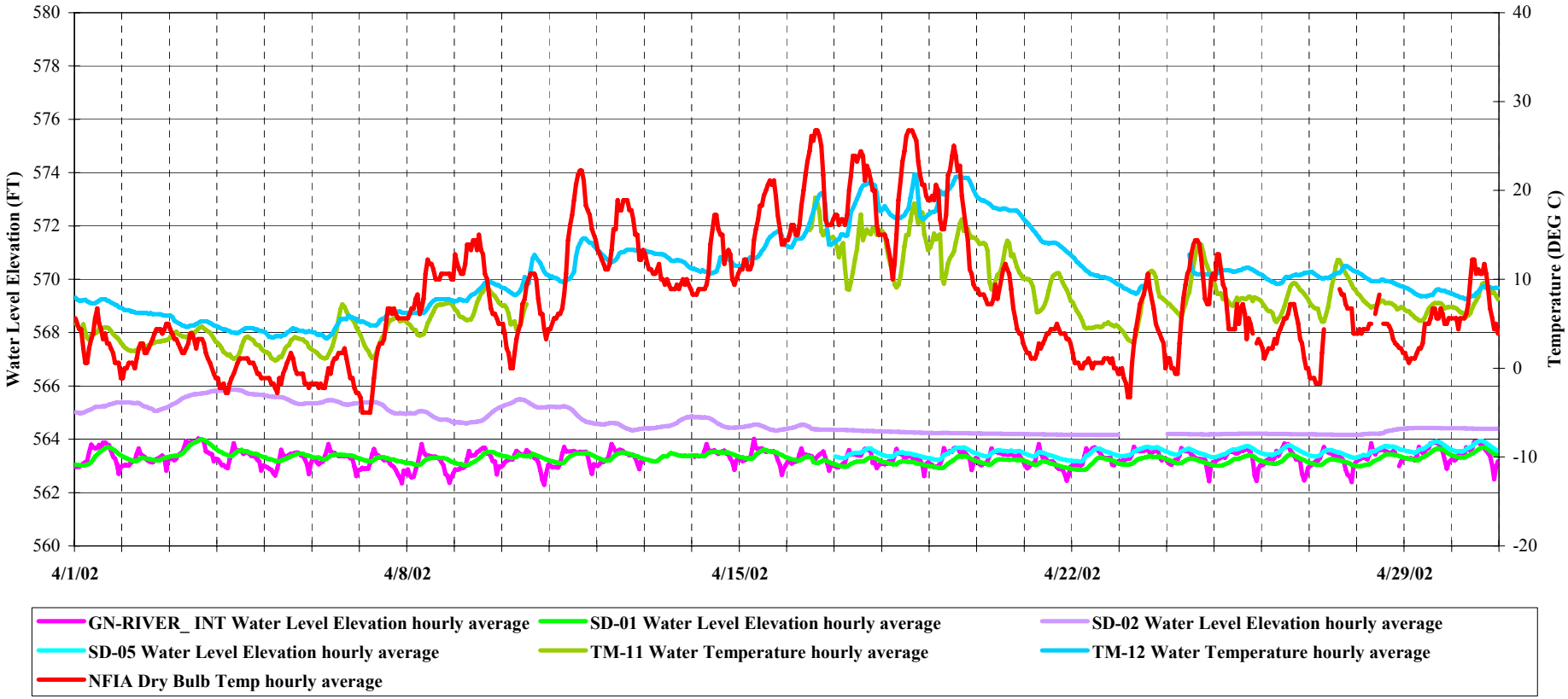

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FIGURE B-30: BUCKHORN MARSH-WEST

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

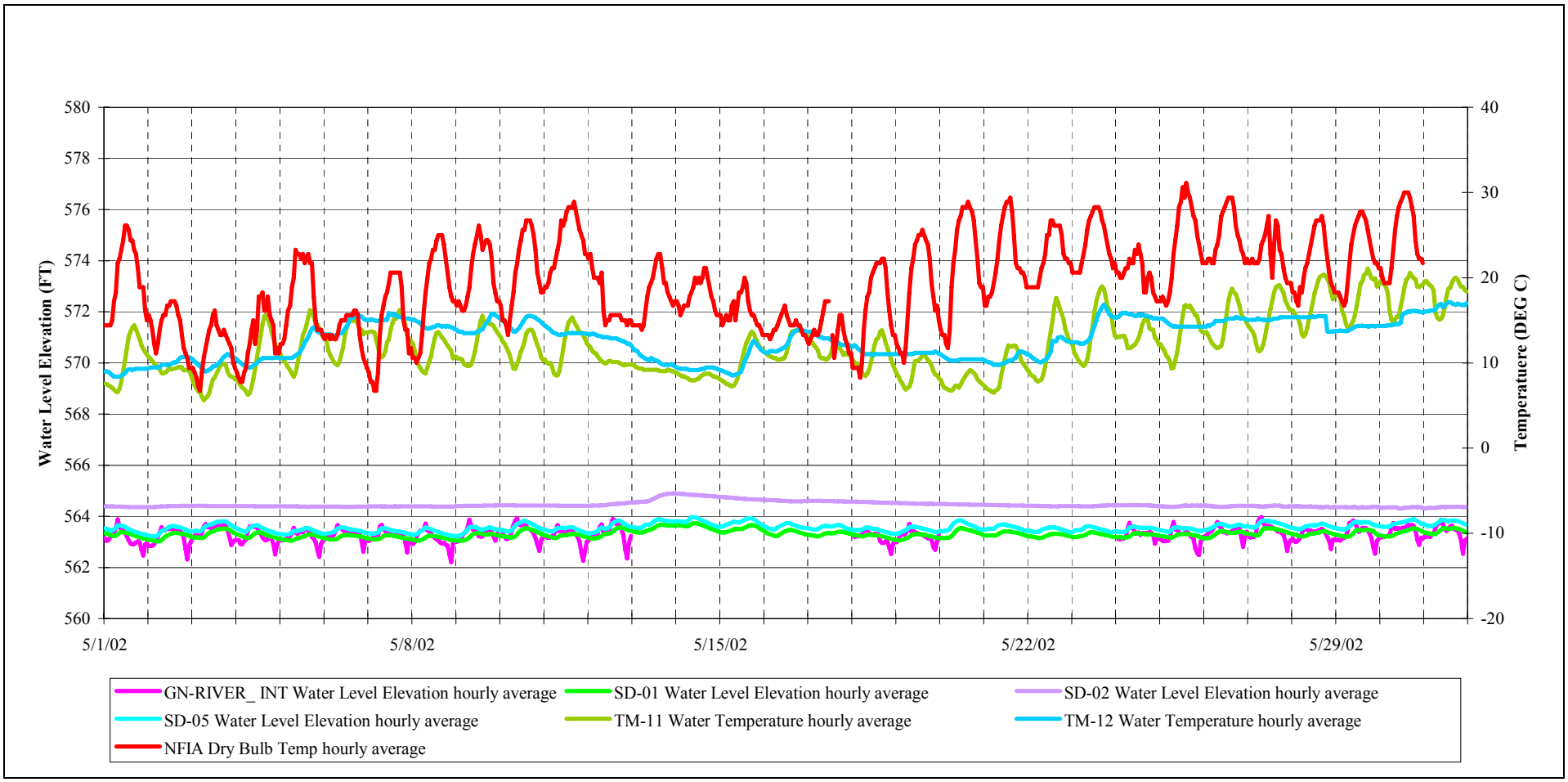

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FIGURE B-31: BUCKHORN MARSH-WEST

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

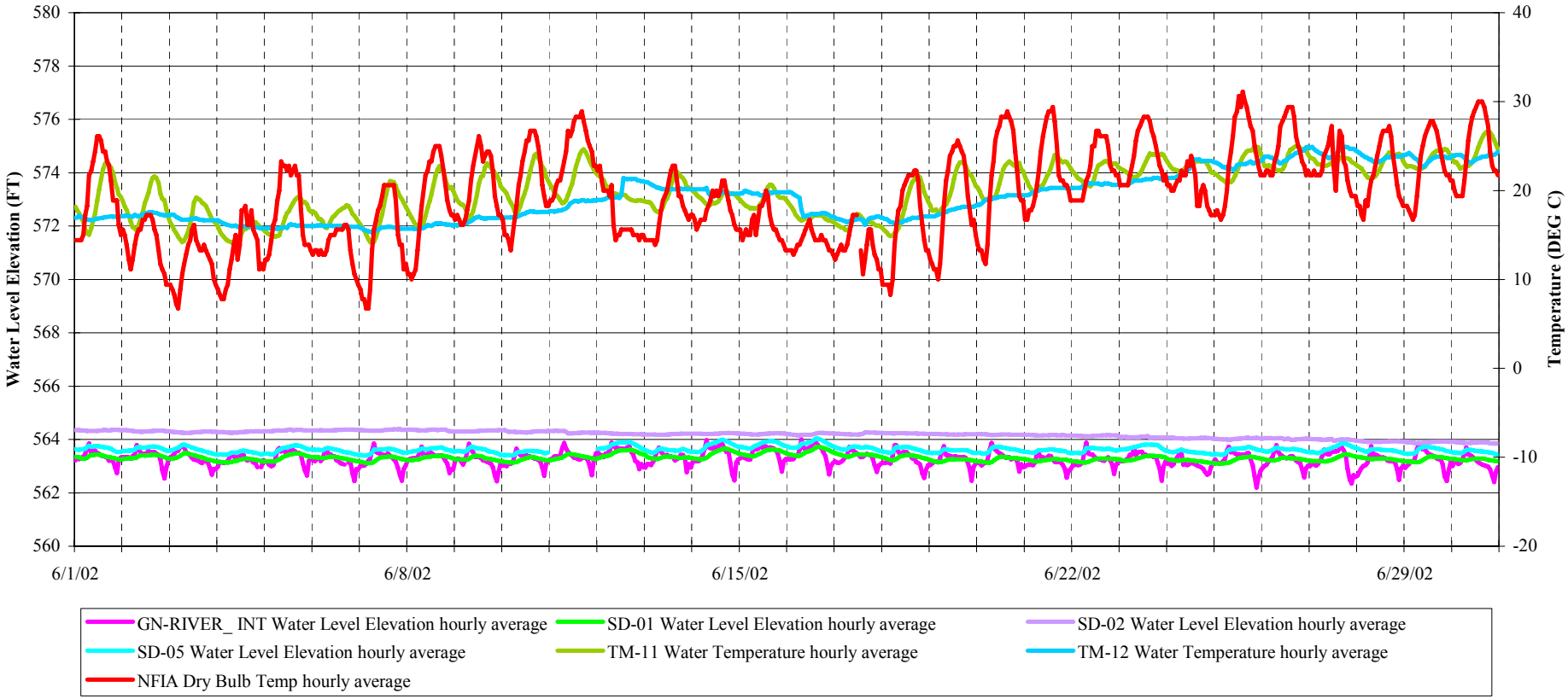

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FIGURE B-32: BUCKHORN MARSH-WEST

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

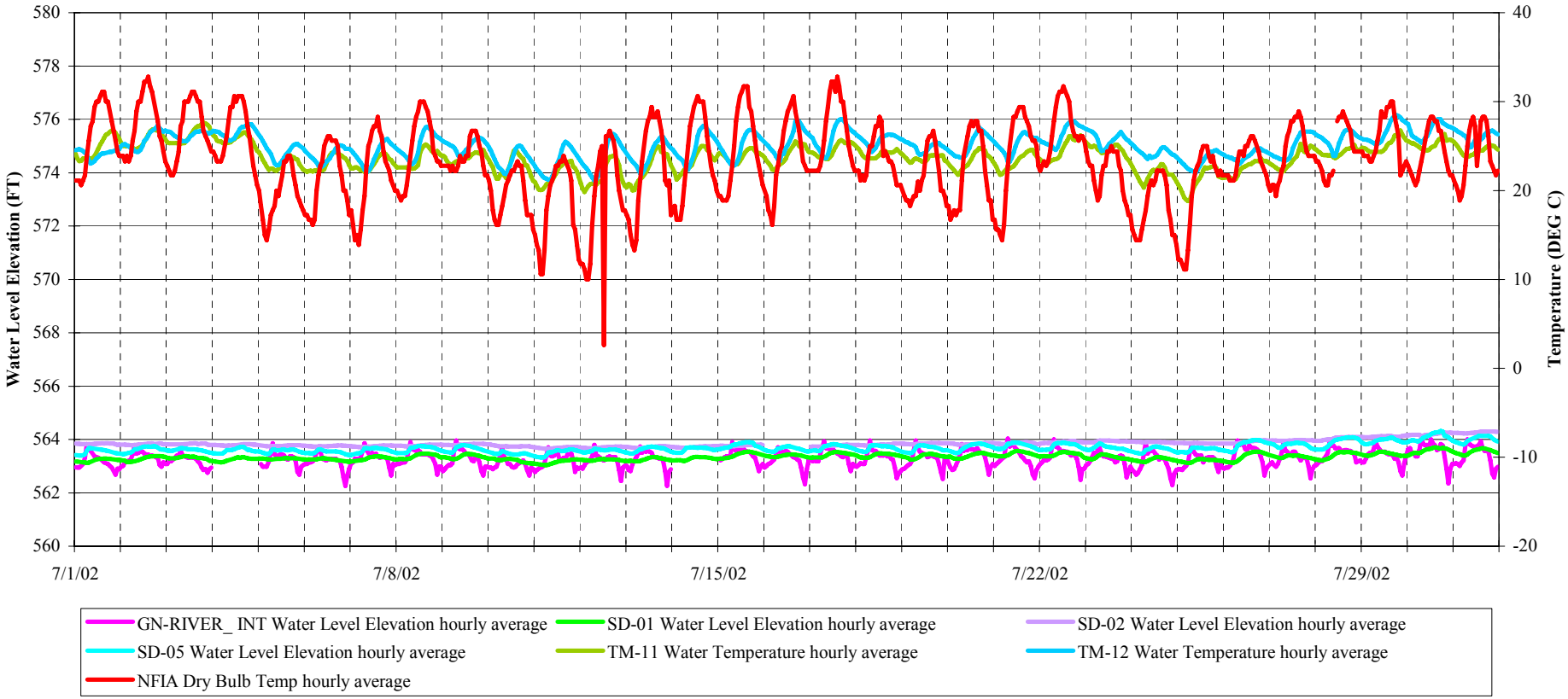

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FIGURE B-33: BUCKHORN MARSH-WEST

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

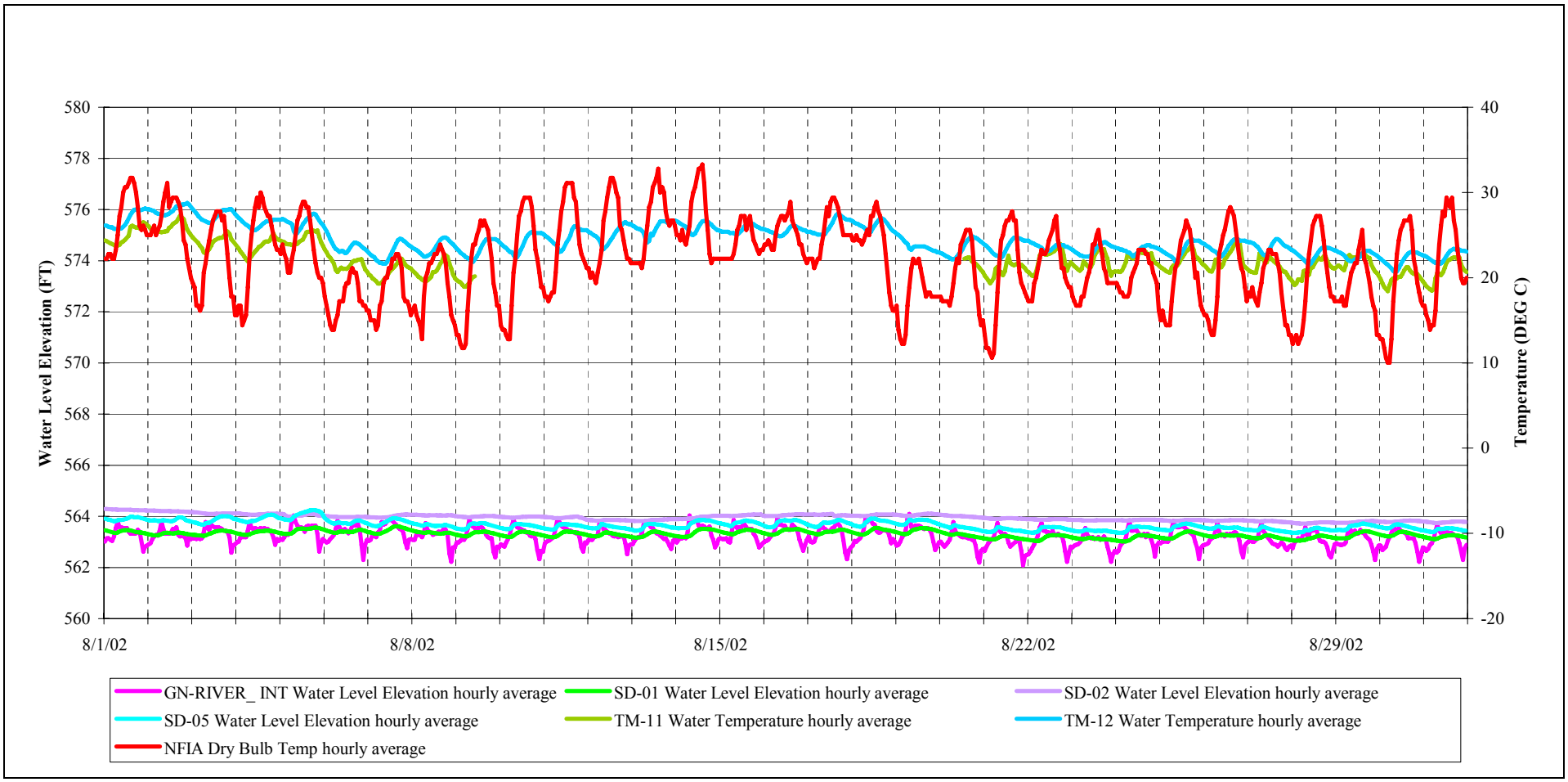

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FIGURE B-34: BUCKHORN MARSH-WEST

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

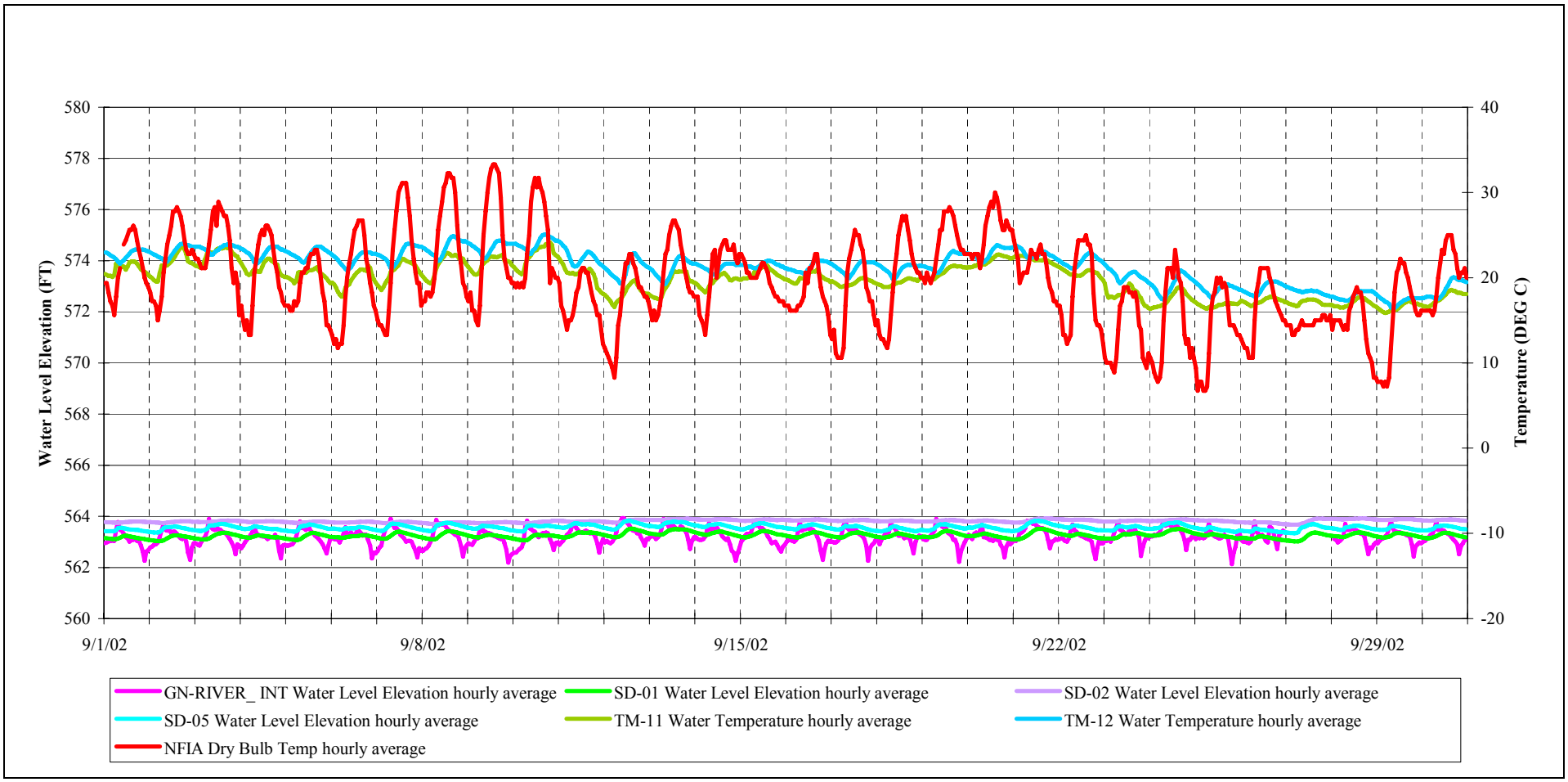

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FIGURE B-35: BUCKHORN MARSH-WEST

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

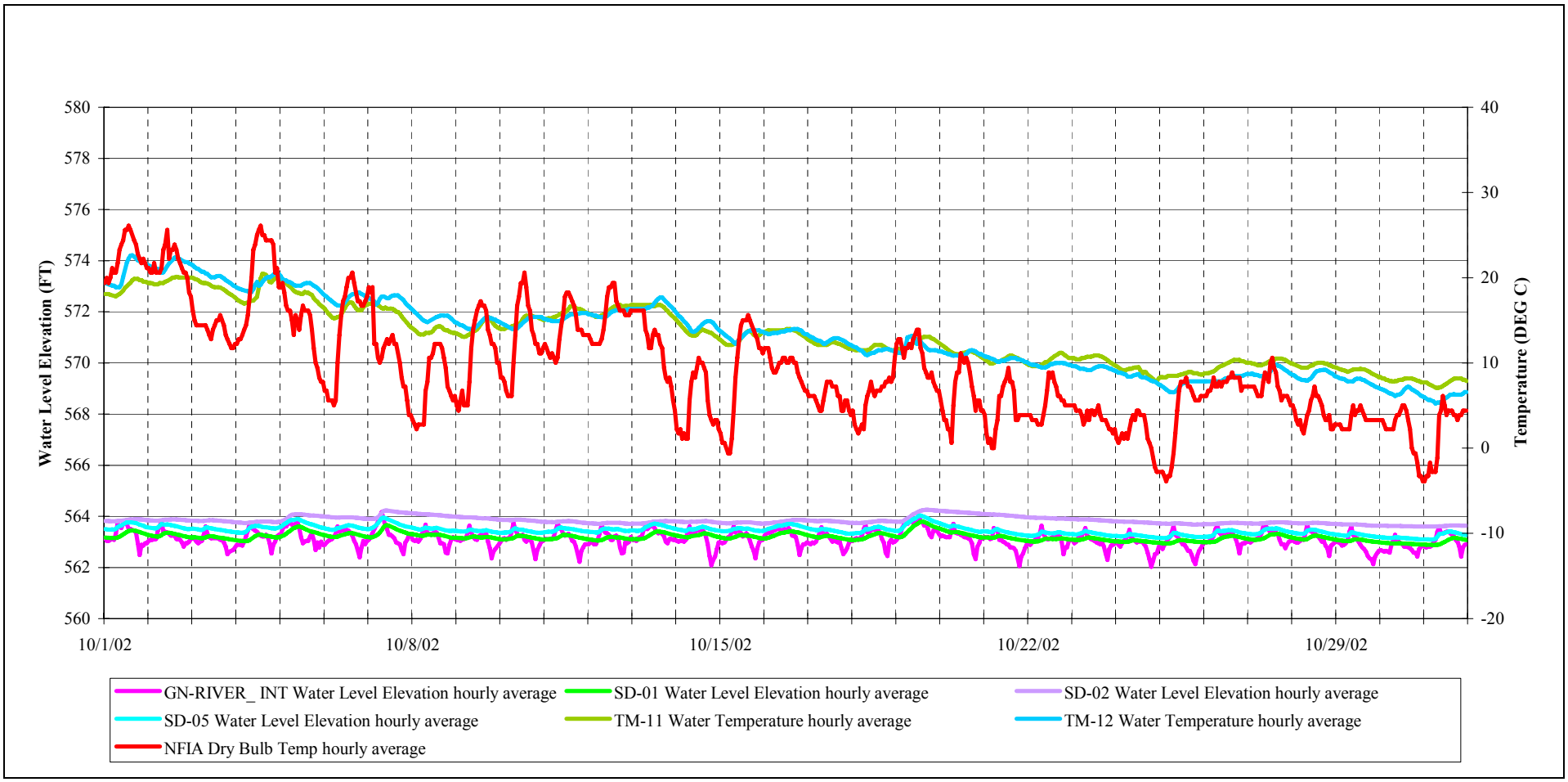

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FIGURE B-36: BUCKHORN MARSH-WEST

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2002

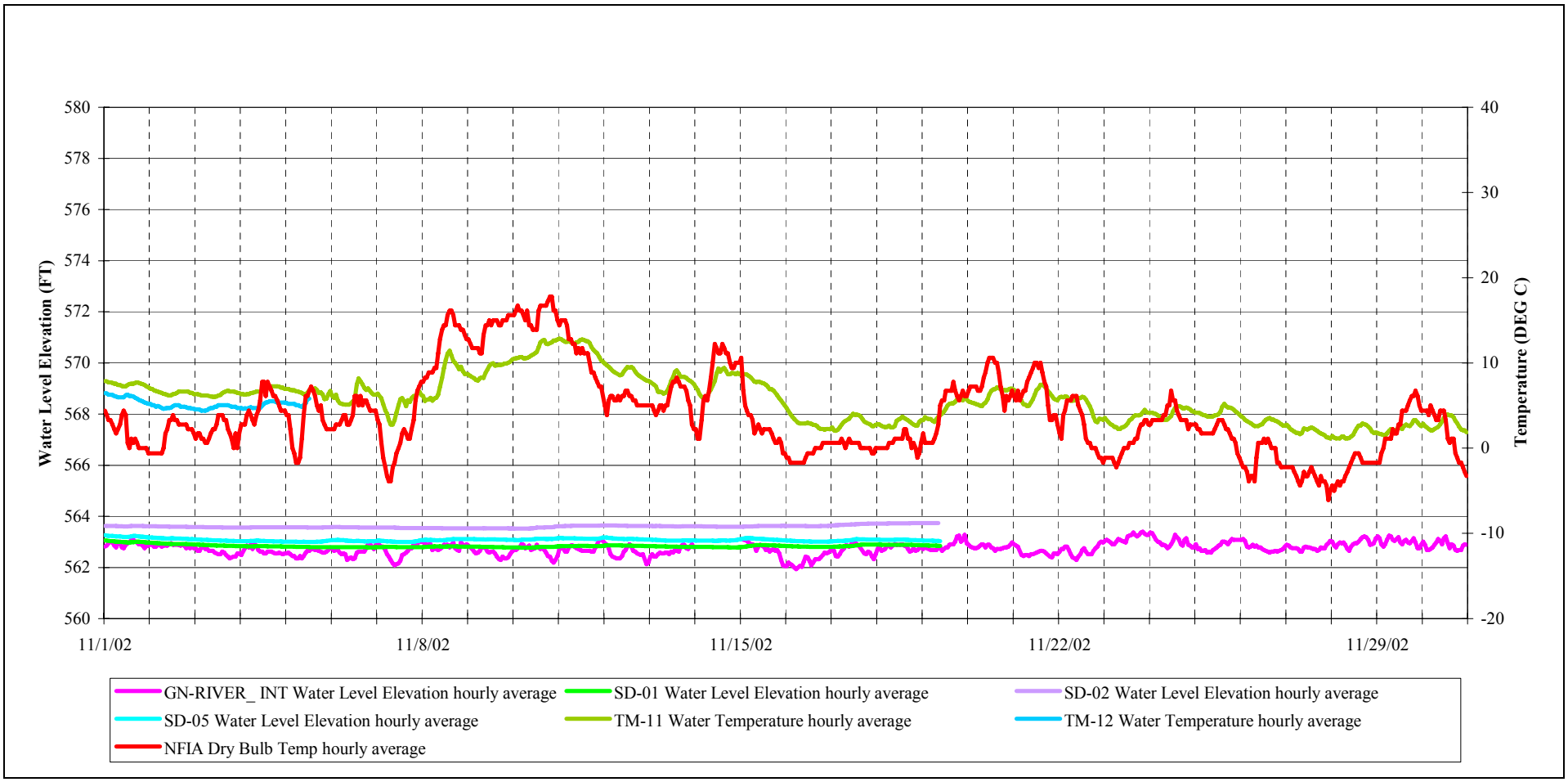

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FIGURE B-37: WEST END BUCKHORN MARSH AND BURNT SHIP CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

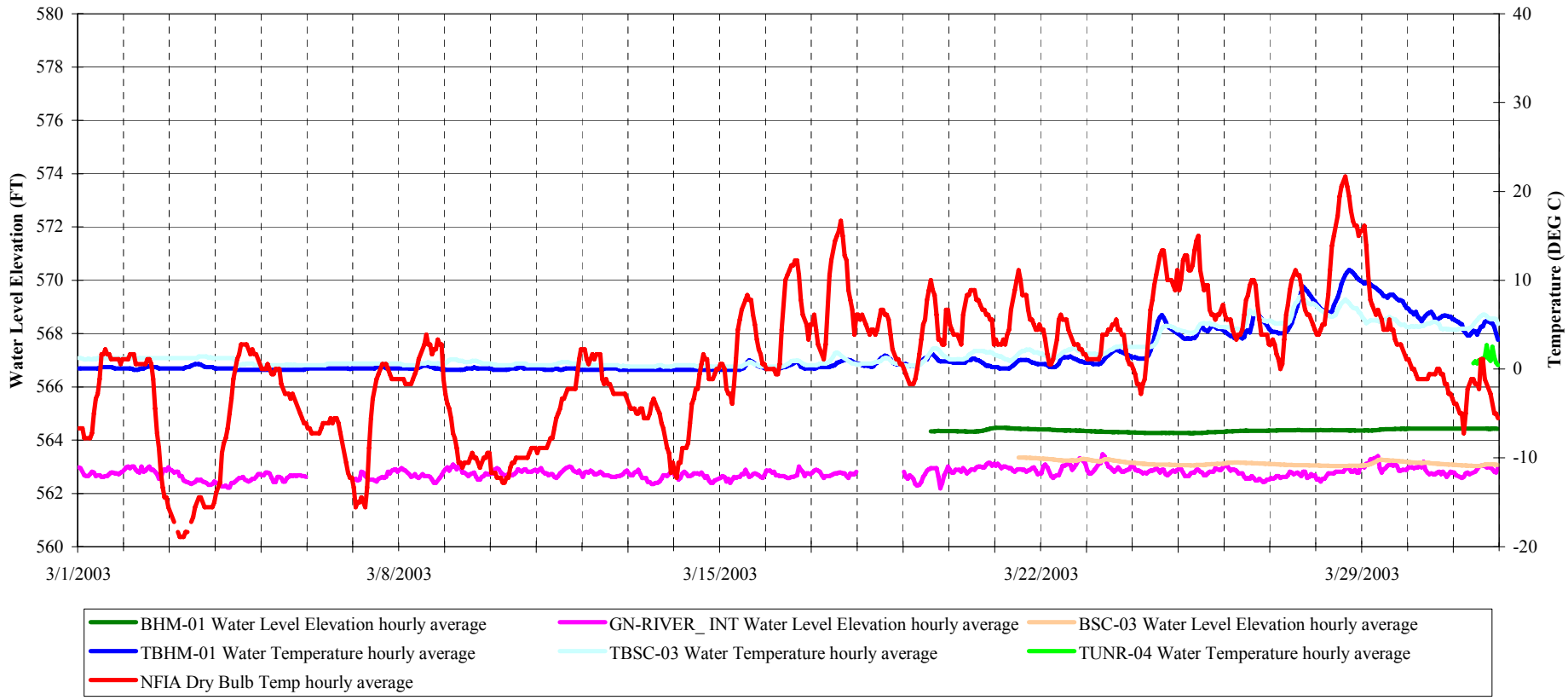

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FIGURE B-38: WEST END BUCKHORN MARSH AND BURNT SHIP CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

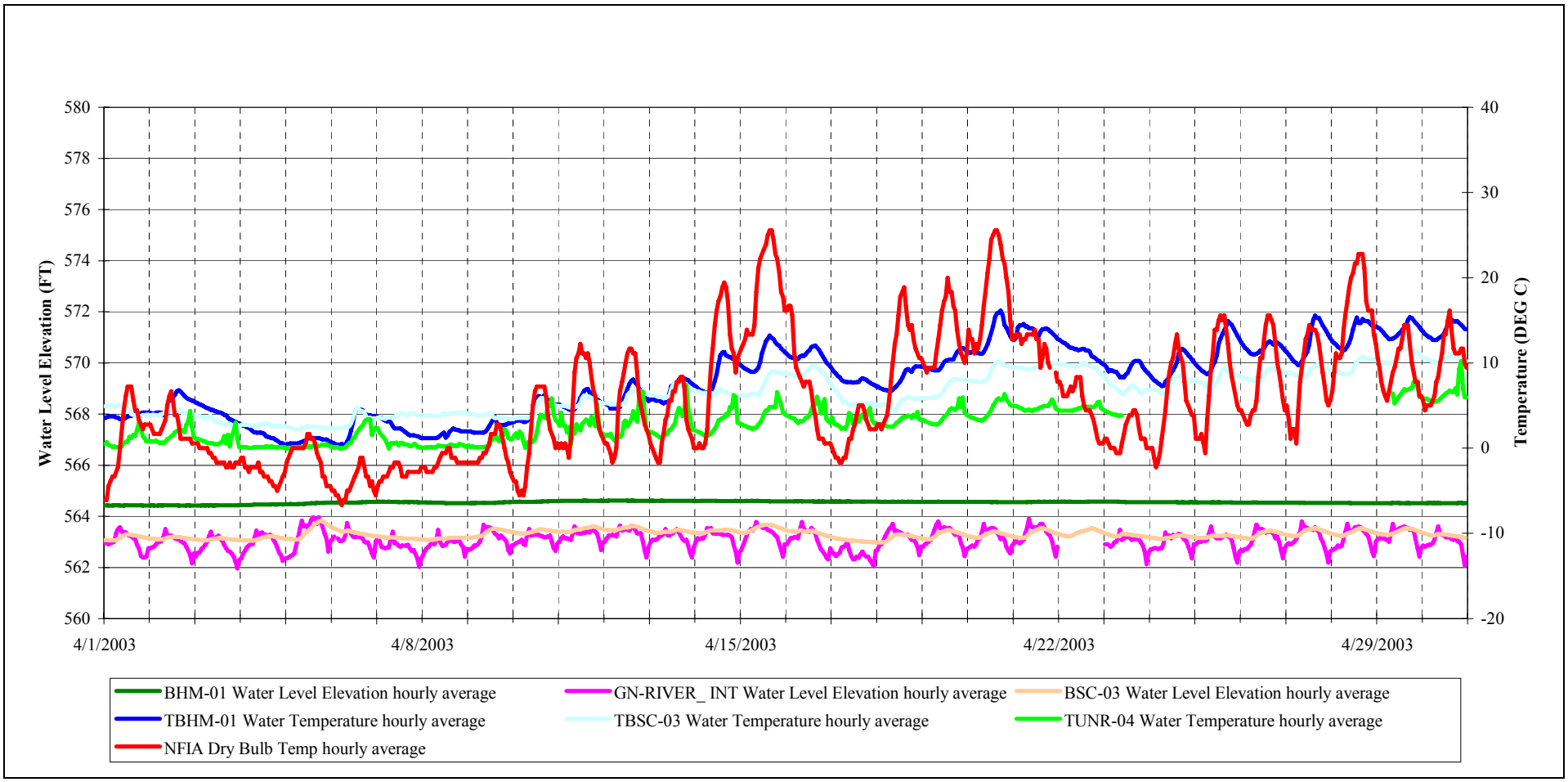

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FIGURE B-39: WEST END BUCKHORN MARSH AND BURNT SHIP CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

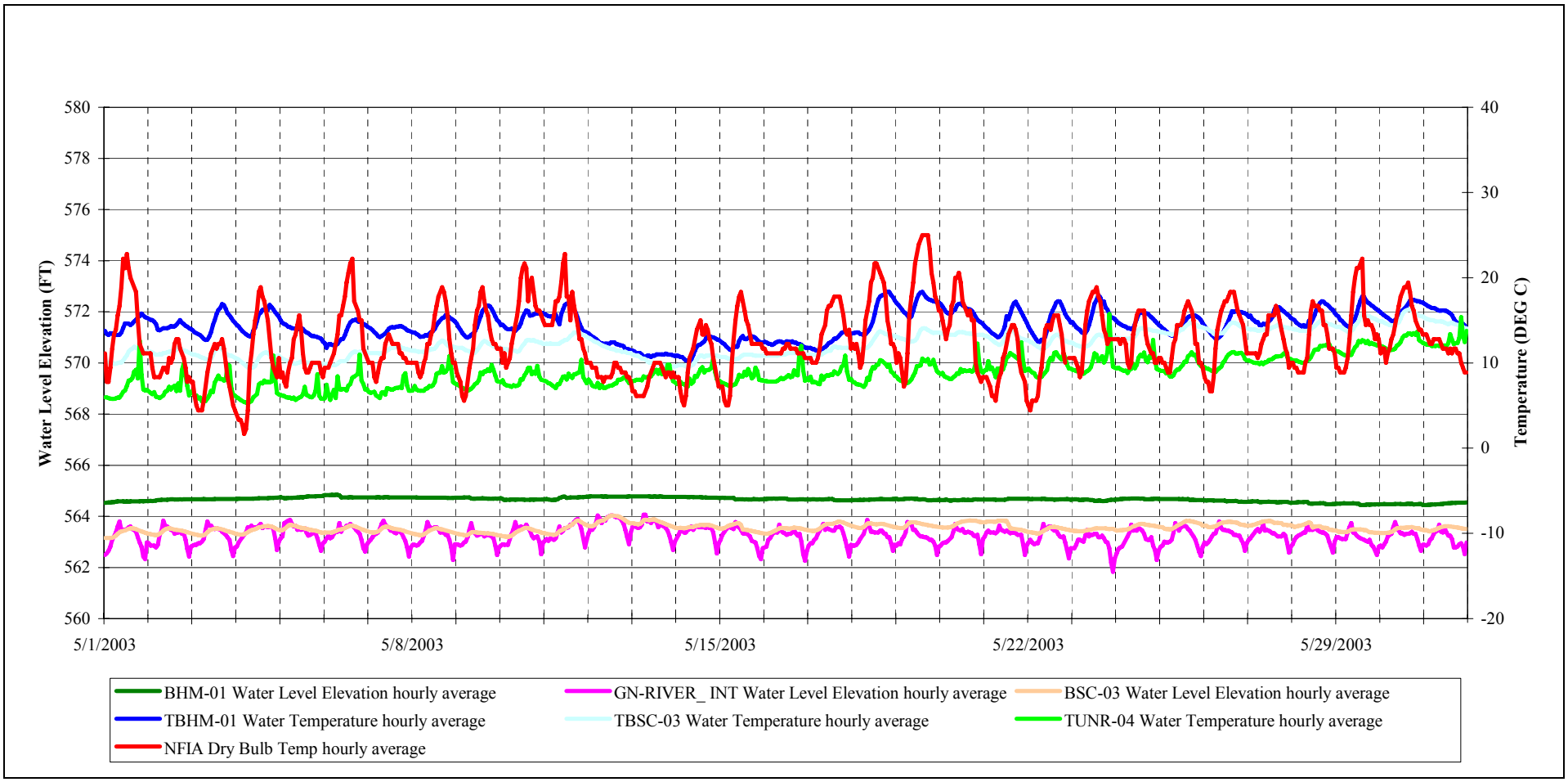

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FIGURE B-40: WEST END BUCKHORN MARSH AND BURNT SHIP CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

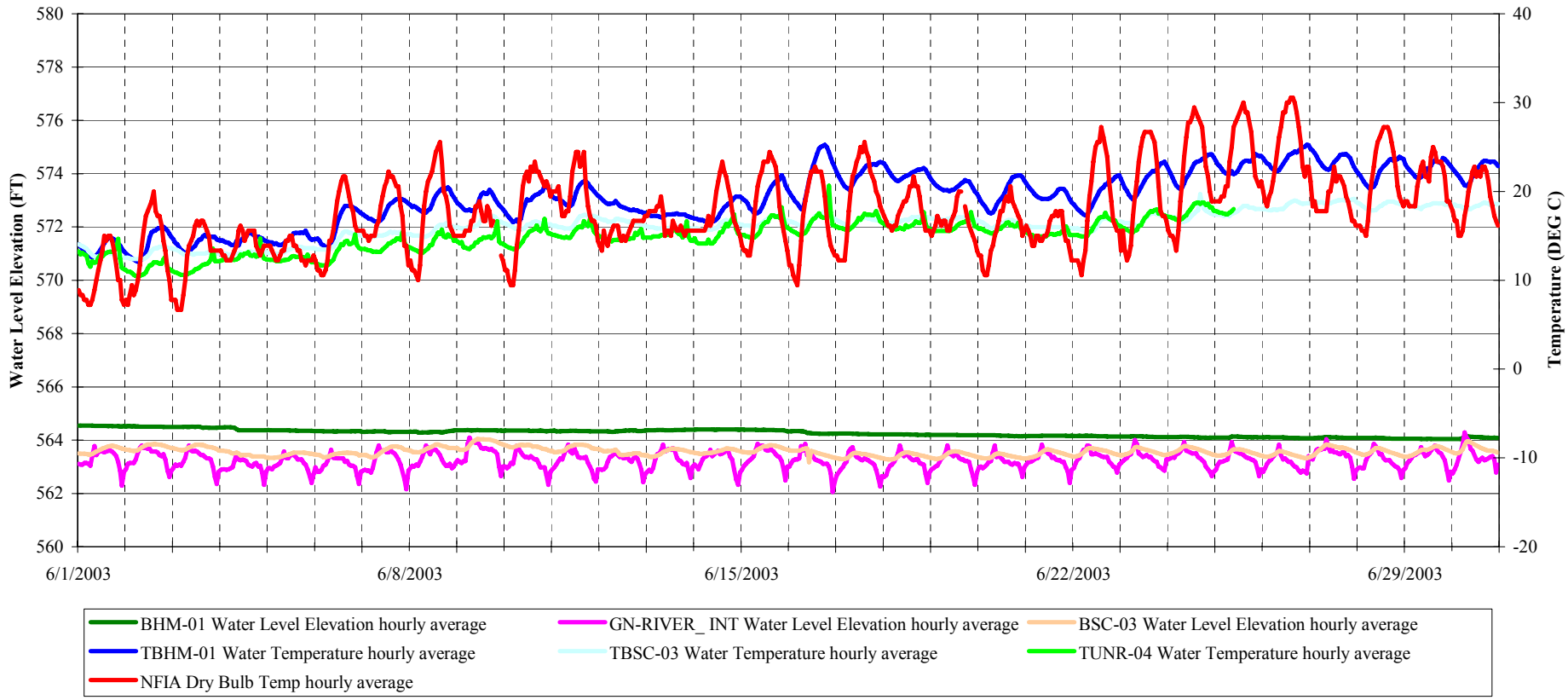

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FIGURE B-41: WEST END BUCKHORN MARSH AND BURNT SHIP CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

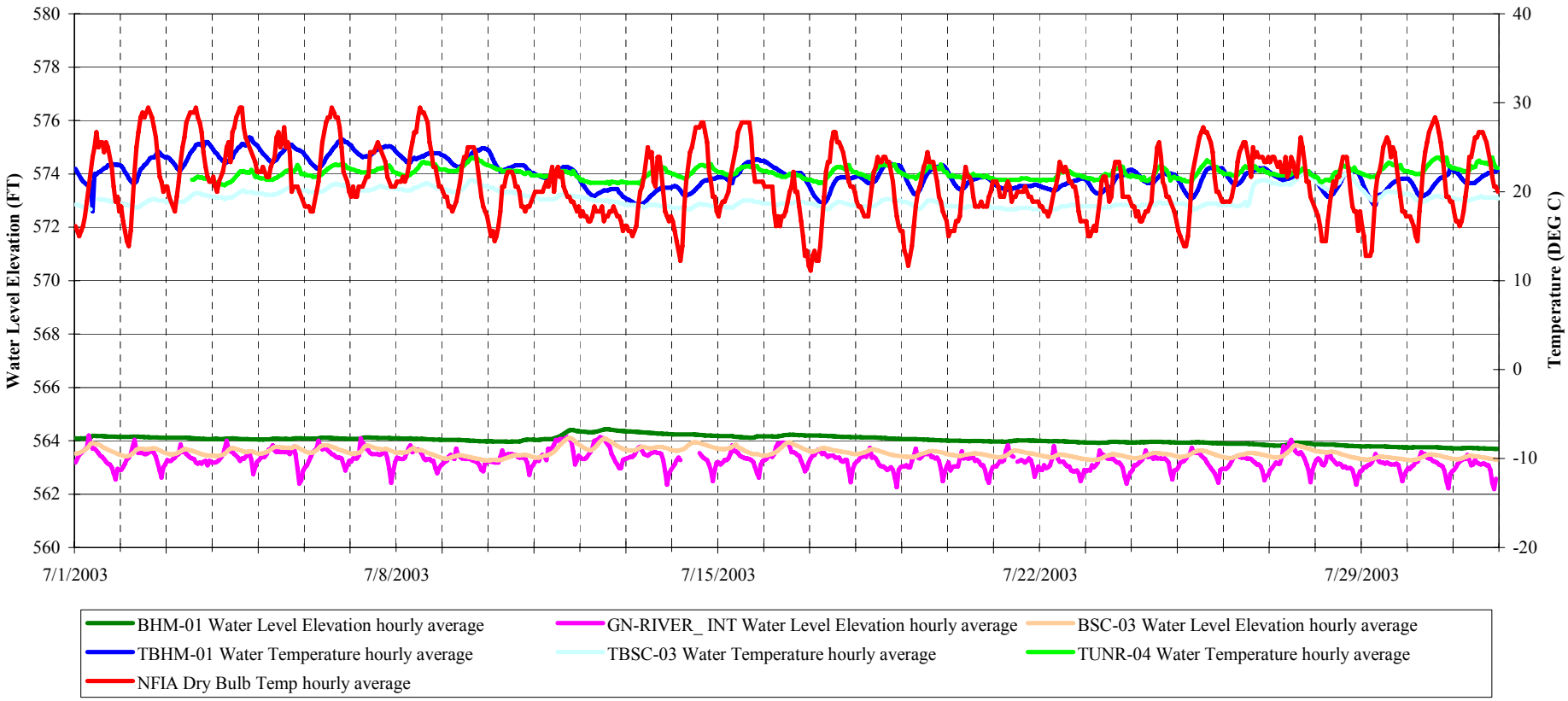

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FIGURE B-42: WEST END BUCKHORN MARSH AND BURNT SHIP CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

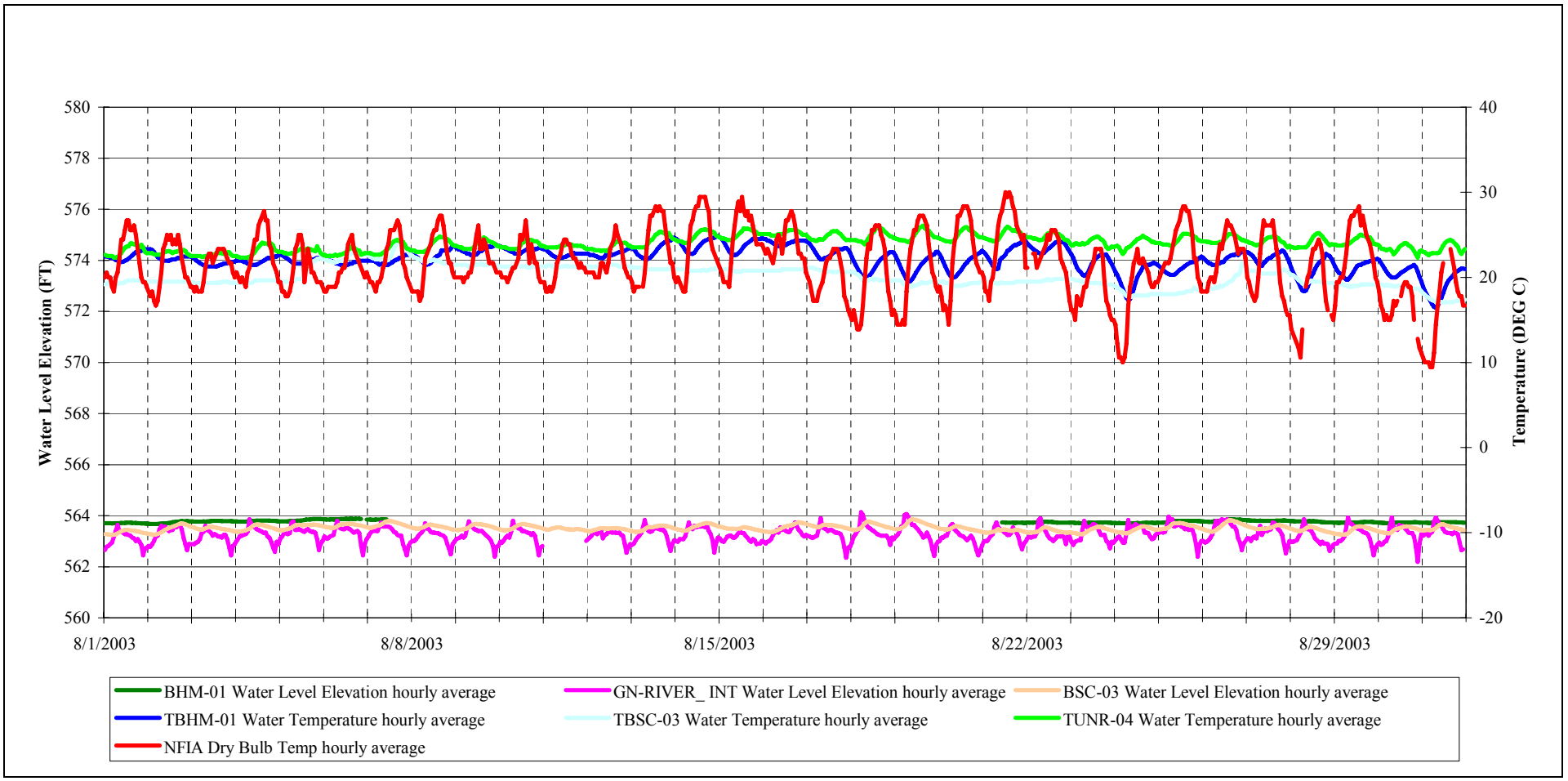

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FIGURE B-43: WEST END BUCKHORN MARSH AND BURNT SHIP CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

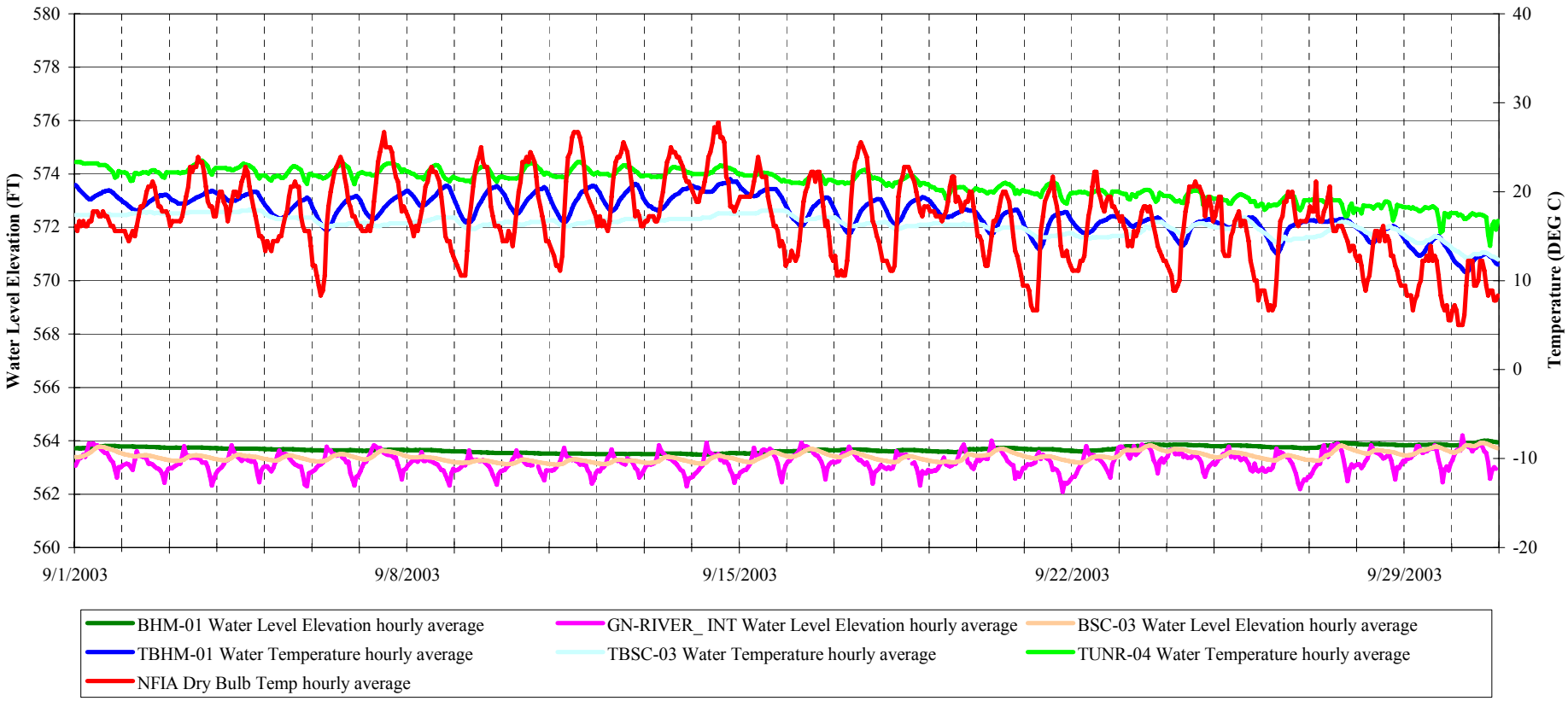

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FIGURE B-44: WEST END BUCKHORN MARSH AND BURNT SHIP CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

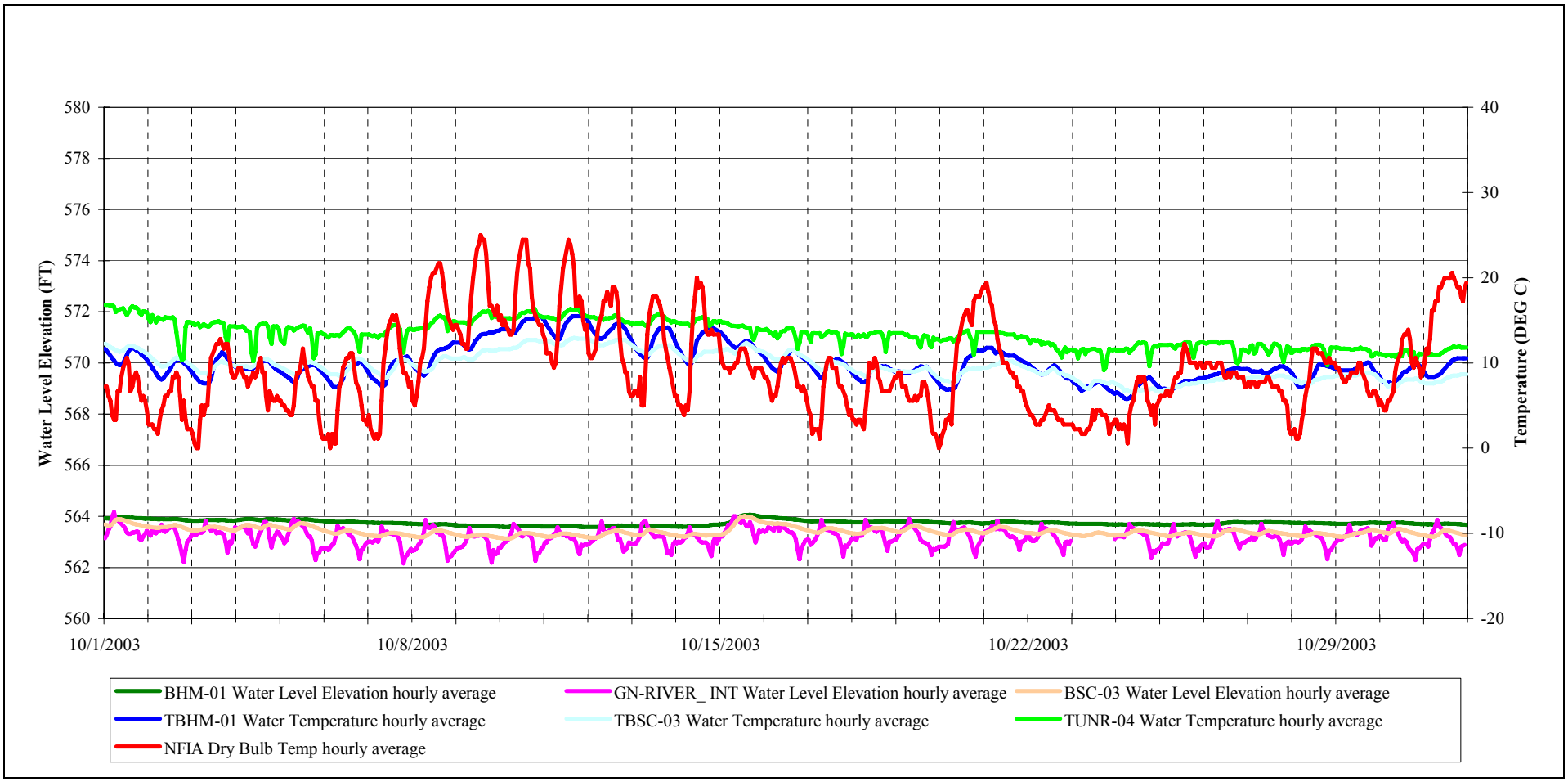

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FIGURE B-45: WEST END BUCKHORN MARSH AND BURNT SHIP CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

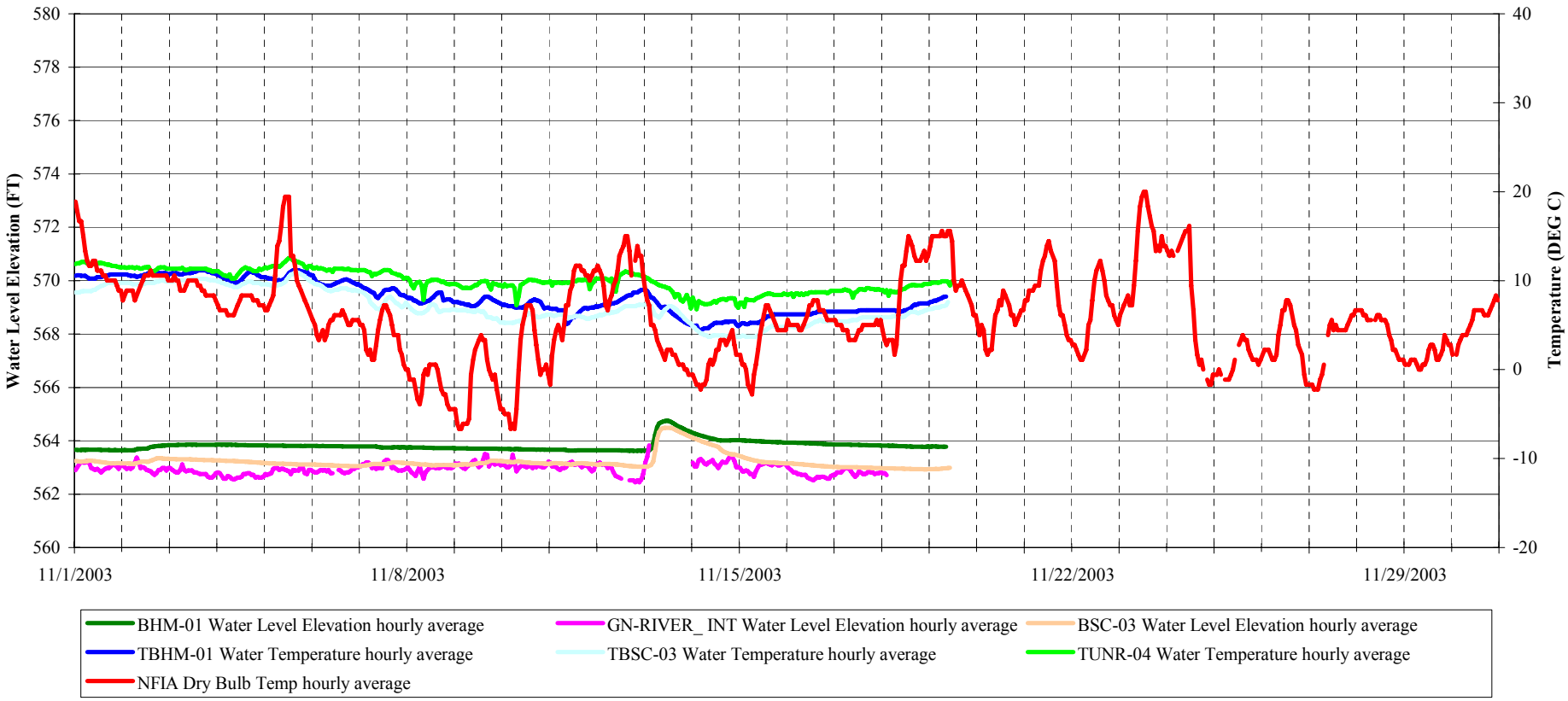

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FIGURE B-46: EAST END OF BUCKHORN MARSH AND WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

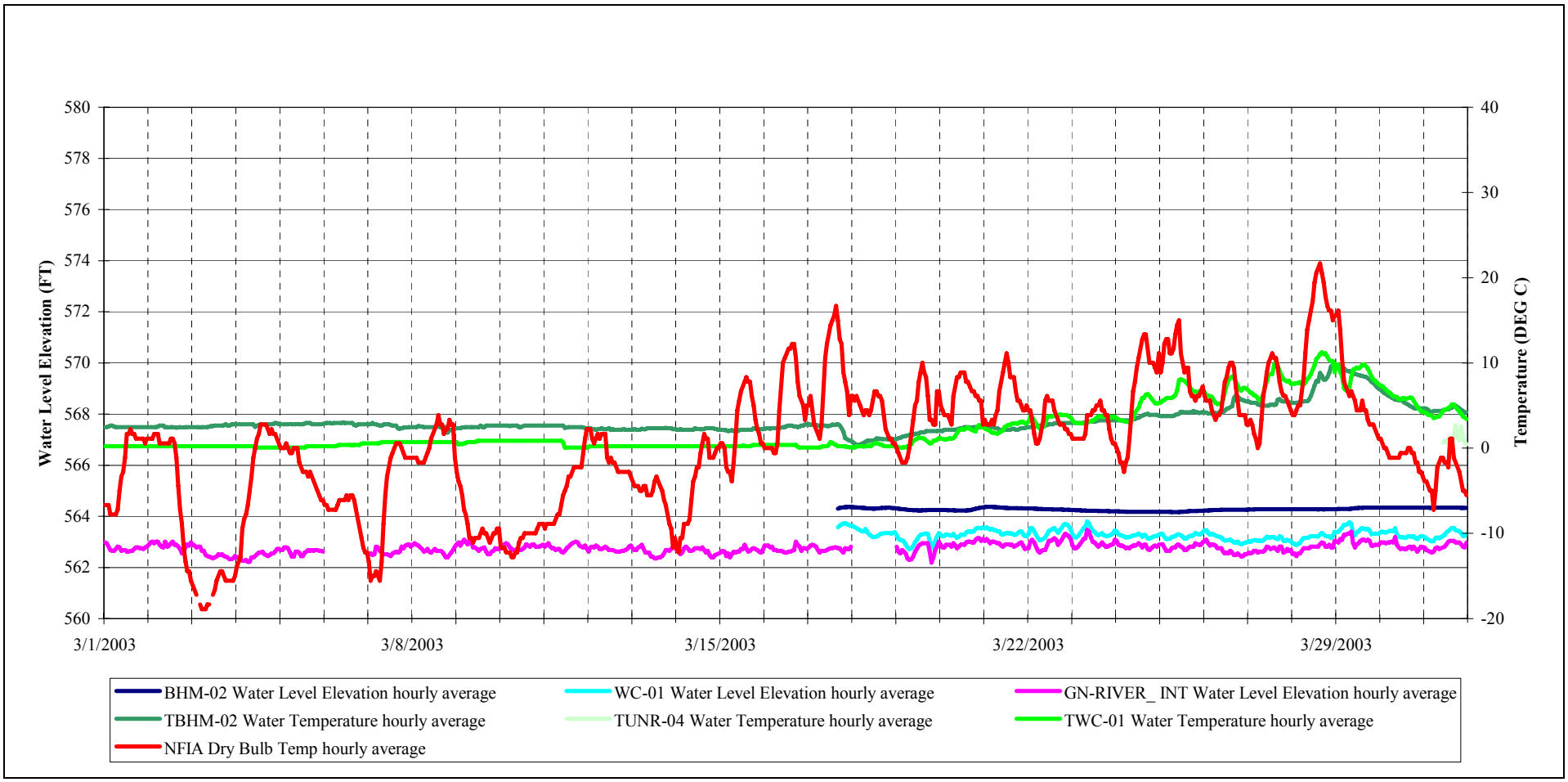

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FIGURE B-47: EAST END OF BUCKHORN MARSH AND WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

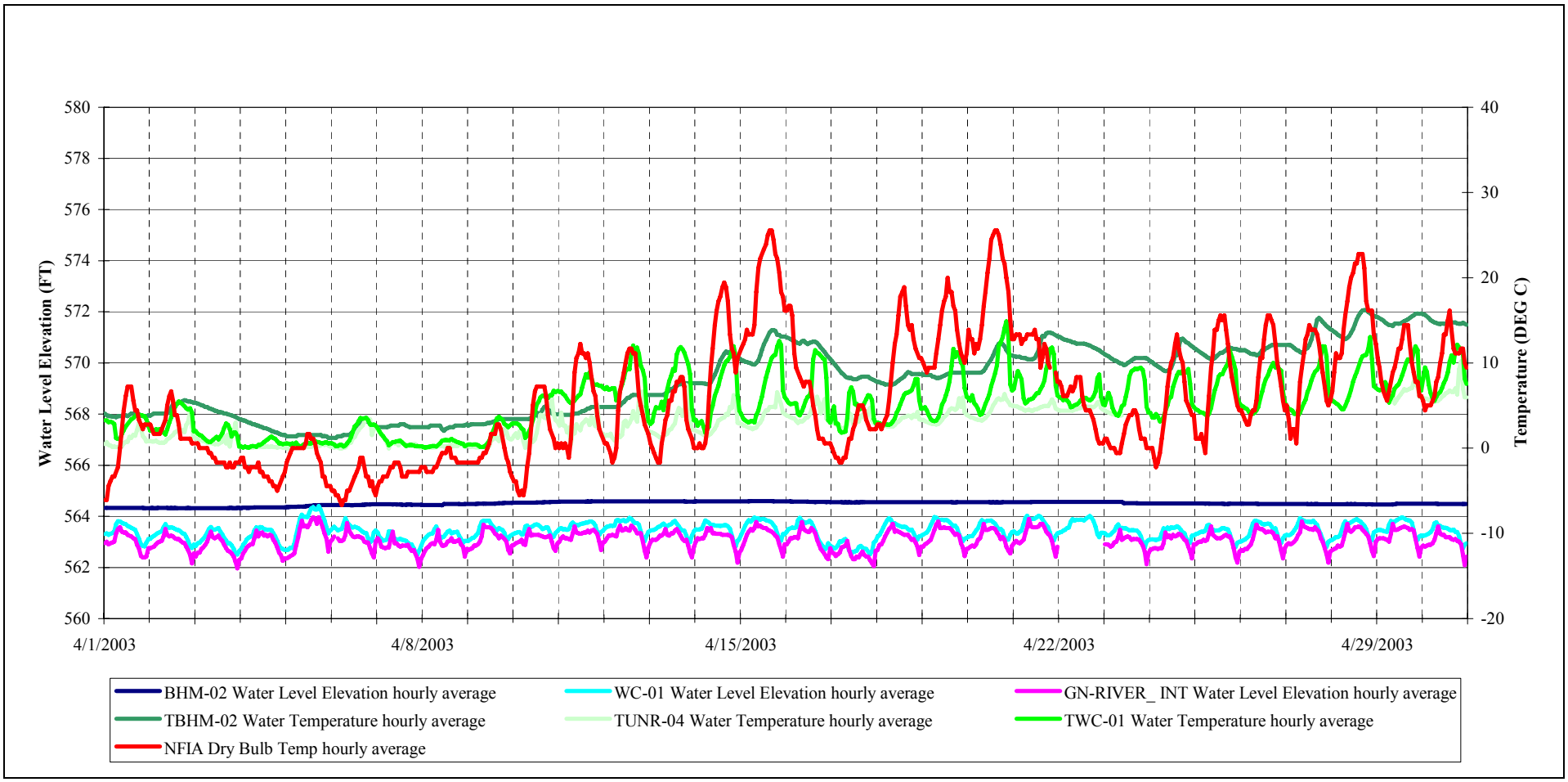

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FIGURE B-48: EAST END OF BUCKHORN MARSH AND WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

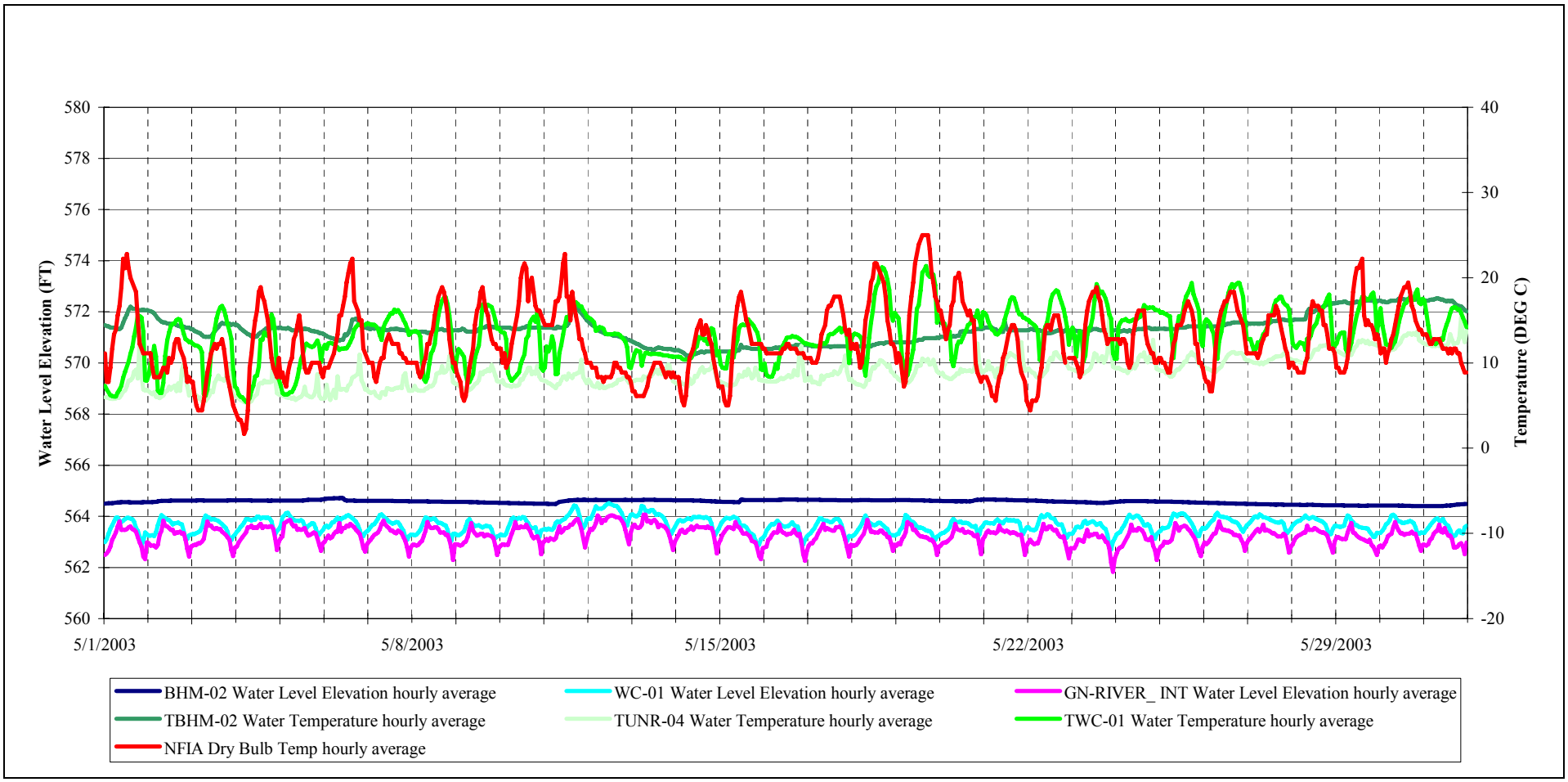

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FIGURE B-49: EAST END OF BUCKHORN MARSH AND WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

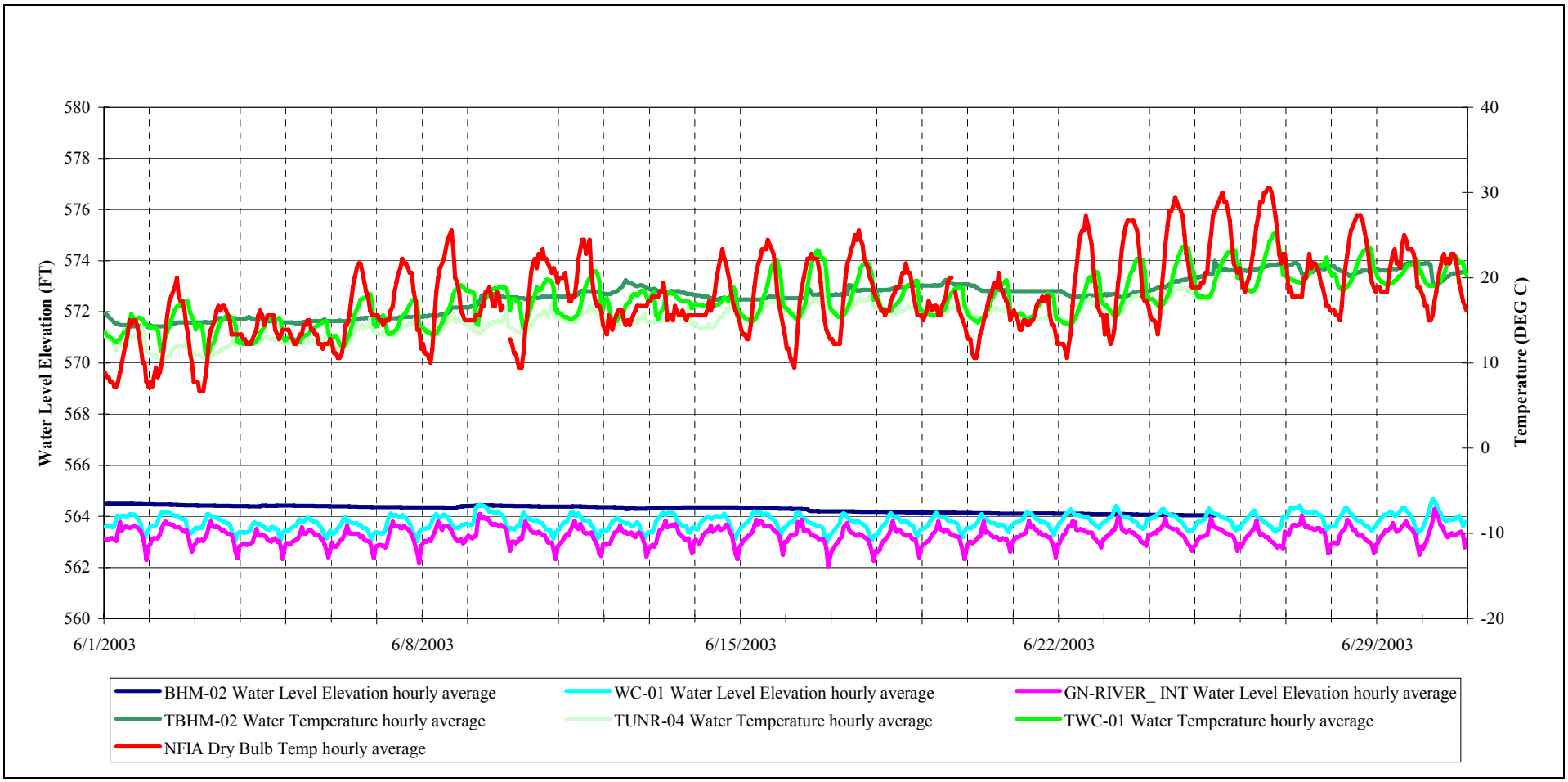

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FIGURE B-50: EAST END OF BUCKHORN MARSH AND WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

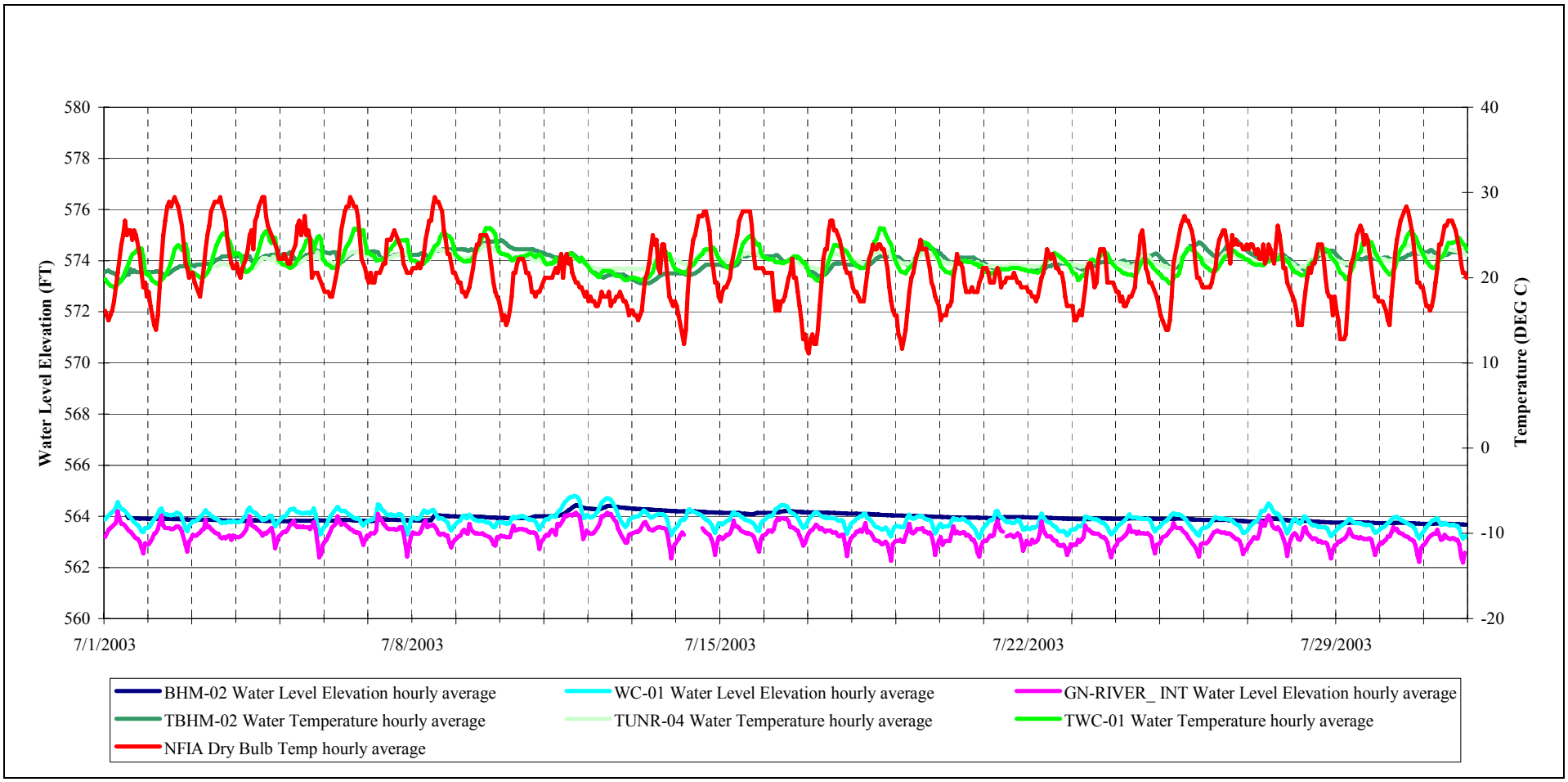

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FIGURE B-51: EAST END OF BUCKHORN MARSH AND WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

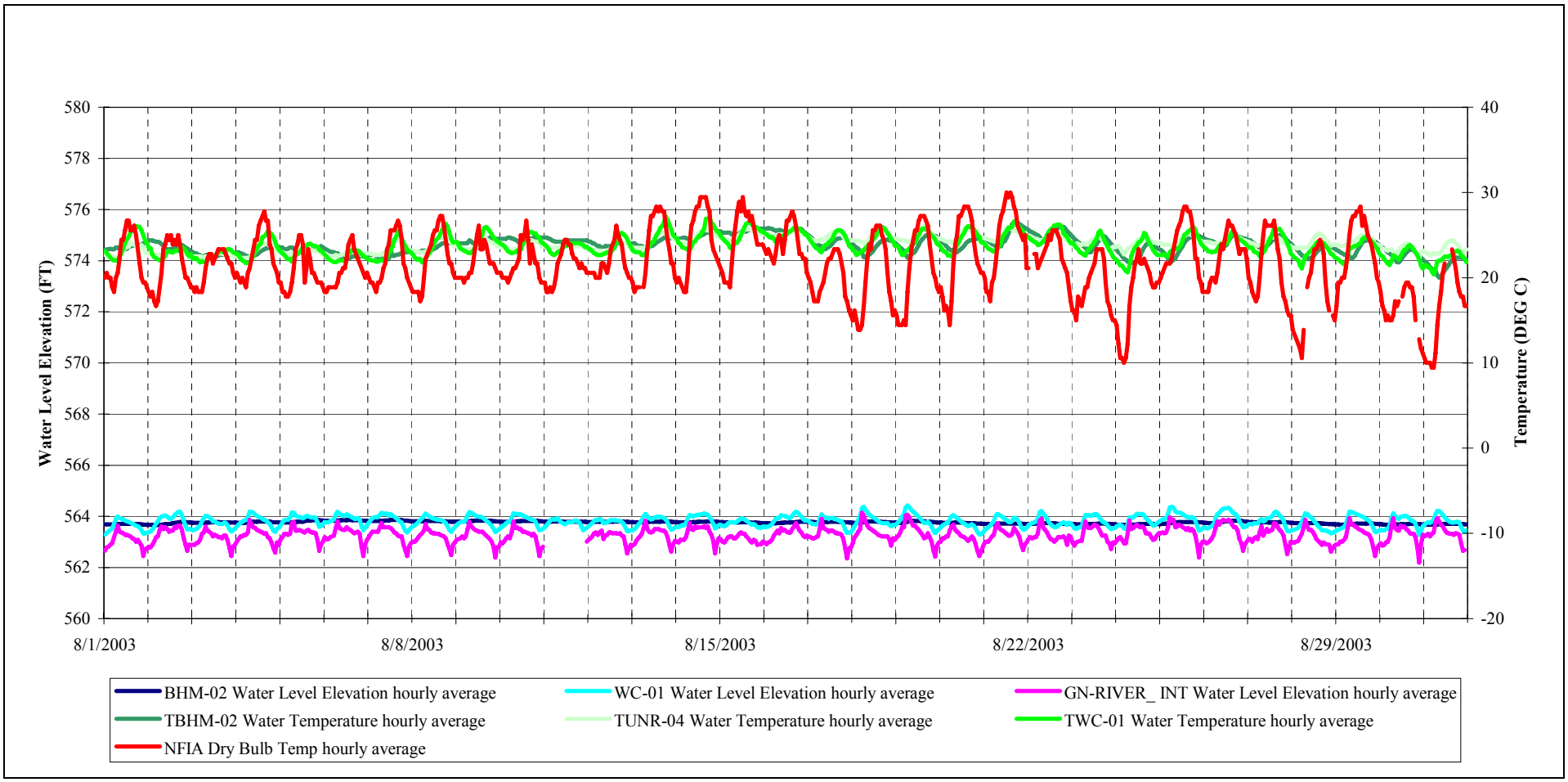

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FIGURE B-52: EAST END OF BUCKHORN MARSH AND WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

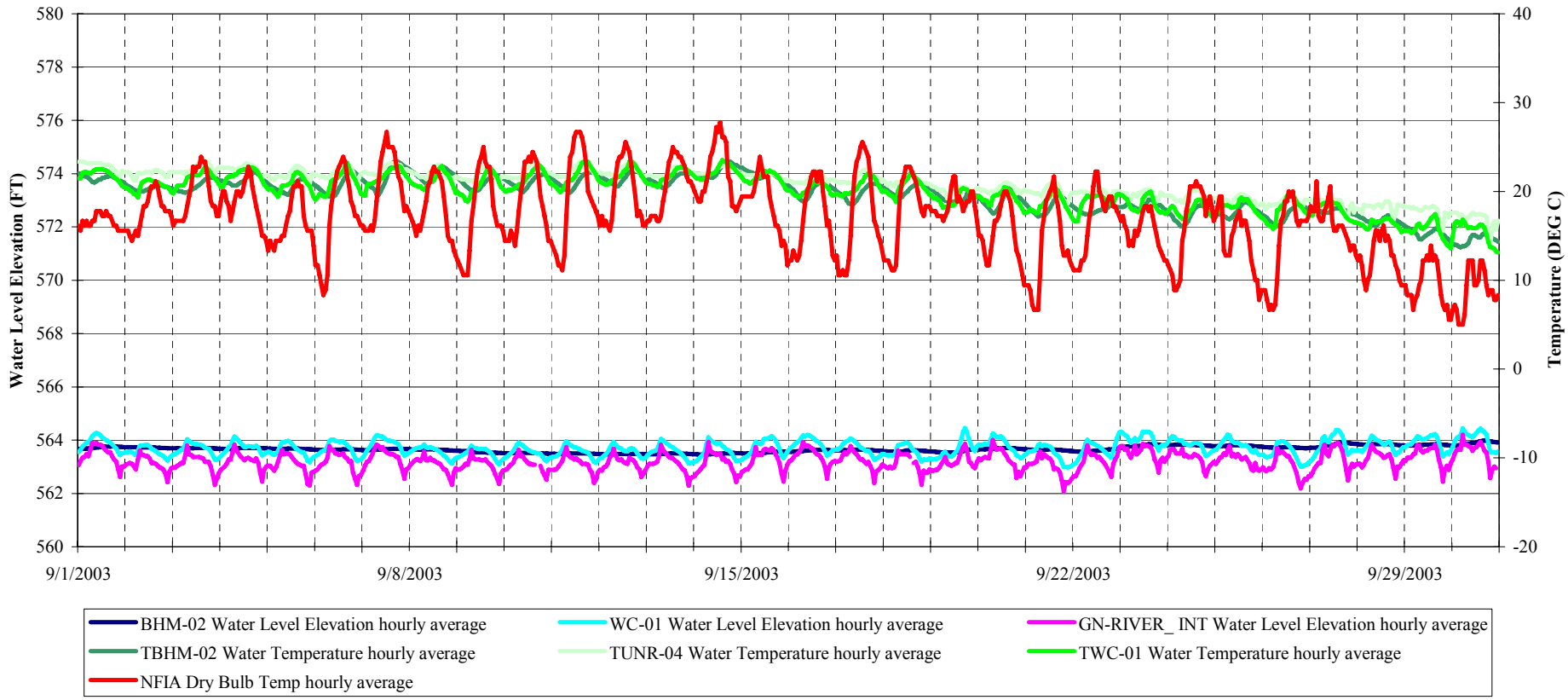

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FIGURE B-53: EAST END OF BUCKHORN MARSH AND WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

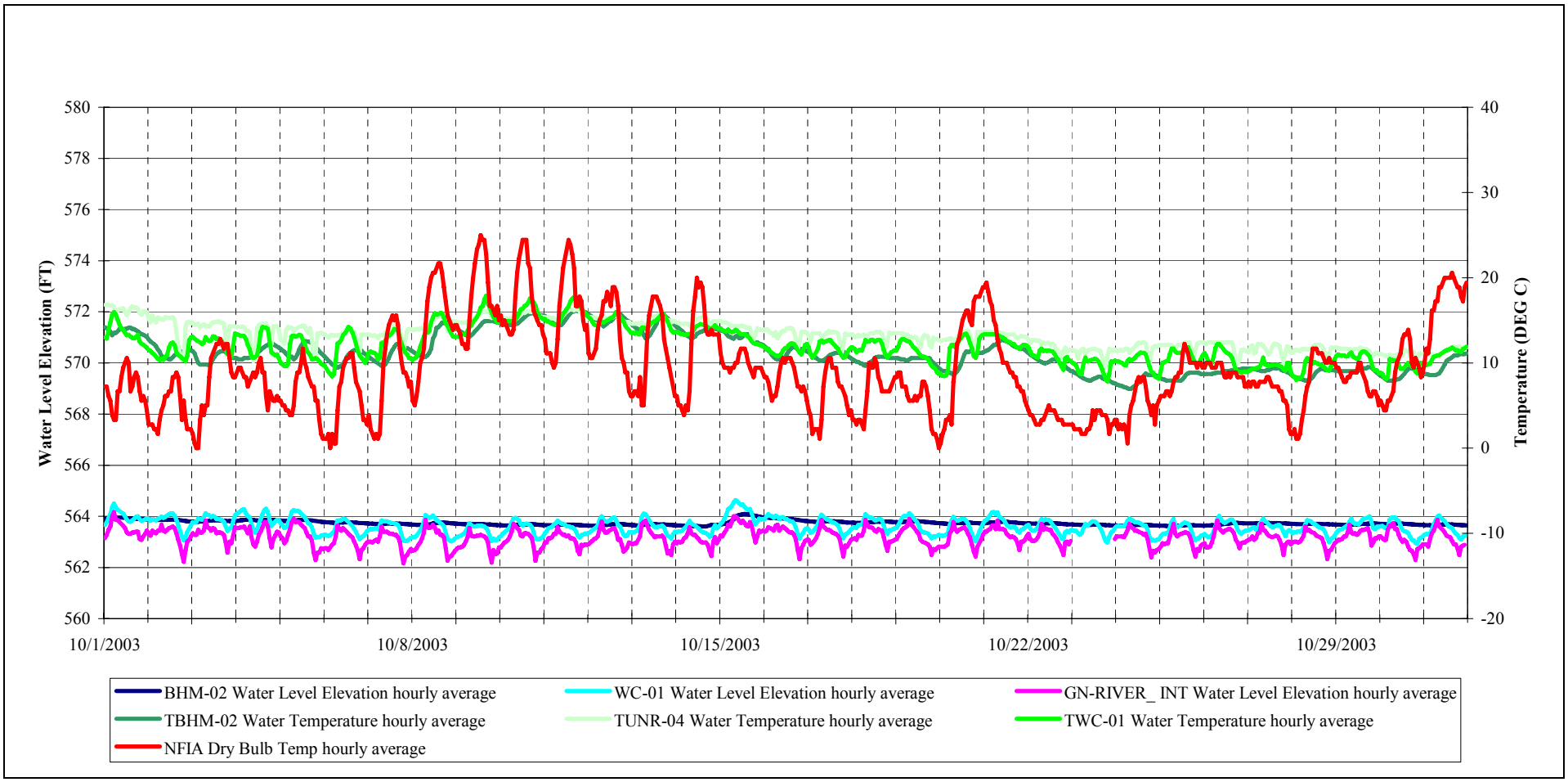

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FIGURE B-54: EAST END OF BUCKHORN MARSH AND WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

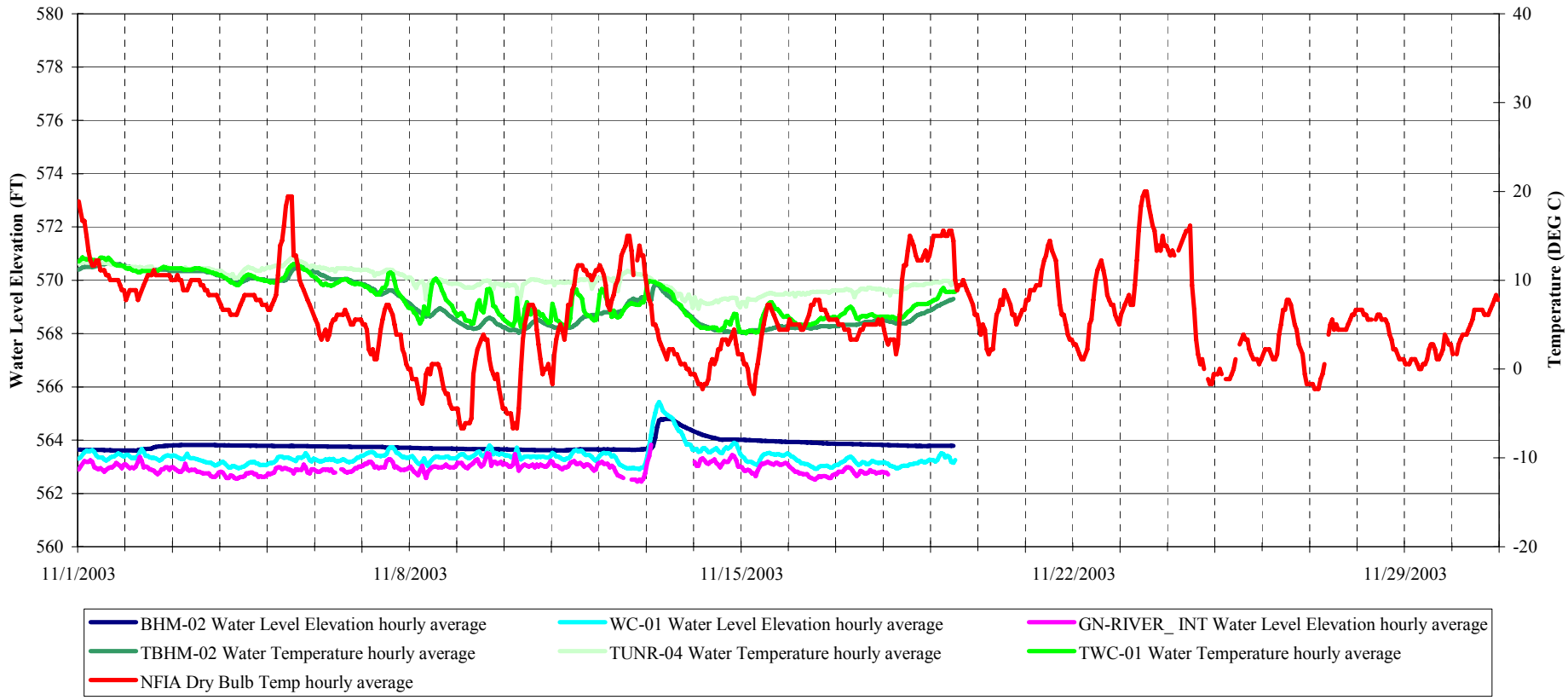

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FIGURE B-55: WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2002

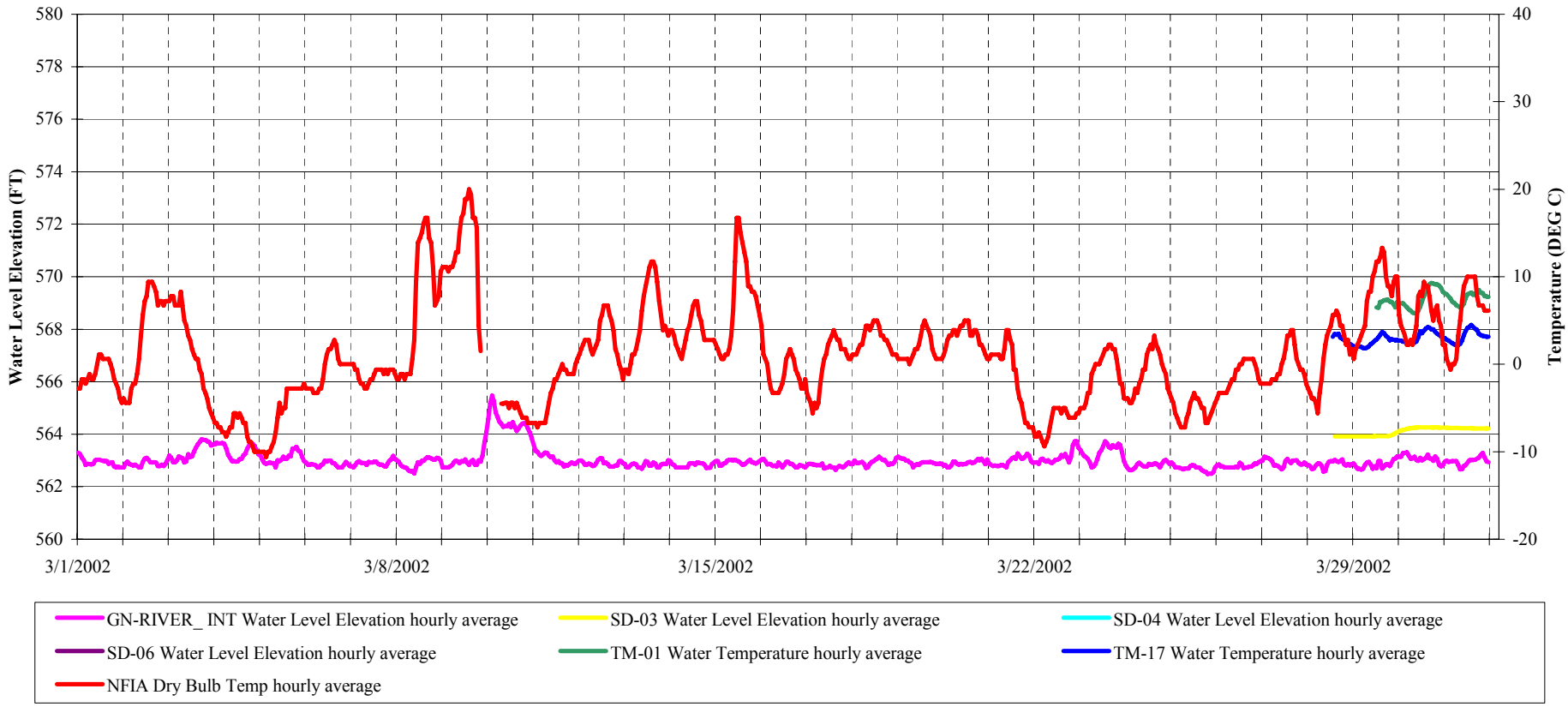

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FIGURE B-56: WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

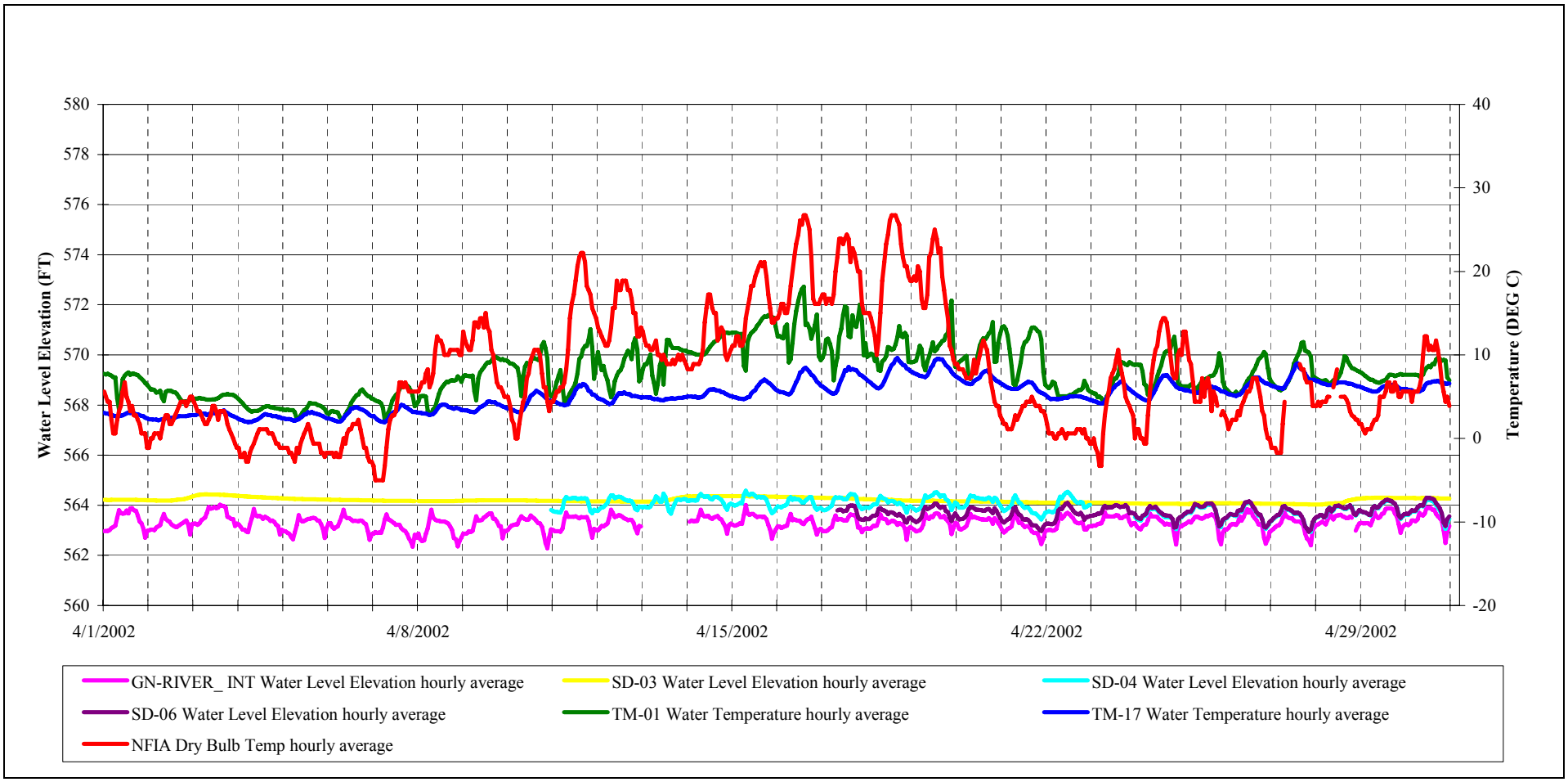

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FIGURE B-57: WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

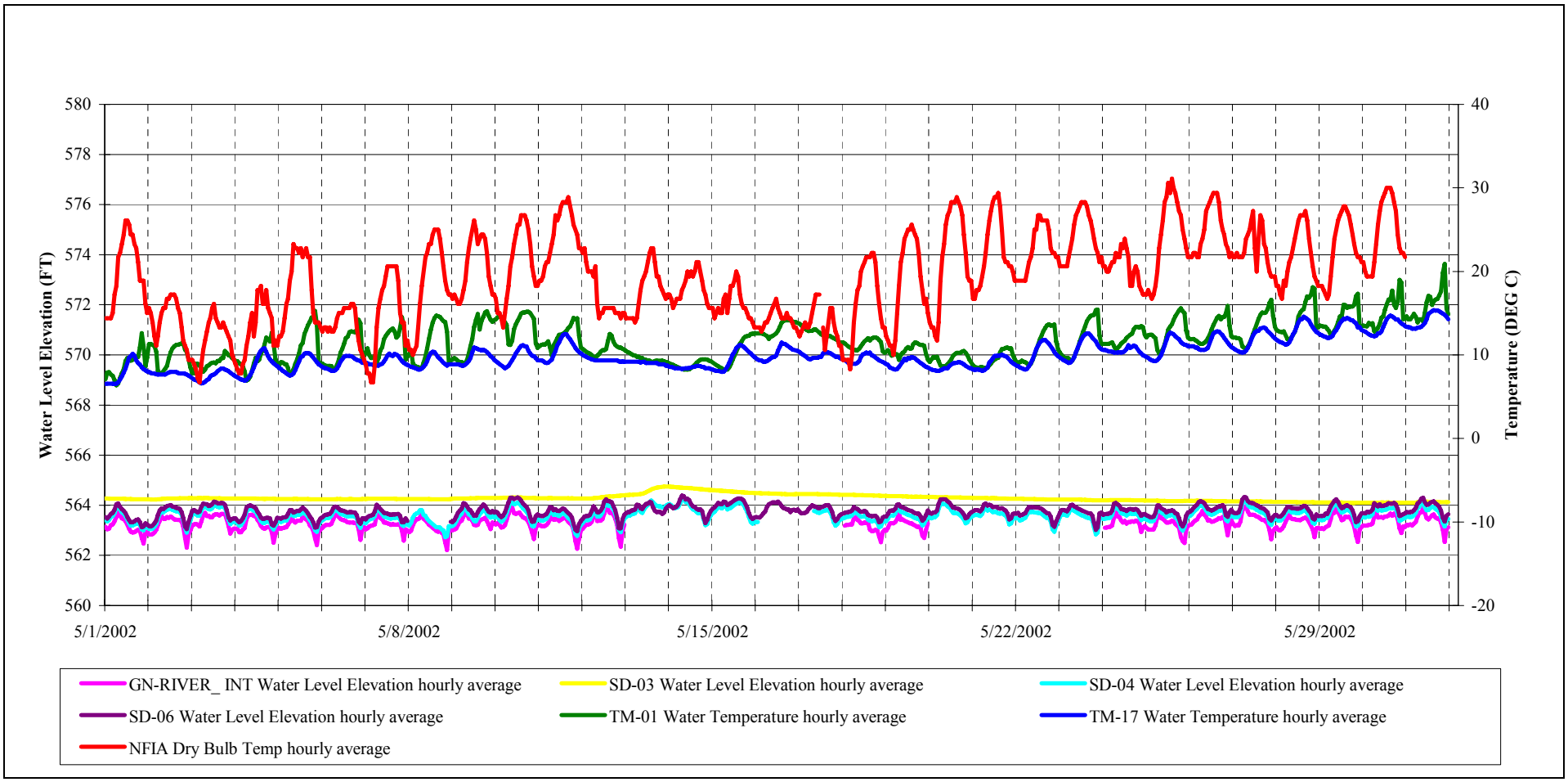

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FIGURE B-58: WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

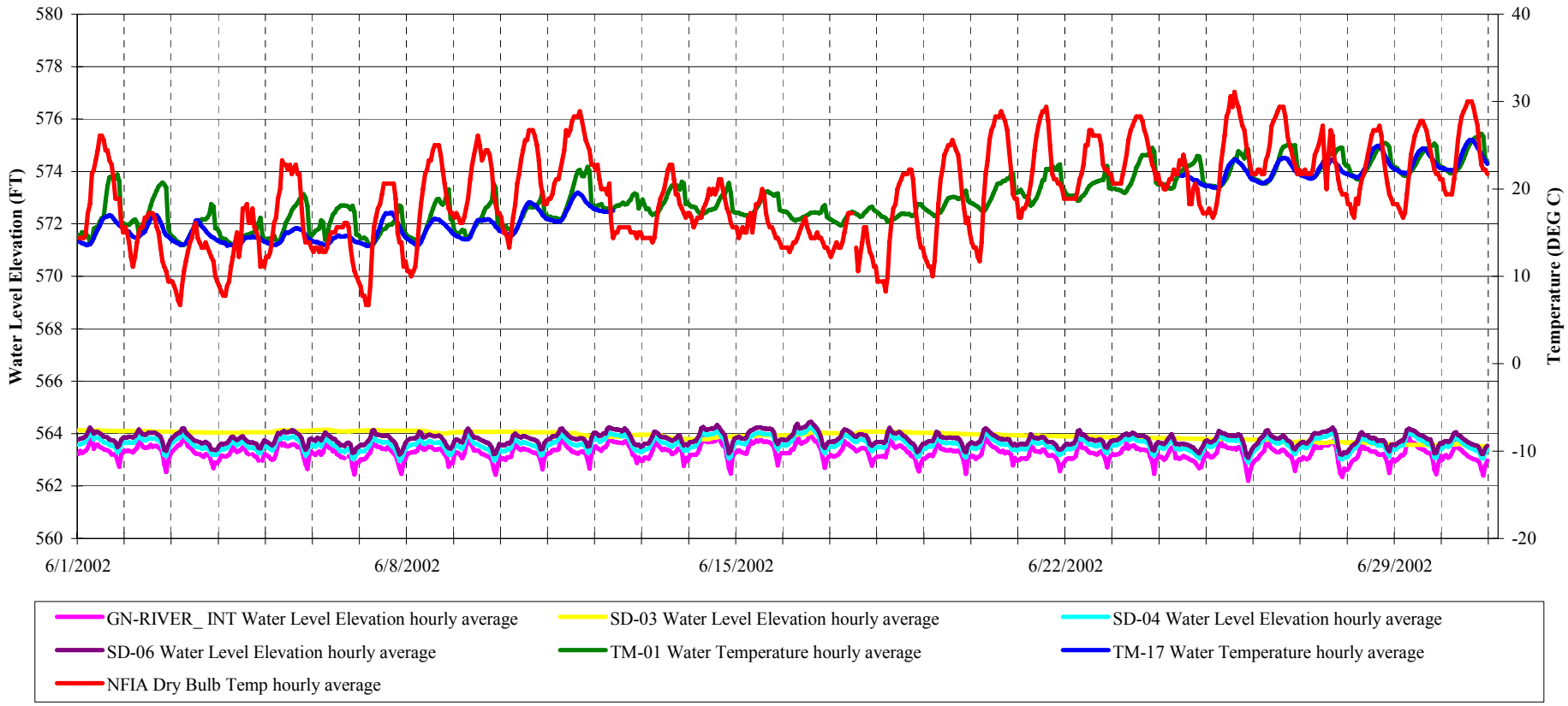

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FIGURE B-59: WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

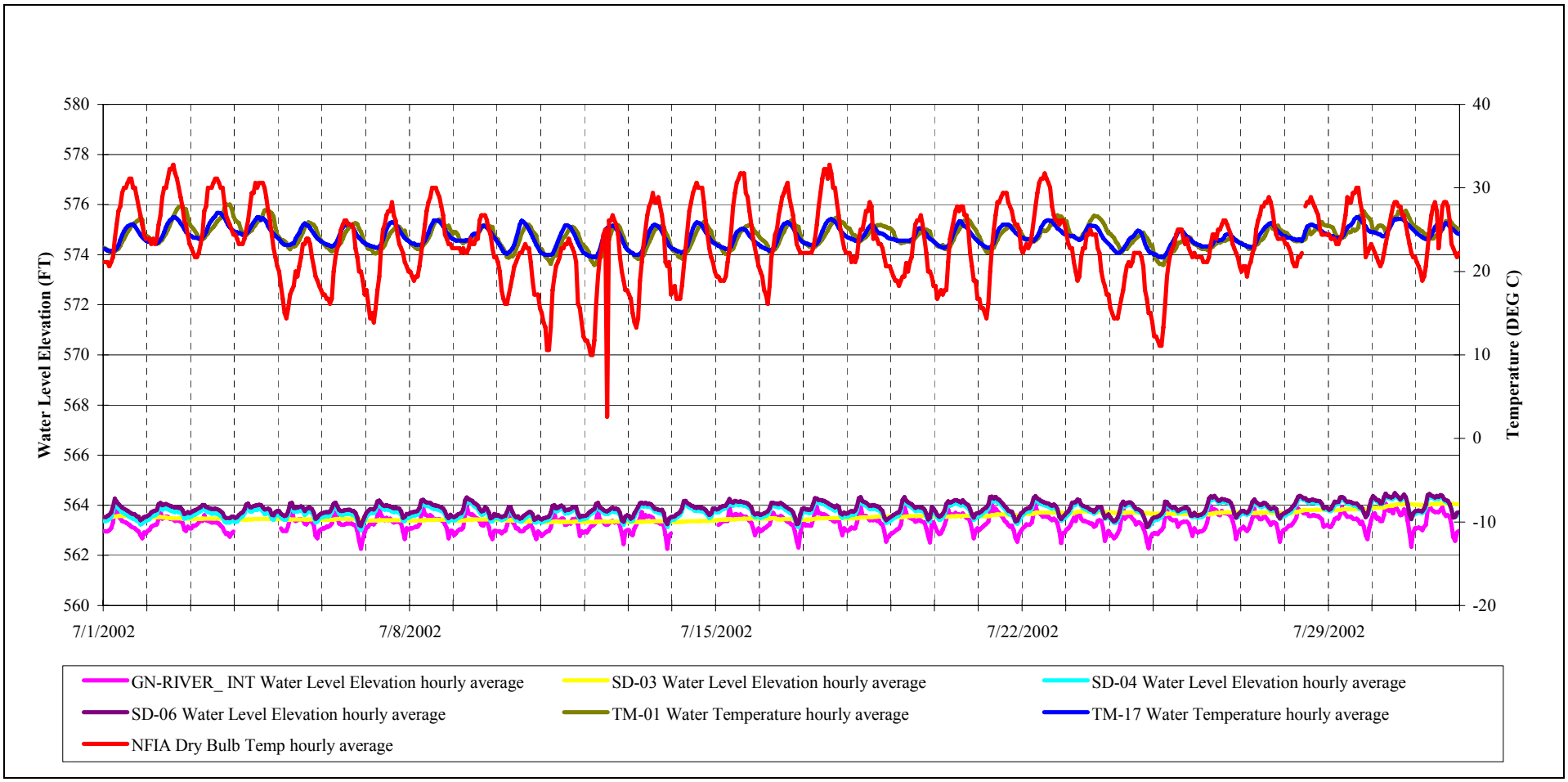

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FIGURE B-60: WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

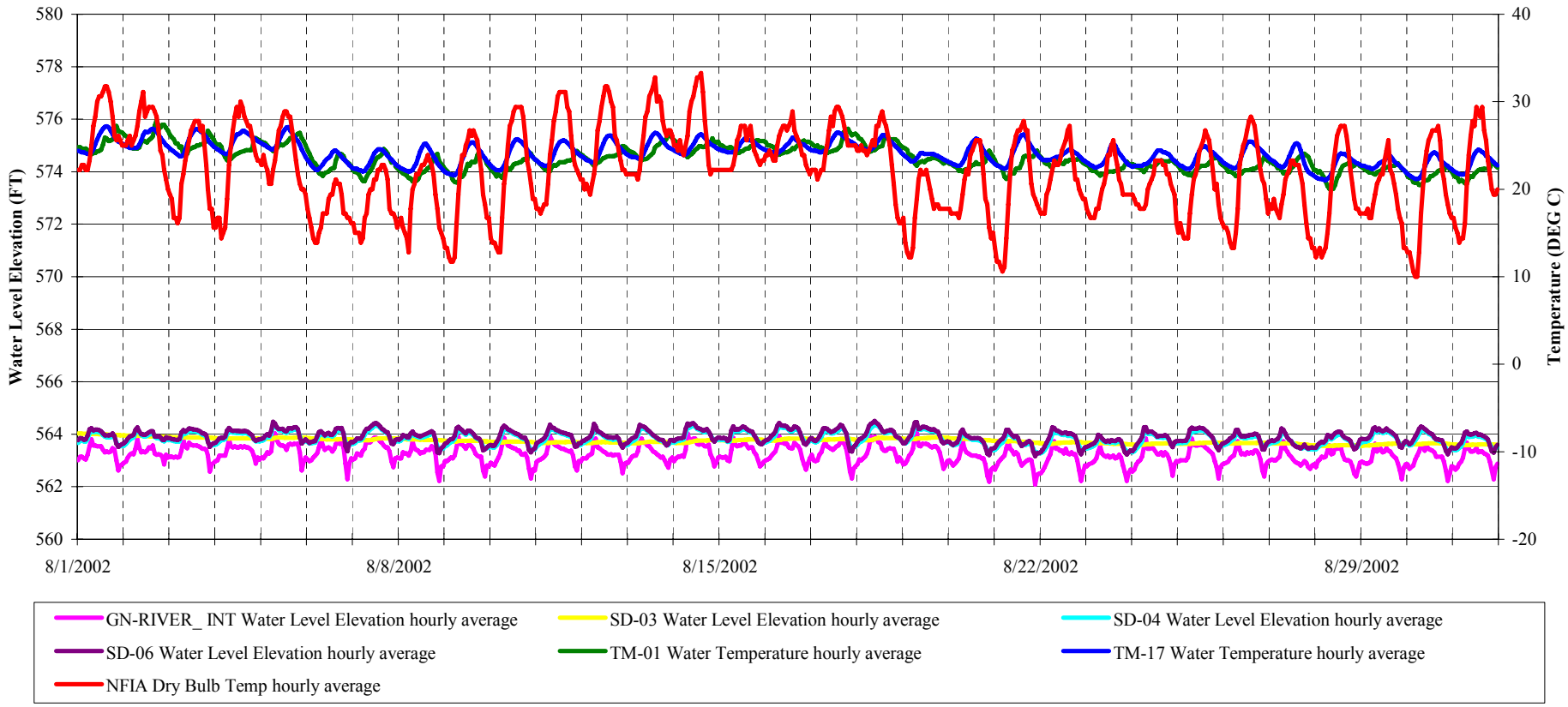

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FIGURE B-61: WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

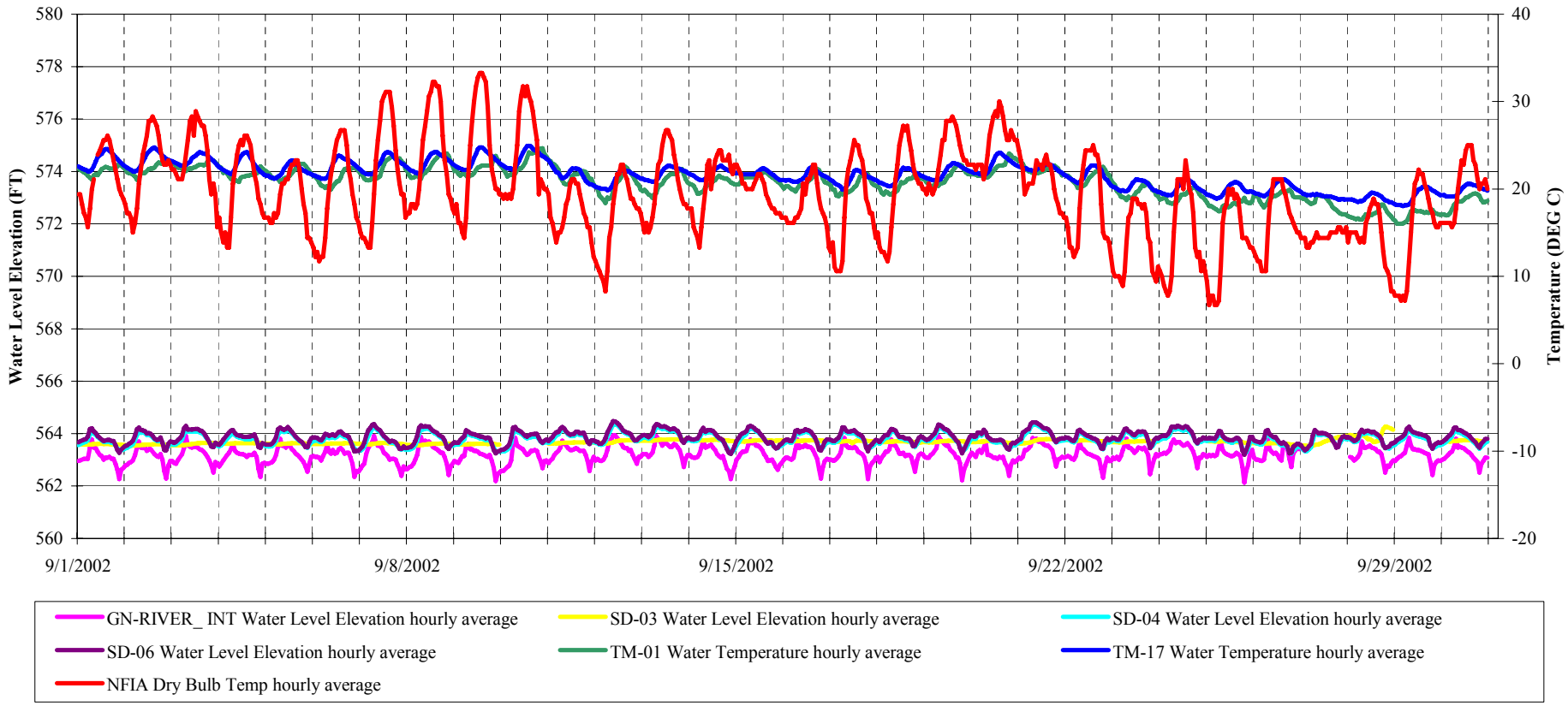

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FIGURE B-62: WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

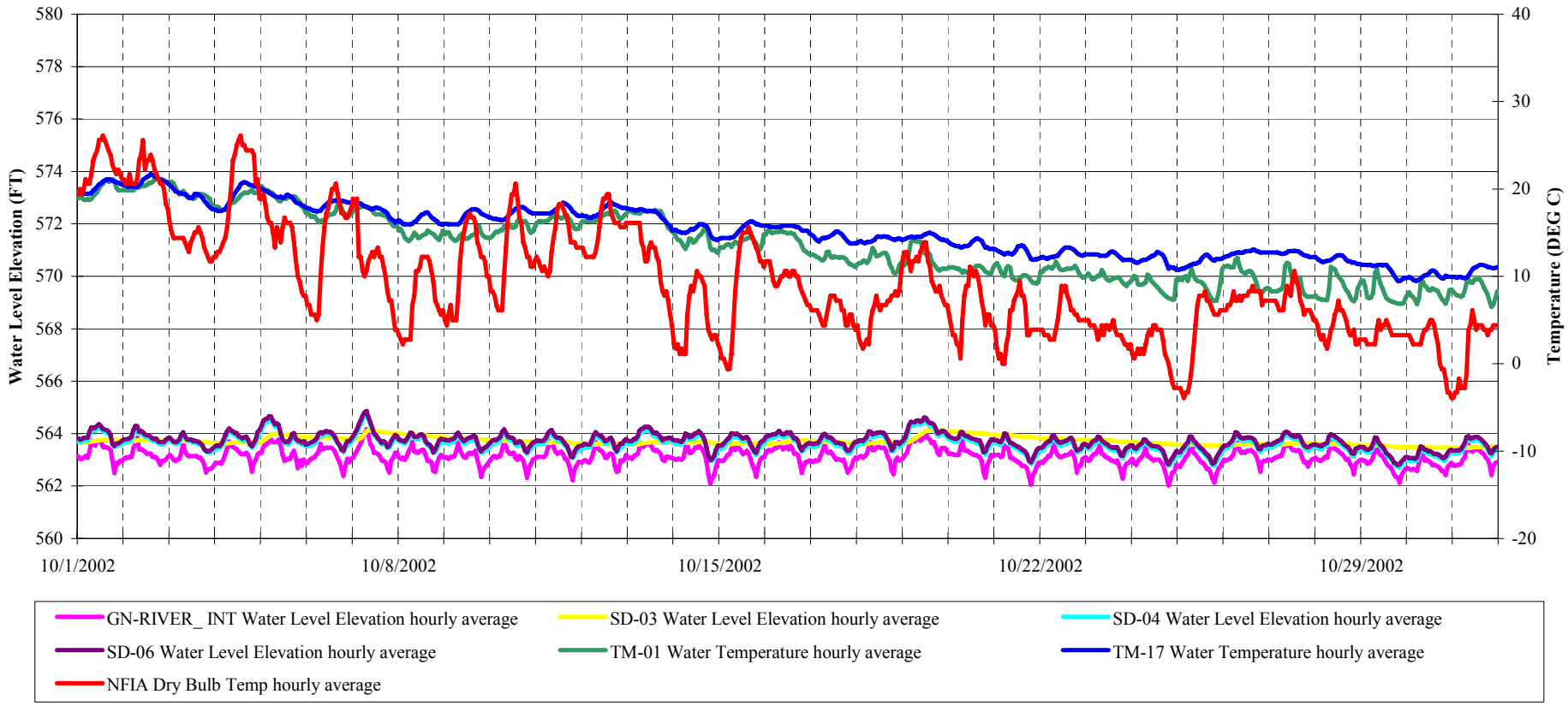

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FIGURE B-63: WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2002

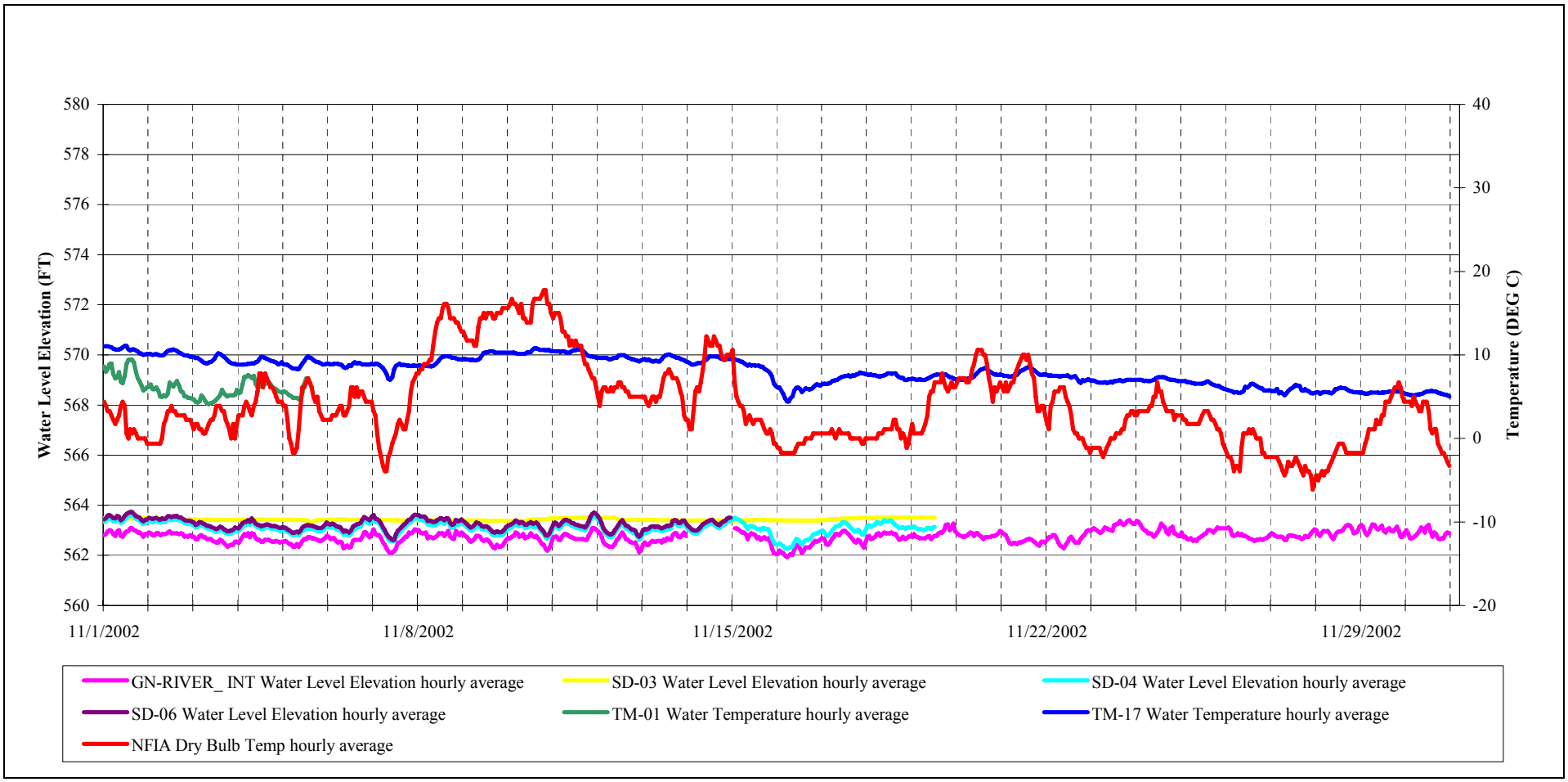

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FIGURE B-64: UPPER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

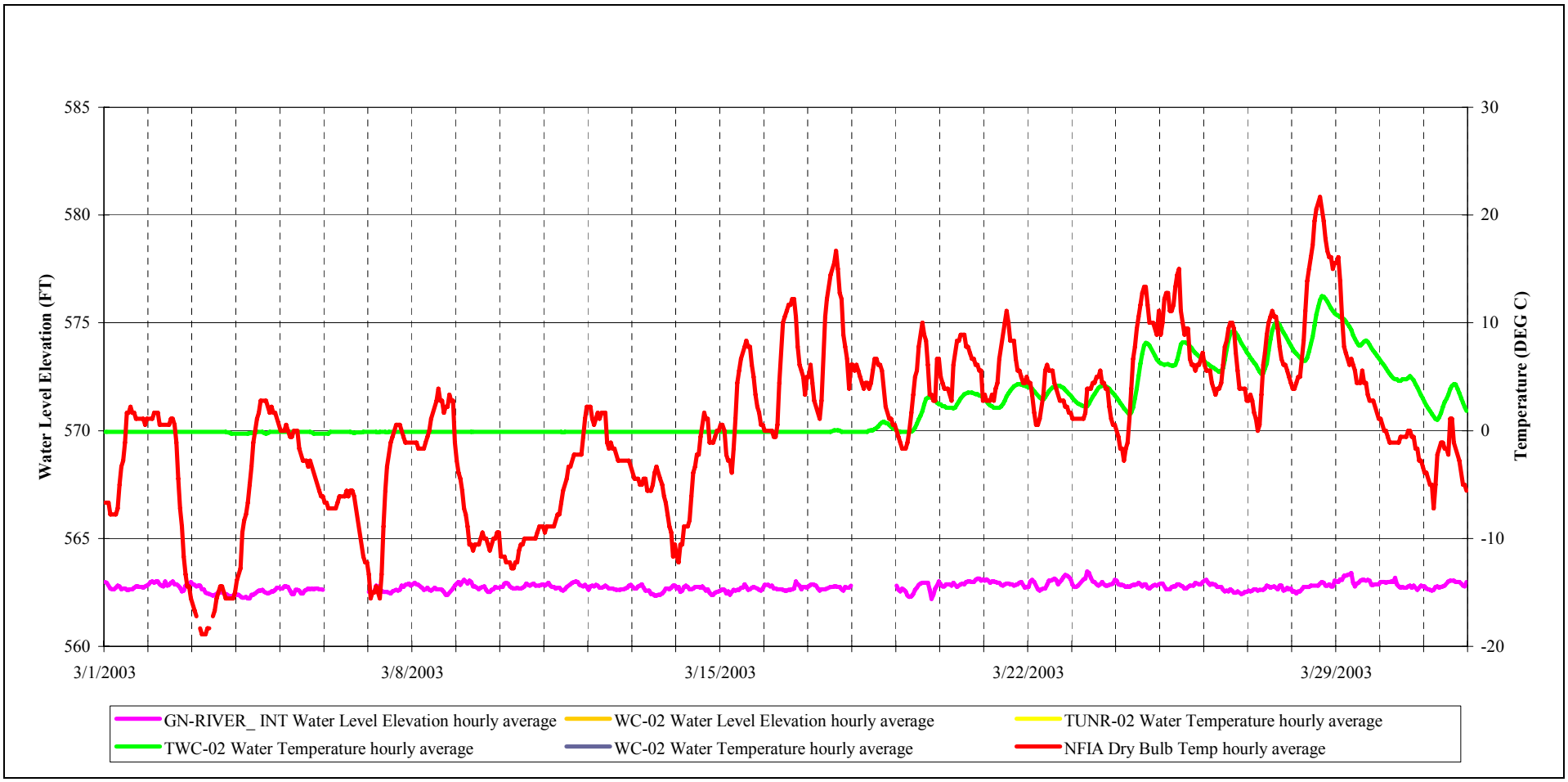

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FIGURE B-65: UPPER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

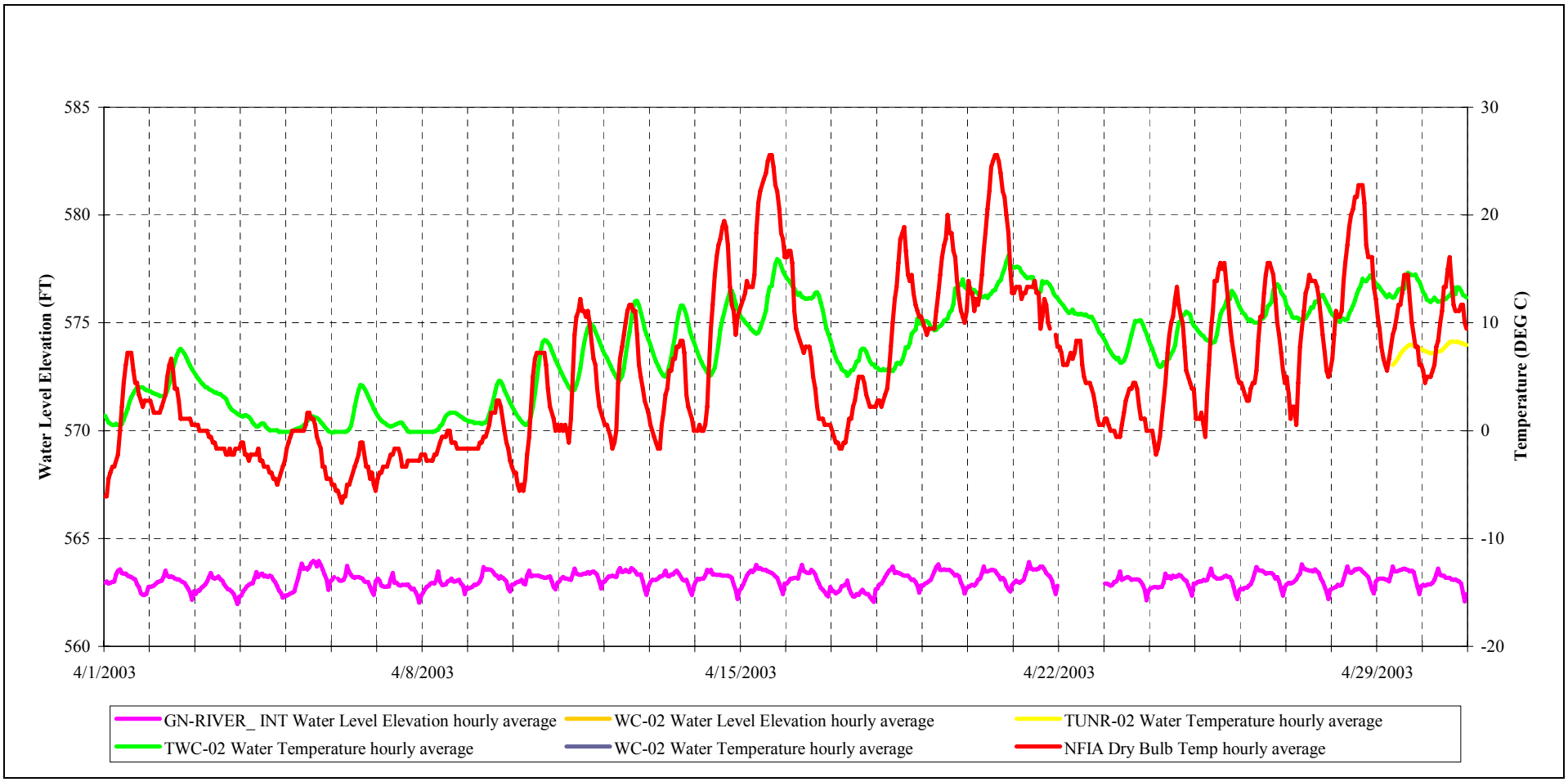

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FIGURE B-66: UPPER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

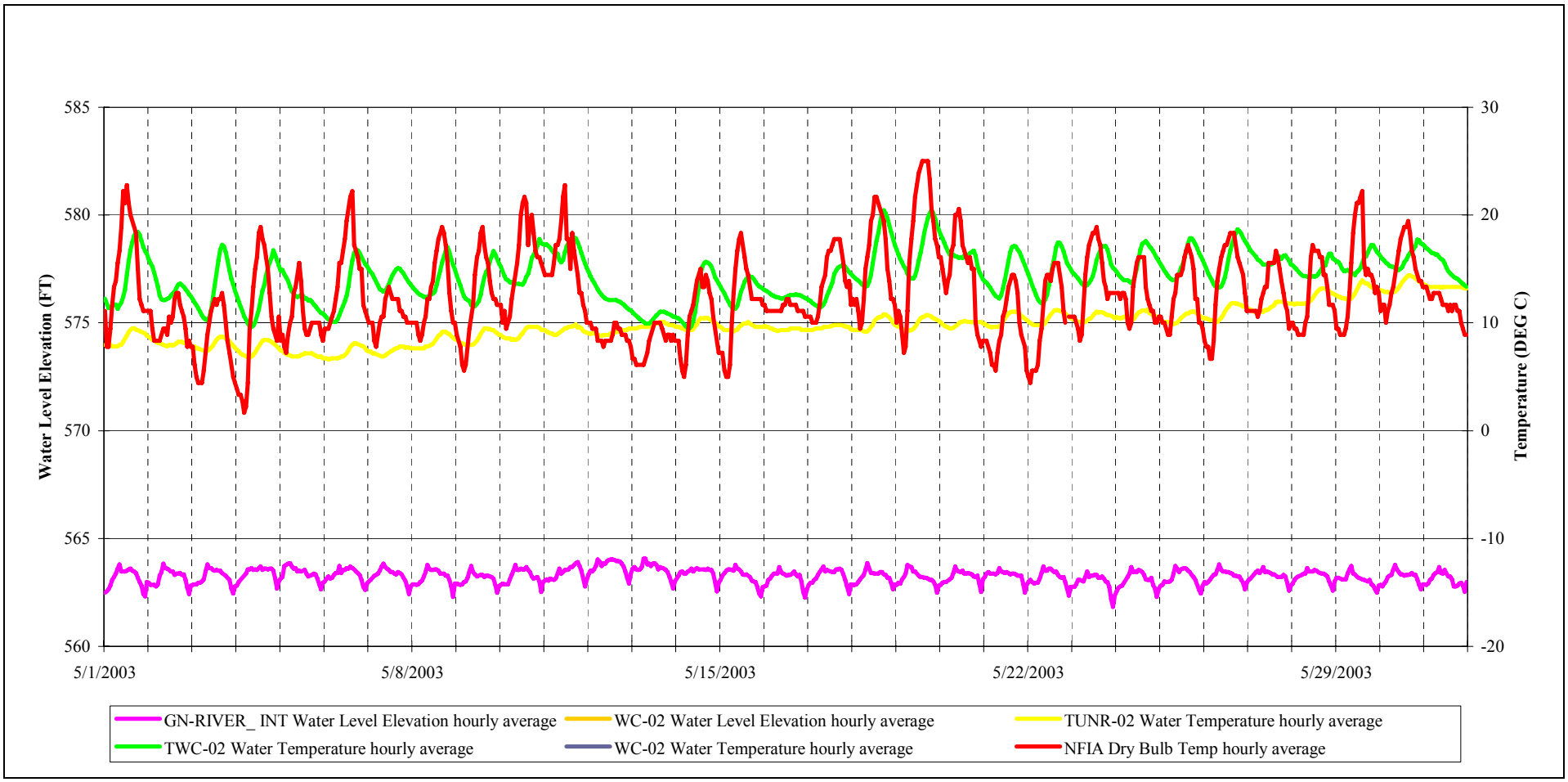

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FIGURE B-67: UPPER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

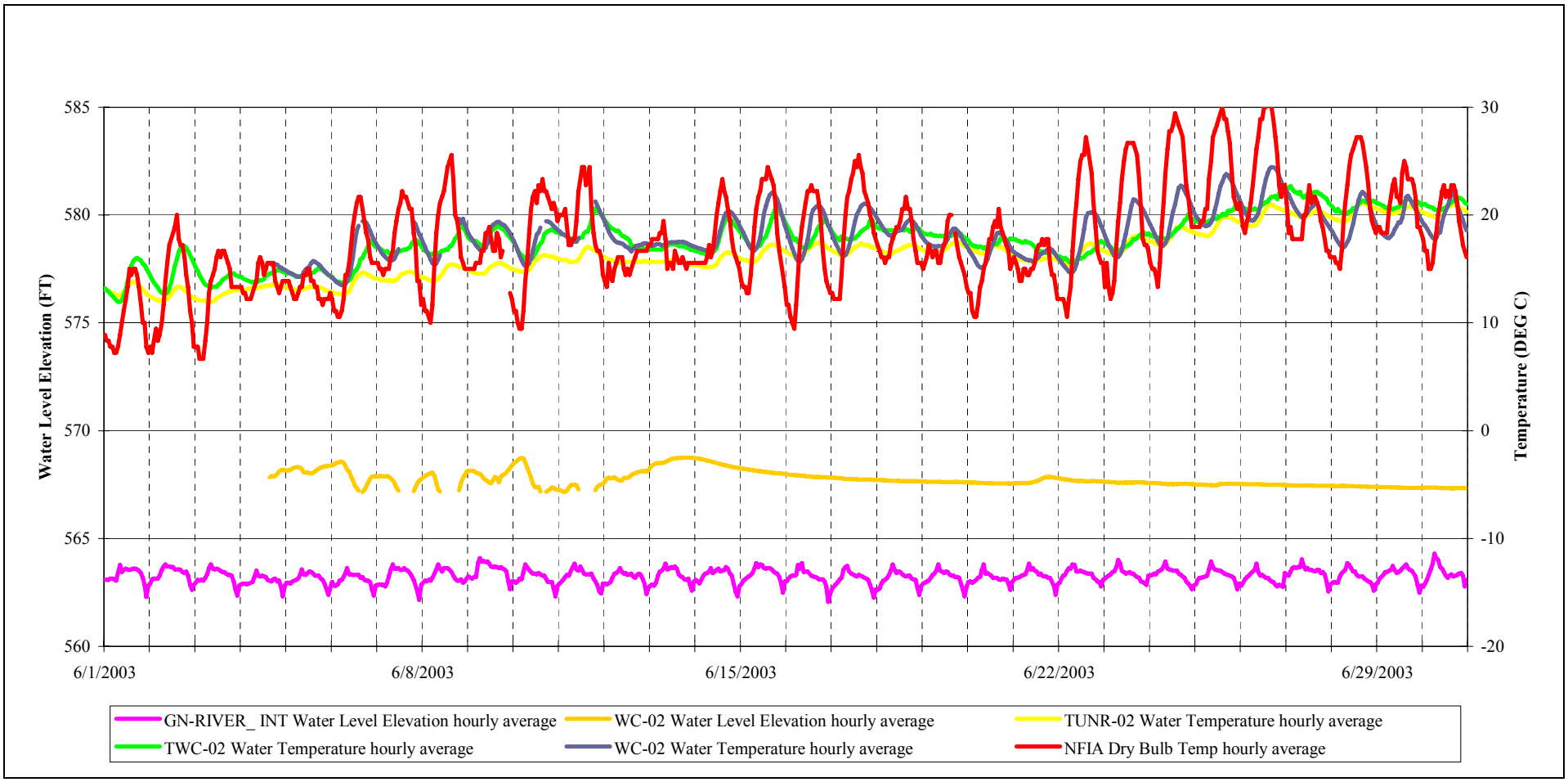

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FIGURE B-68: UPPER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

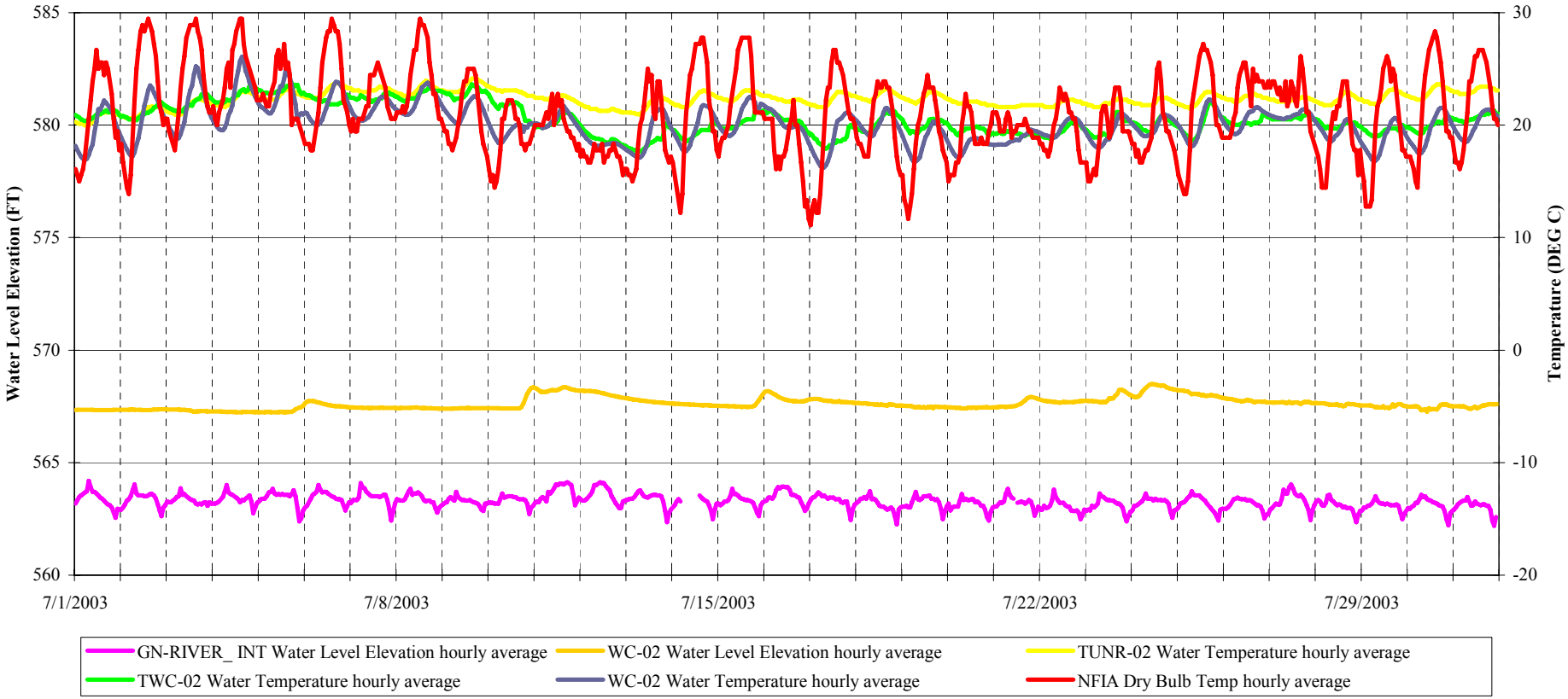

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FIGURE B-69: UPPER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

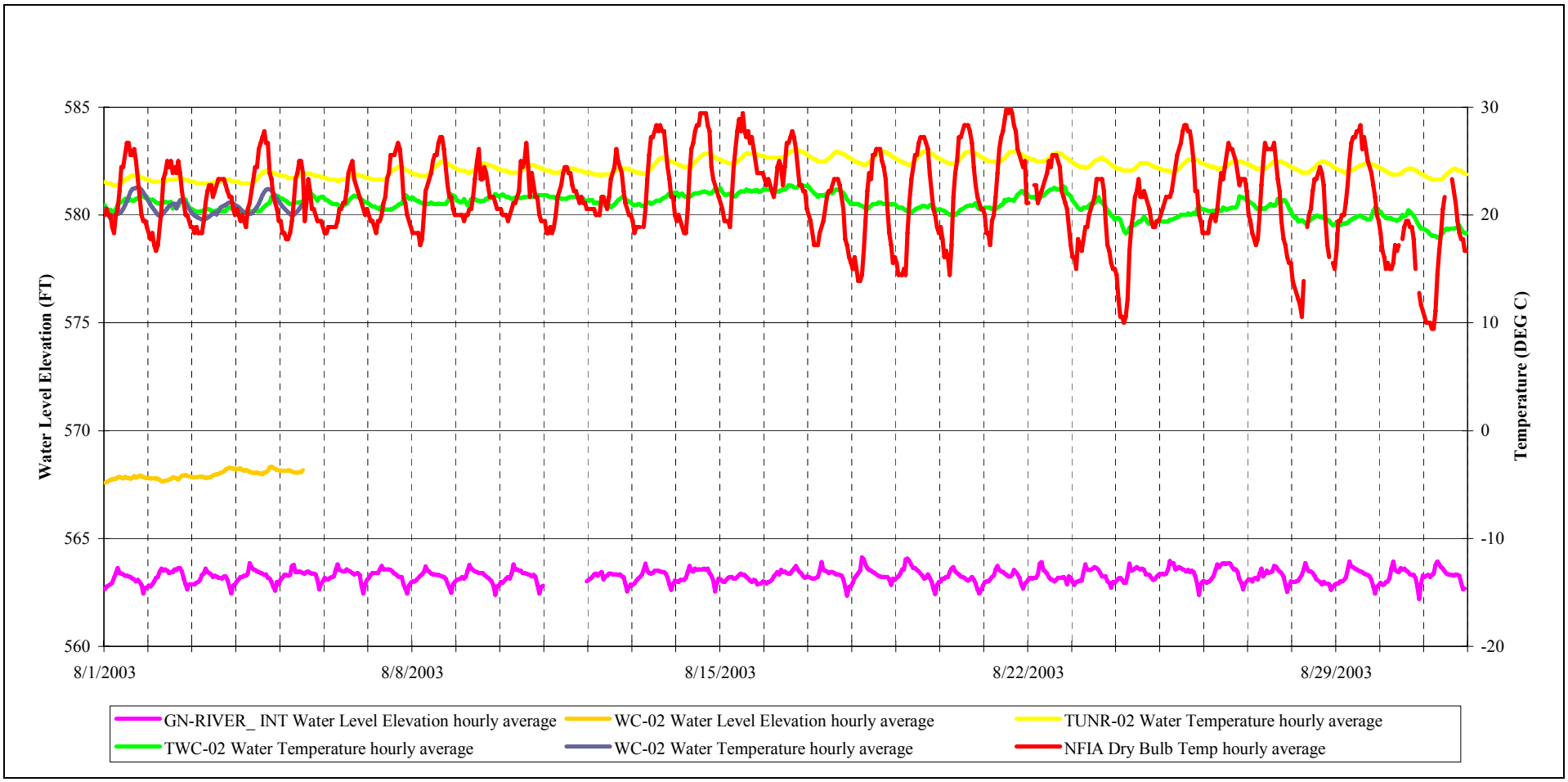

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FIGURE B-70: UPPER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

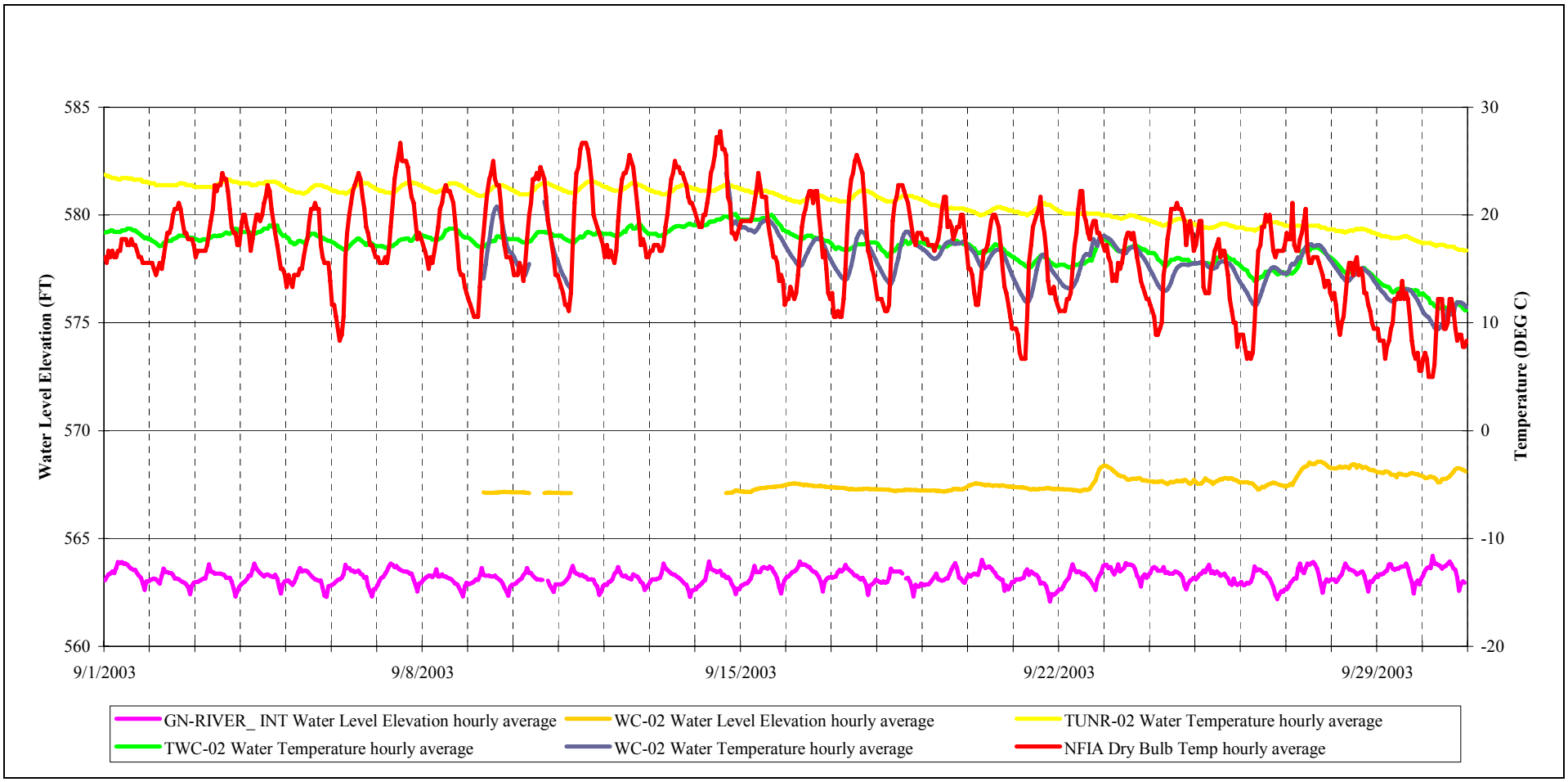

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FIGURE B-71: UPPER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

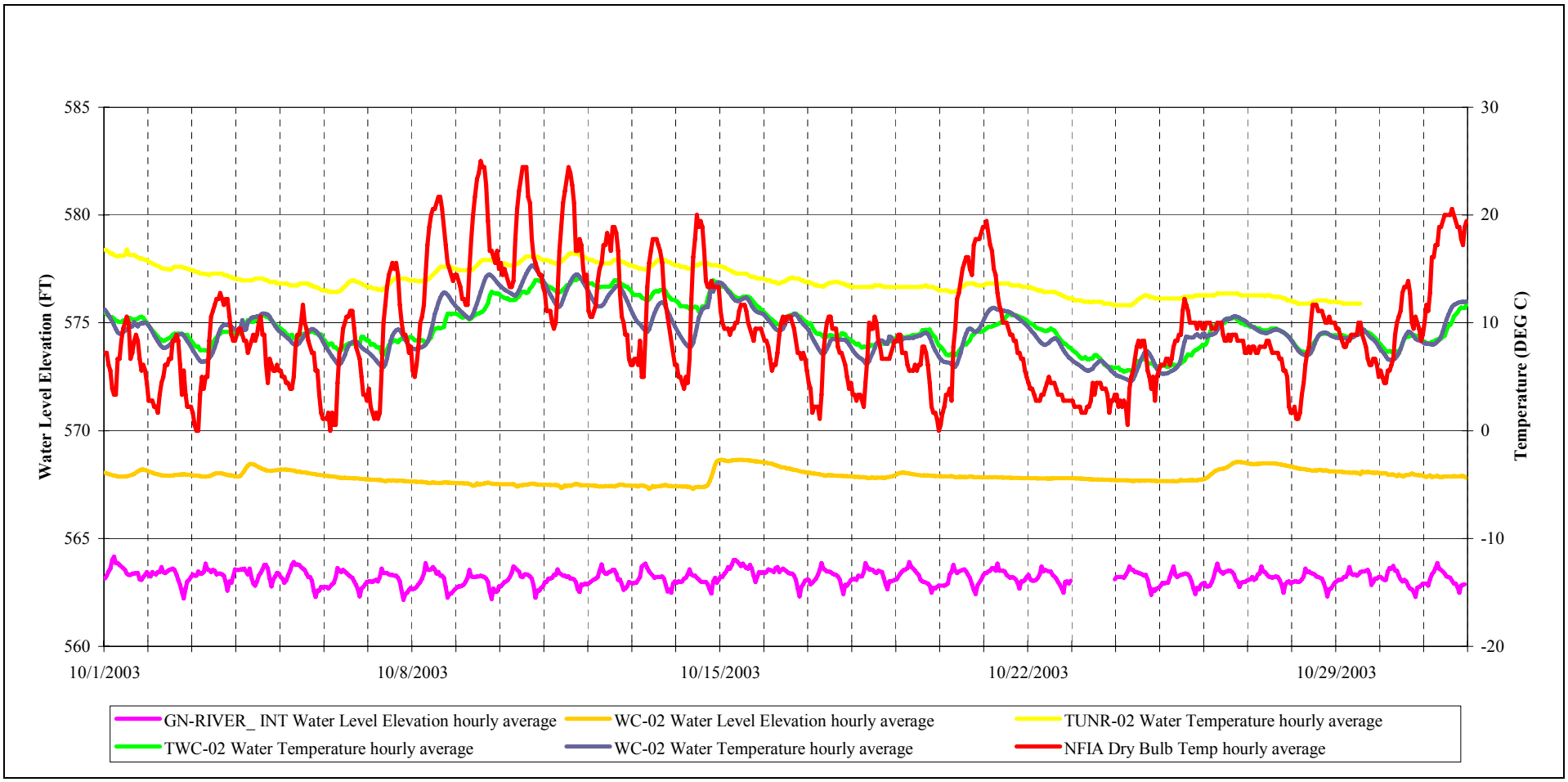

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FIGURE B-72: UPPER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

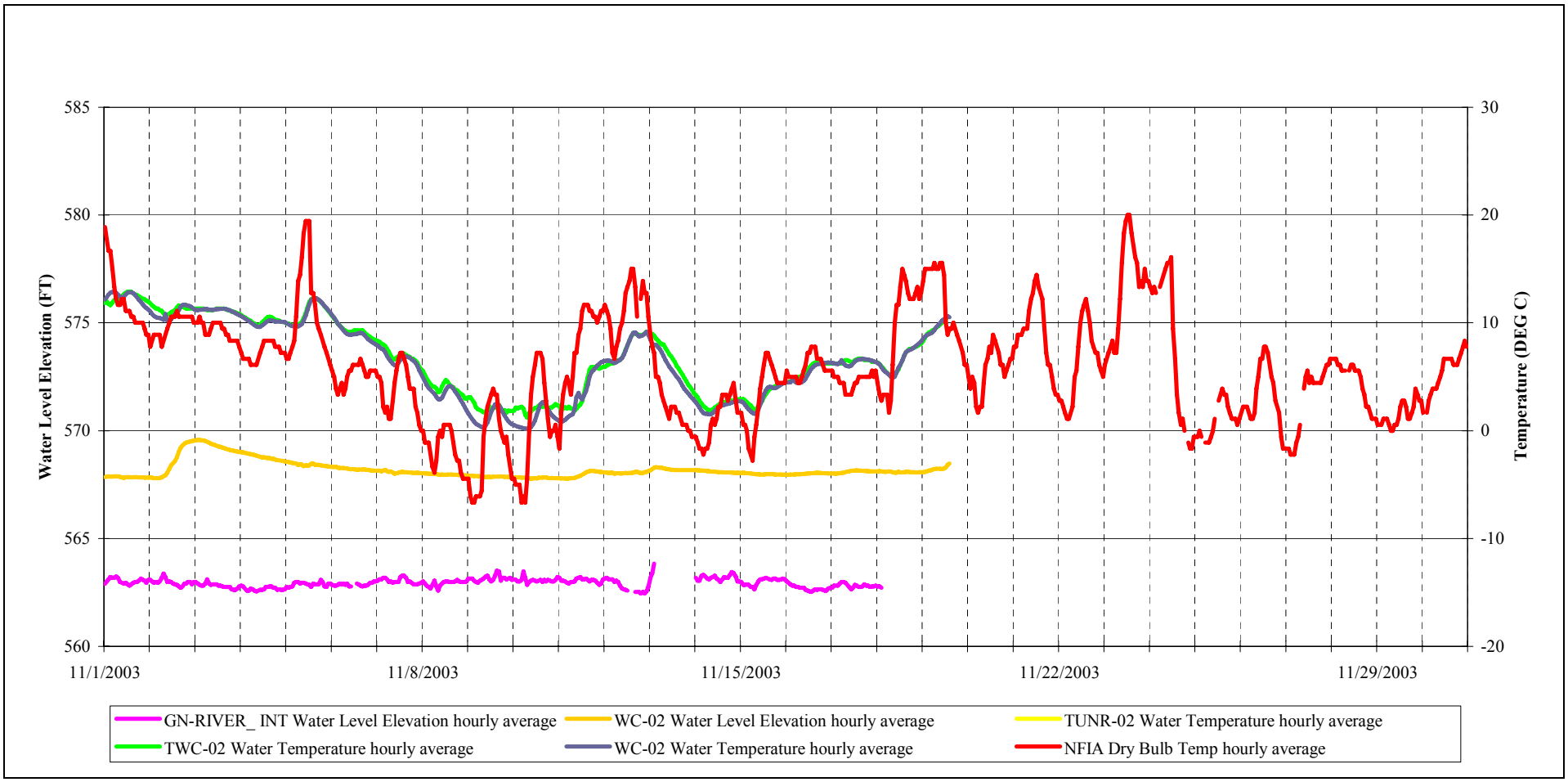

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FIGURE B-73: LOWER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

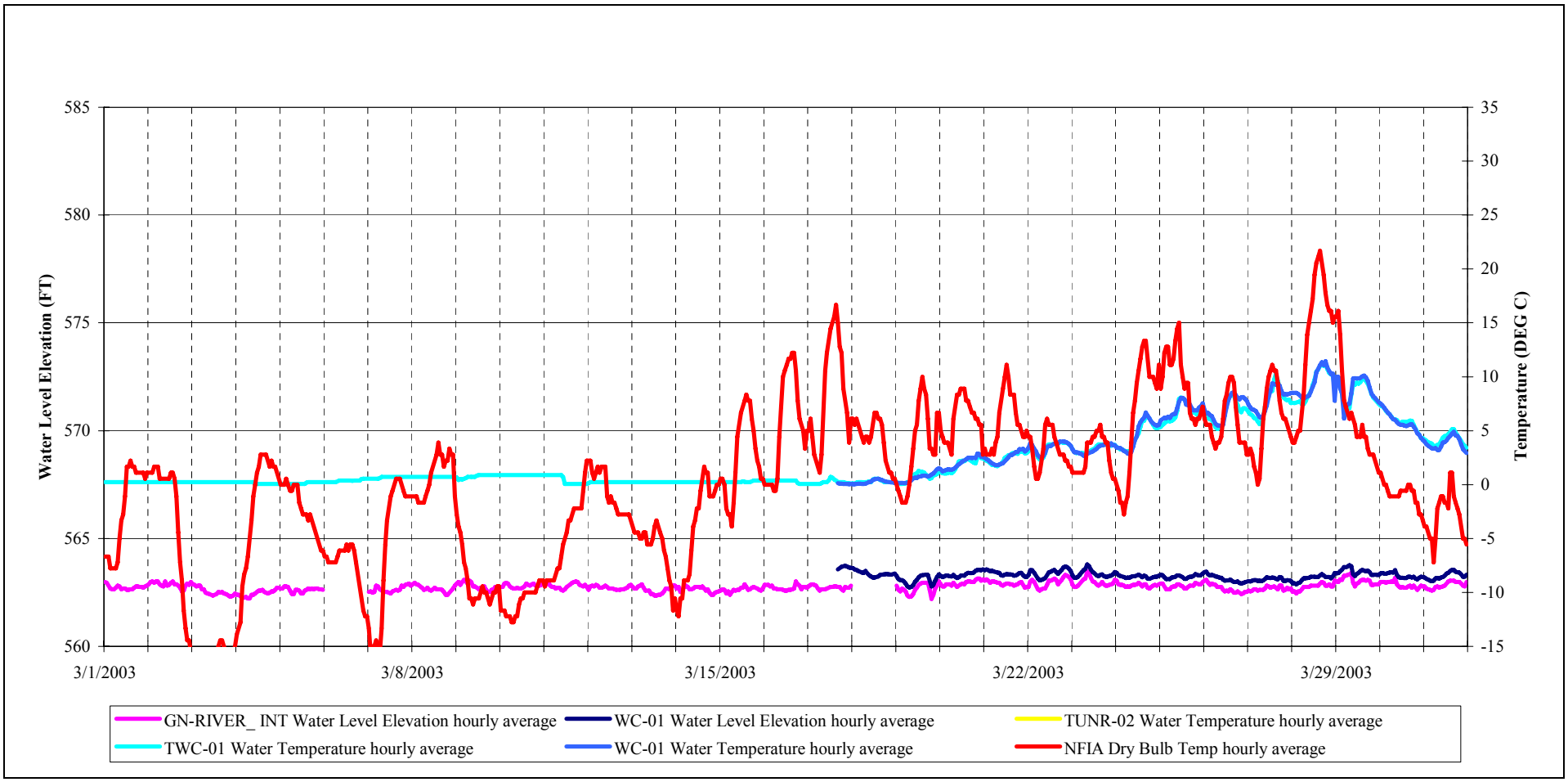

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FIGURE B-74: LOWER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

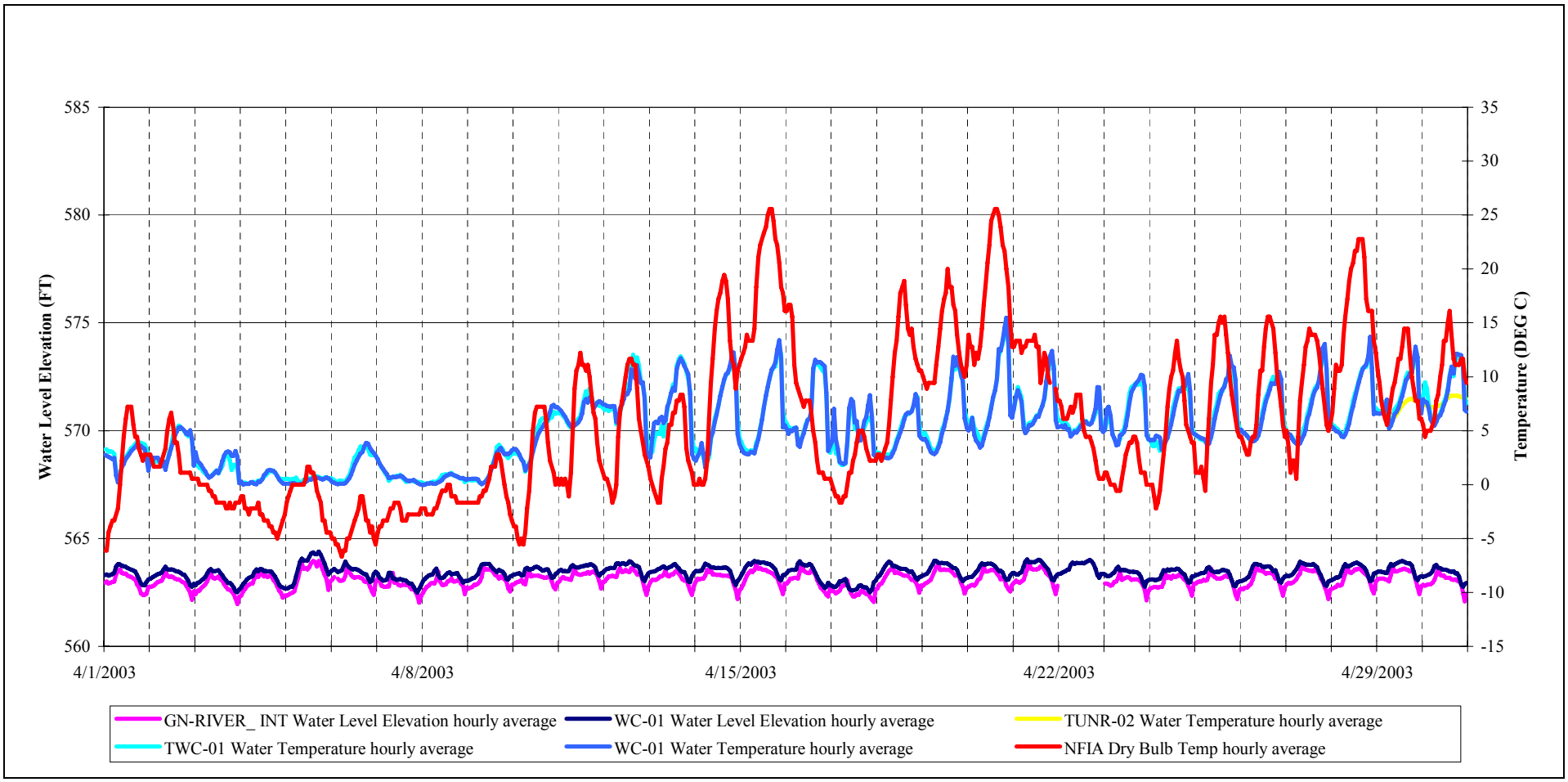

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FIGURE B-75: LOWER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

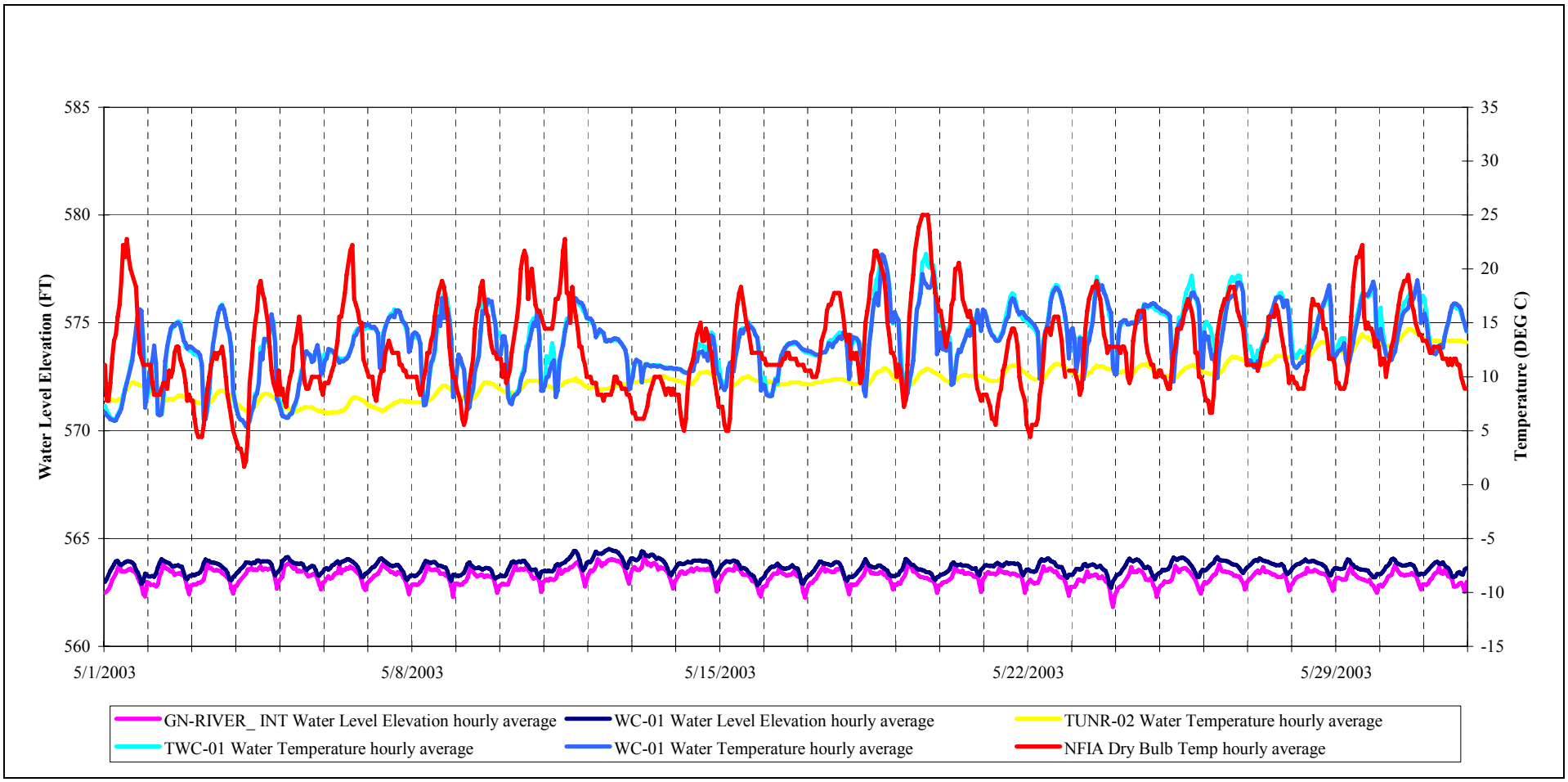

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FIGURE B-76: LOWER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

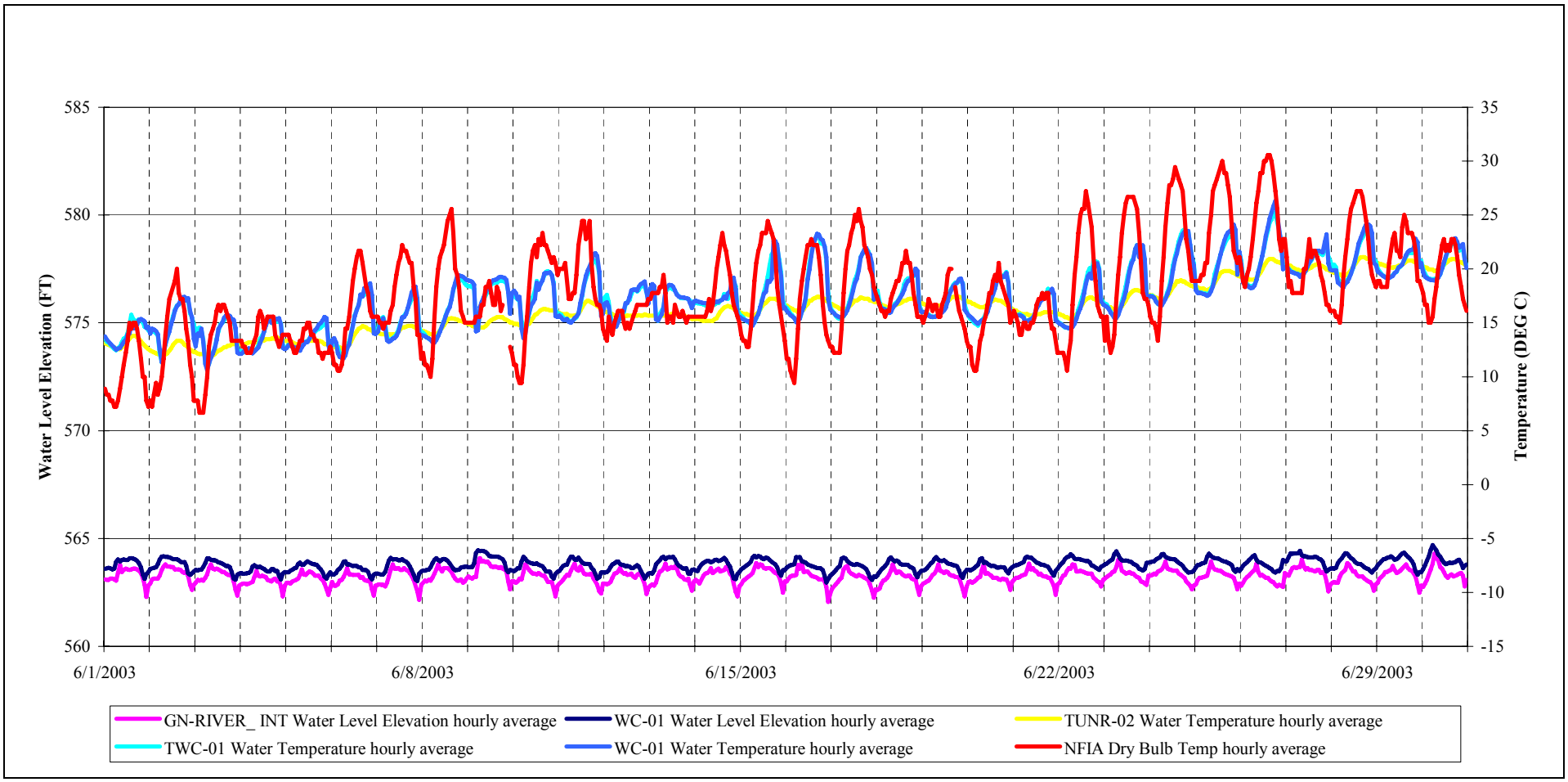

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FIGURE B-77: LOWER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

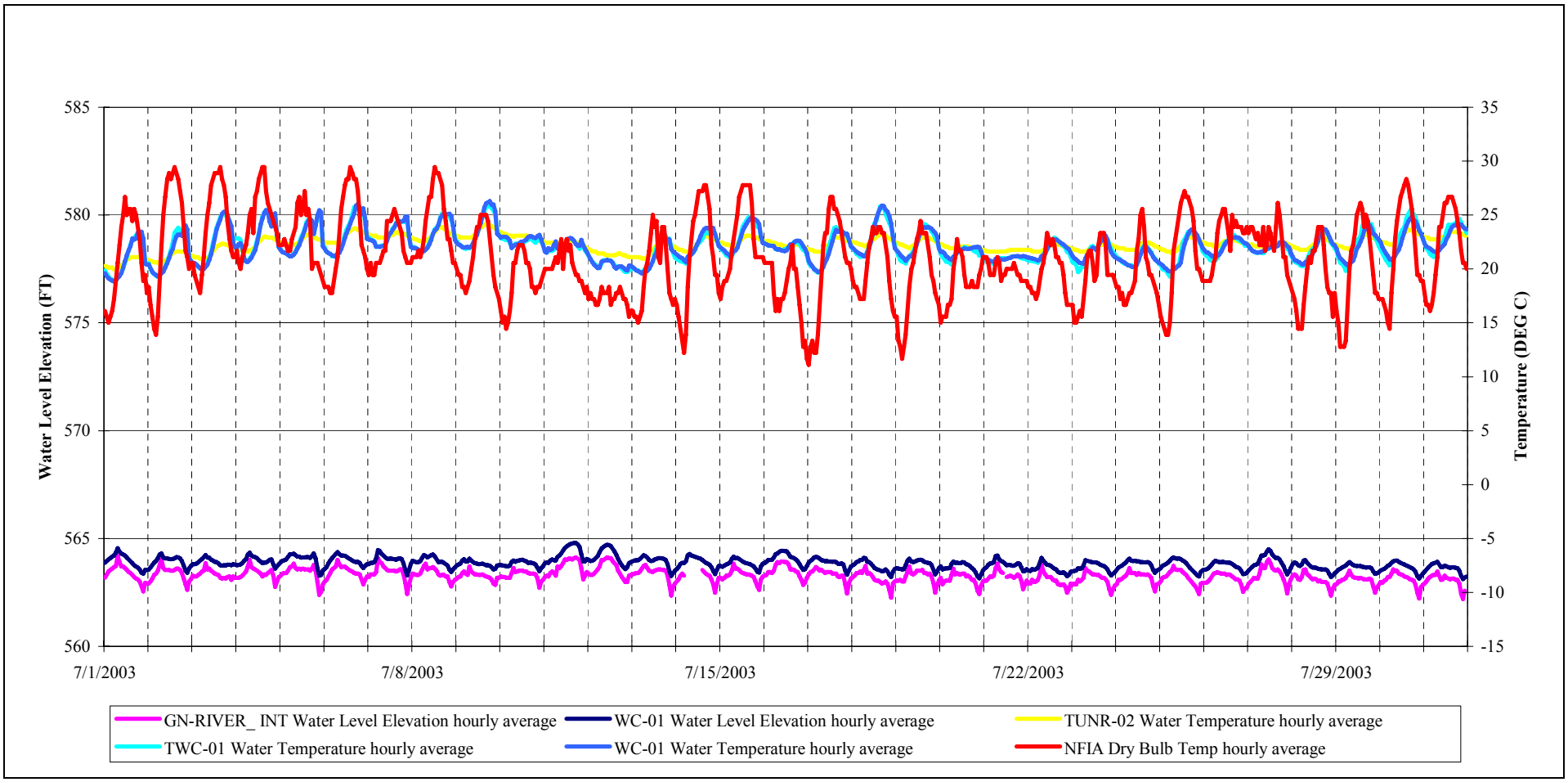

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FIGURE B-78: LOWER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

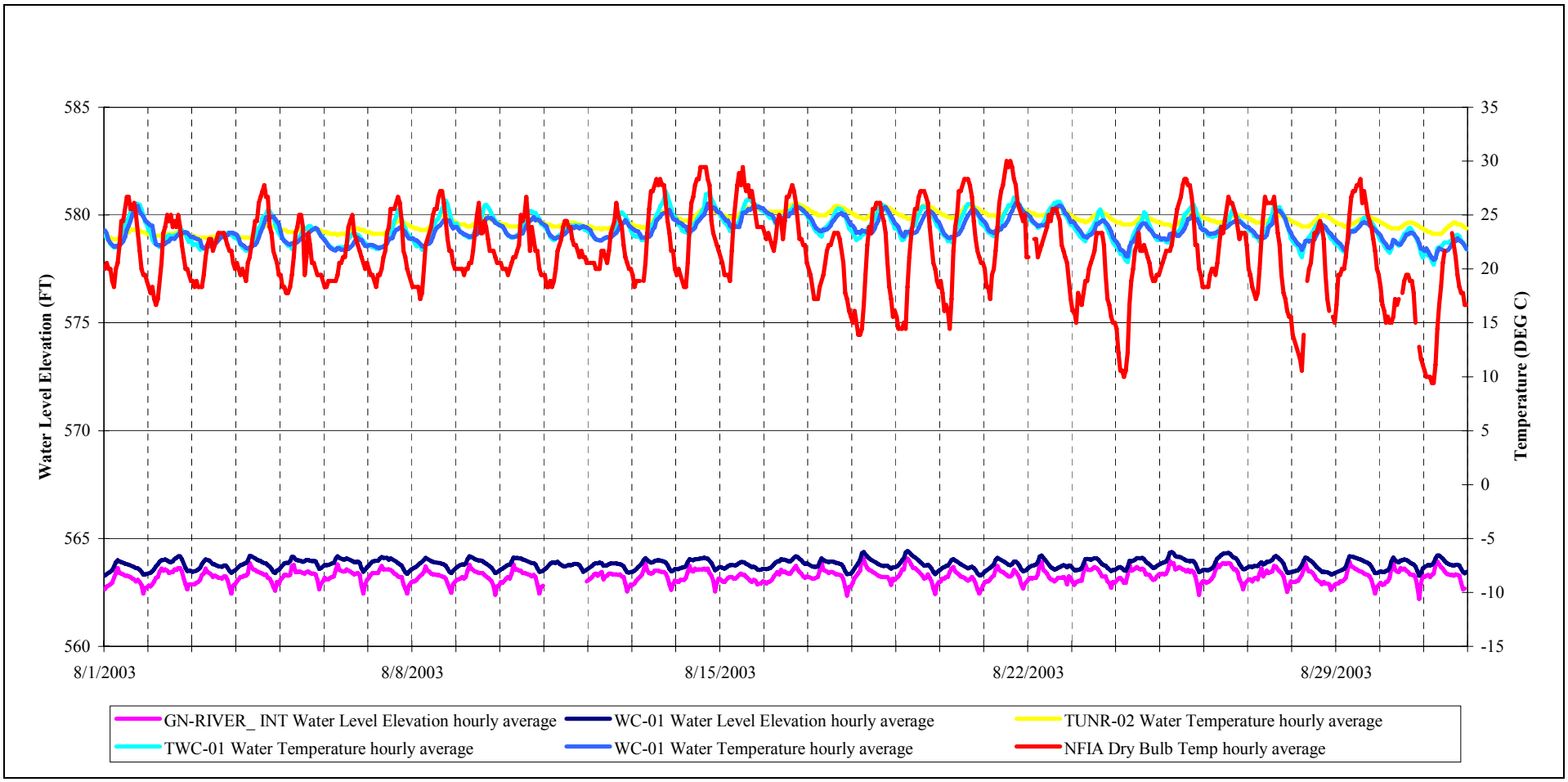

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FIGURE B-79: LOWER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

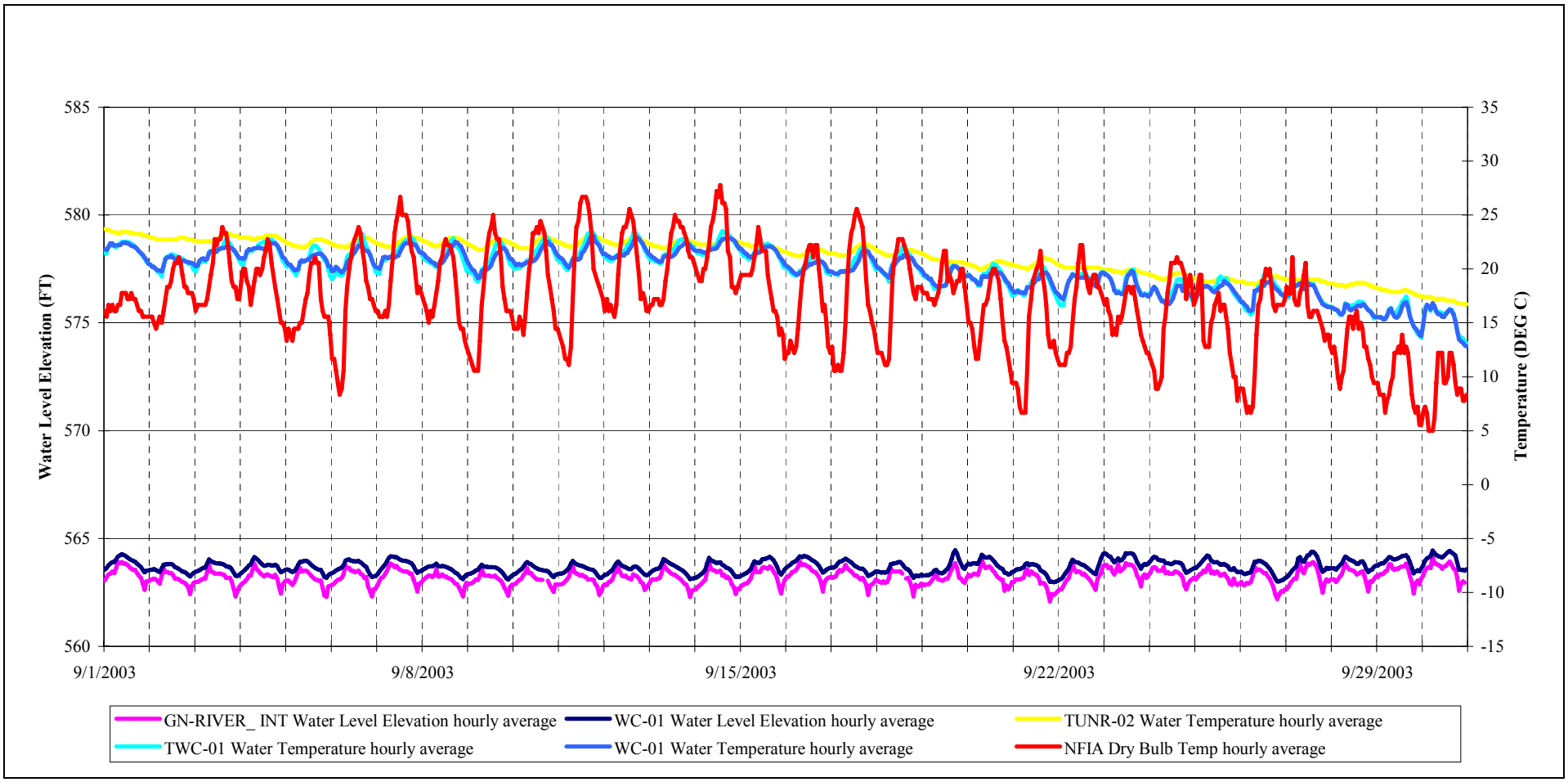

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FIGURE B-80: LOWER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

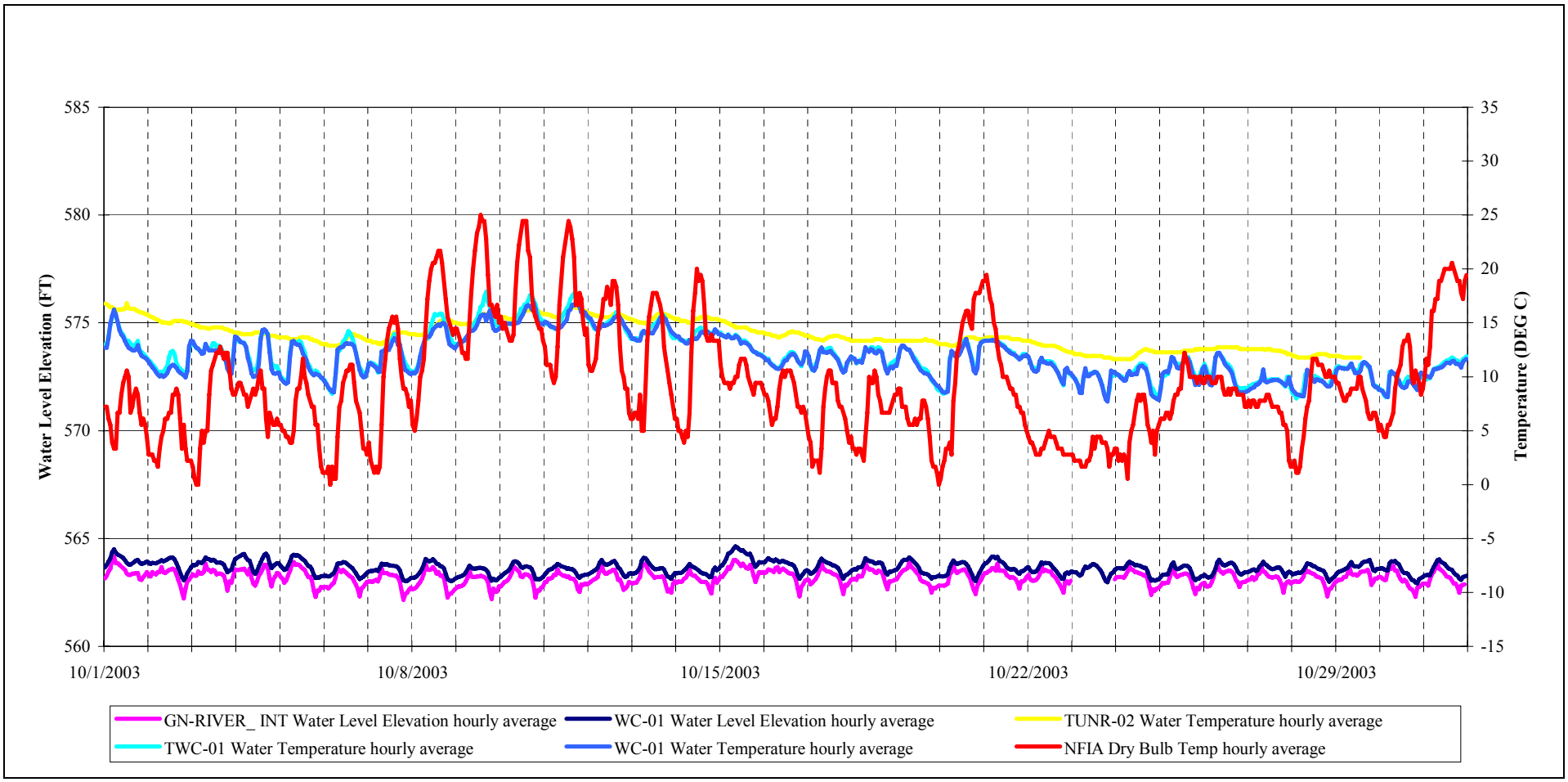

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FIGURE B-81: LOWER WOODS CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

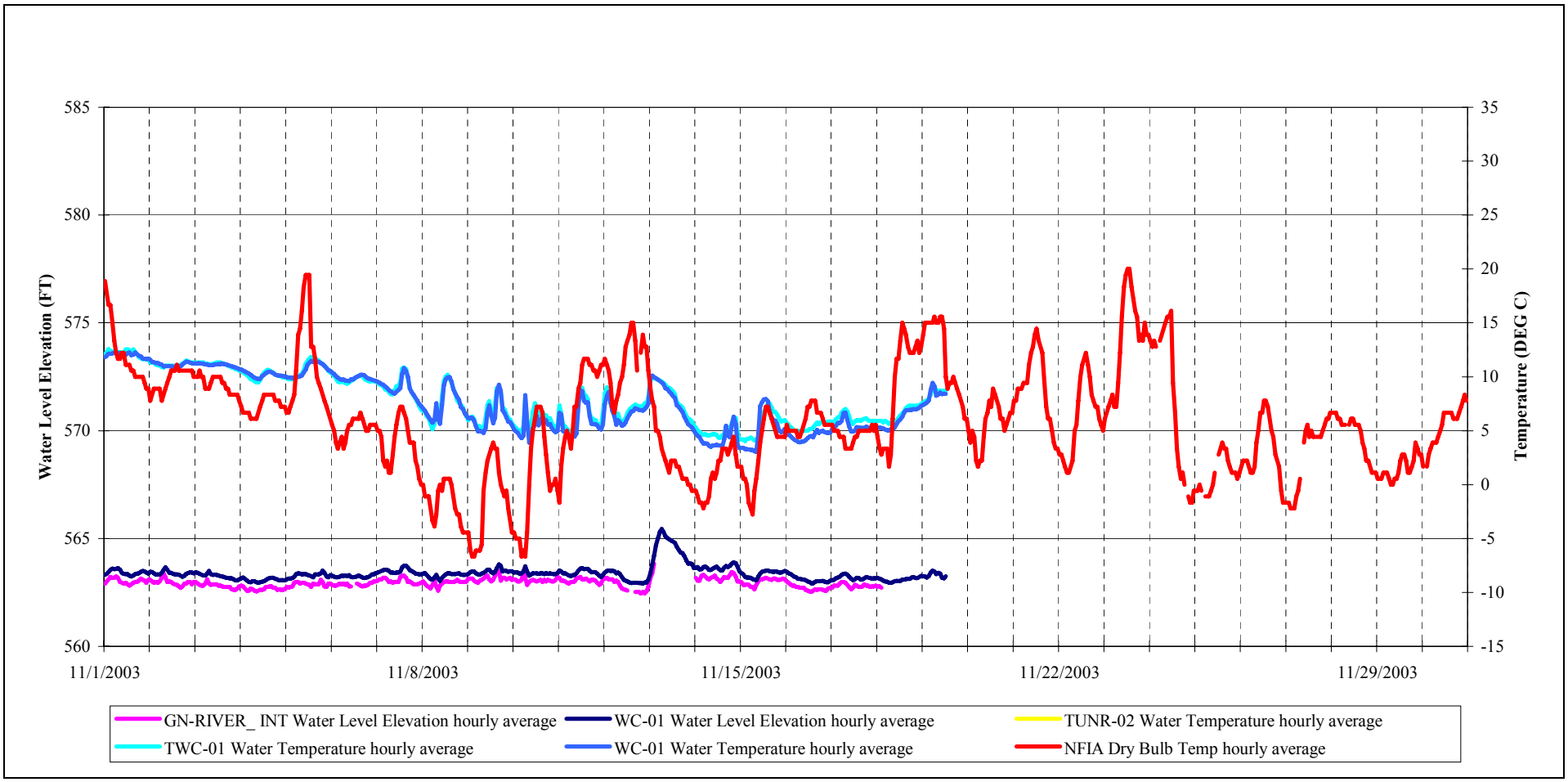

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FIGURE B-82: GUN CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

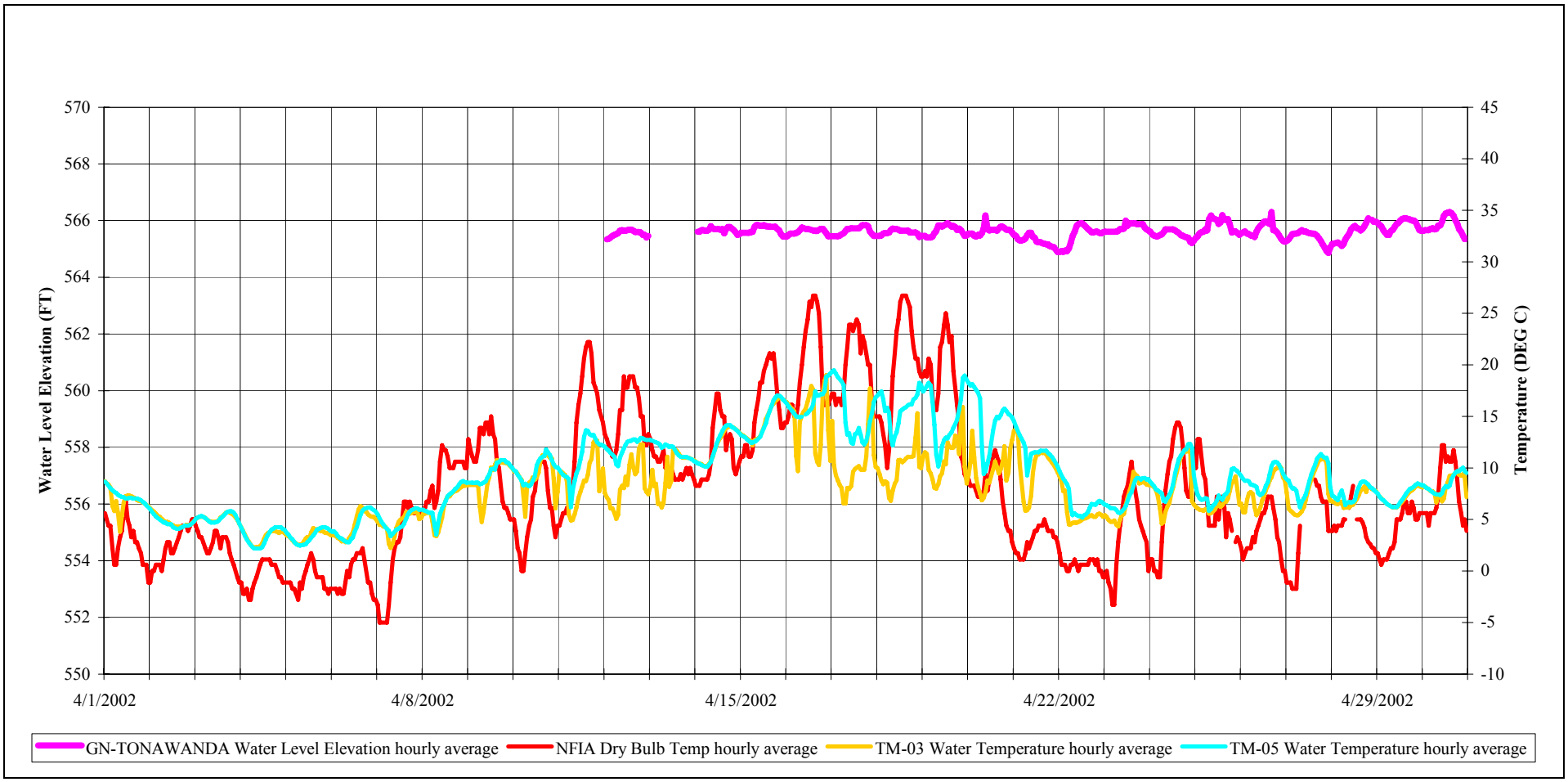

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FIGURE B-83: GUN CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

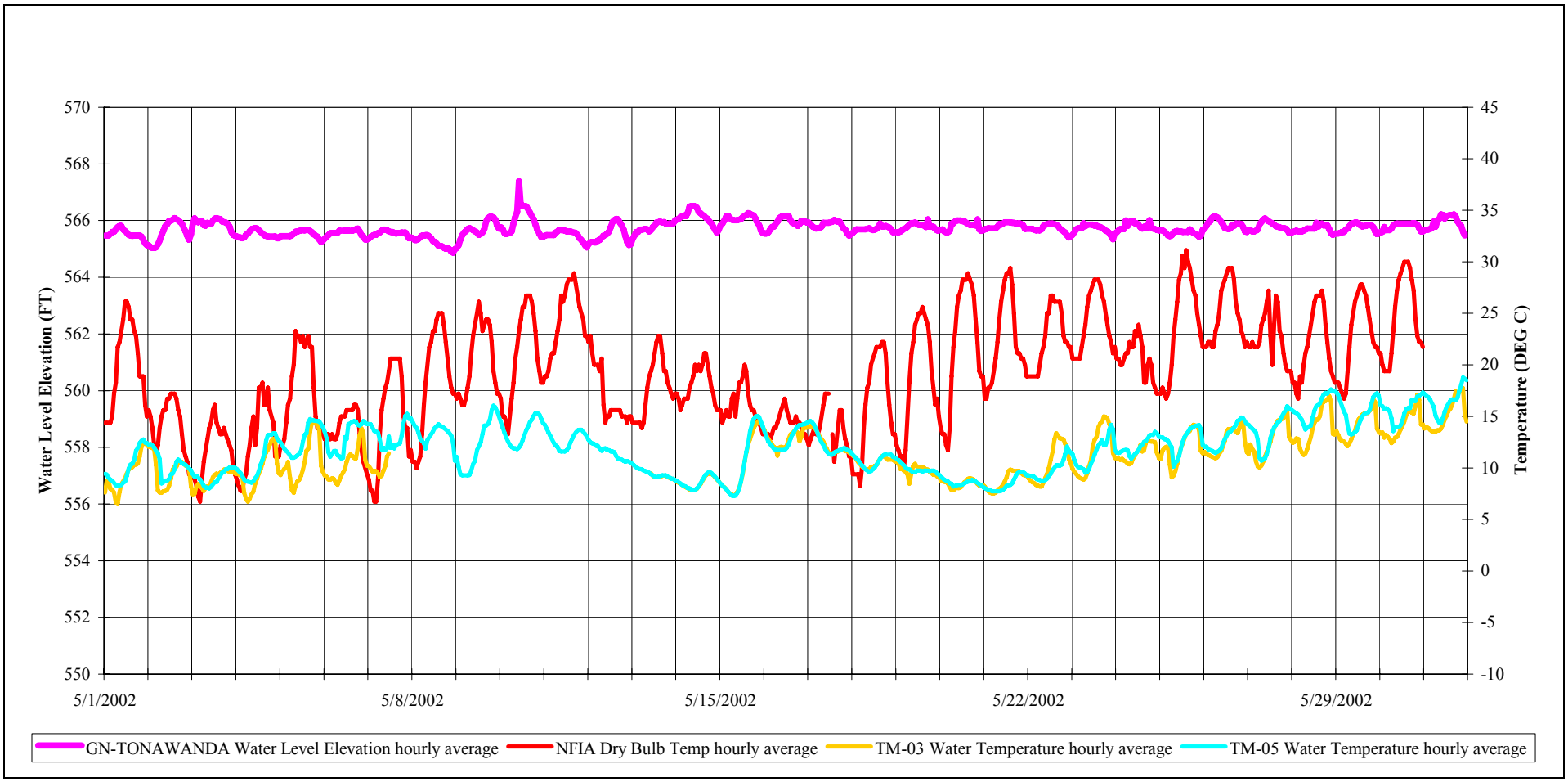

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FIGURE B-84: GUN CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

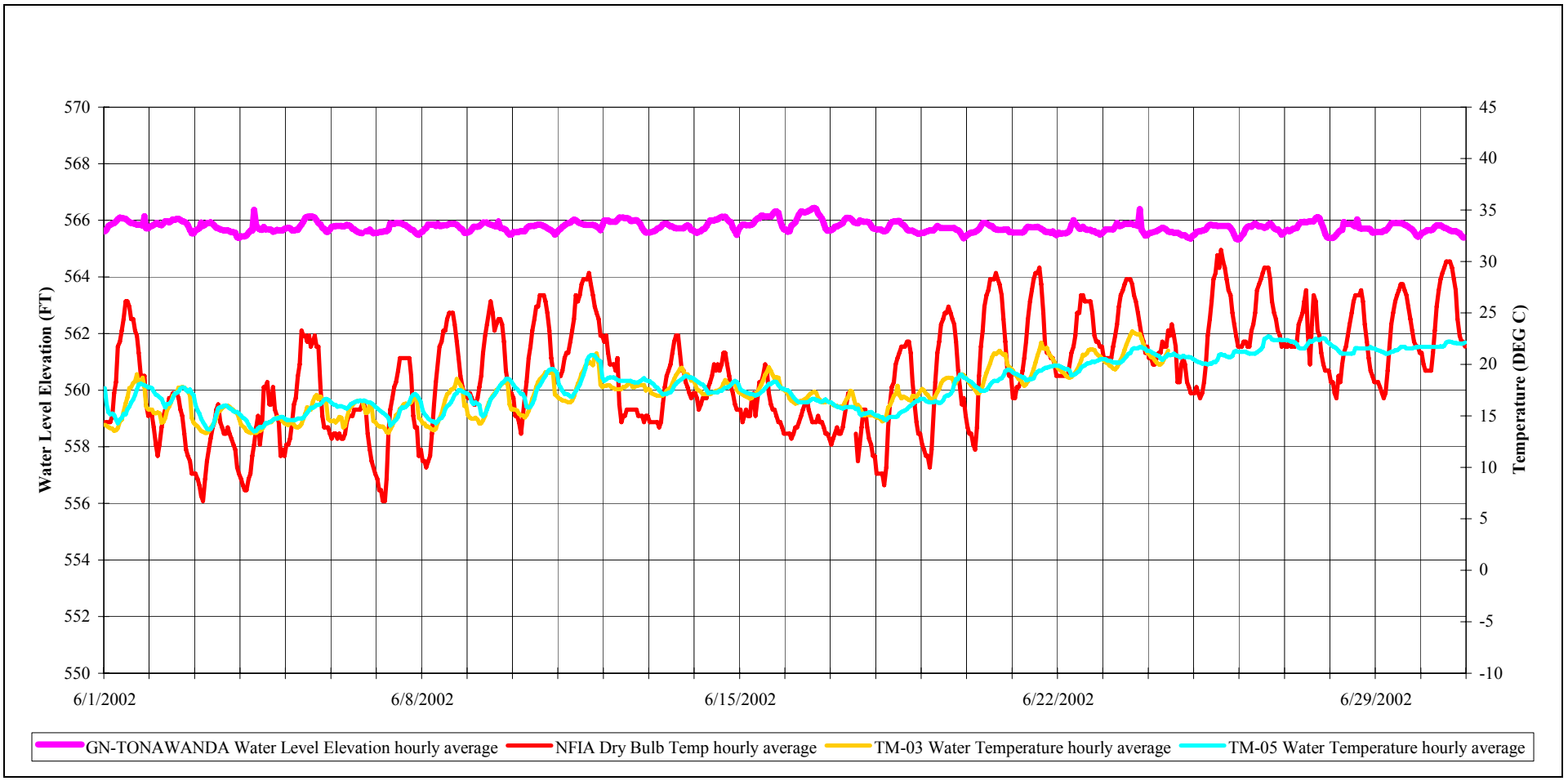

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FIGURE B-85: GUN CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

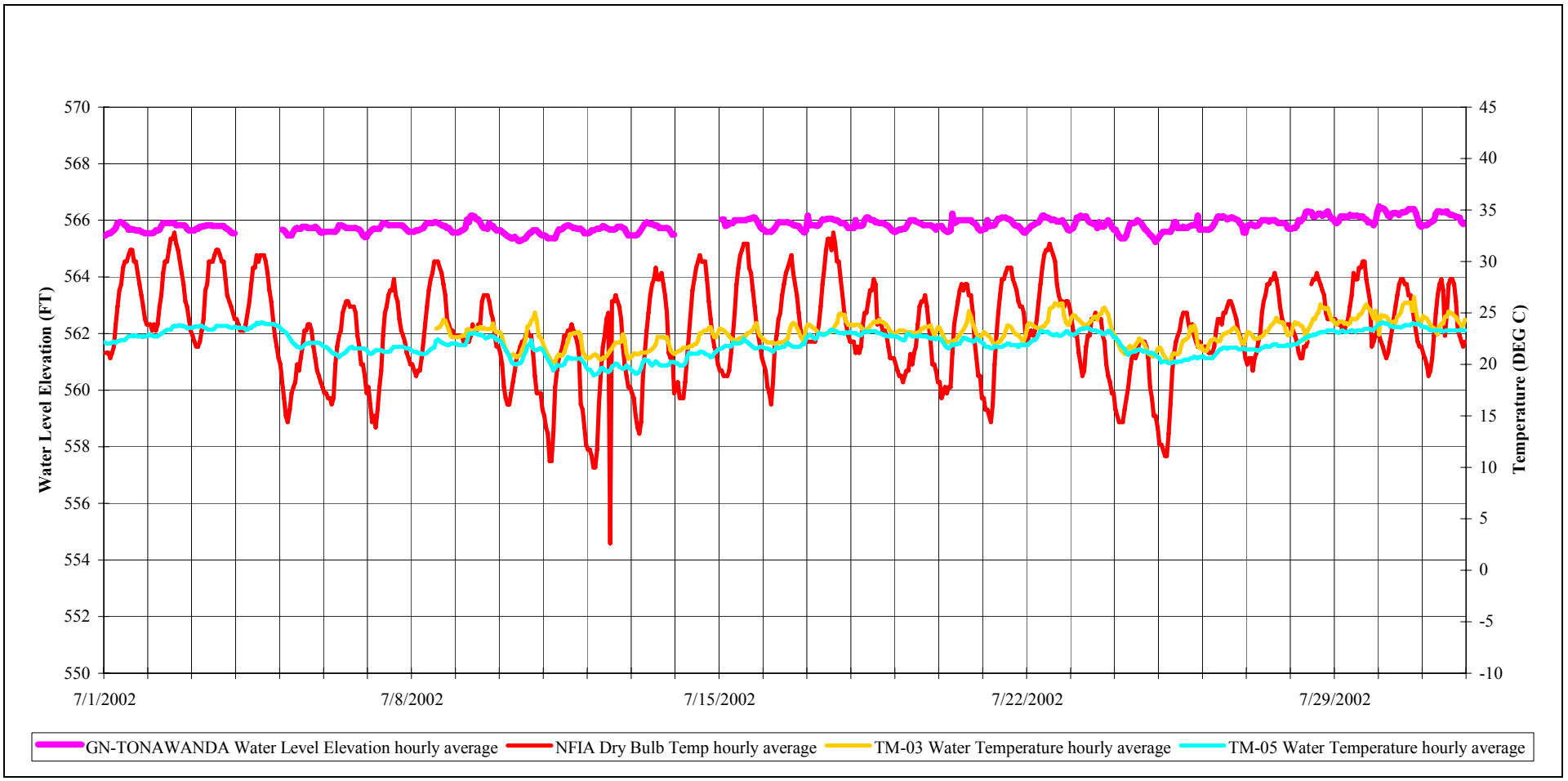

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FIGURE B-86: GUN CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

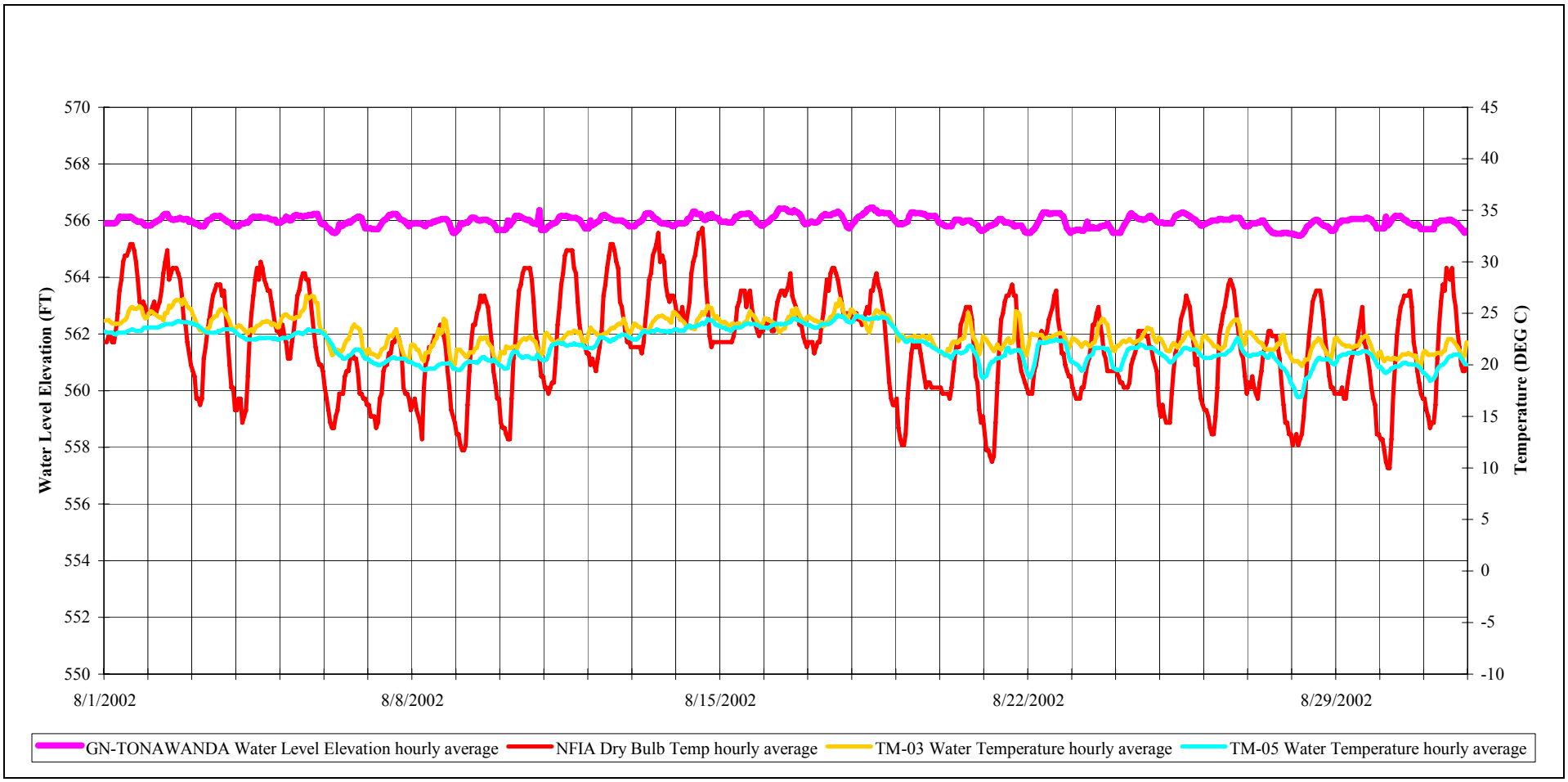

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FIGURE B-87: GUN CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

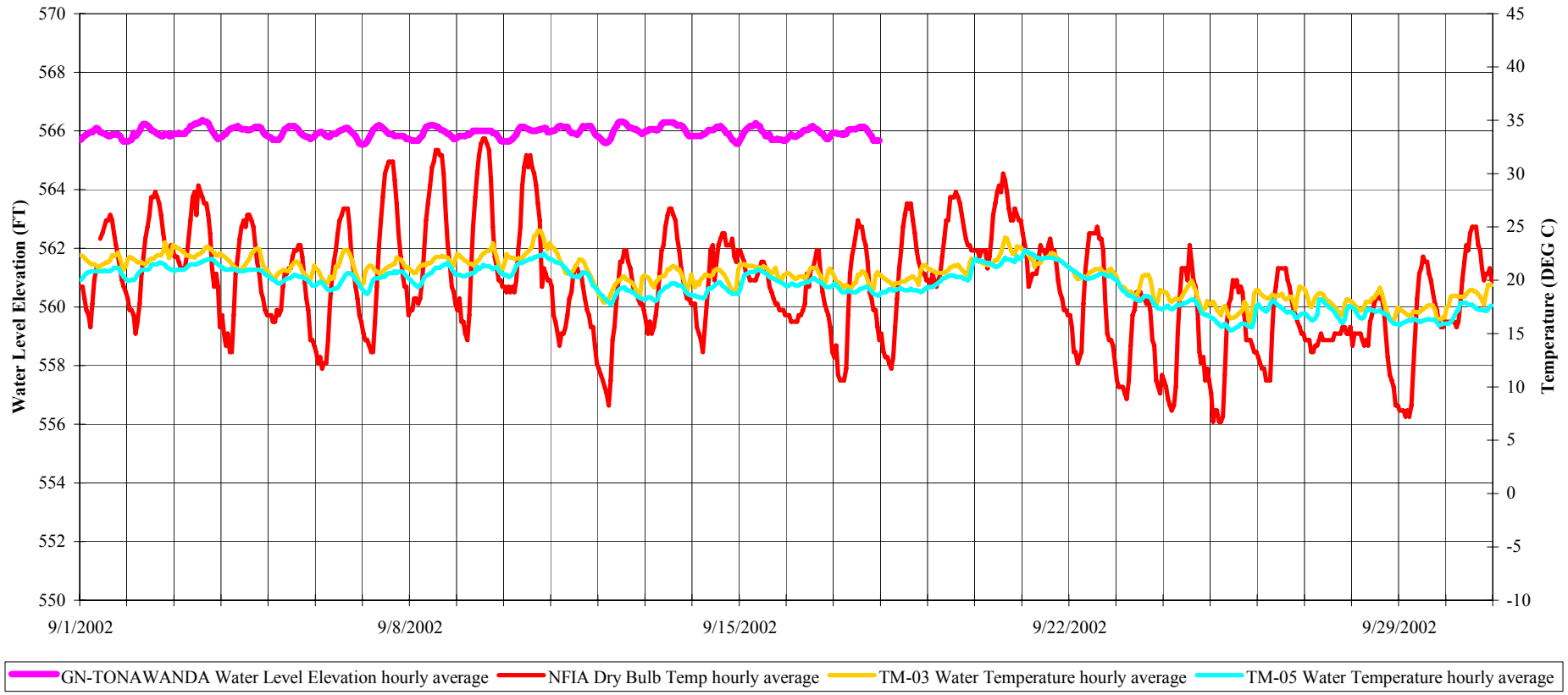

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FIGURE B-88: GUN CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

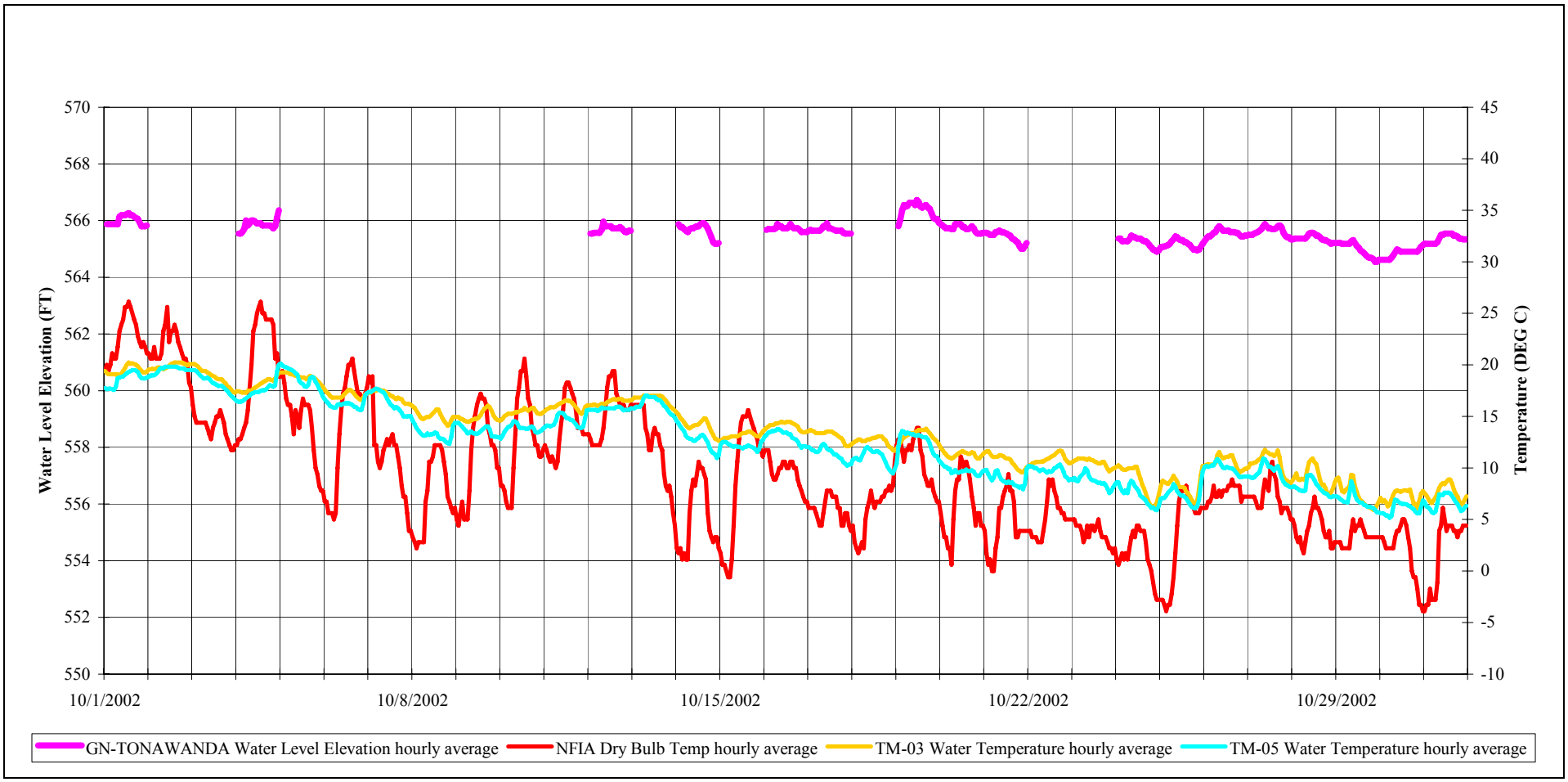

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FIGURE B-89: GUN CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2002

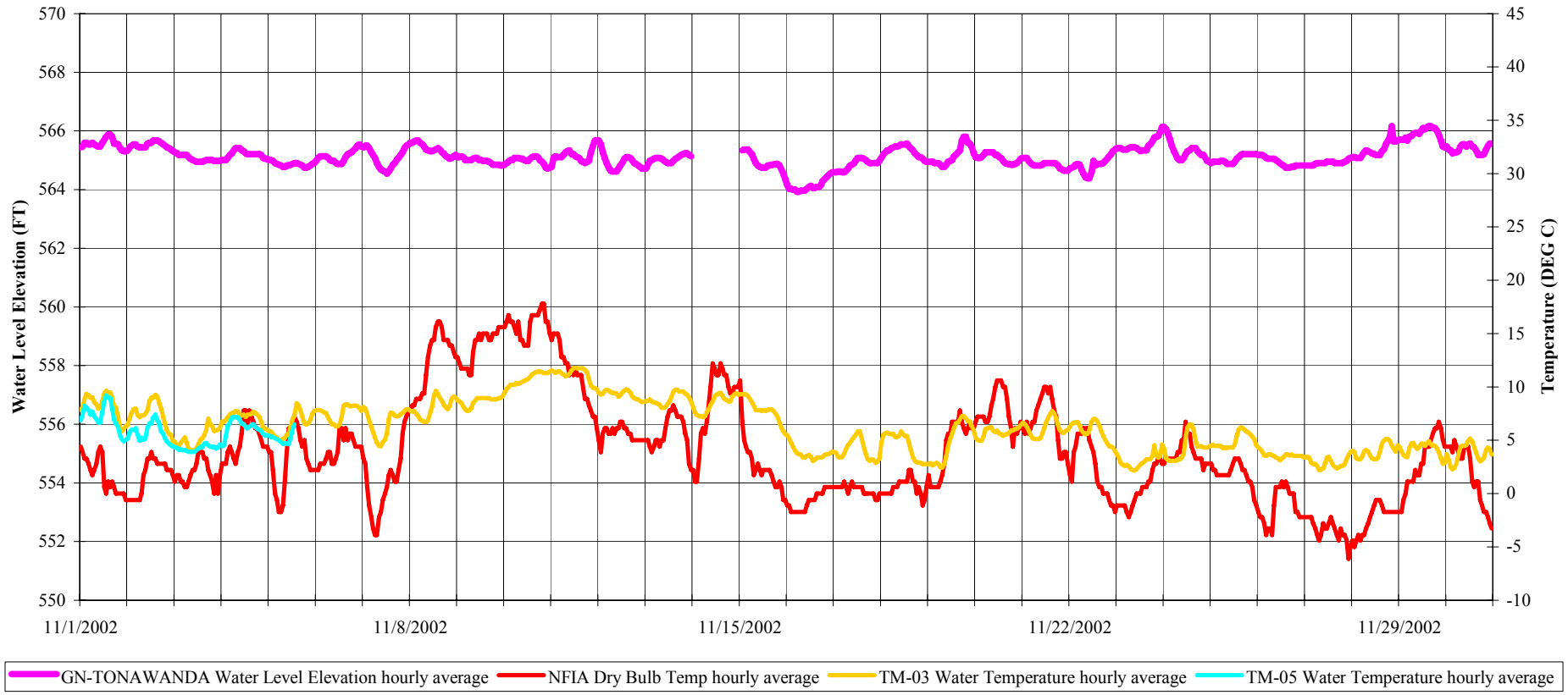

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FIGURE B-90: LOWER GUN CREEK (GC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

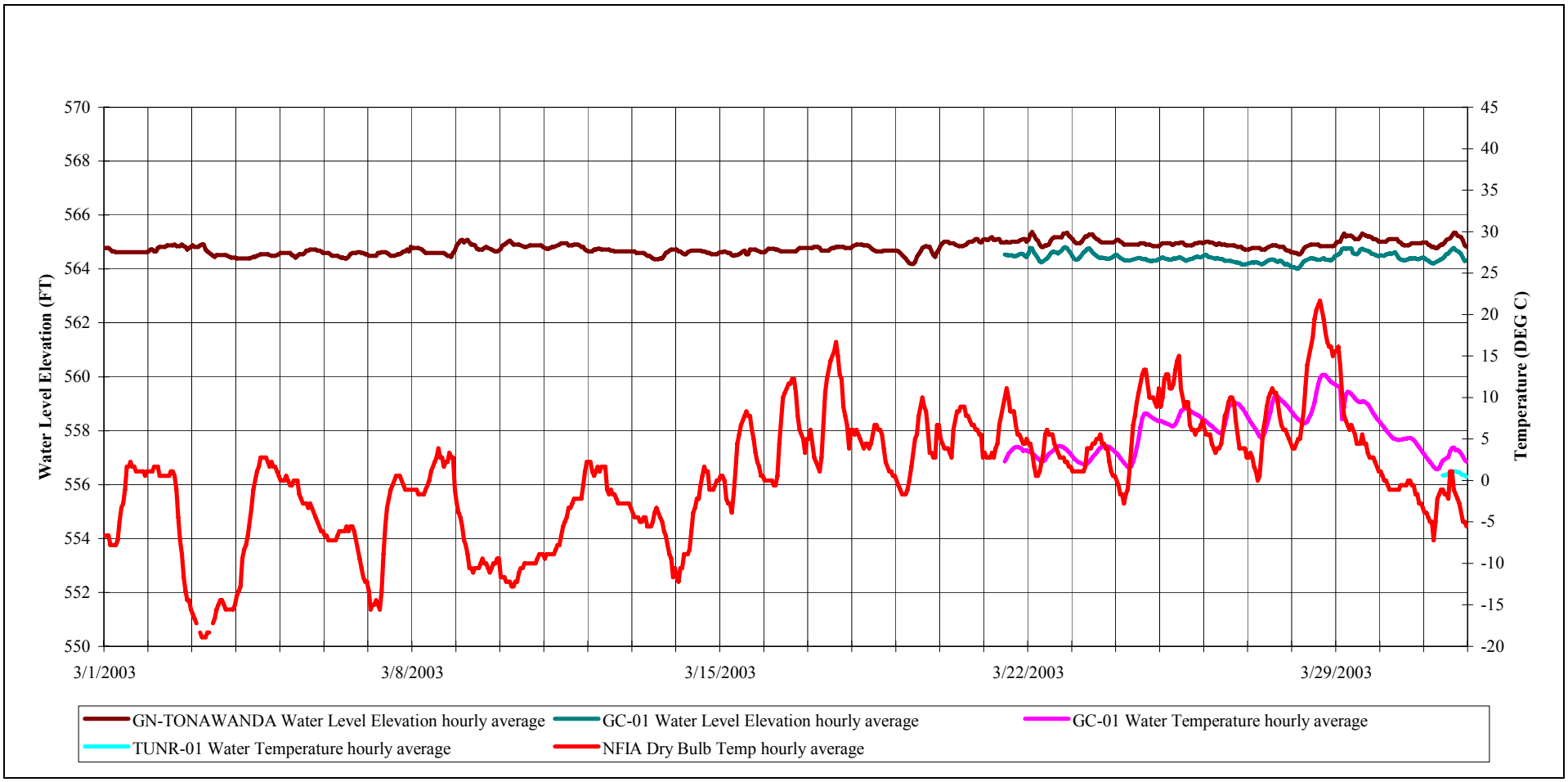

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FIGURE B-91: LOWER GUN CREEK (GC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

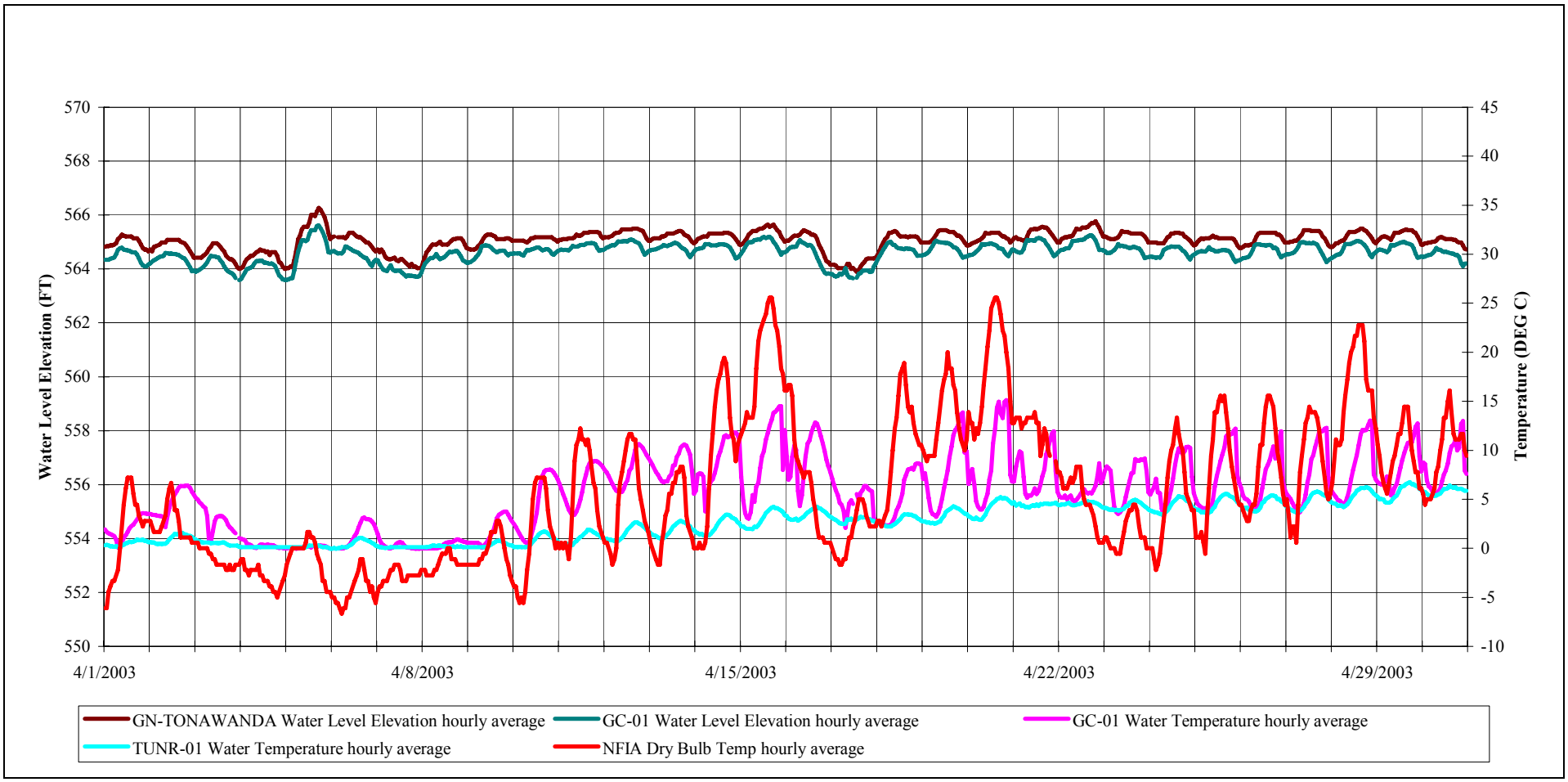

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FIGURE B-92: LOWER GUN CREEK (GC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

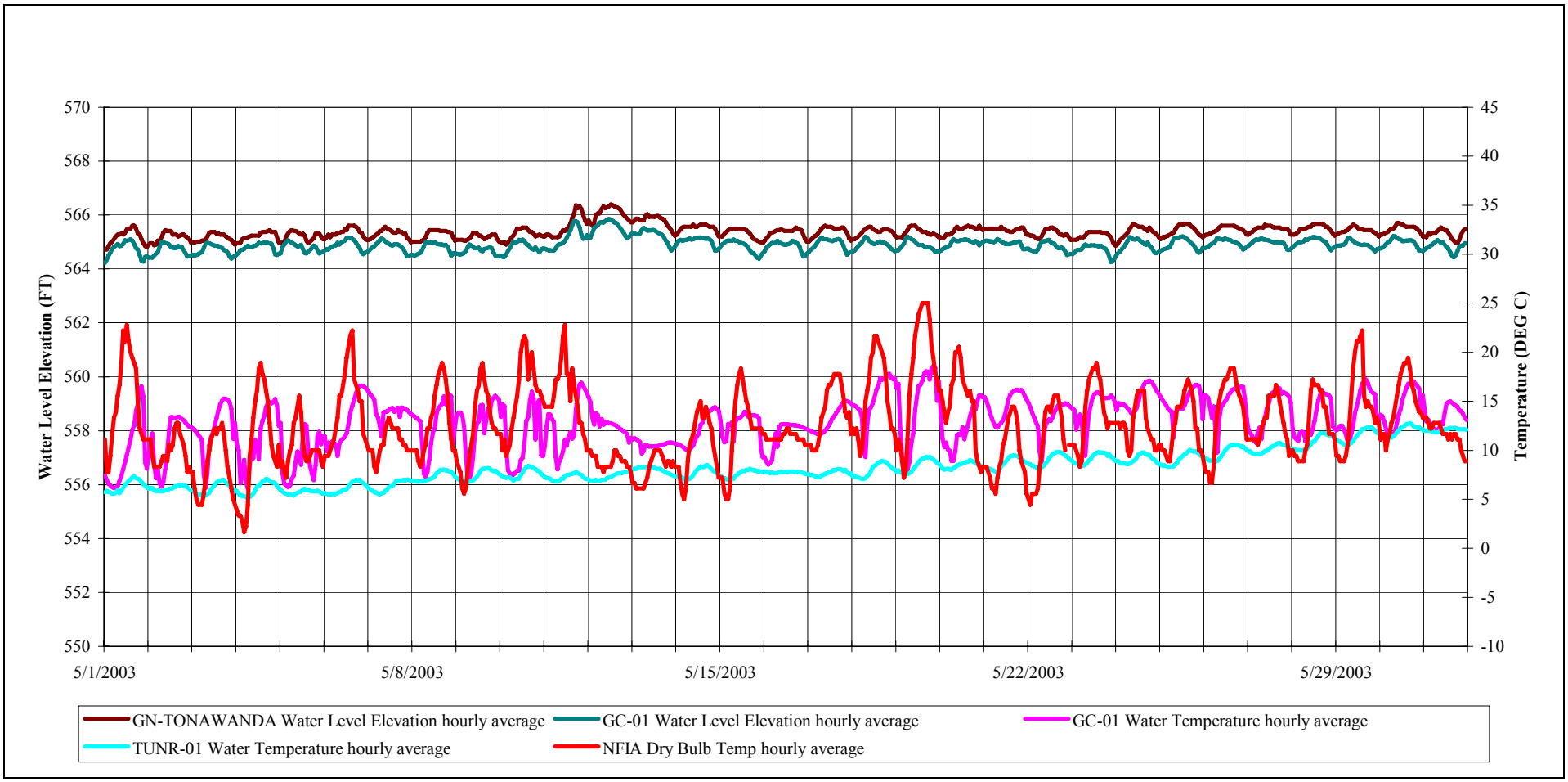

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FIGURE B-93: LOWER GUN CREEK (GC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

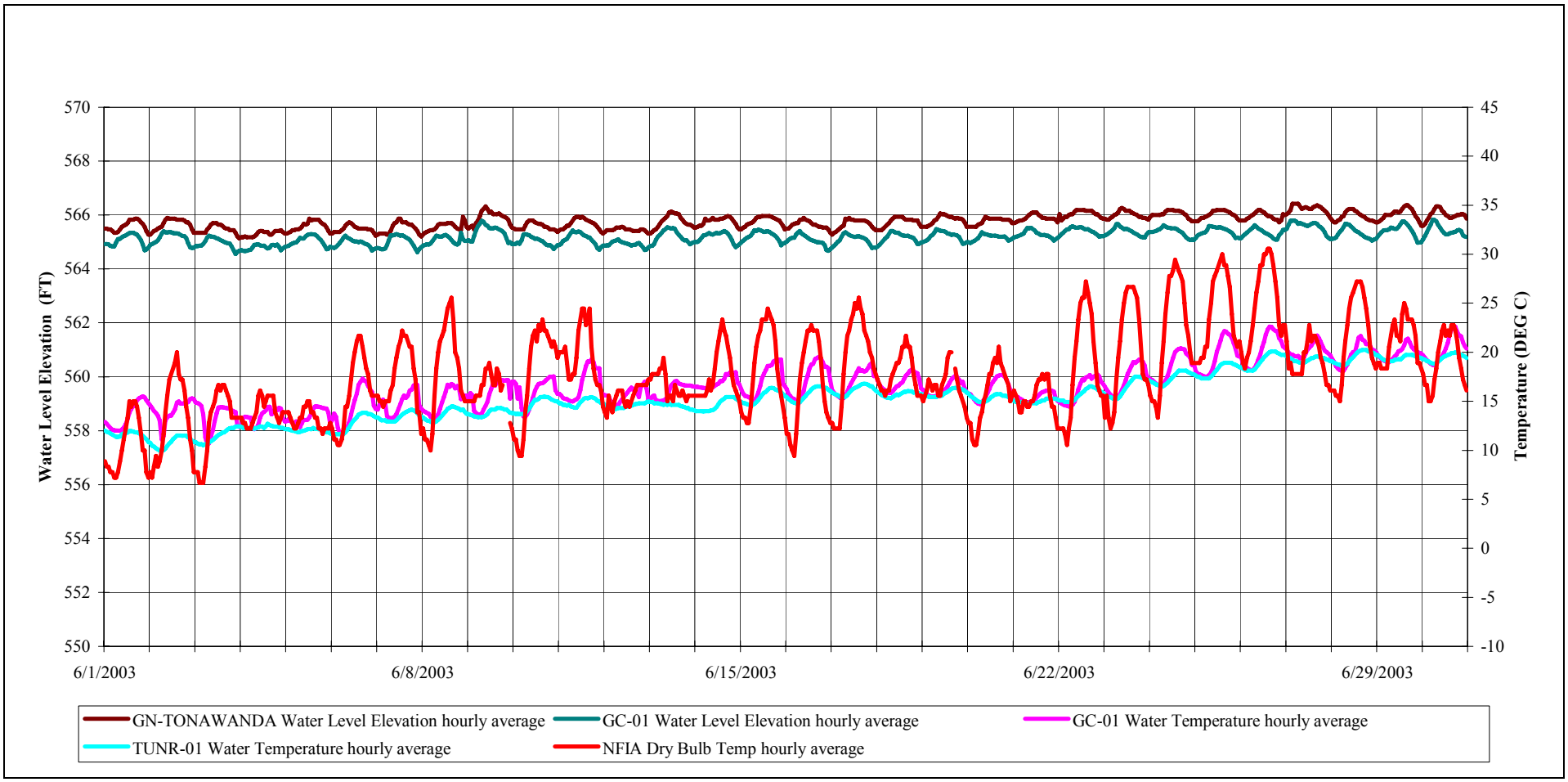

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FIGURE B-94: LOWER GUN CREEK (GC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

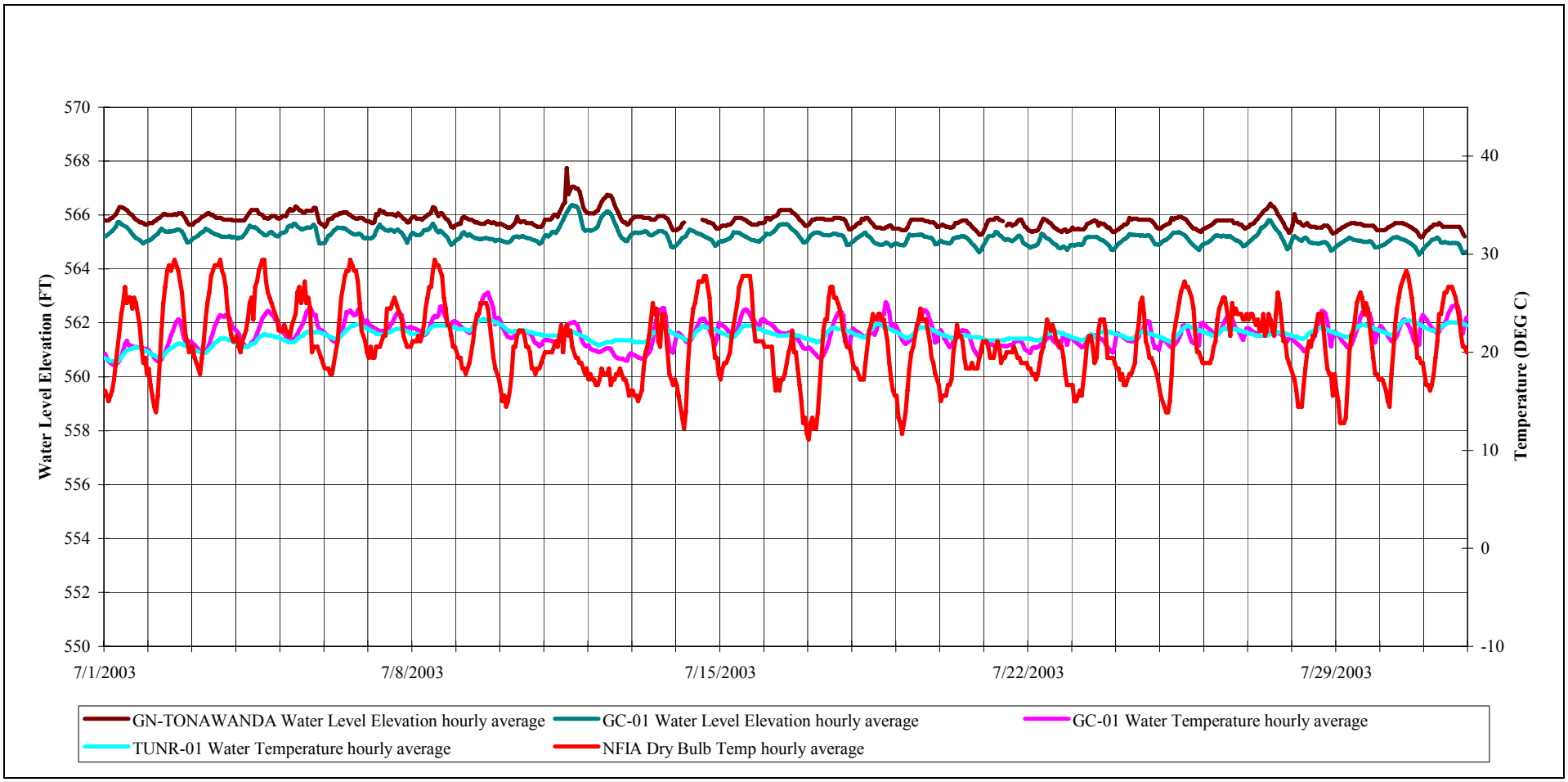

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FIGURE B-95: LOWER GUN CREEK (GC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

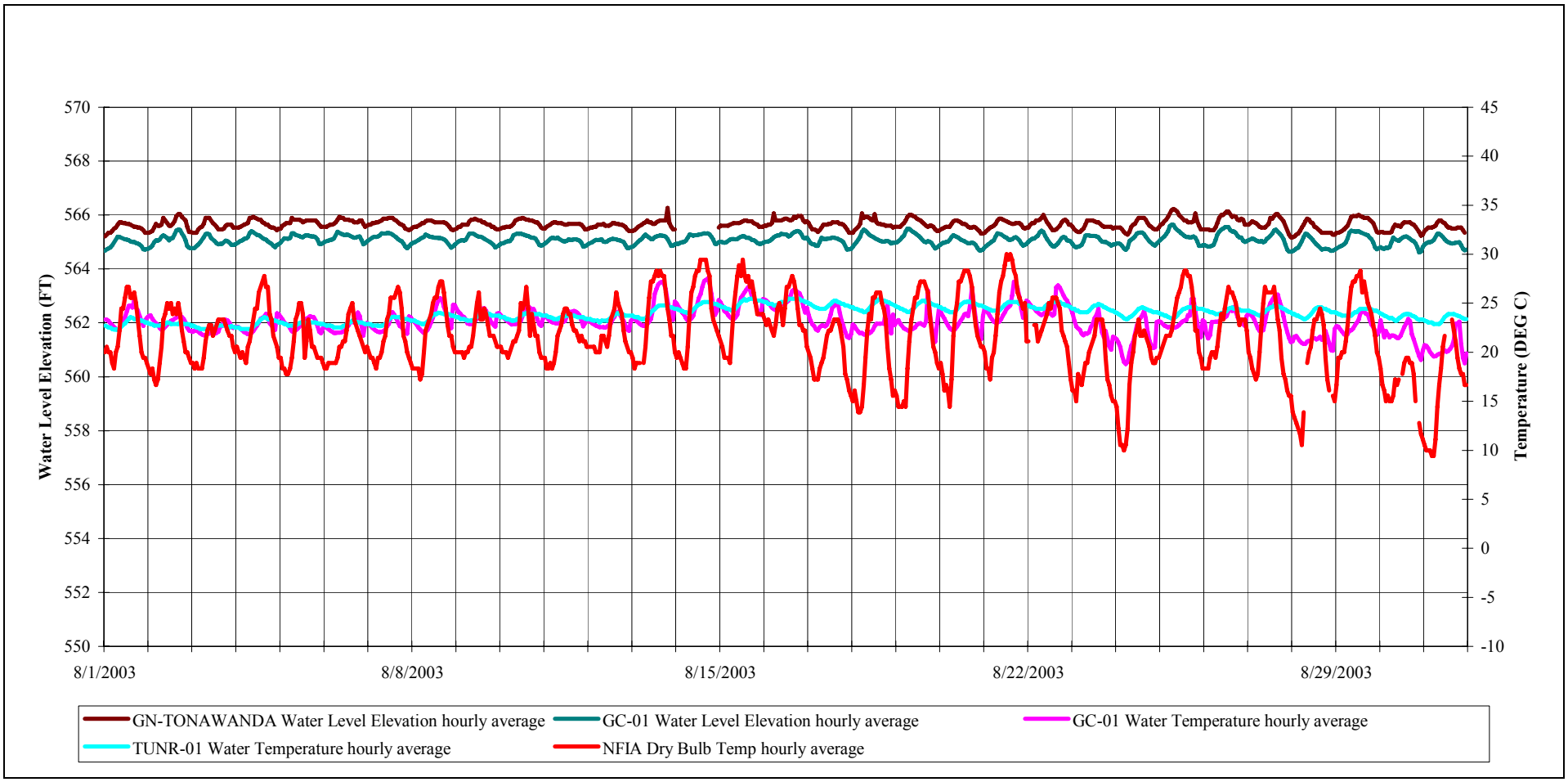

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FIGURE B-96: LOWER GUN CREEK (GC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

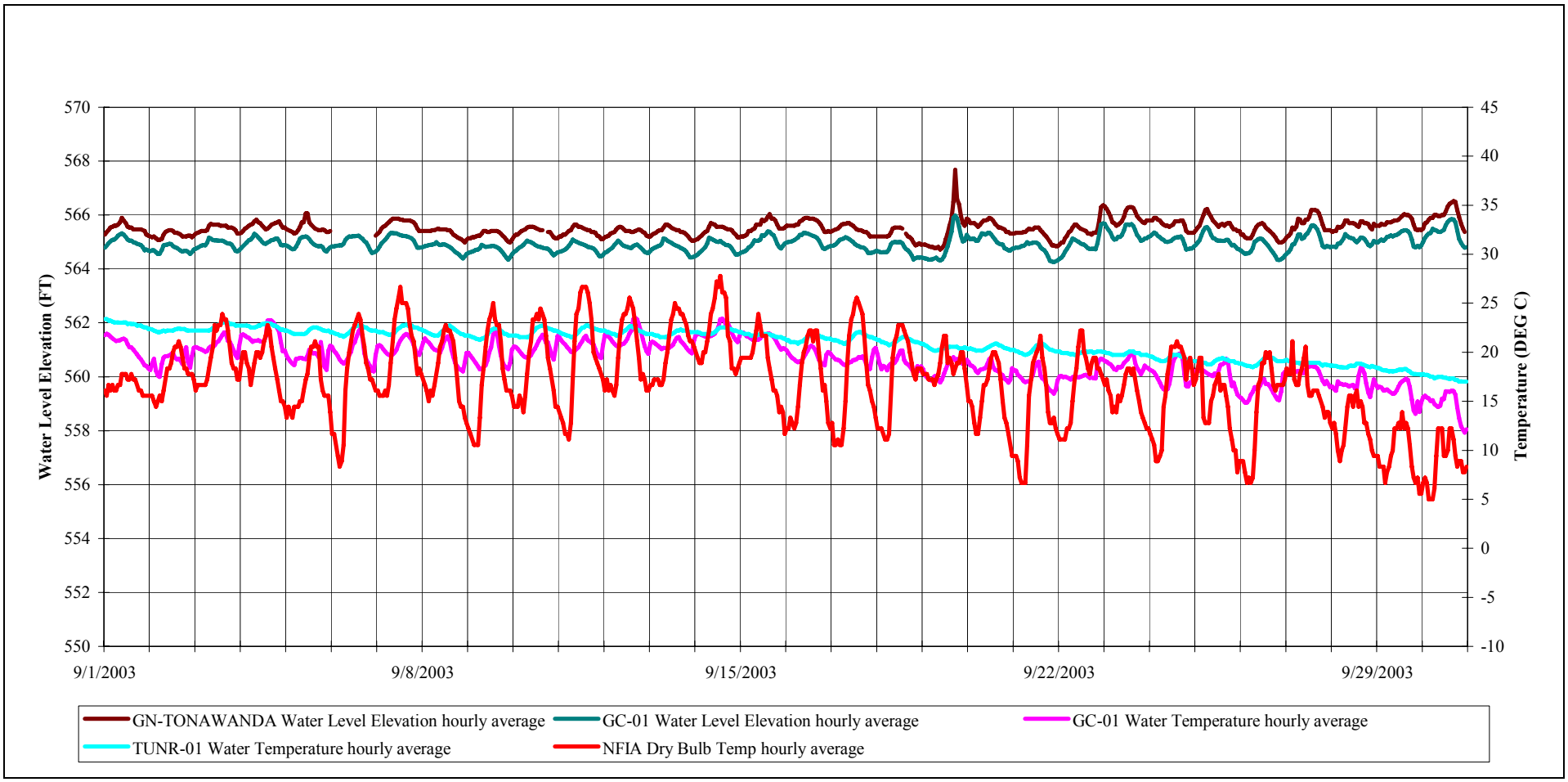

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FIGURE B-97: LOWER GUN CREEK (GC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

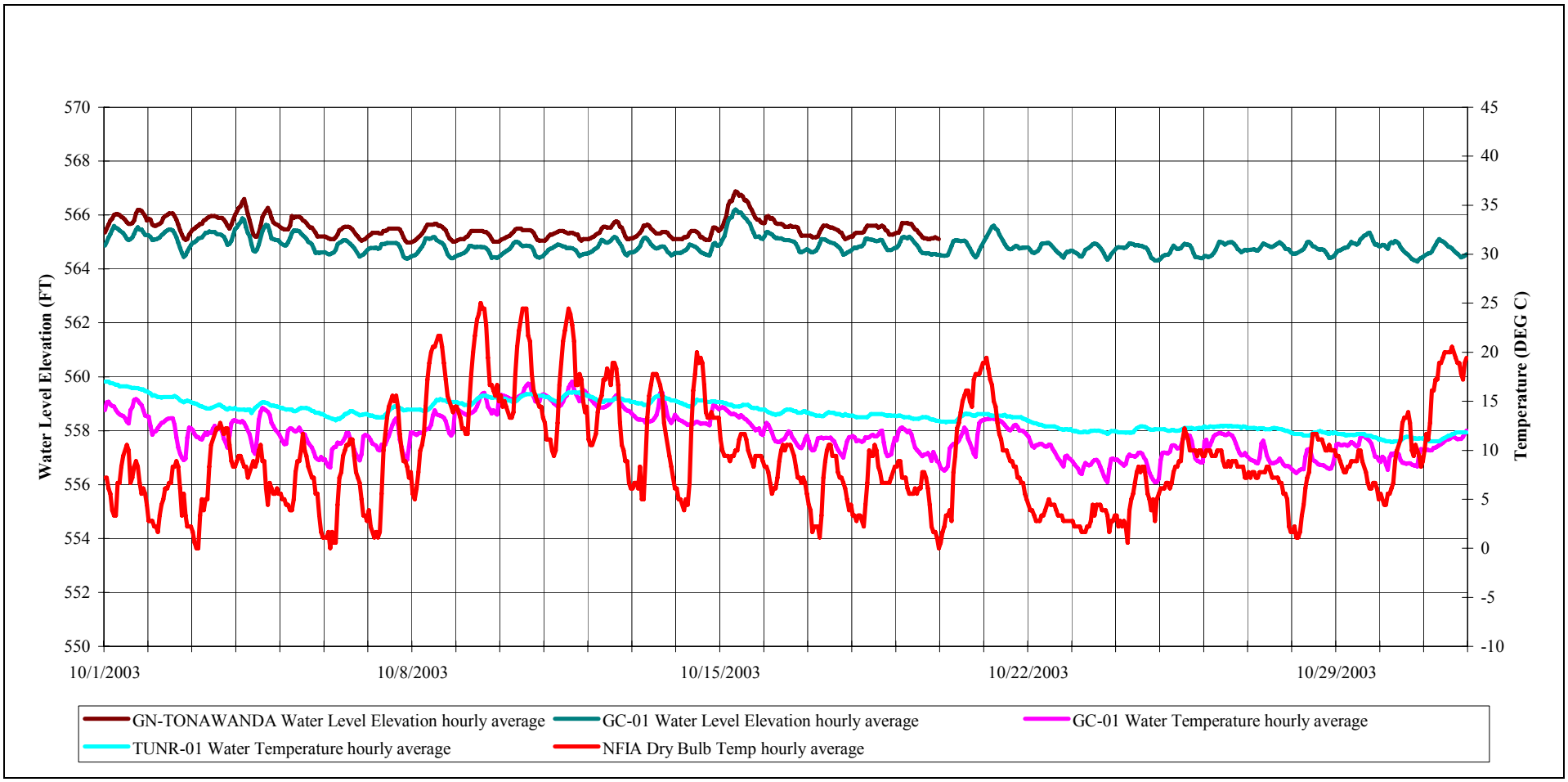

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FIGURE B-98: LOWER GUN CREEK (GC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

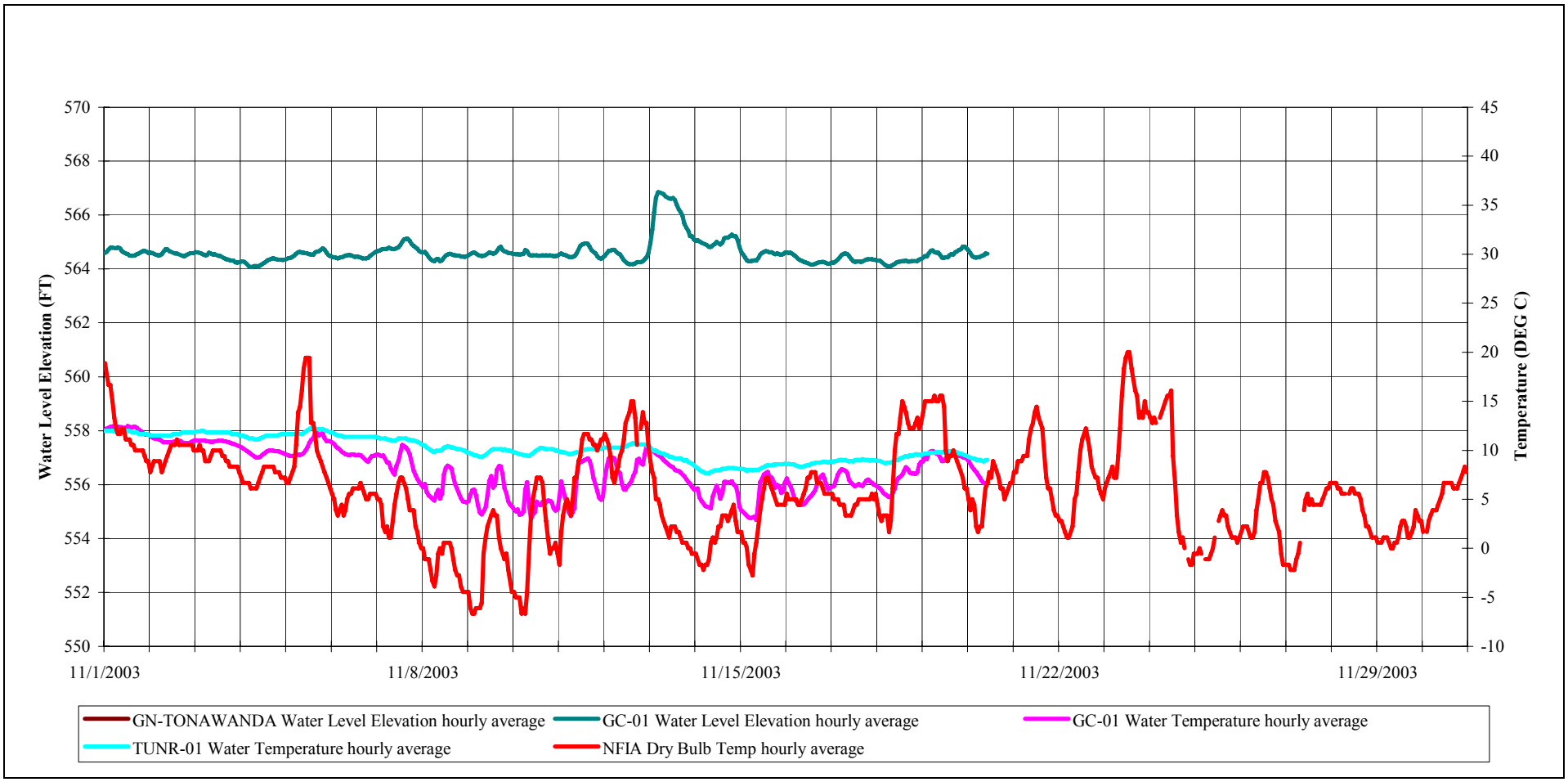

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FIGURE B-99: MIDDLE GUN CREEK (GC-02A)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

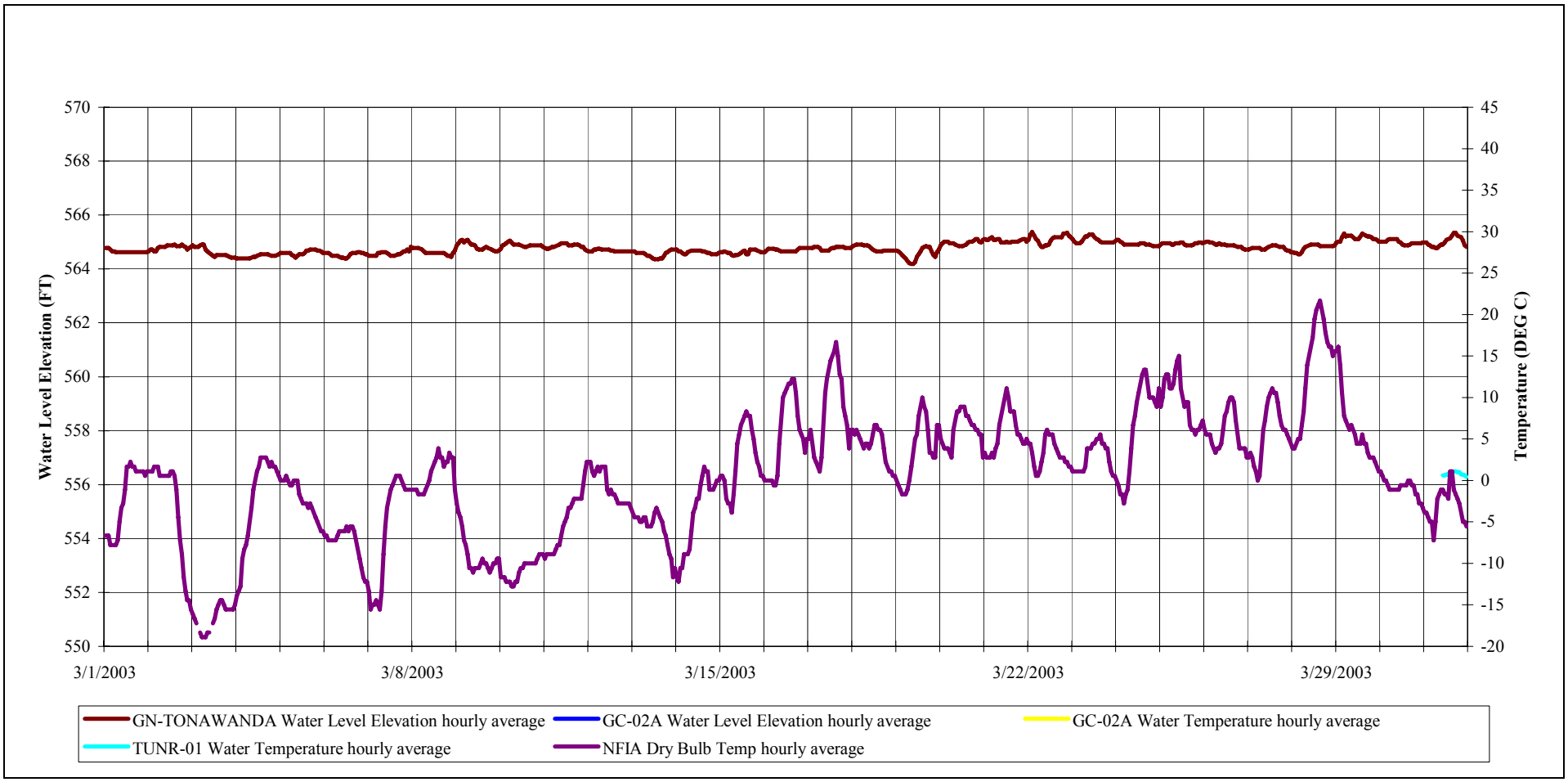

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FIGURE B-100: MIDDLE GUN CREEK (GC-02A)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

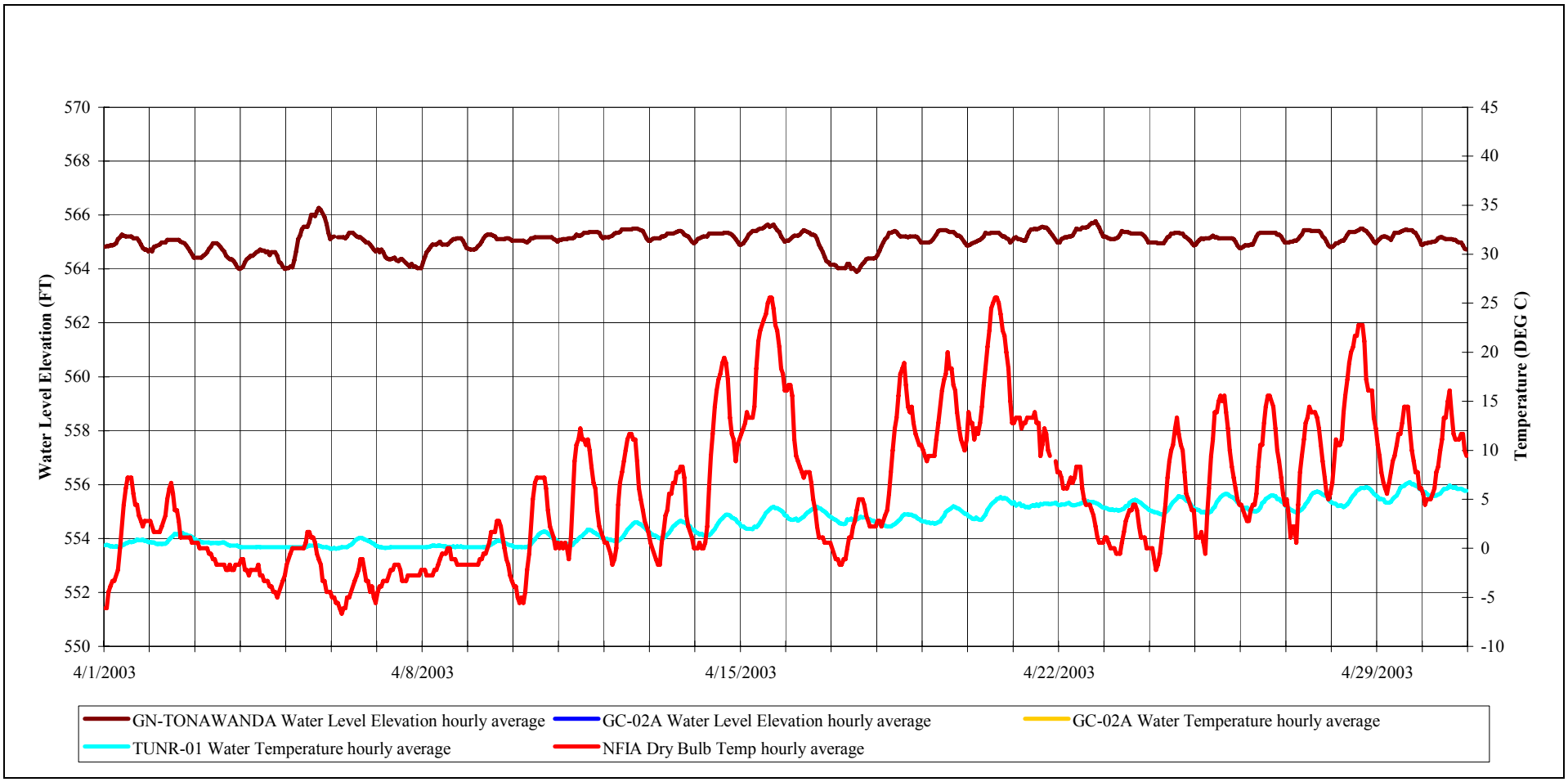

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FIGURE B-101: MIDDLE GUN CREEK (GC-02A)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

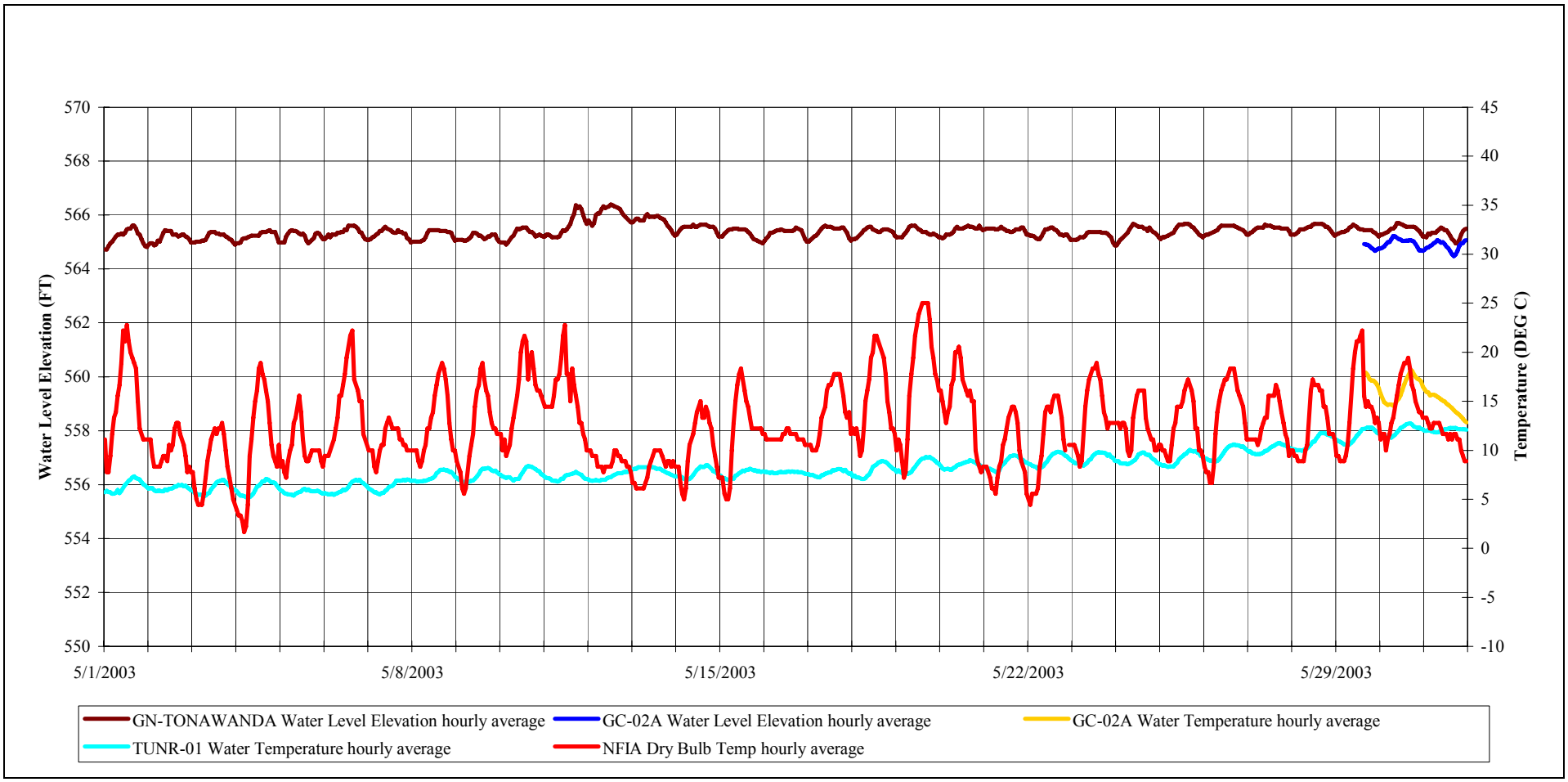

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FIGURE B-102: MIDDLE GUN CREEK (GC-02A)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

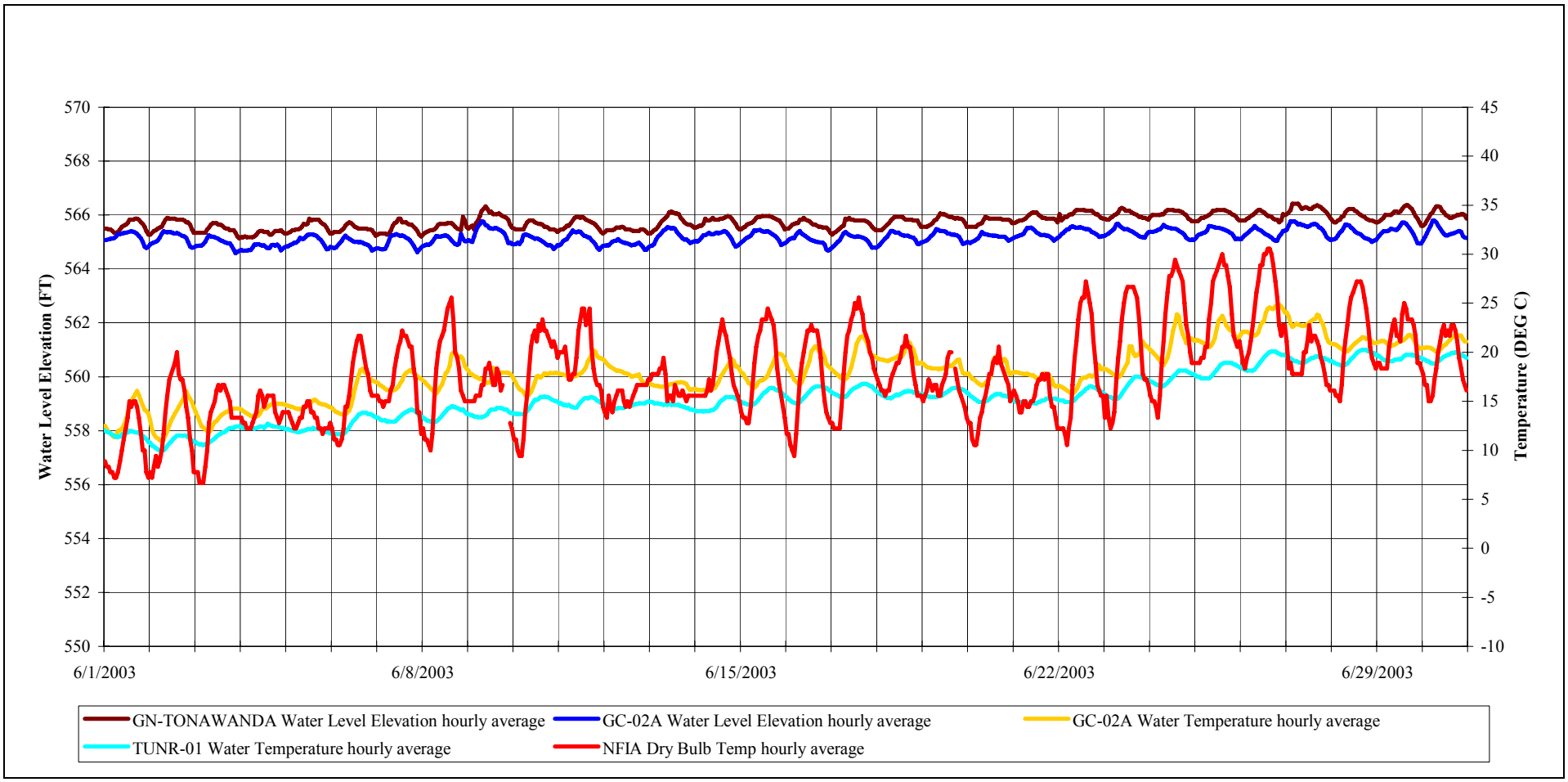

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FIGURE B-103: MIDDLE GUN CREEK (GC-02A)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

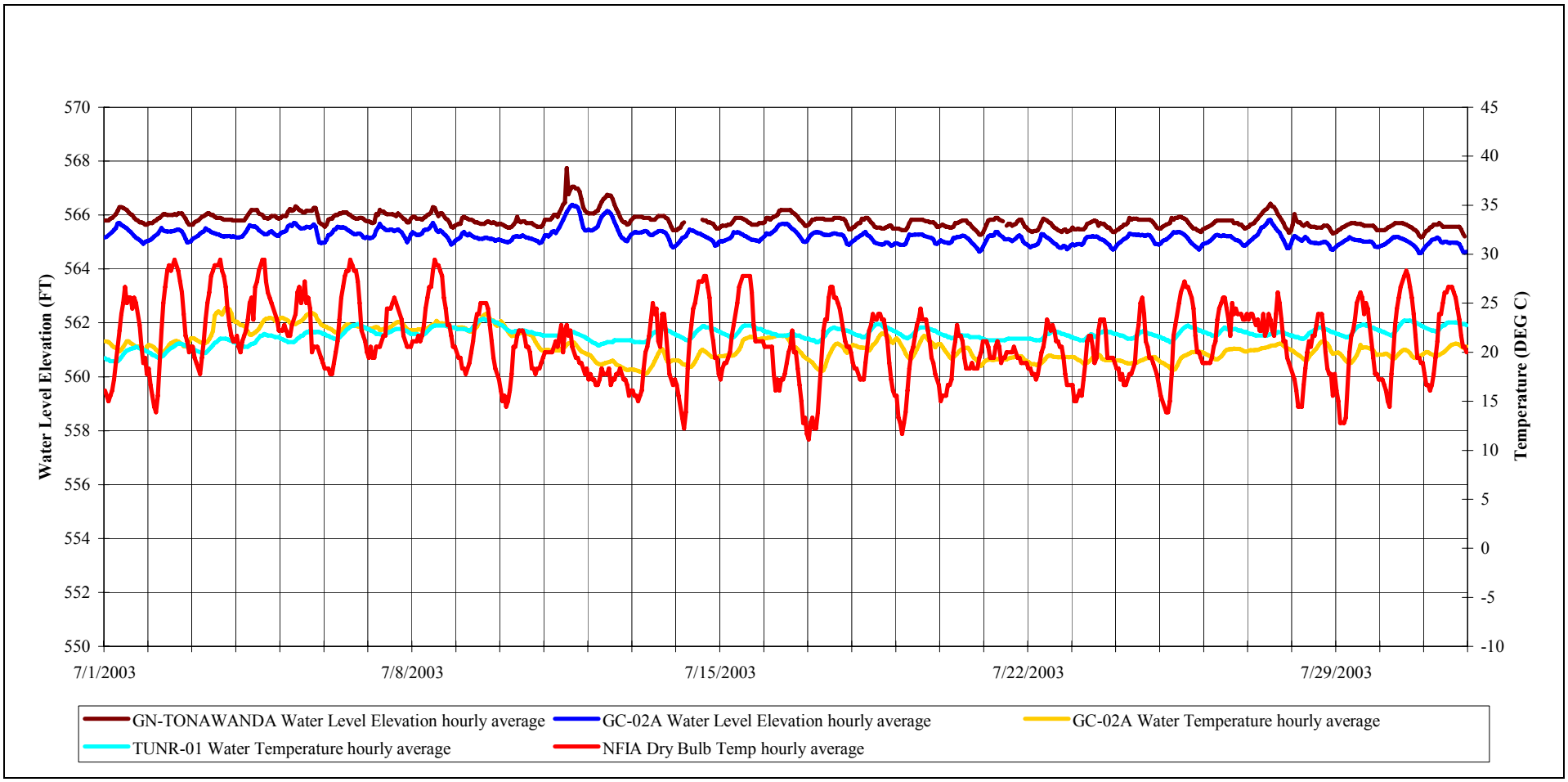

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FIGURE B-104: MIDDLE GUN CREEK (GC-02A)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

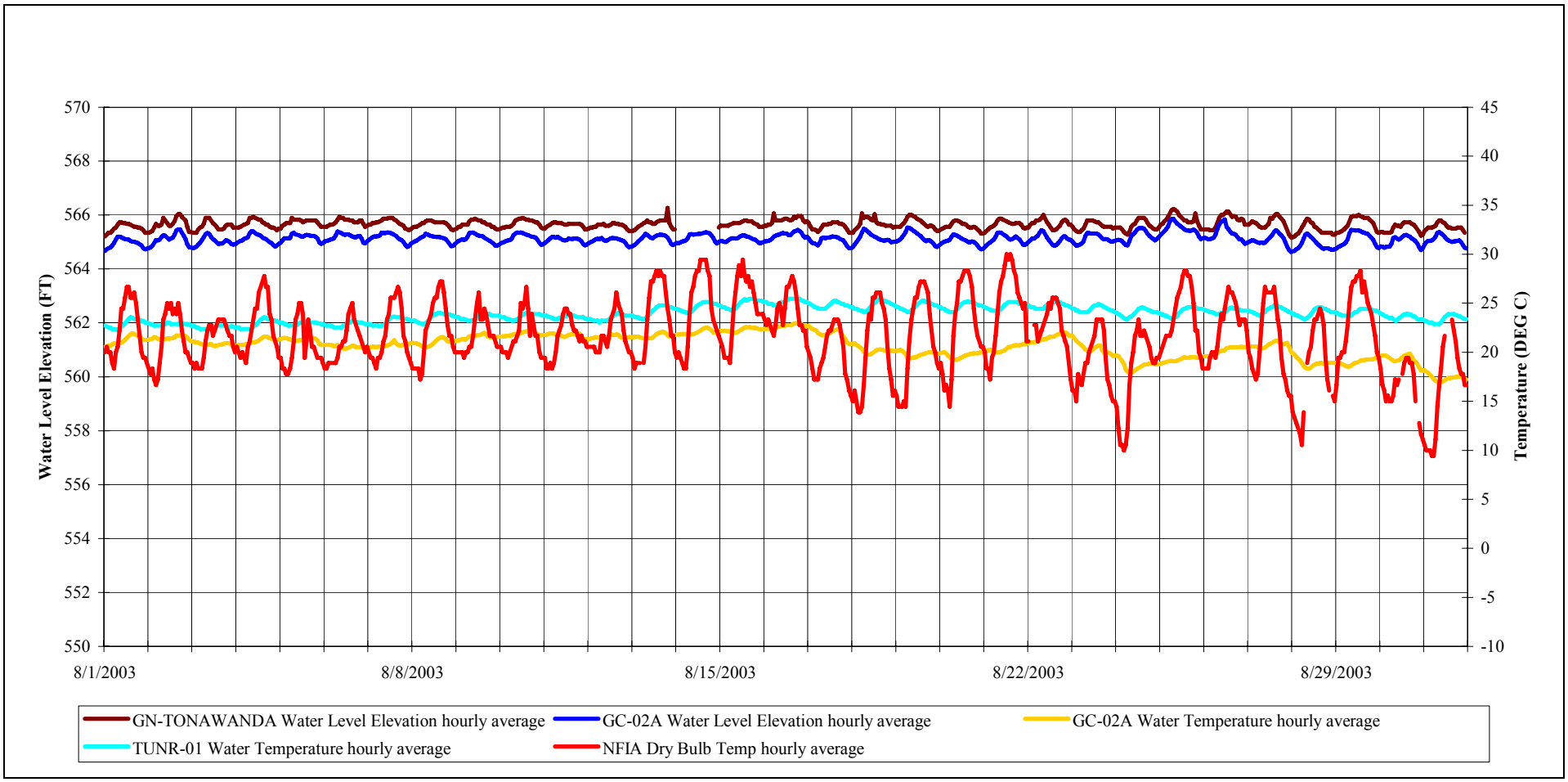

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FIGURE B-105: MIDDLE GUN CREEK (GC-02A)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

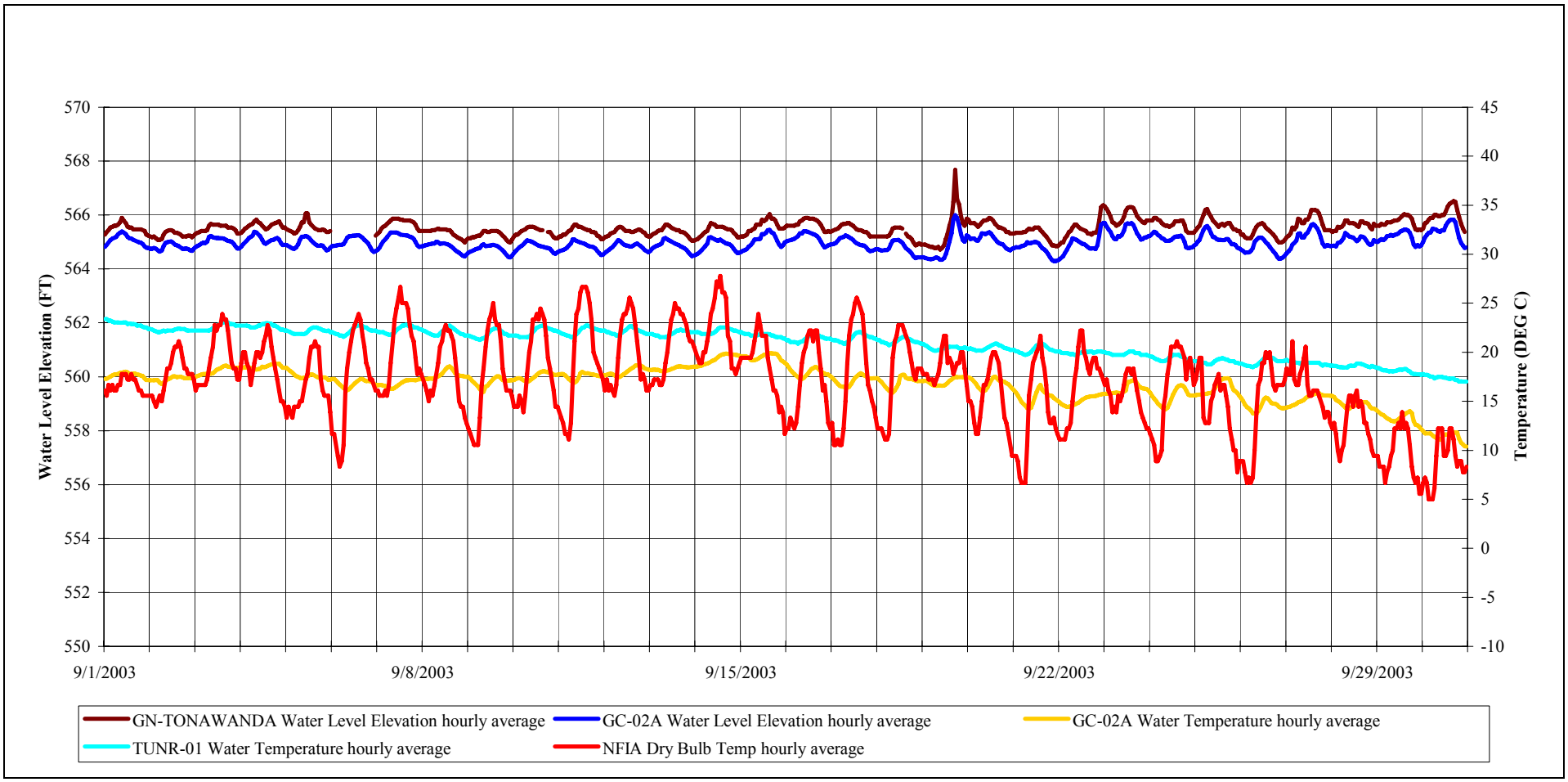

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FIGURE B-106: MIDDLE GUN CREEK (GC-02A)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

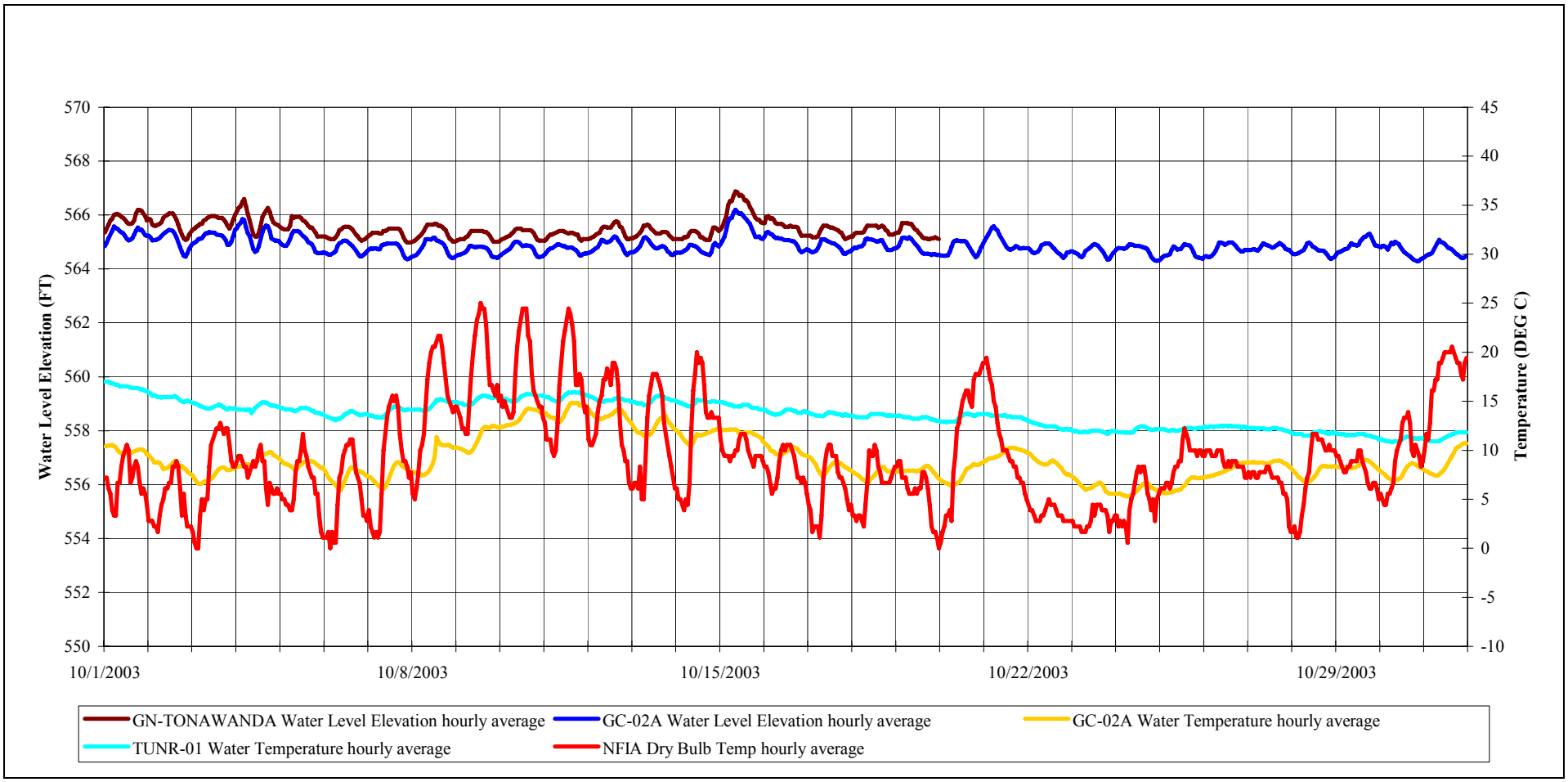

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FIGURE B-107: MIDDLE GUN CREEK (GC-02A)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

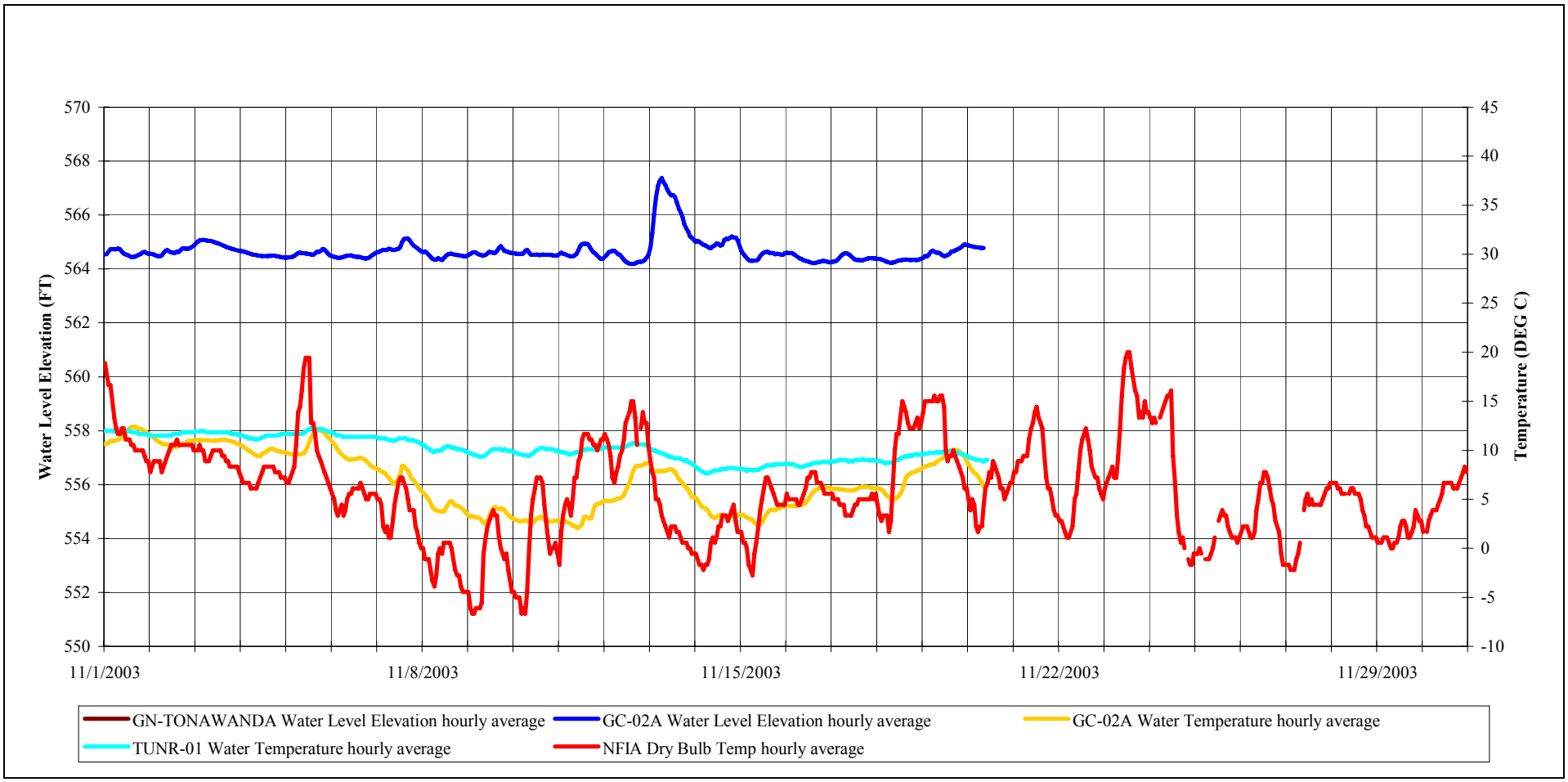

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FIGURE B-108: SPICER CREEK (TM-06)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2002

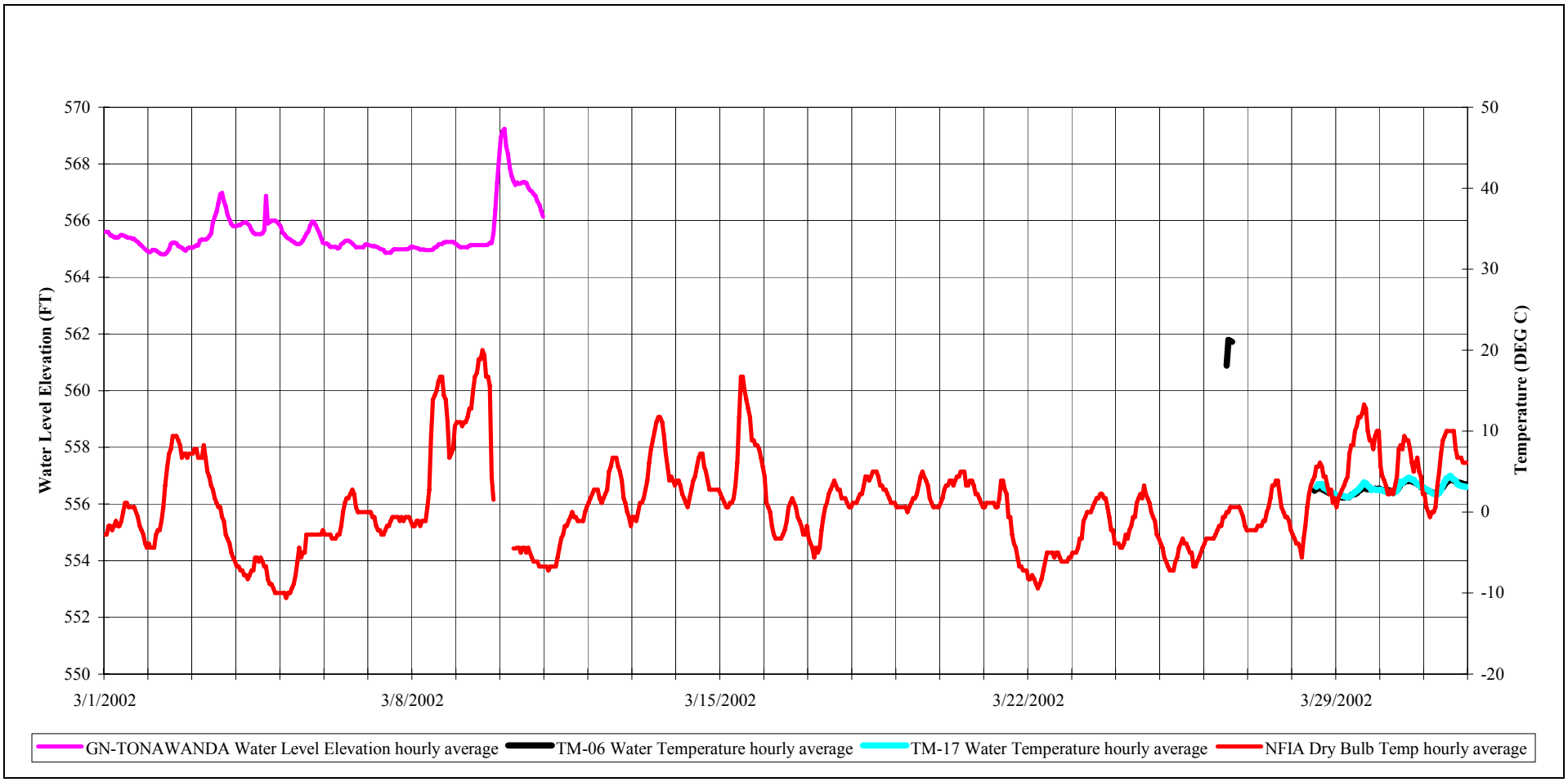

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FIGURE B-109: SPICER CREEK (TM-06)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

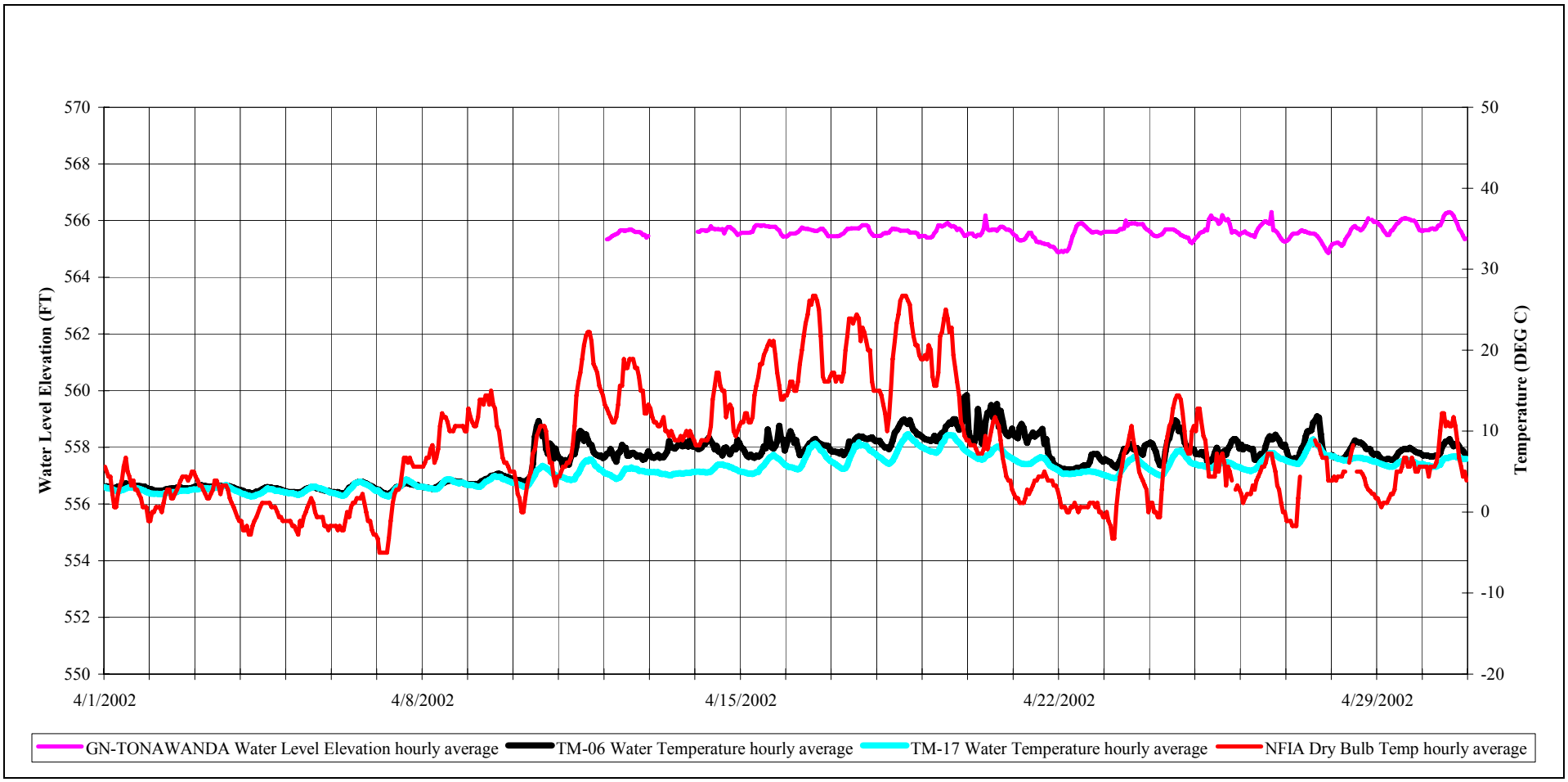

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FIGURE B-110: SPICER CREEK (TM-06)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

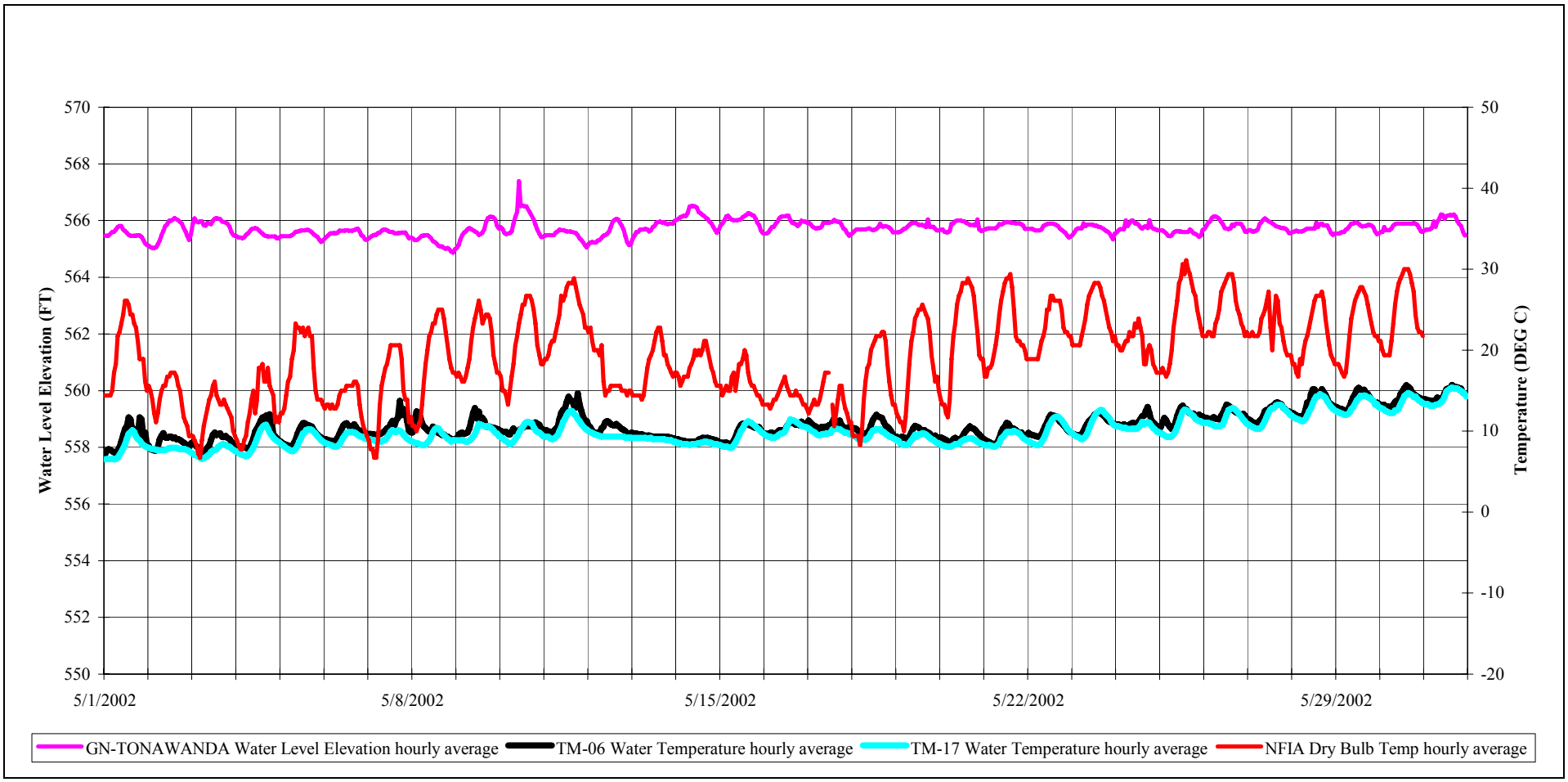

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FIGURE B-111: SPICER CREEK (TM-06)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

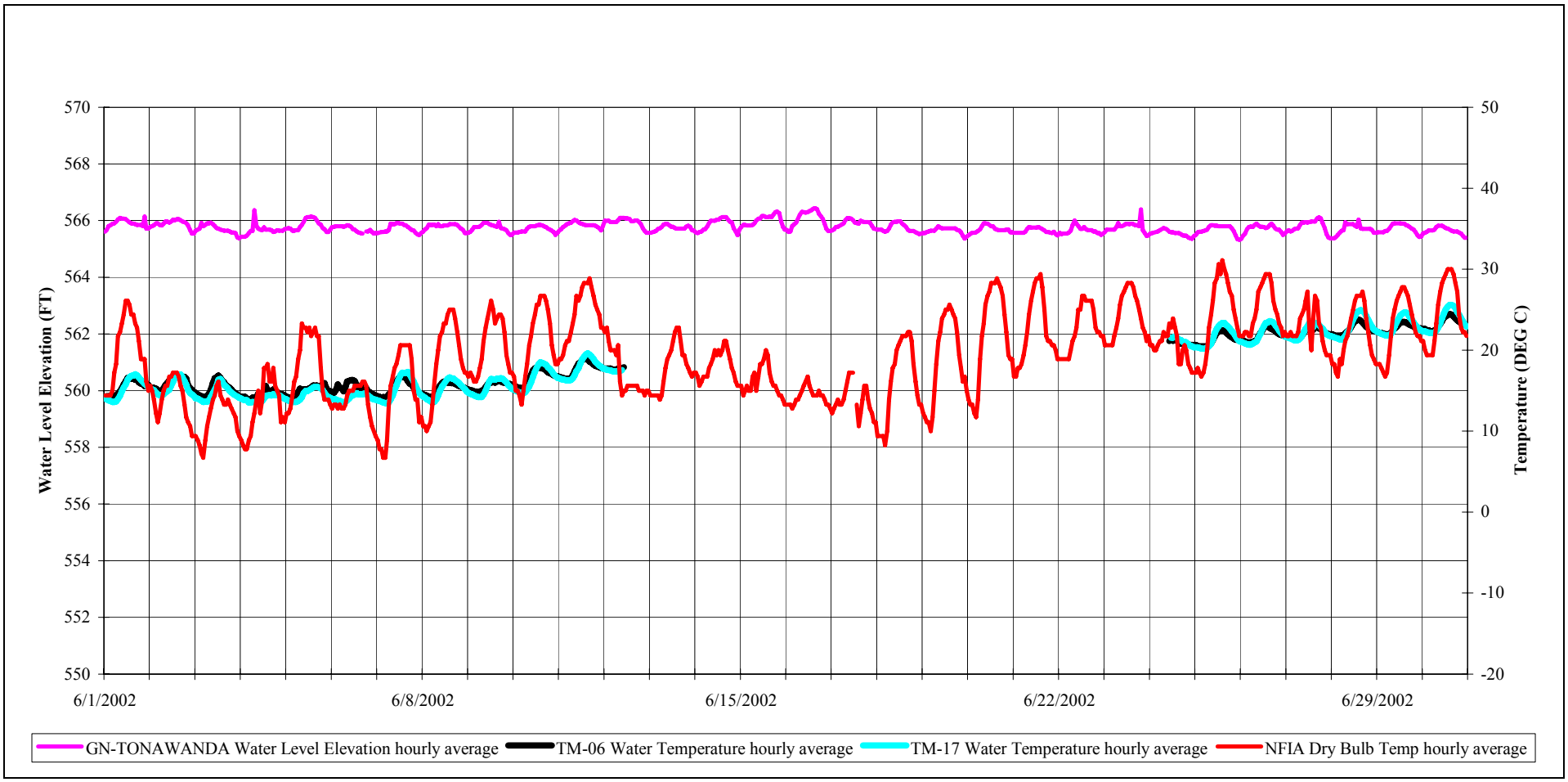

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FIGURE B-112: SPICER CREEK (TM-06)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

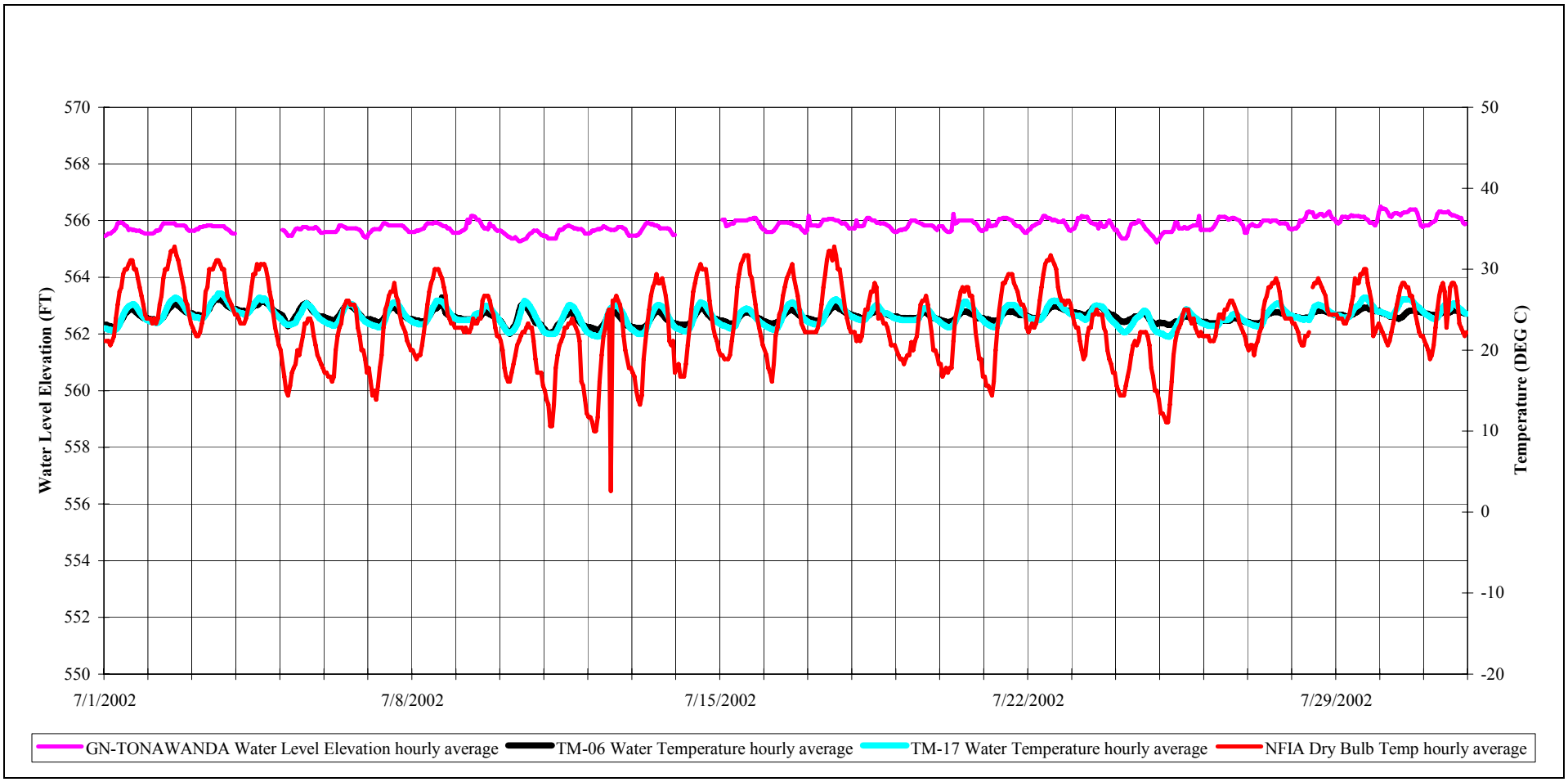

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FIGURE B-113: SPICER CREEK (TM-06)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

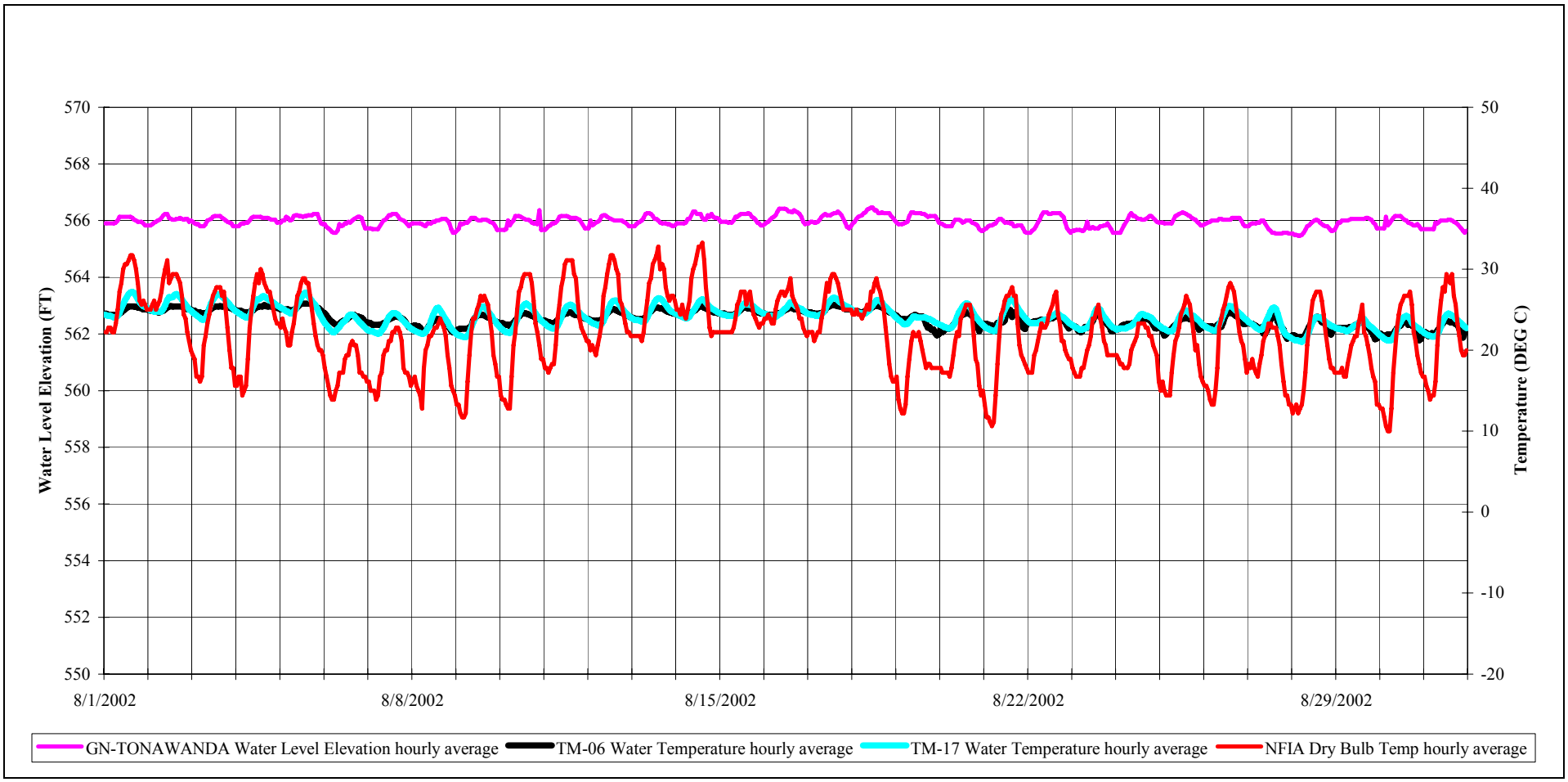

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FIGURE B-114: SPICER CREEK (TM-06)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

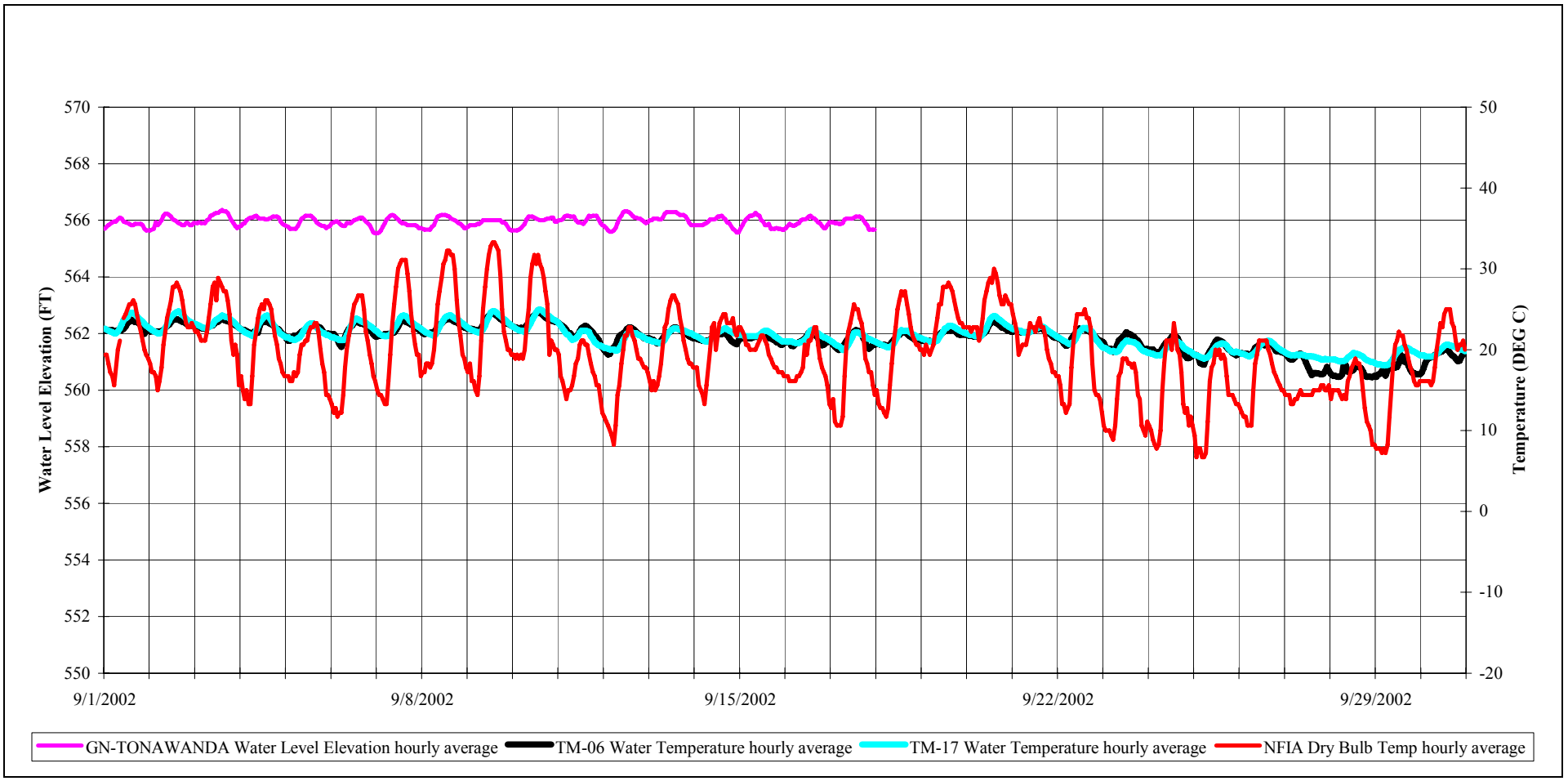

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FIGURE B-115: SPICER CREEK (TM-06)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

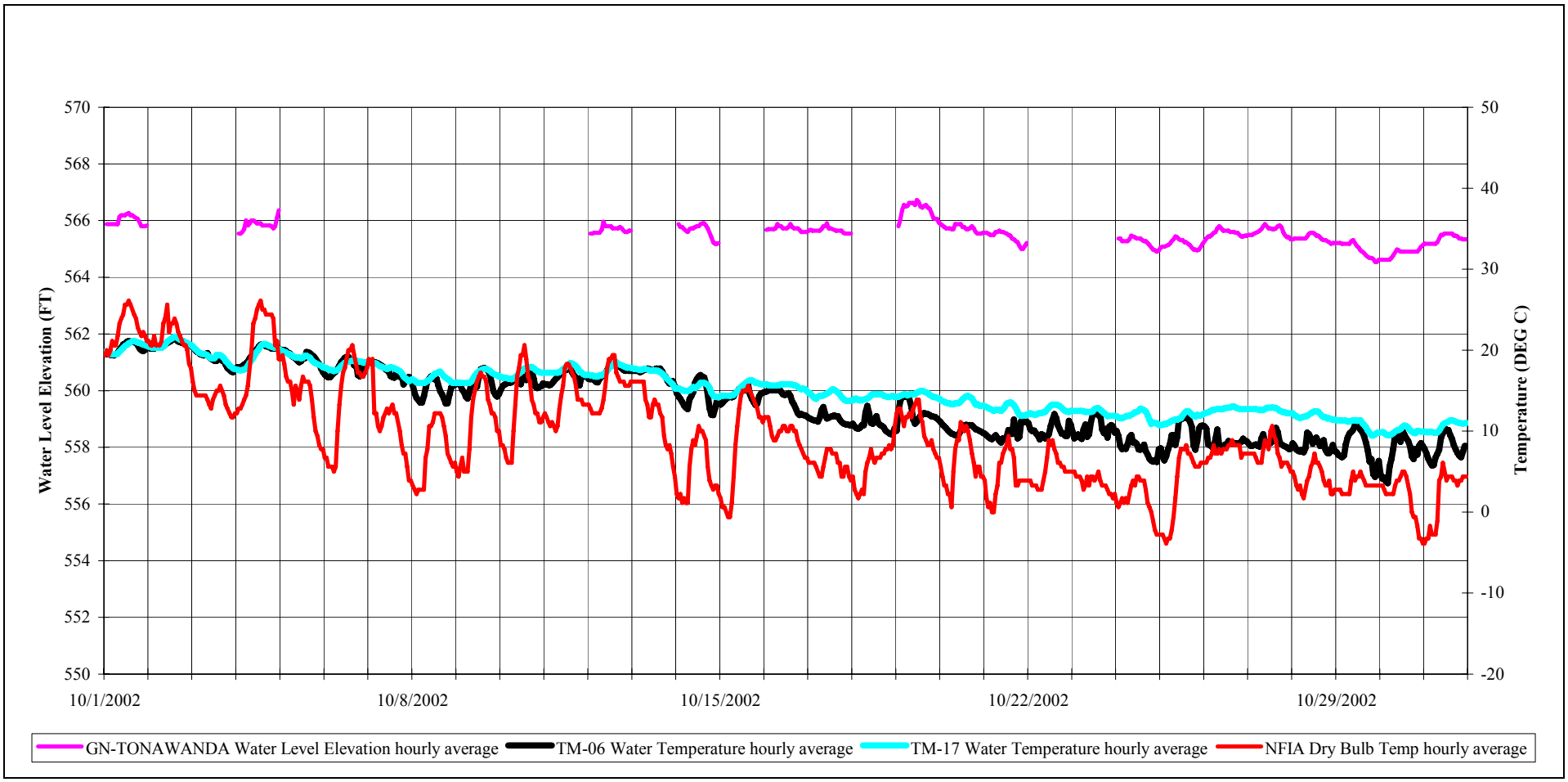

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FIGURE B-116: SPICER CREEK (TM-06)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2002

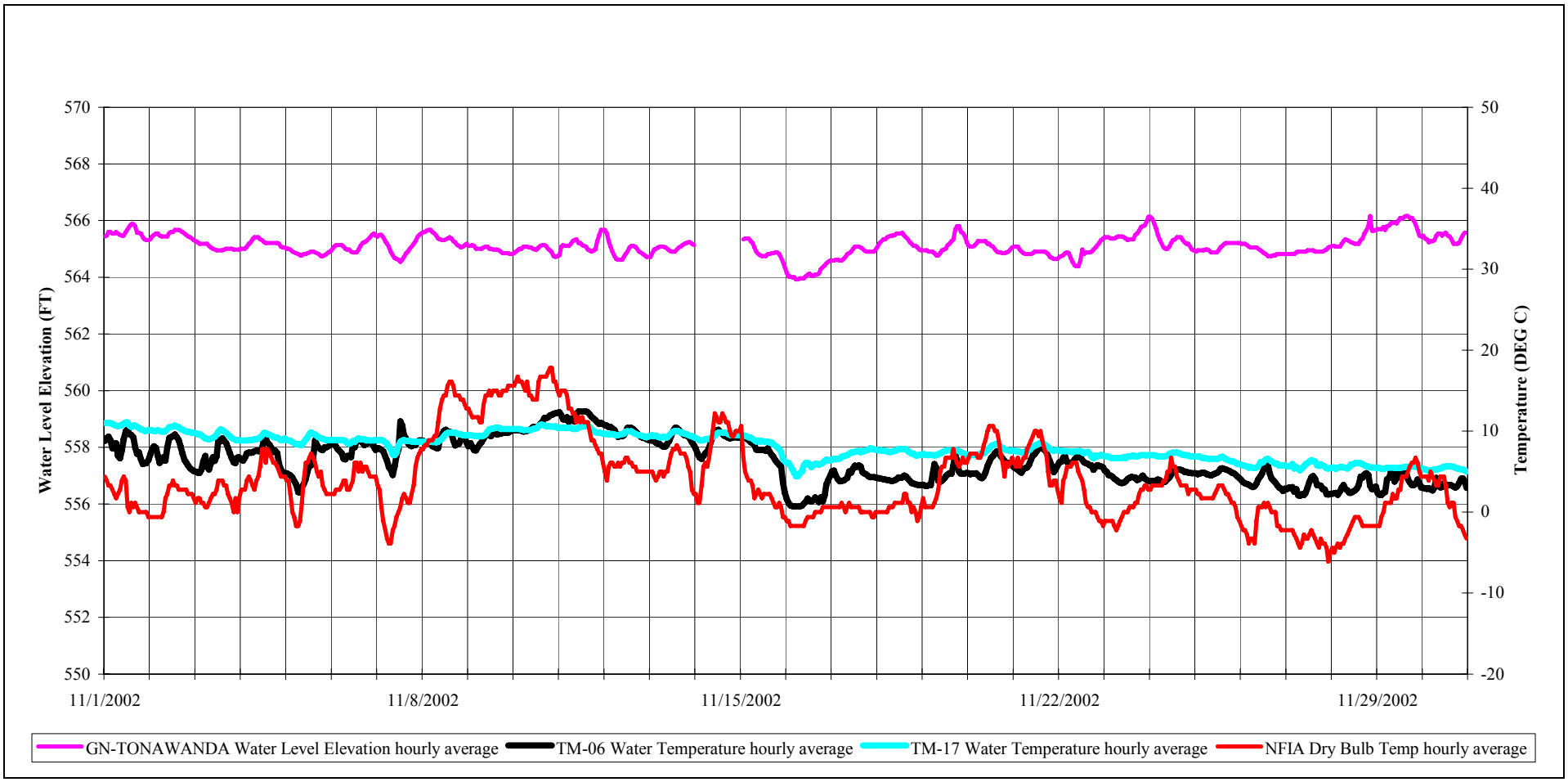

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FIGURE B-117: SPICER CREEK (TM-07)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2002

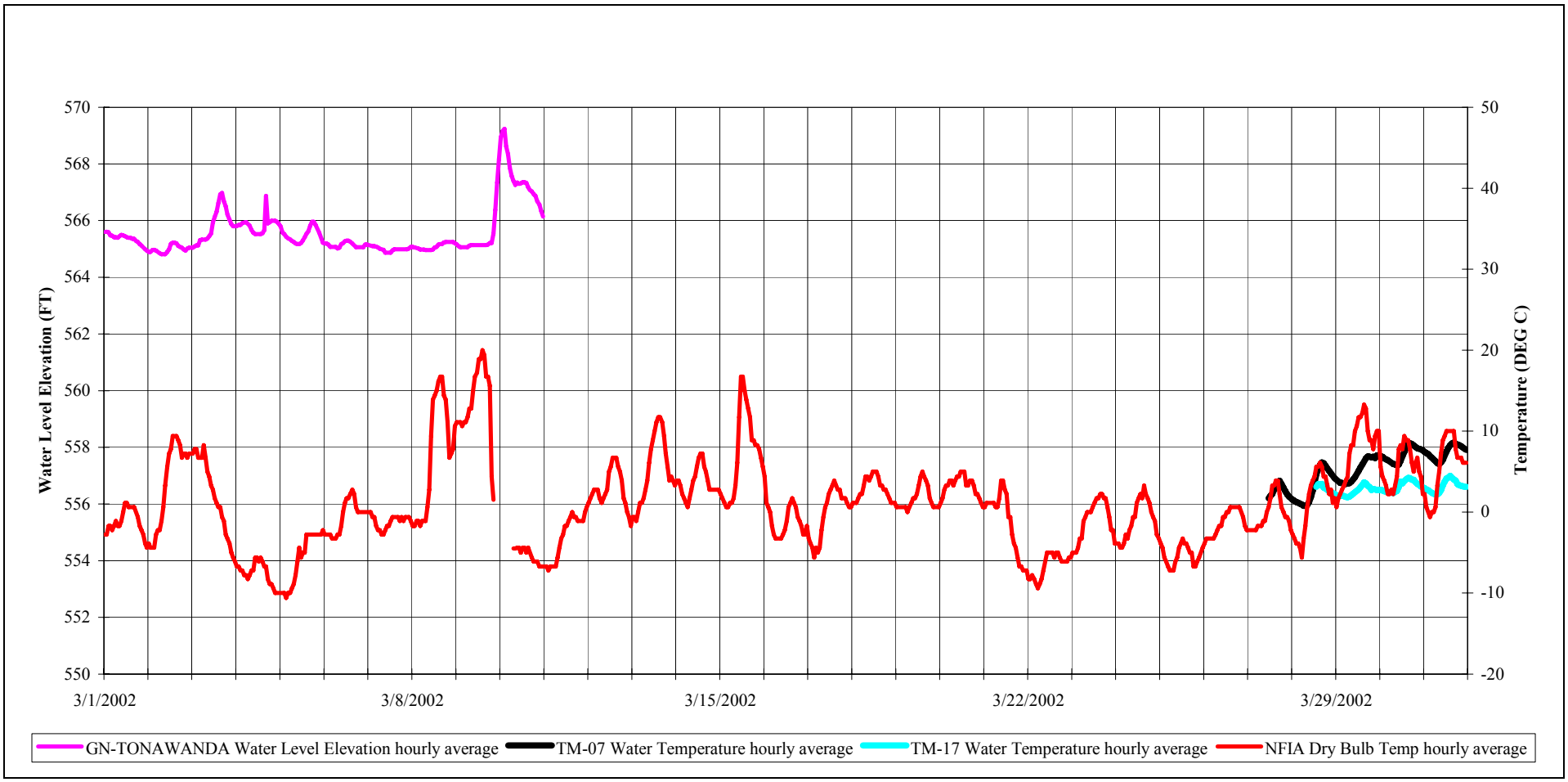

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FIGURE B-118: SPICER CREEK (TM-07)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

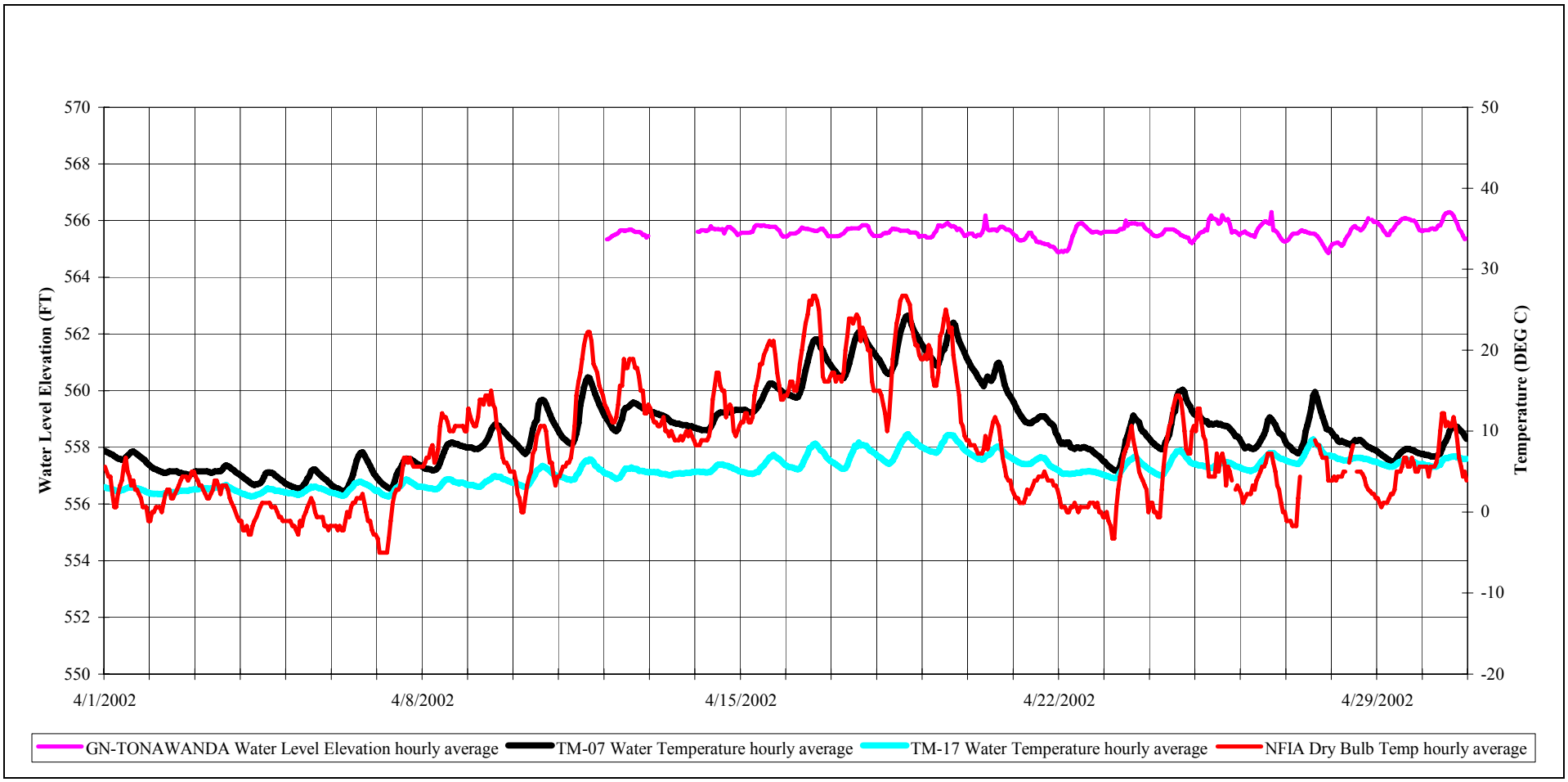

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FIGURE B-119: SPICER CREEK (TM-07)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

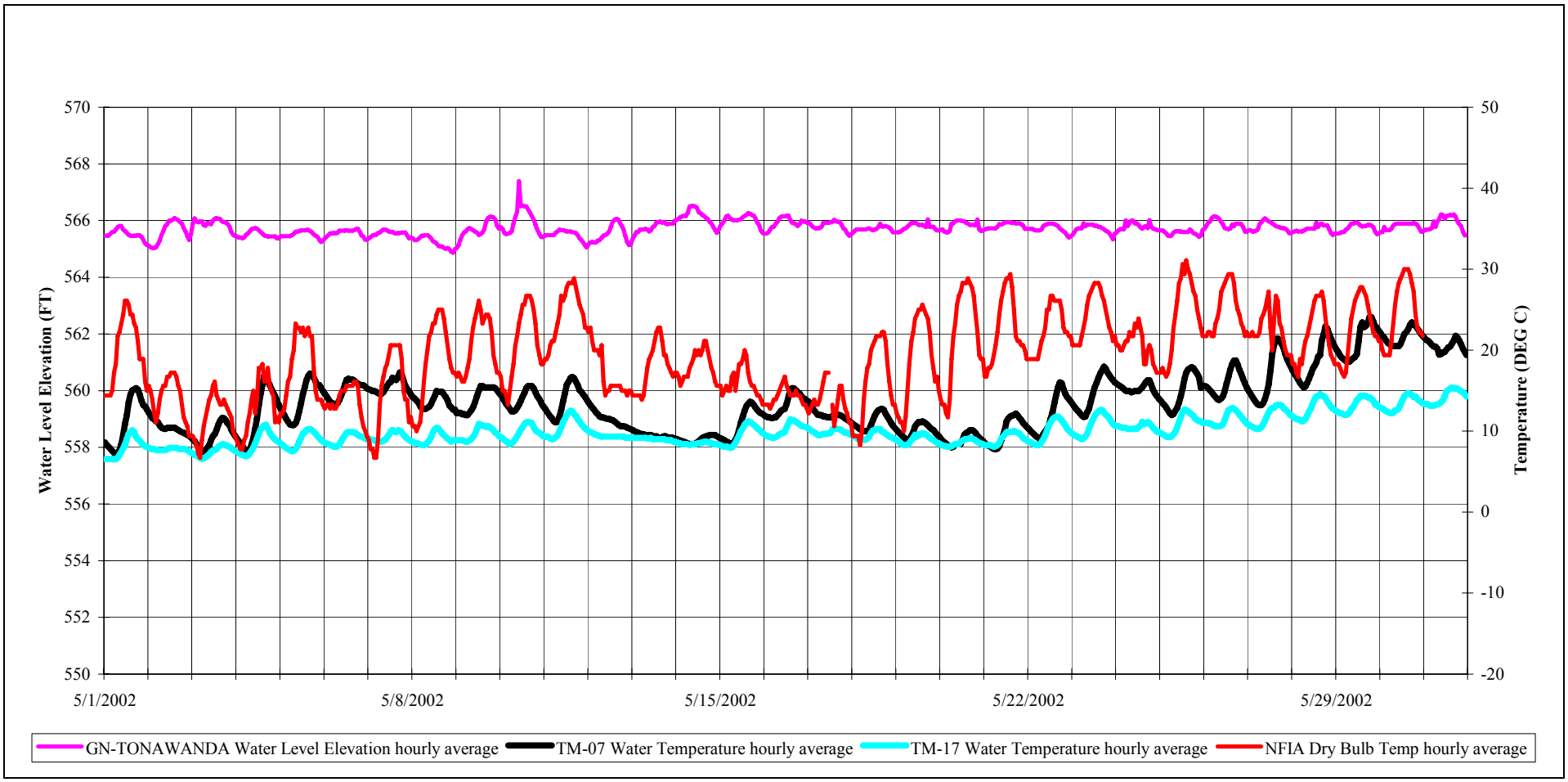

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FIGURE B-120: SPICER CREEK (TM-07)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

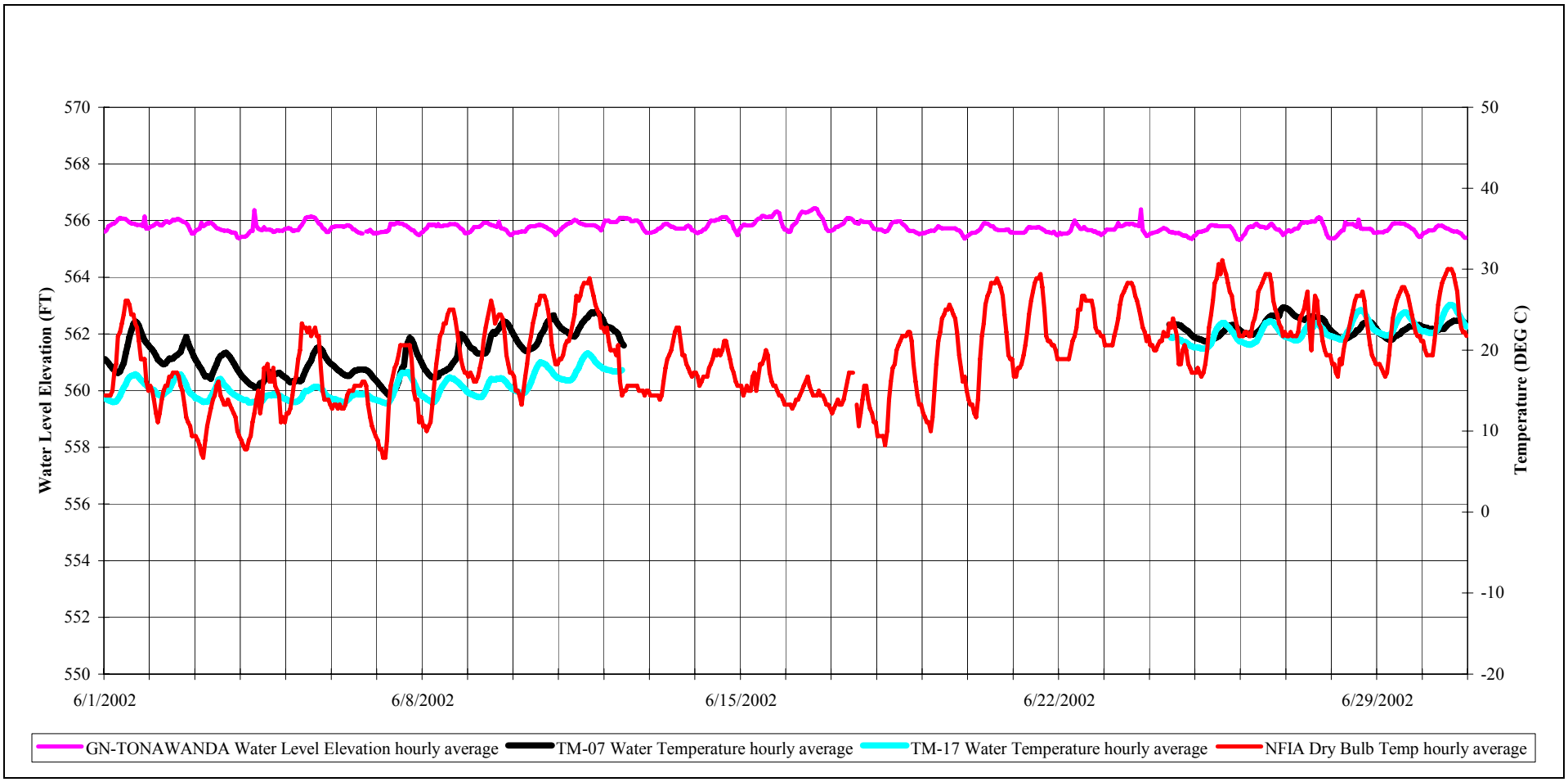

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FIGURE B-121: SPICER CREEK (TM-07)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

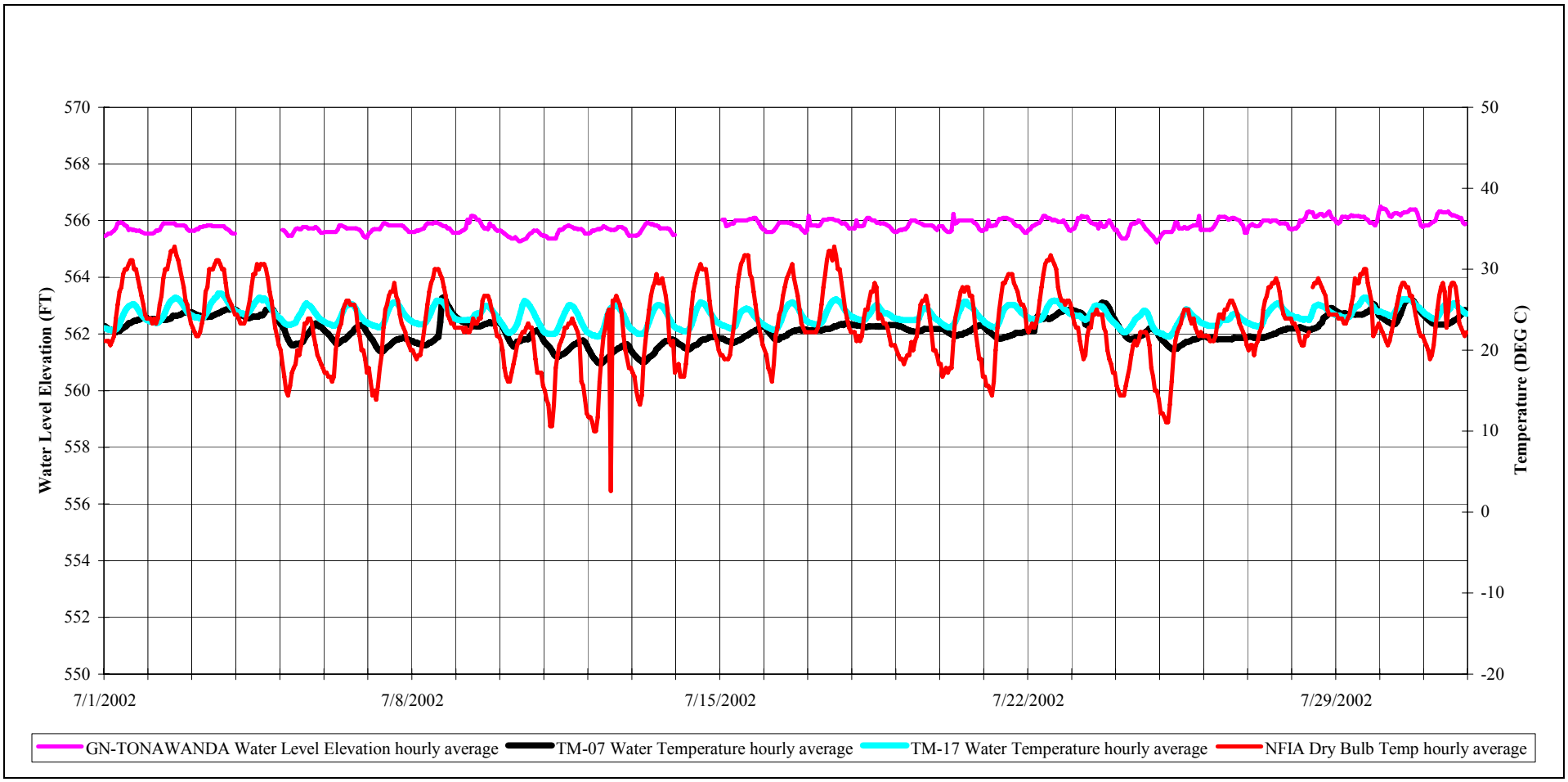

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FIGURE B-122: SPICER CREEK (TM-07)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

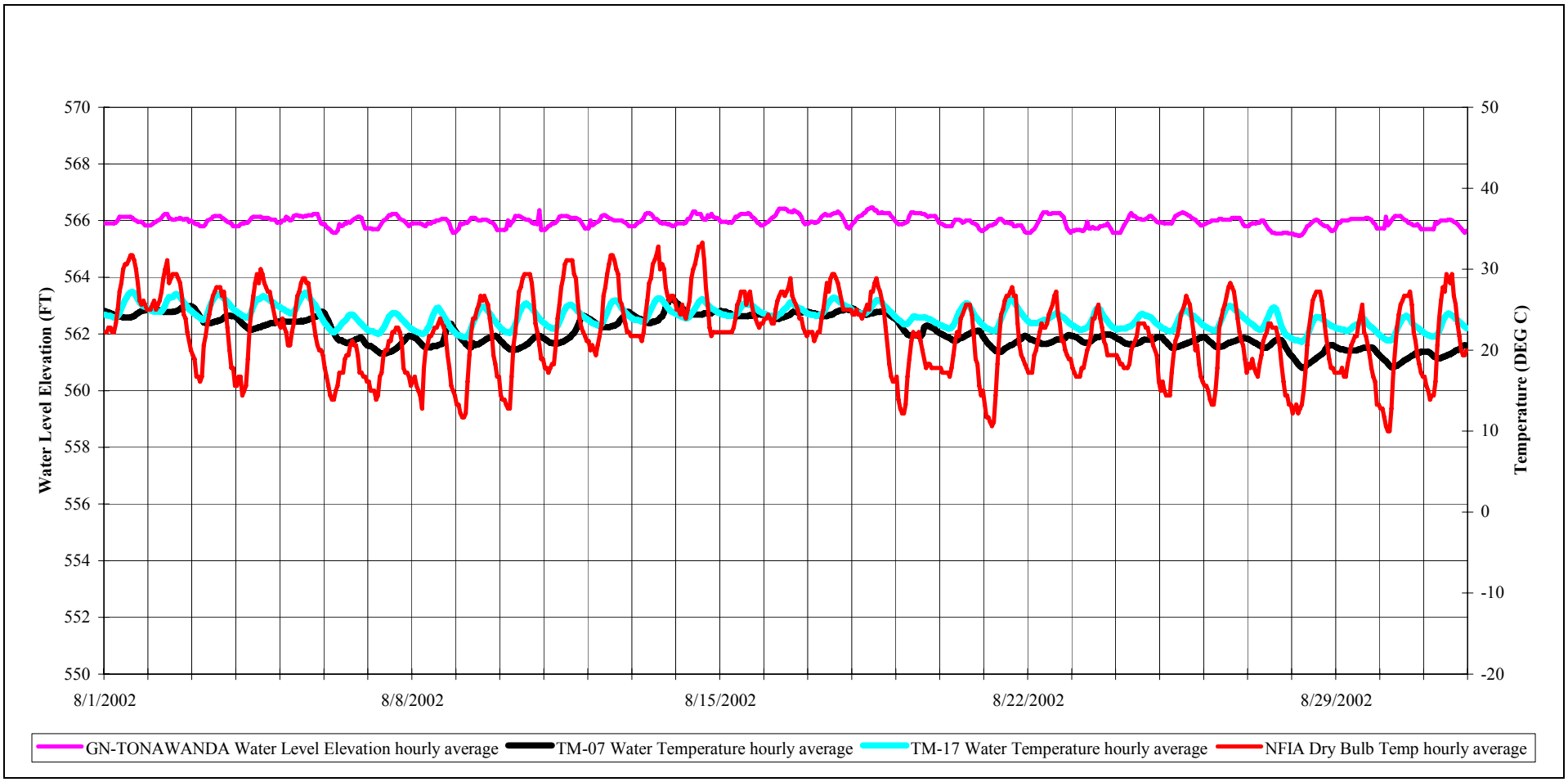

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FIGURE B-123: SPICER CREEK (TM-07)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

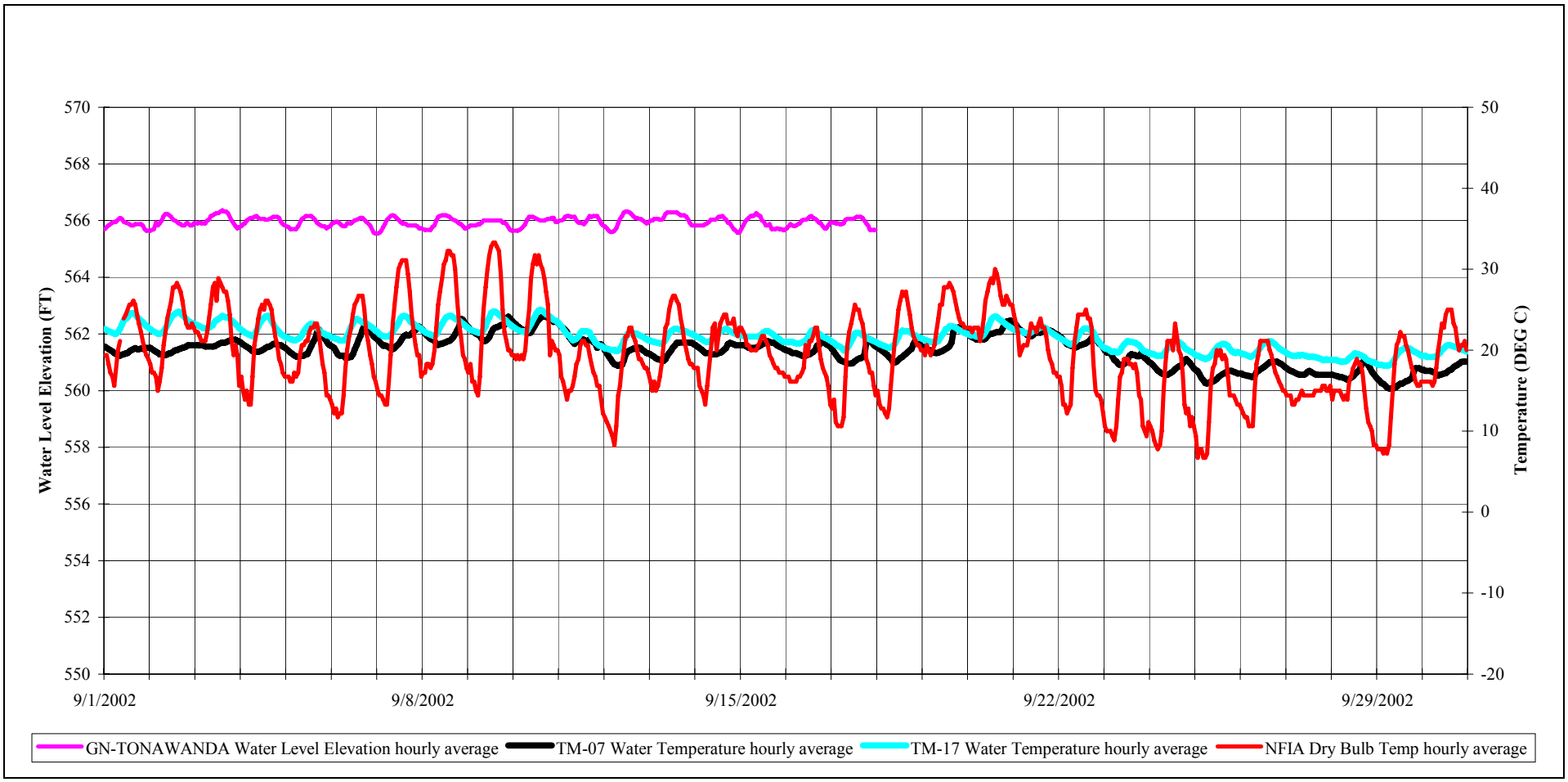

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FIGURE B-124: SPICER CREEK (TM-07)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

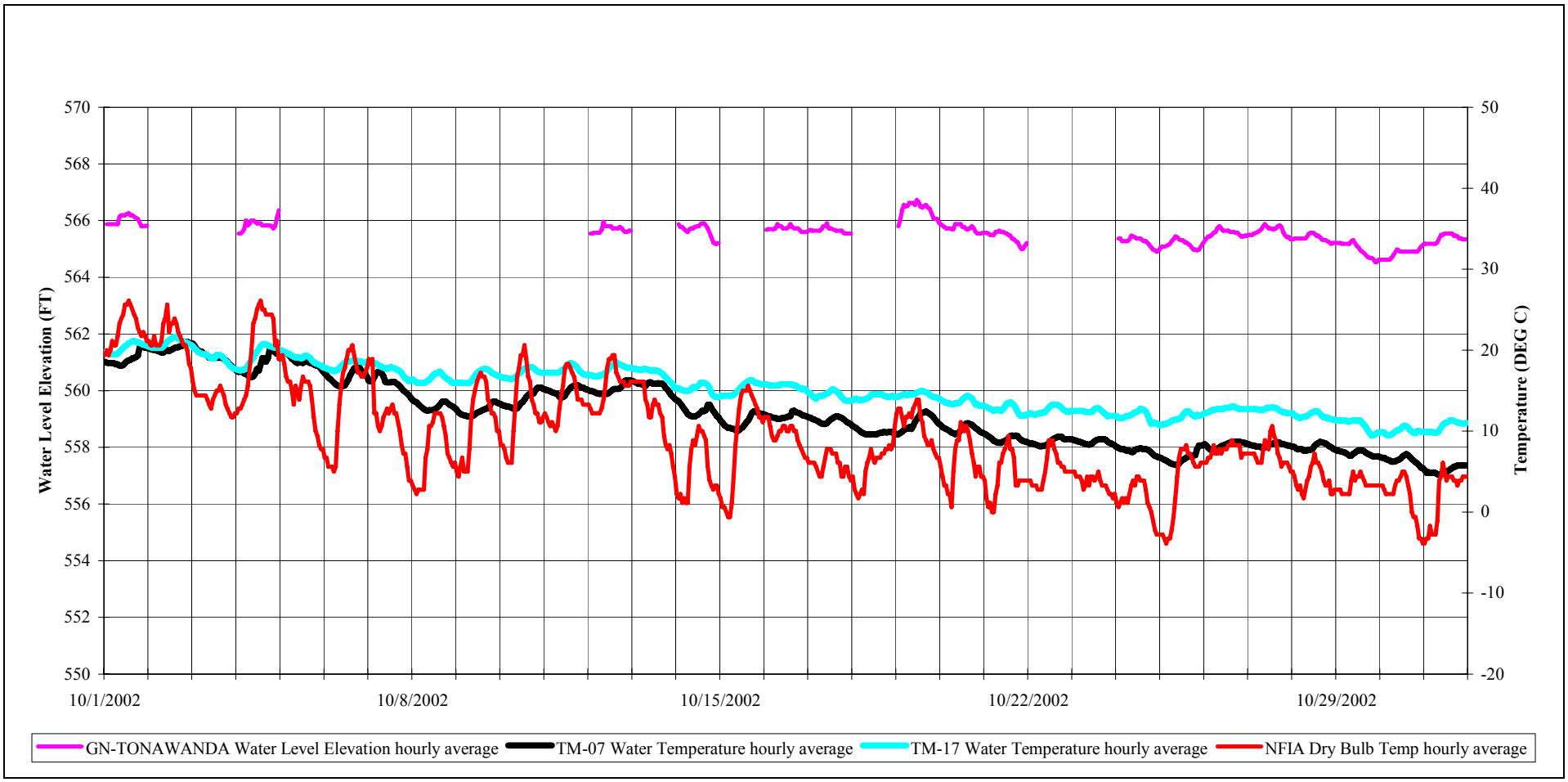

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FIGURE B-125: SPICER CREEK (TM-07)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2002

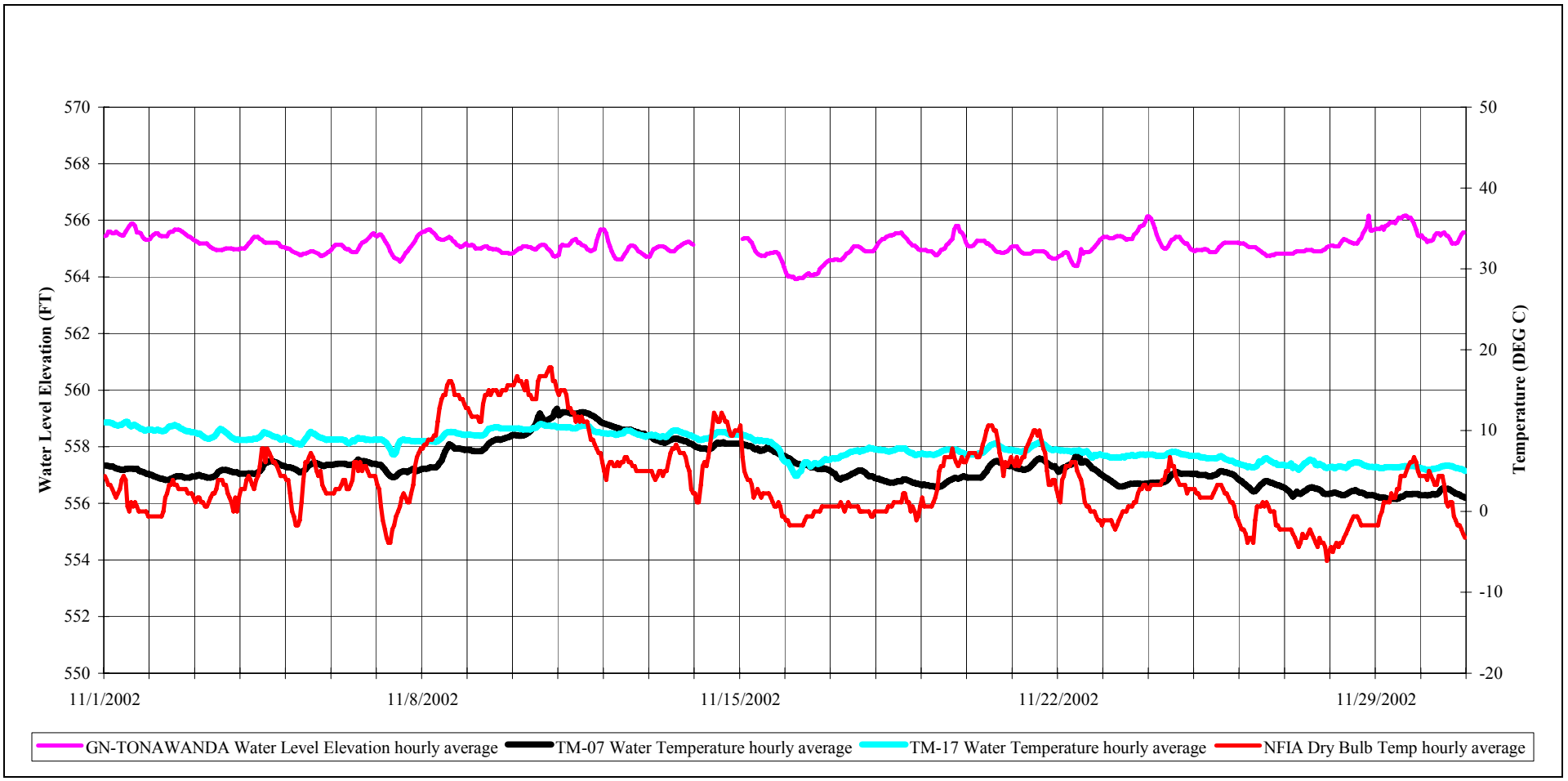

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FIGURE B-126: SPICER CREEK (TM-08)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2002

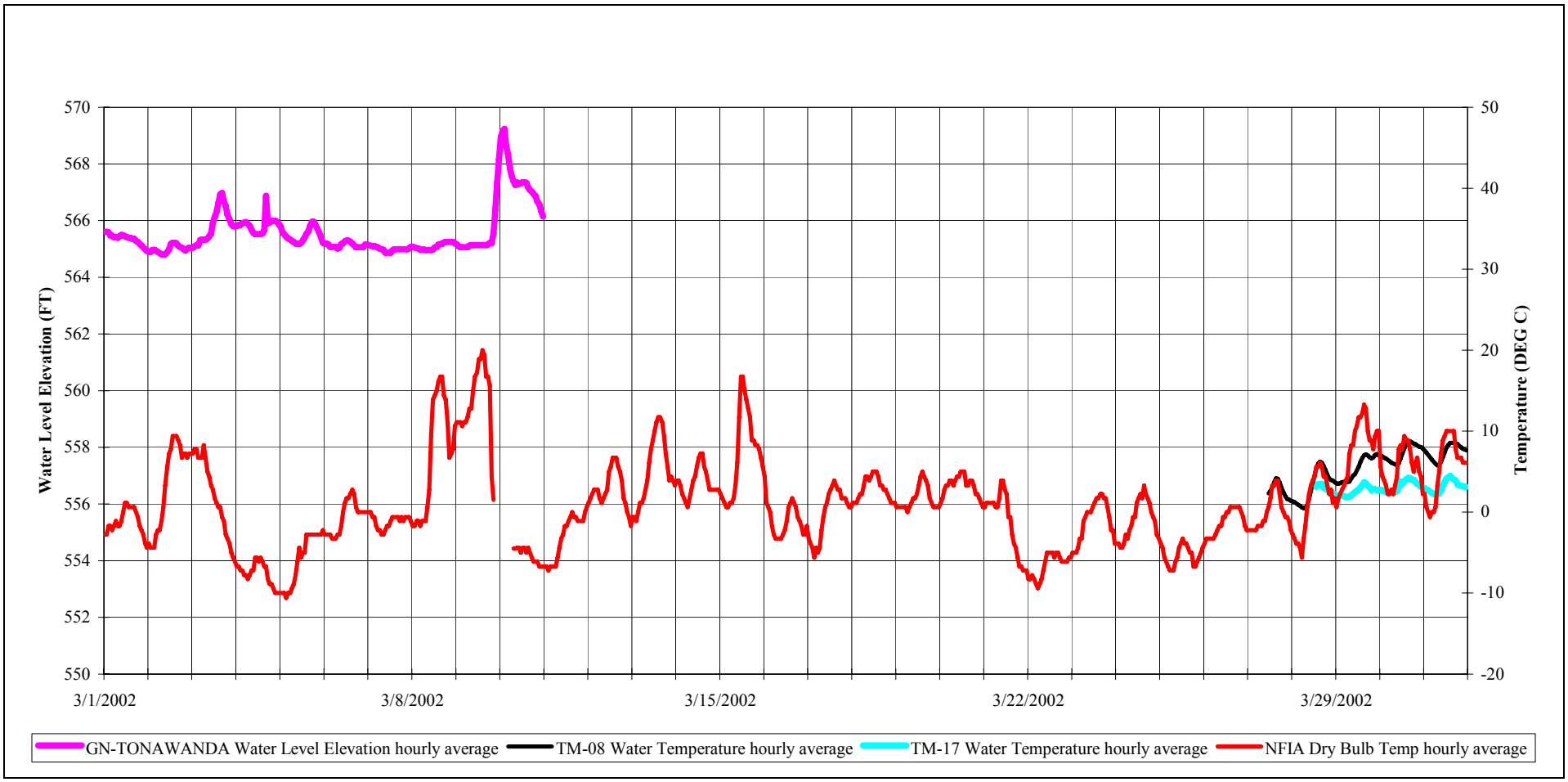

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FIGURE B-127: SPICER CREEK (TM-08)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

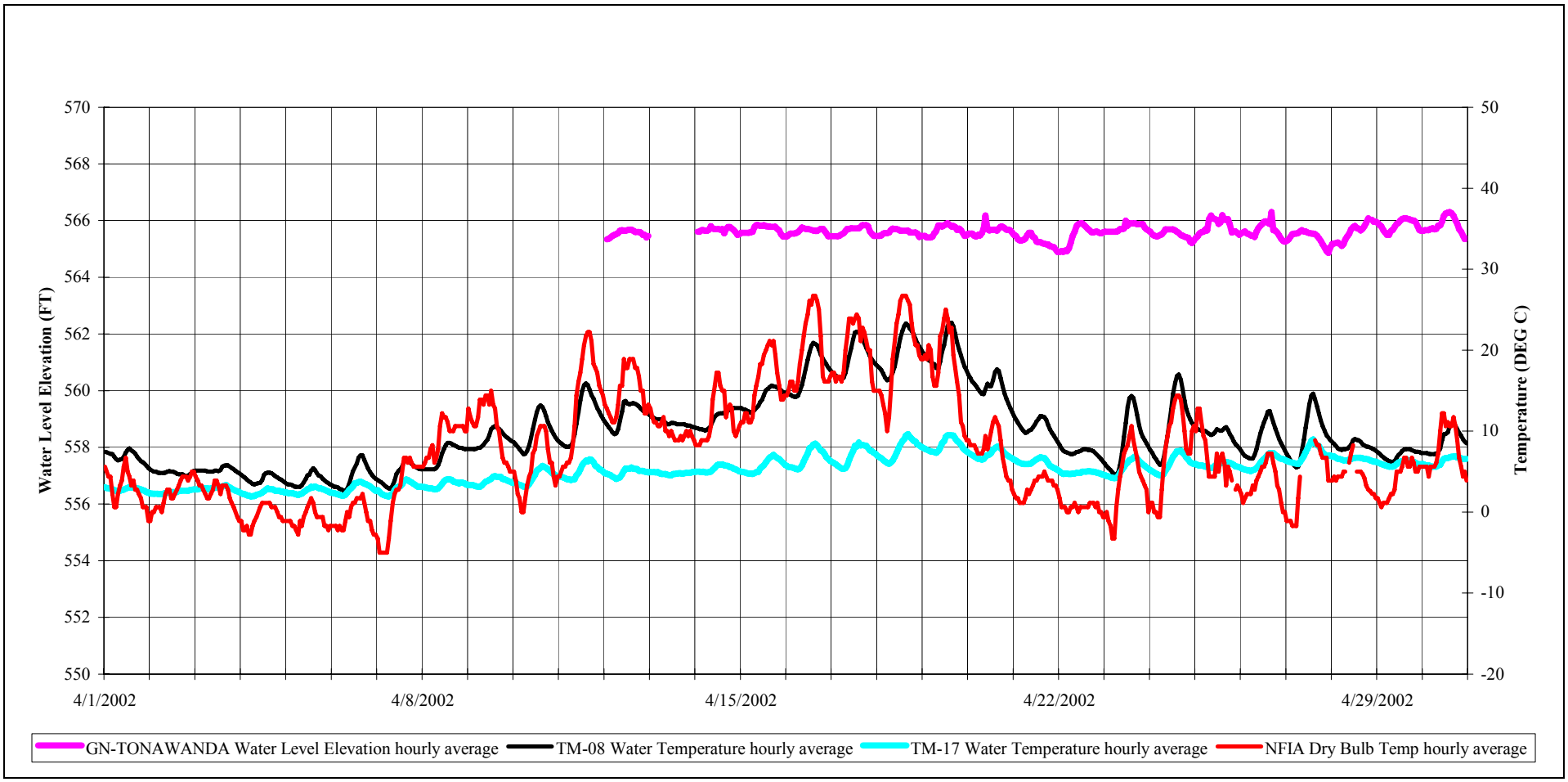

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FIGURE B-128: SPICER CREEK (TM-08)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

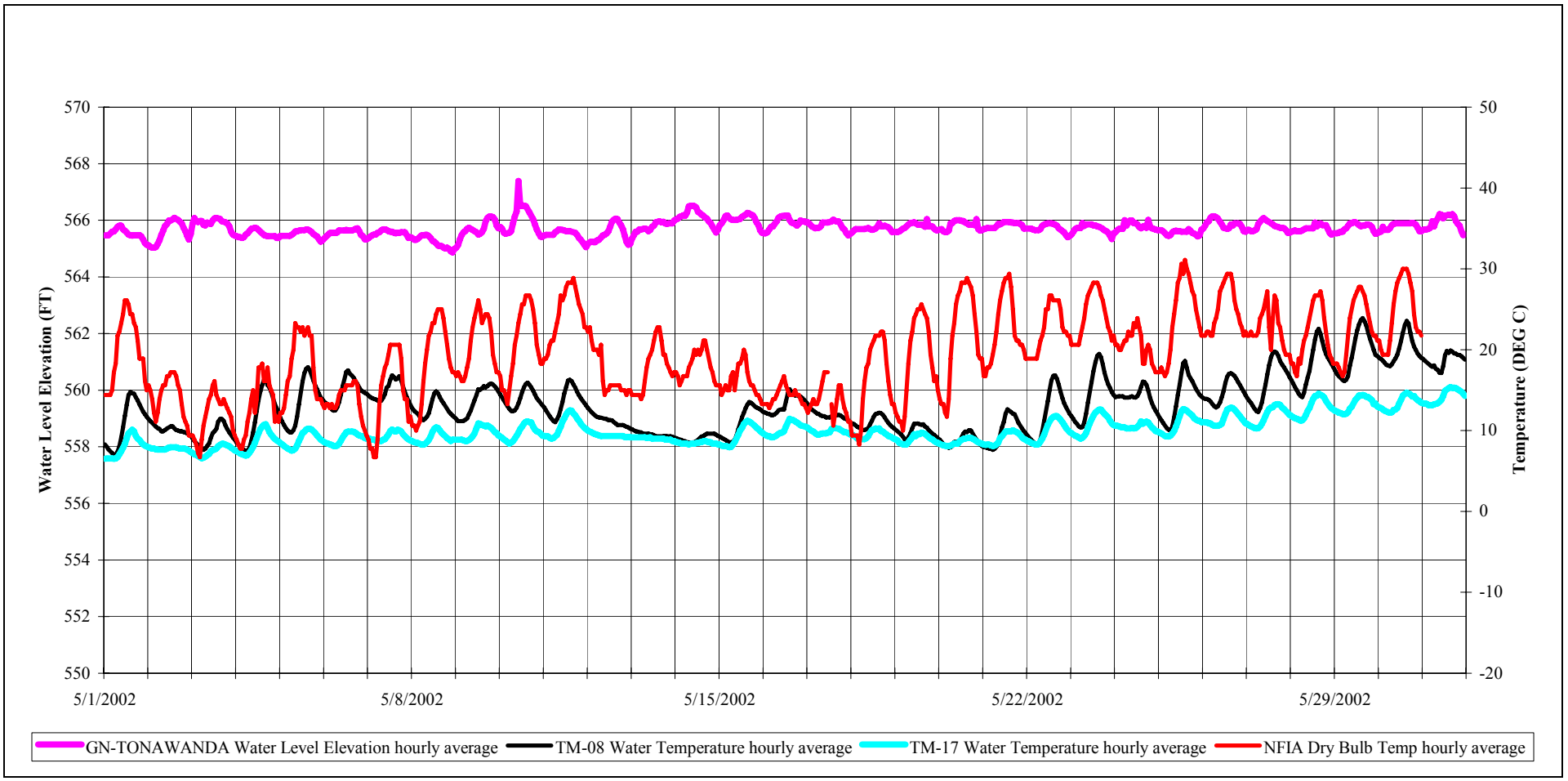

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FIGURE B-129: SPICER CREEK (TM-08)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

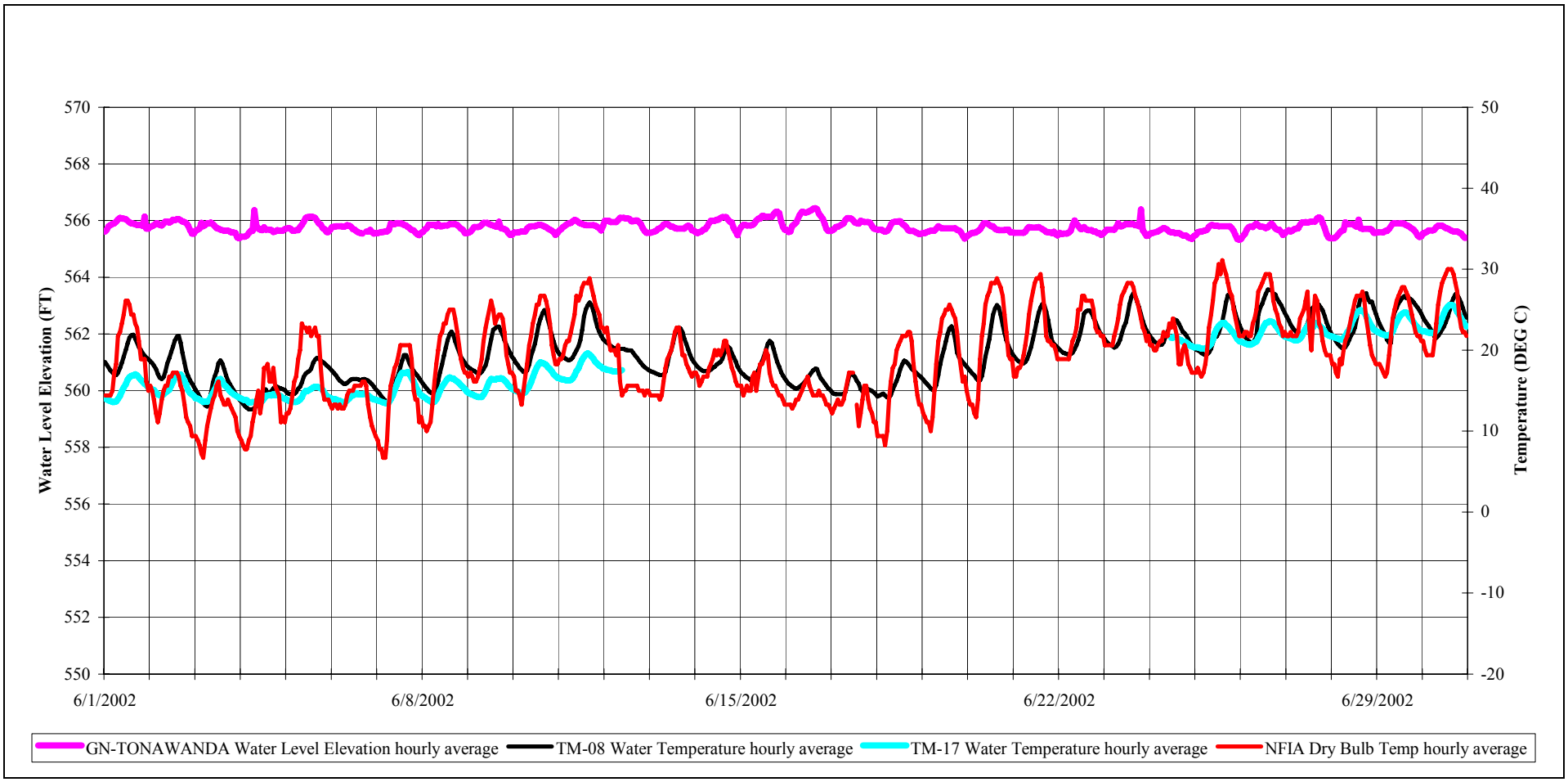

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FIGURE B-130: SPICER CREEK (TM-08)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

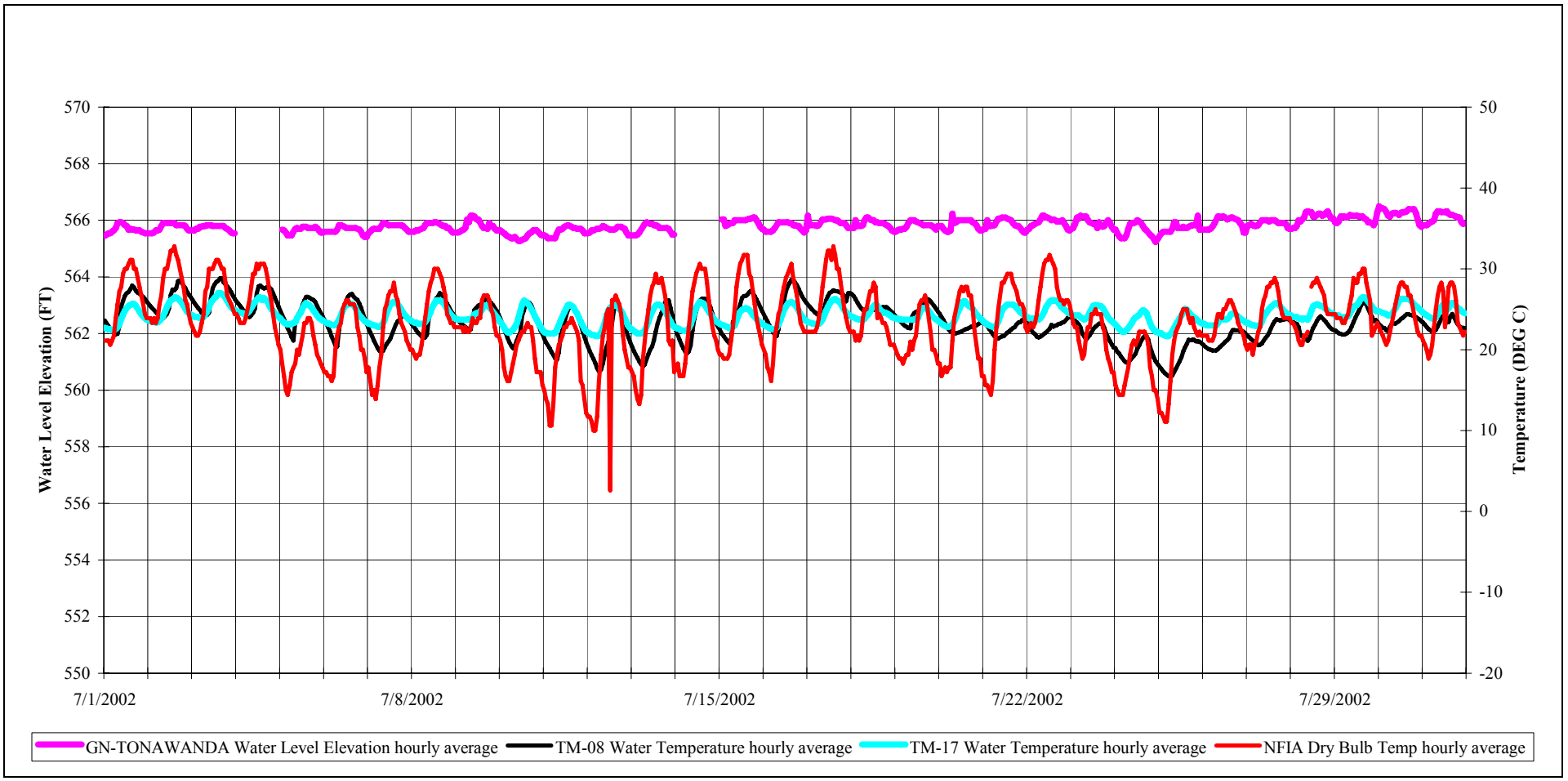

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FIGURE B-131: SPICER CREEK (TM-08)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

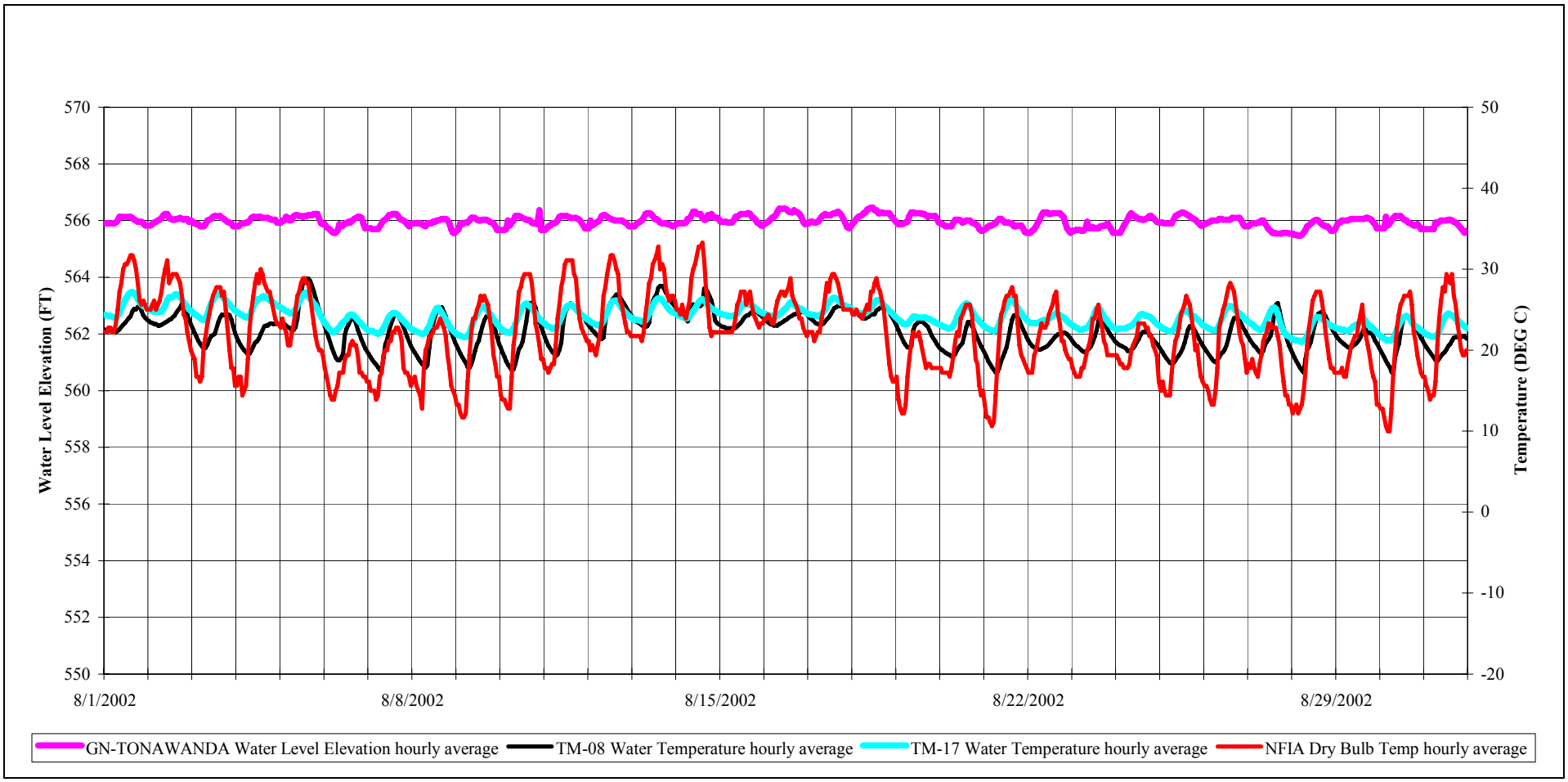

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FIGURE B-132: SPICER CREEK (TM-08)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

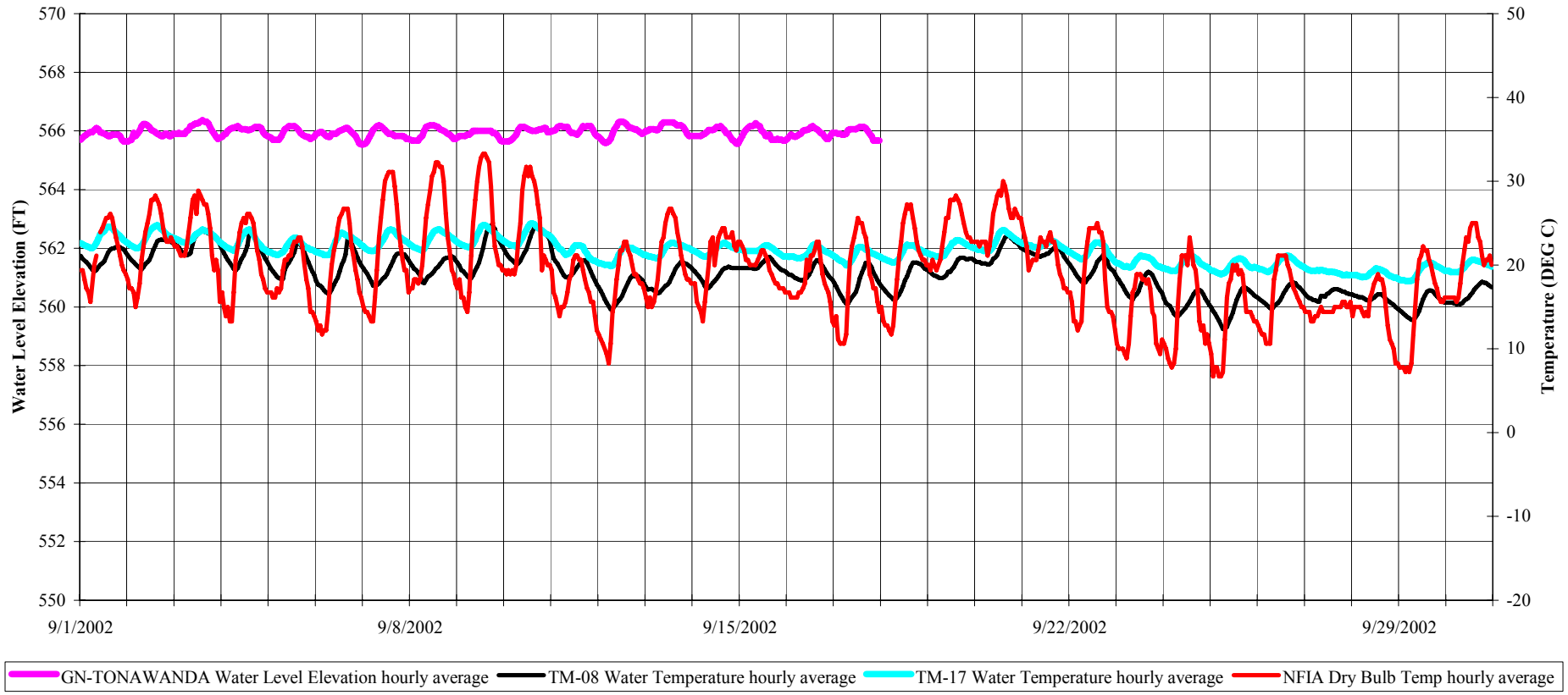

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FIGURE B-133: SPICER CREEK (TM-08)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

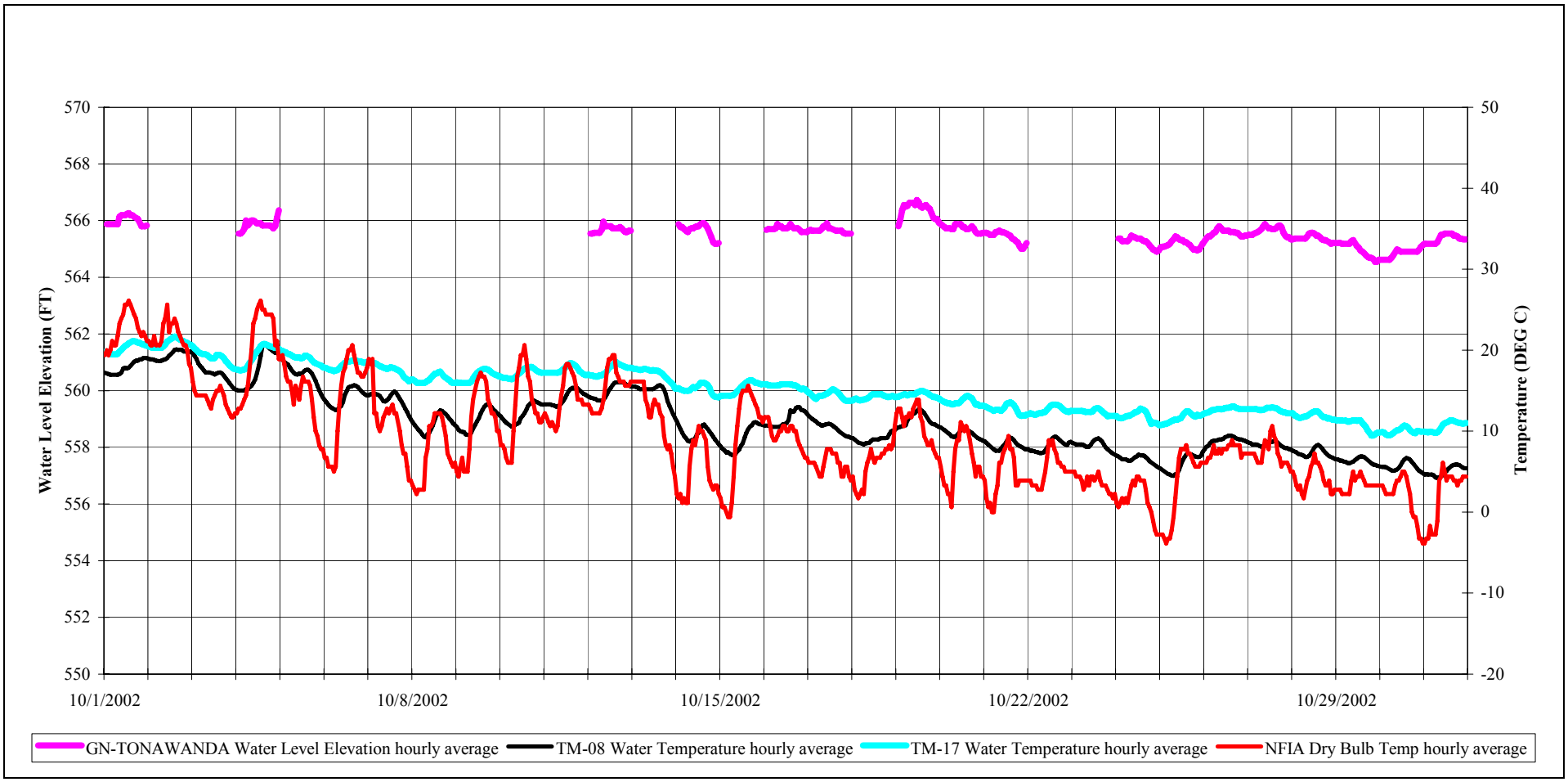

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FIGURE B-134: SPICER CREEK (TM-08)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2002

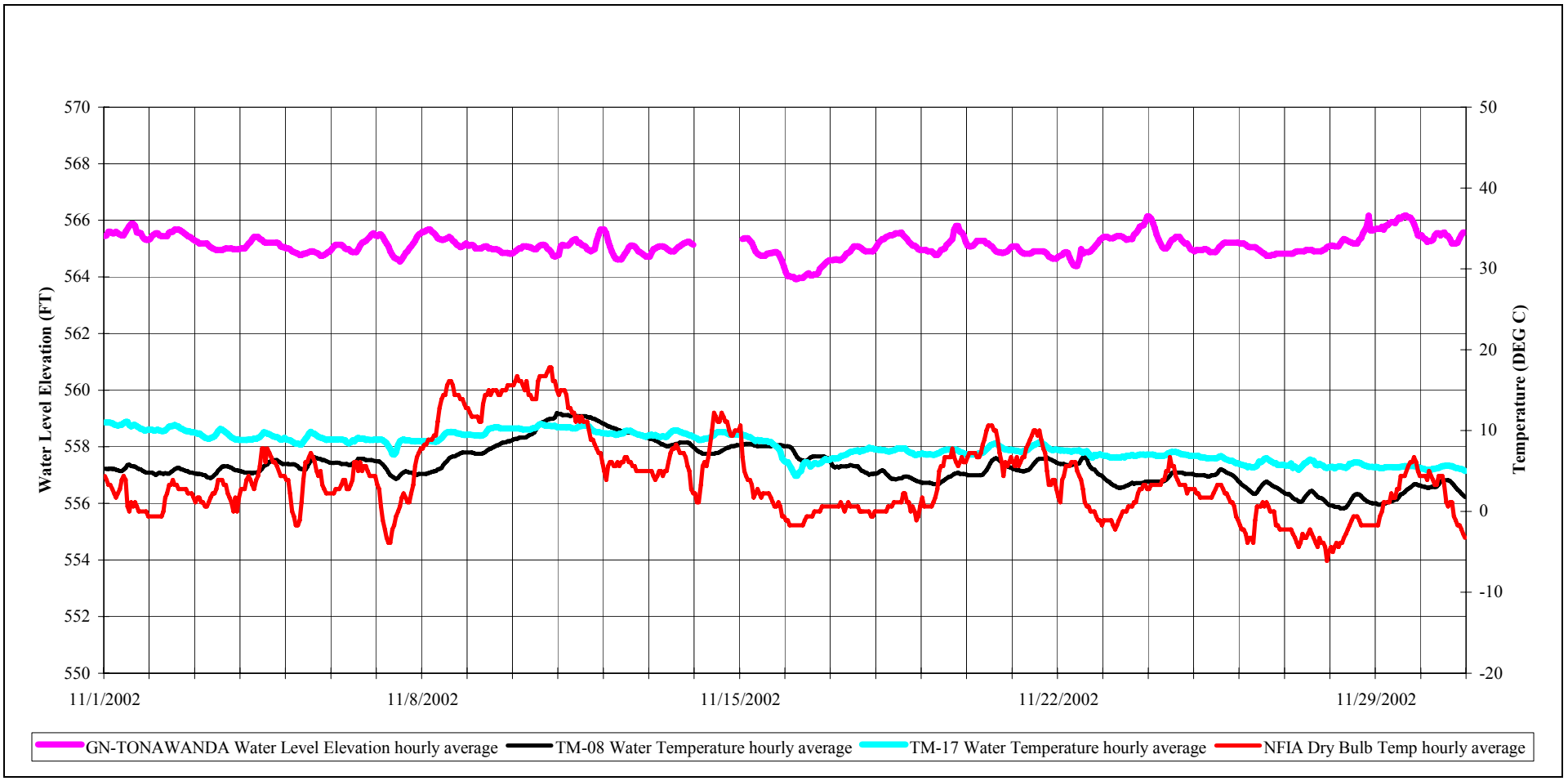

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FIGURE B-135: SPICER CREEK (TSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

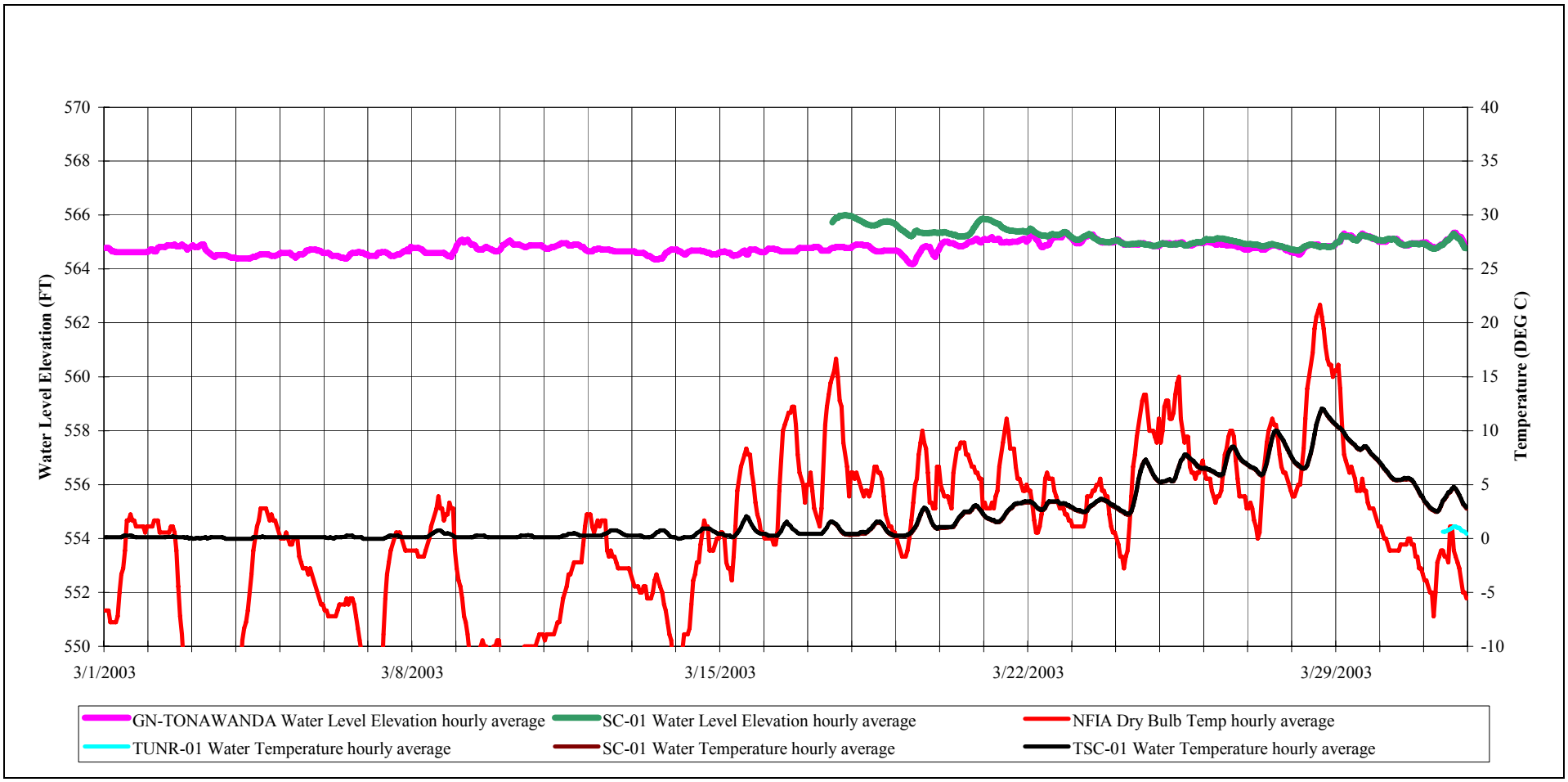

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FIGURE B-136: SPICER CREEK (TSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

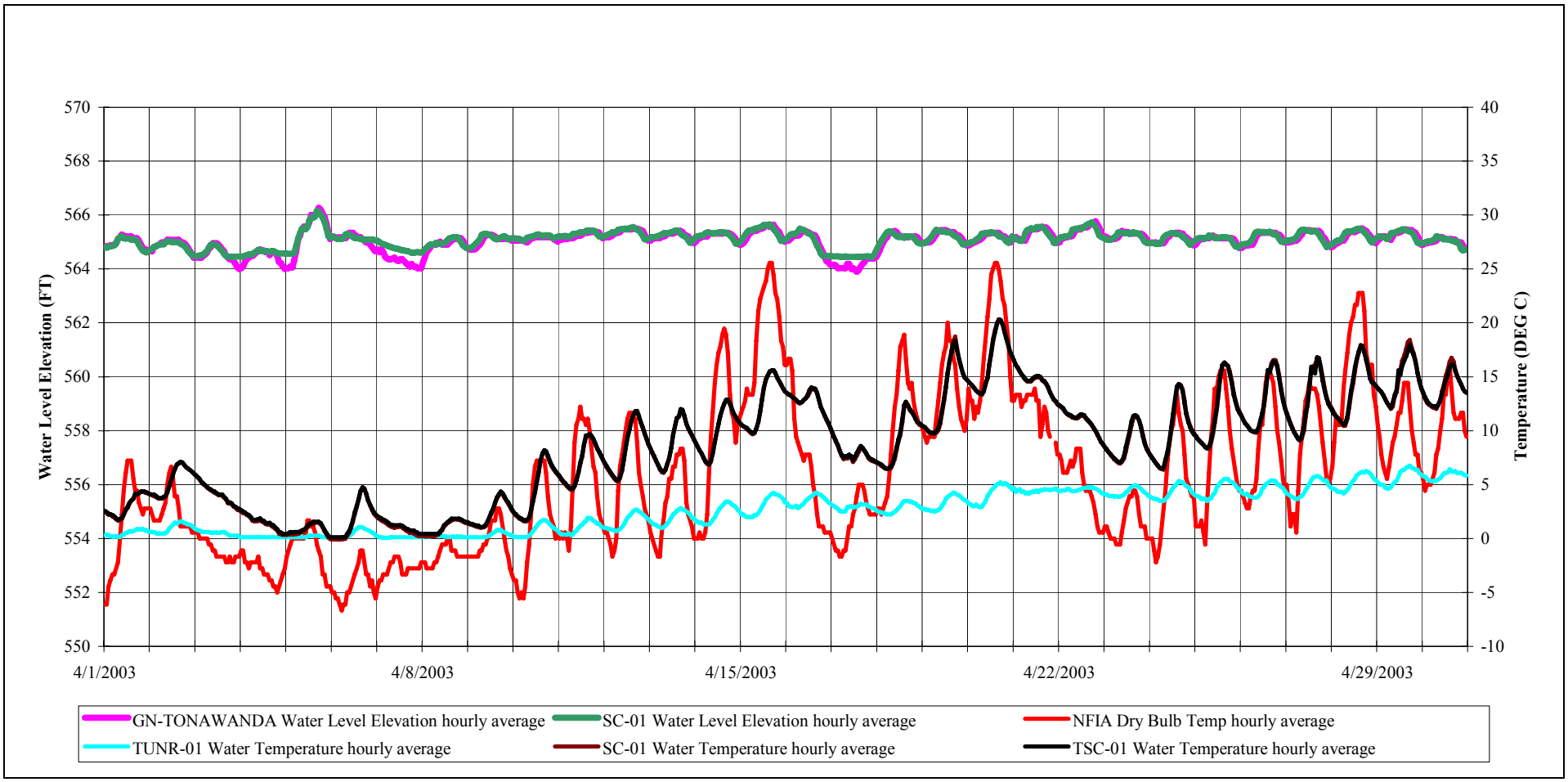

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FIGURE B-137: SPICER CREEK (TSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

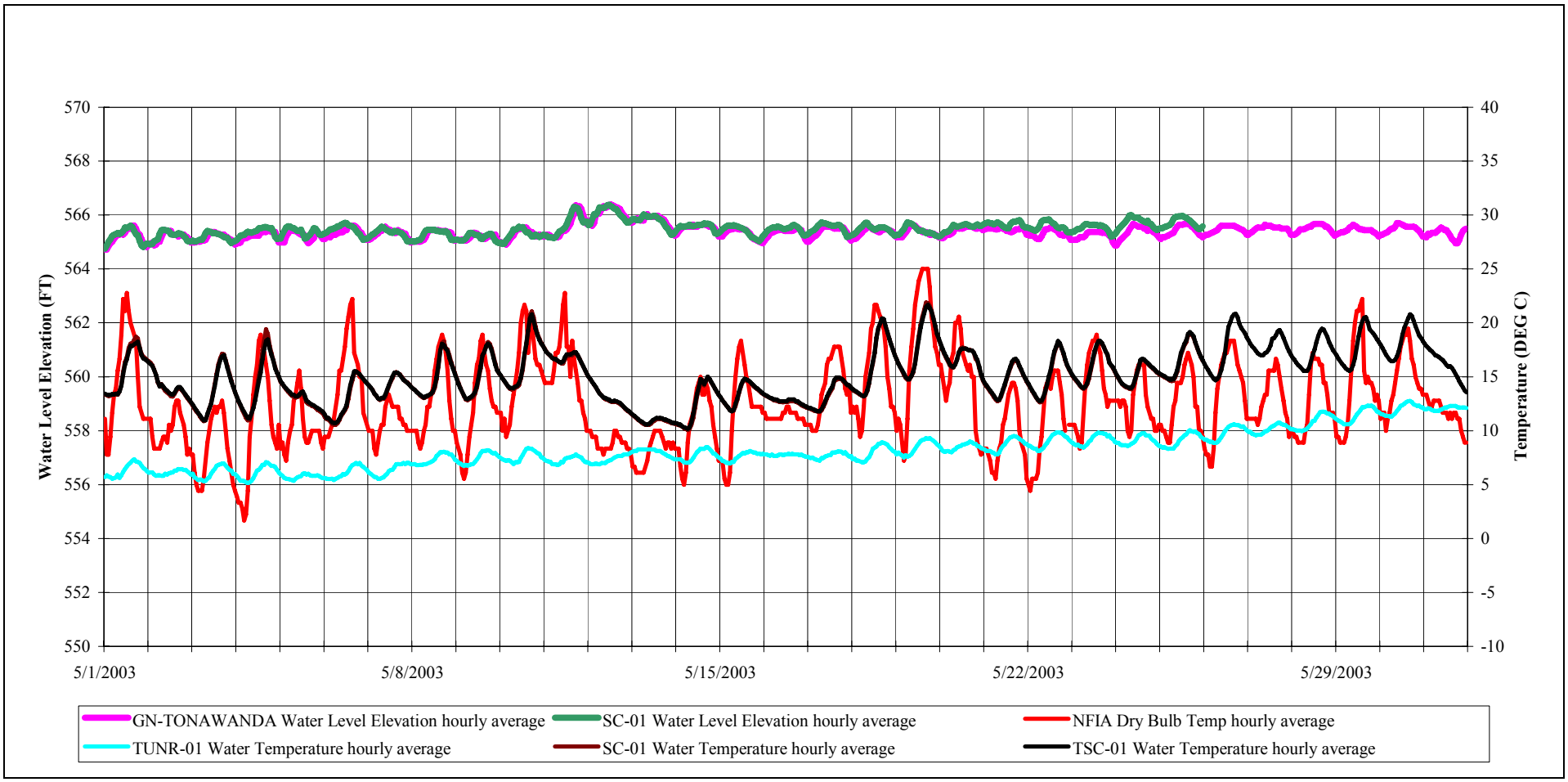

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FIGURE B-138: SPICER CREEK (TSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

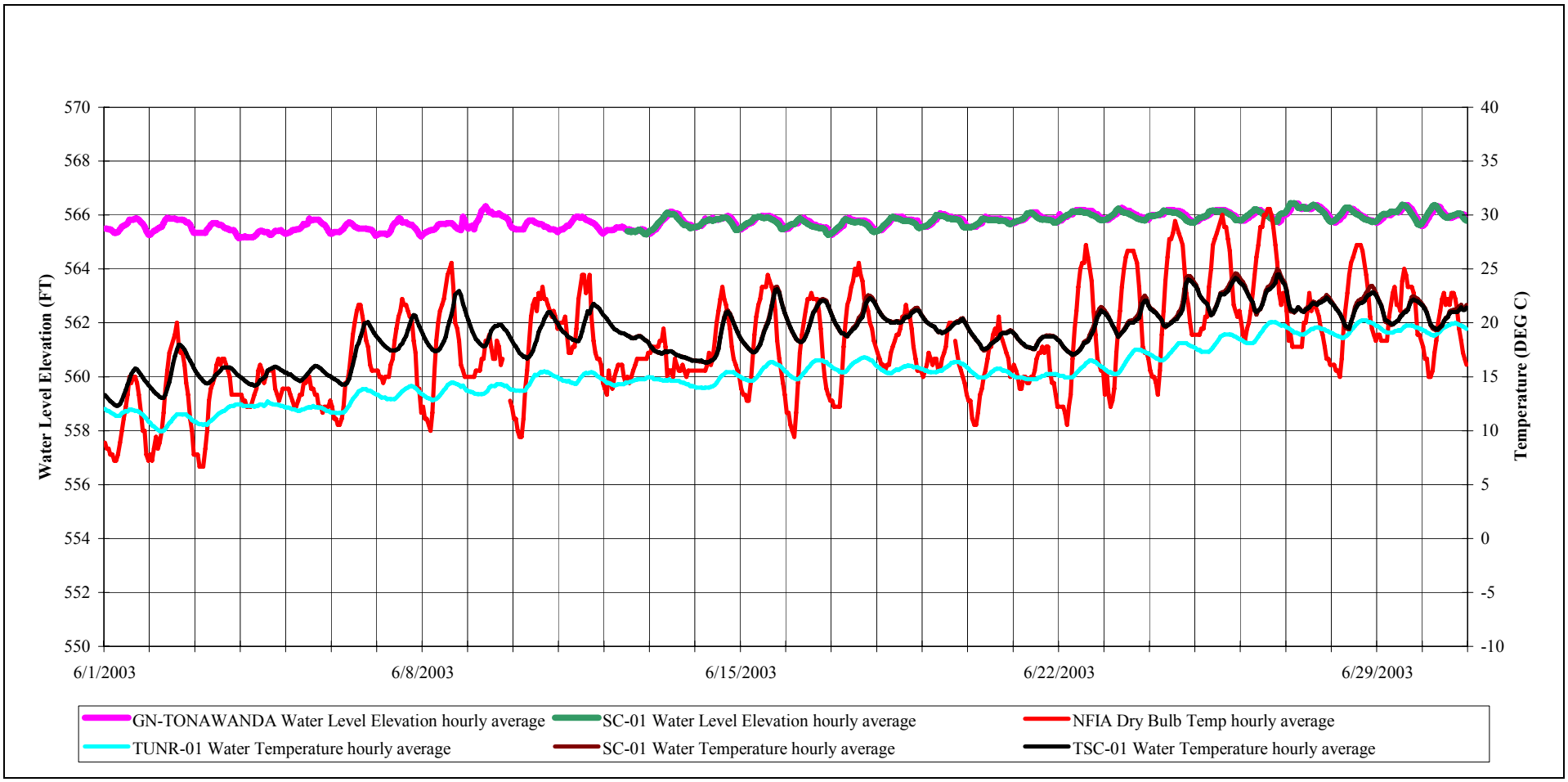

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FIGURE B-139: SPICER CREEK (TSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

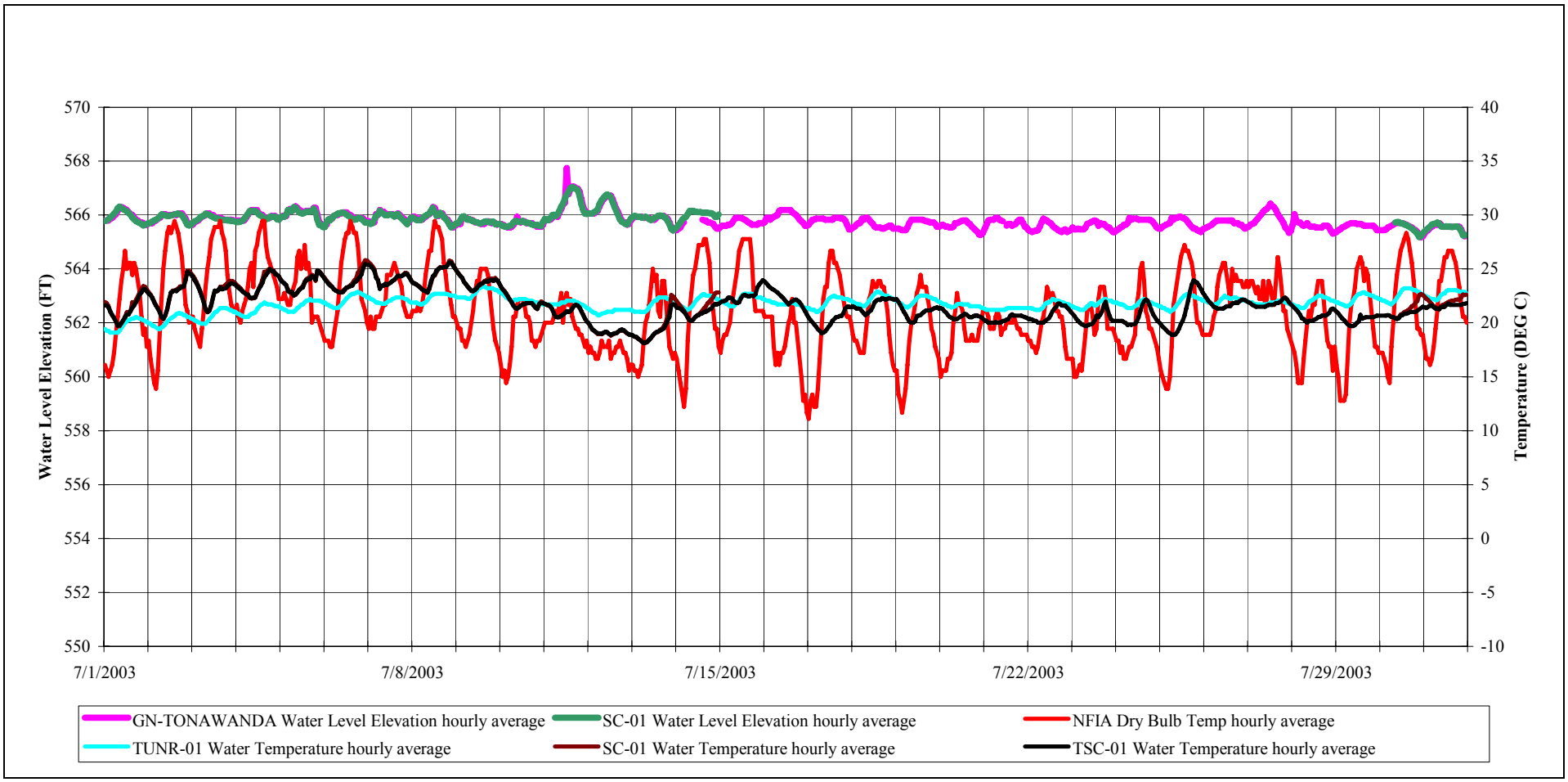

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FIGURE B-140: SPICER CREEK (TSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

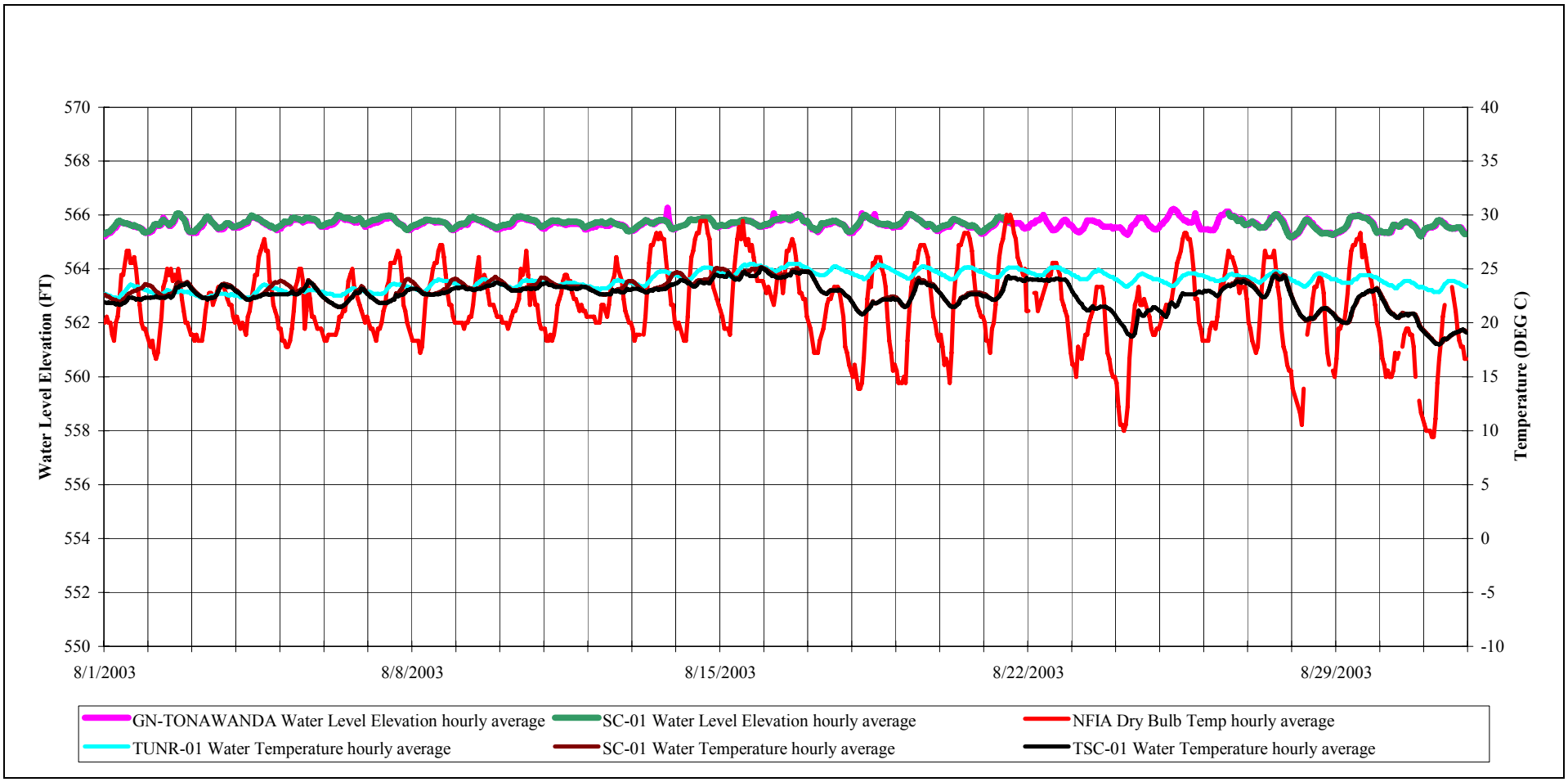

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FIGURE B-141: SPICER CREEK (TSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER2003

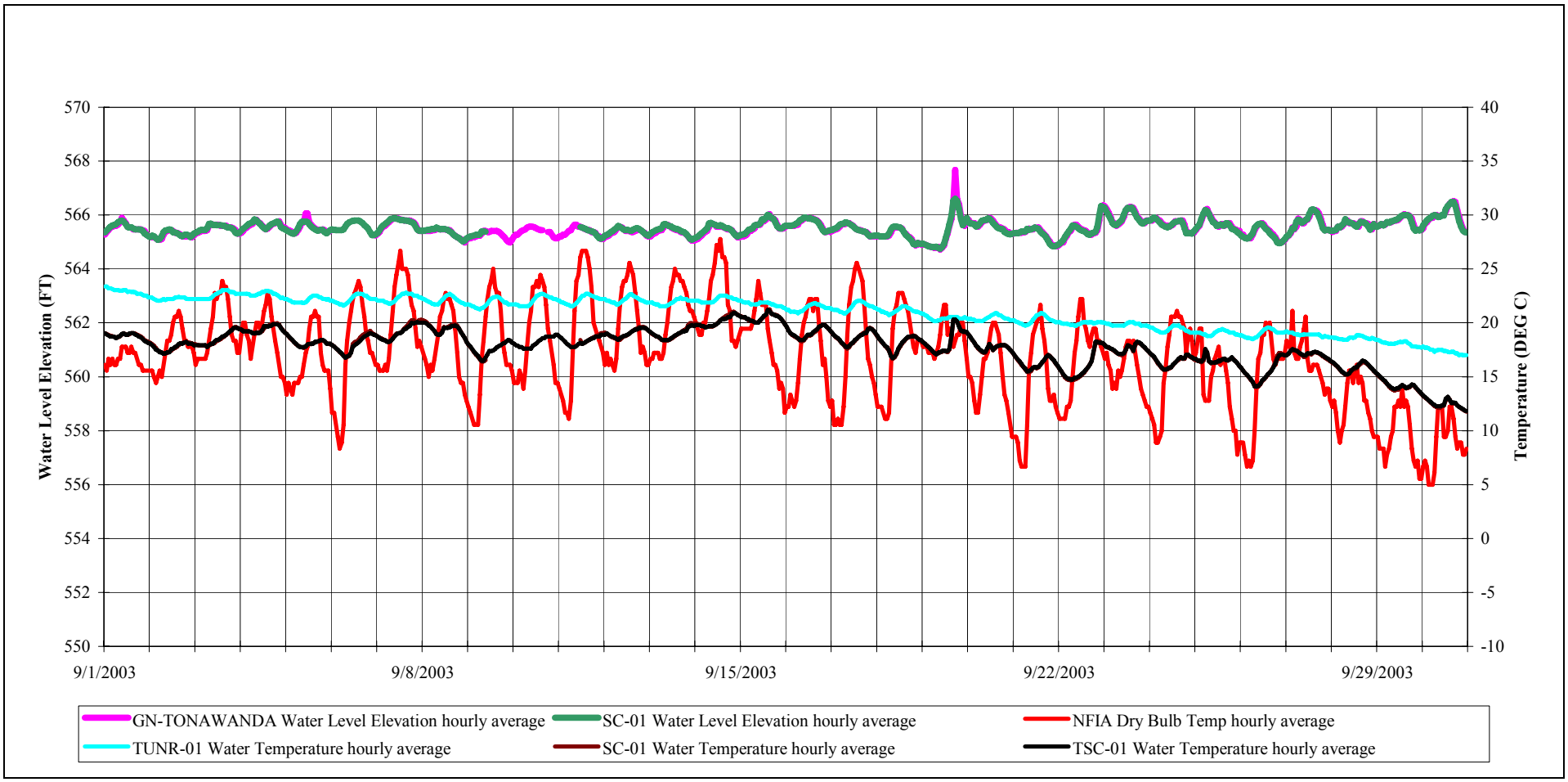

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FIGURE B-142: SPICER CREEK (TSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

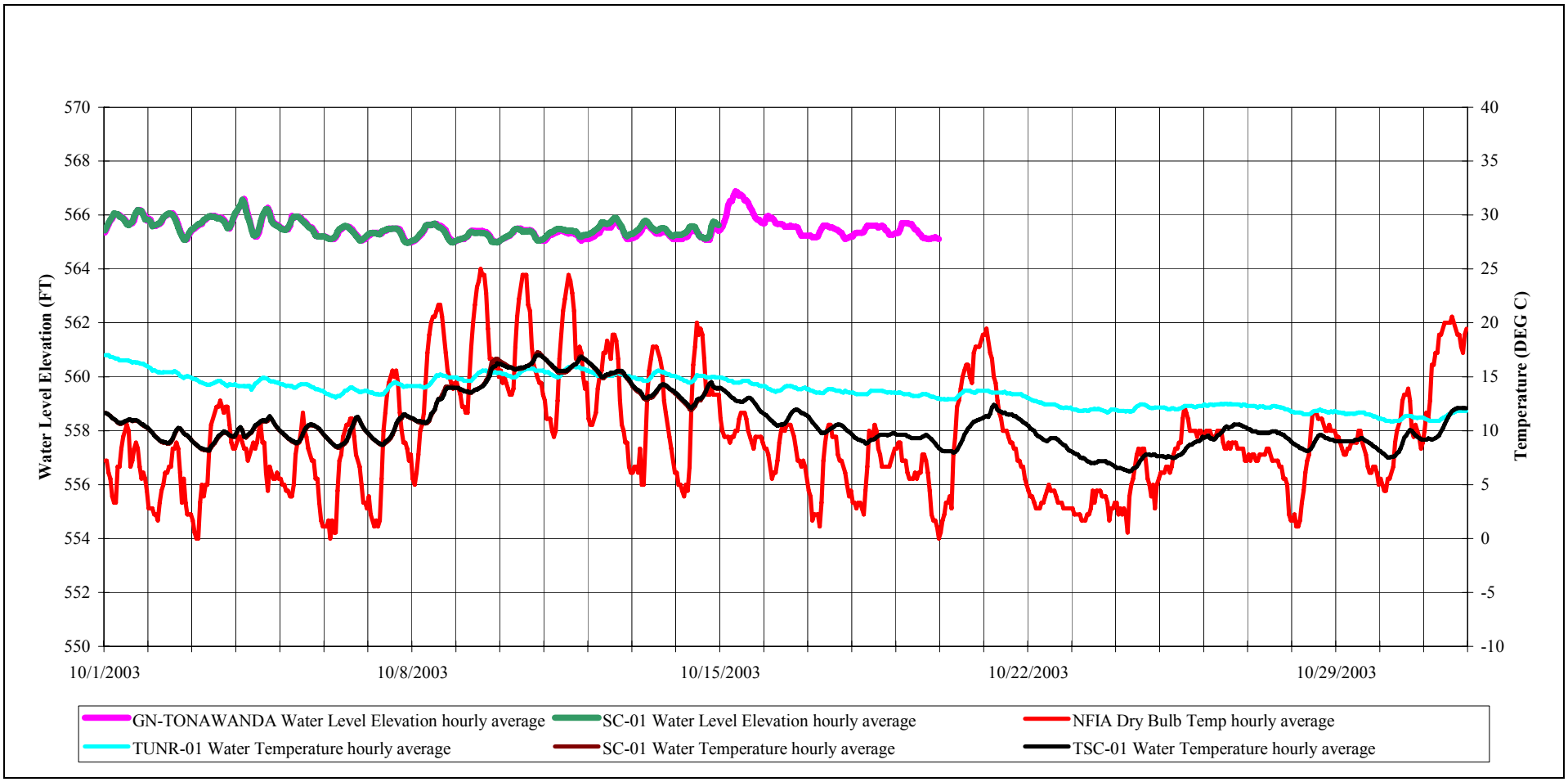

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FIGURE B-143: SPICER CREEK (TSC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

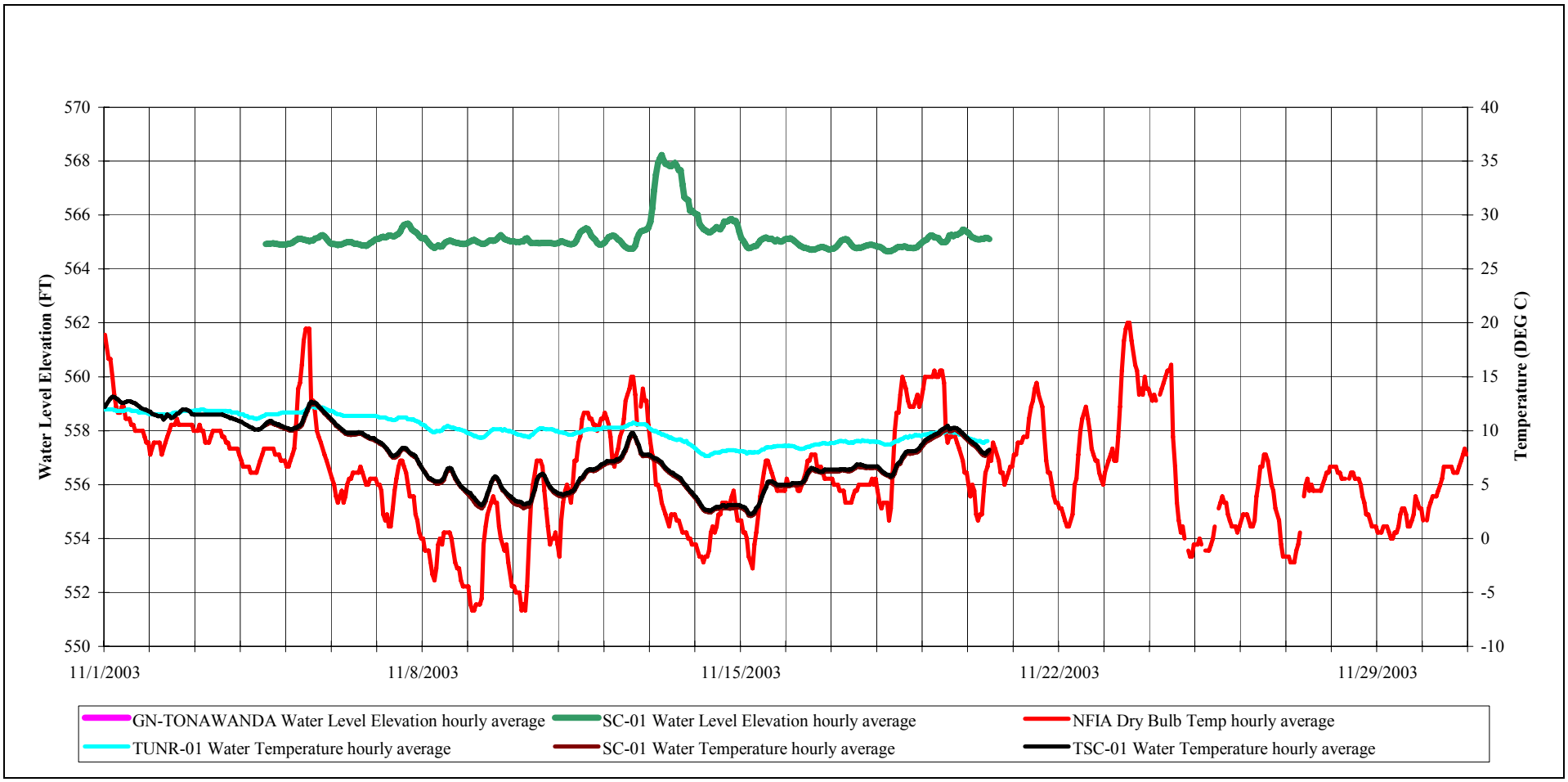

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FIGURE B-144: SPICER CREEK (TSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

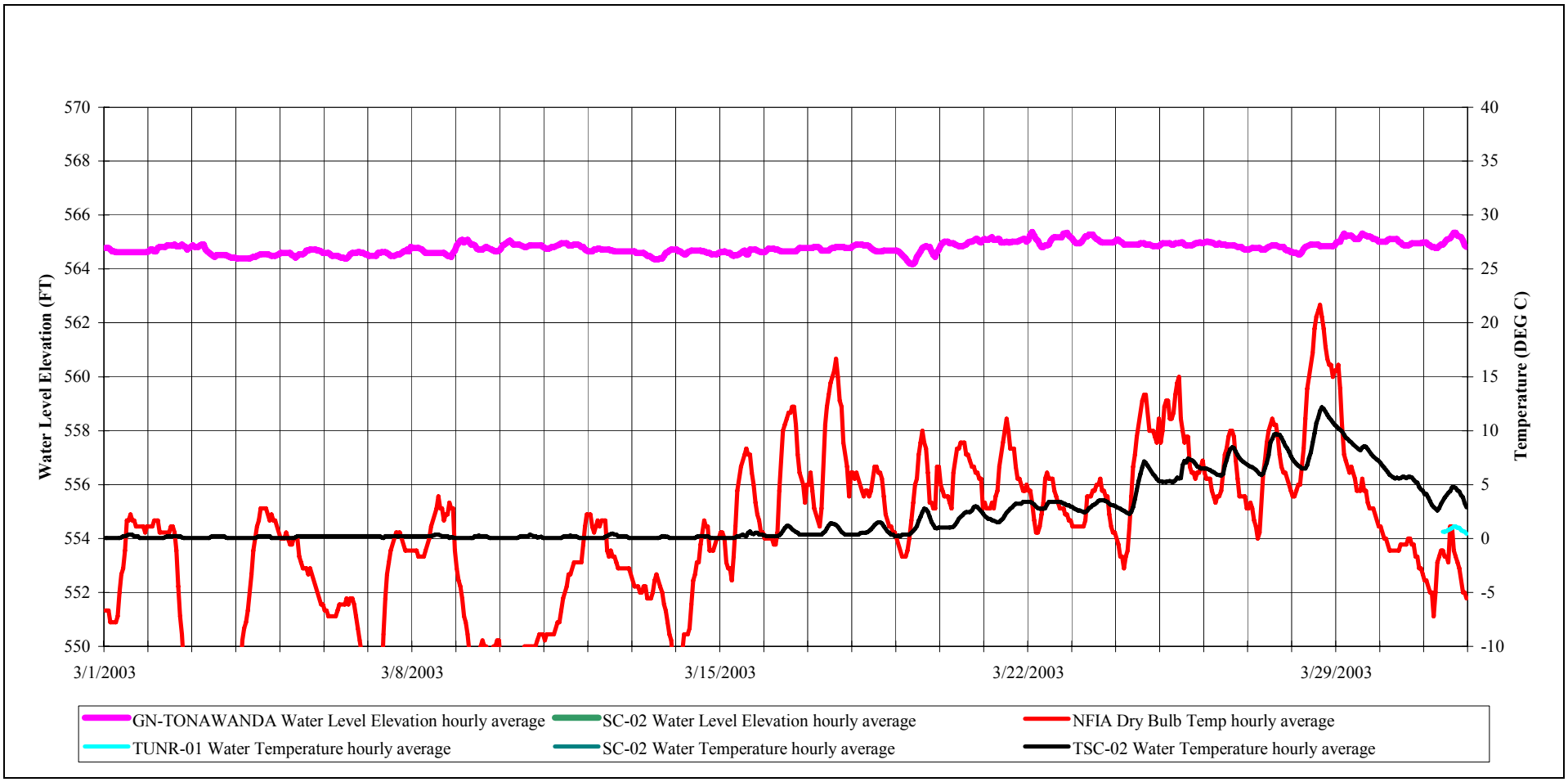

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FIGURE B-145: SPICER CREEK (TSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

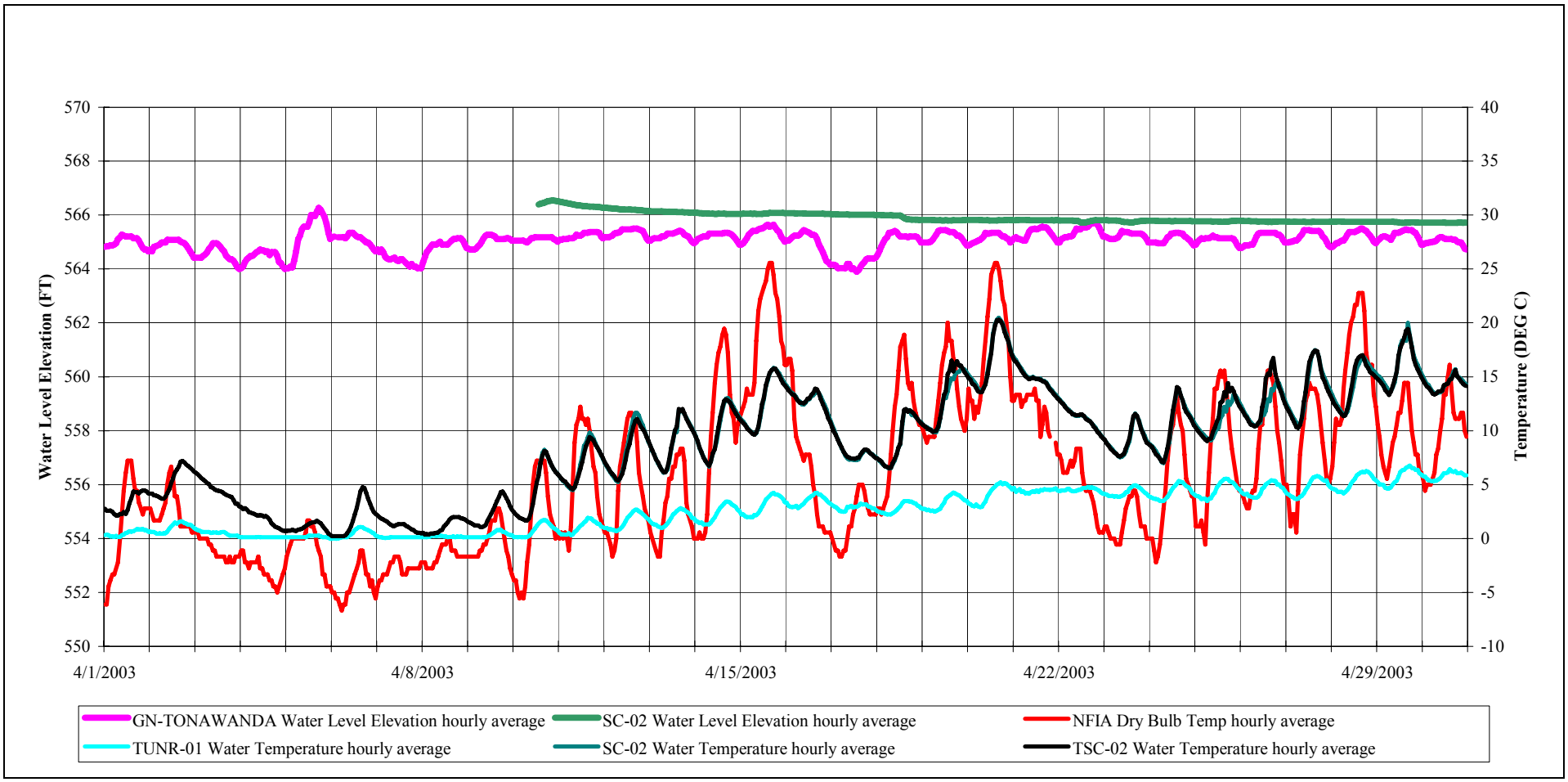

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FIGURE B-146: SPICER CREEK (TSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

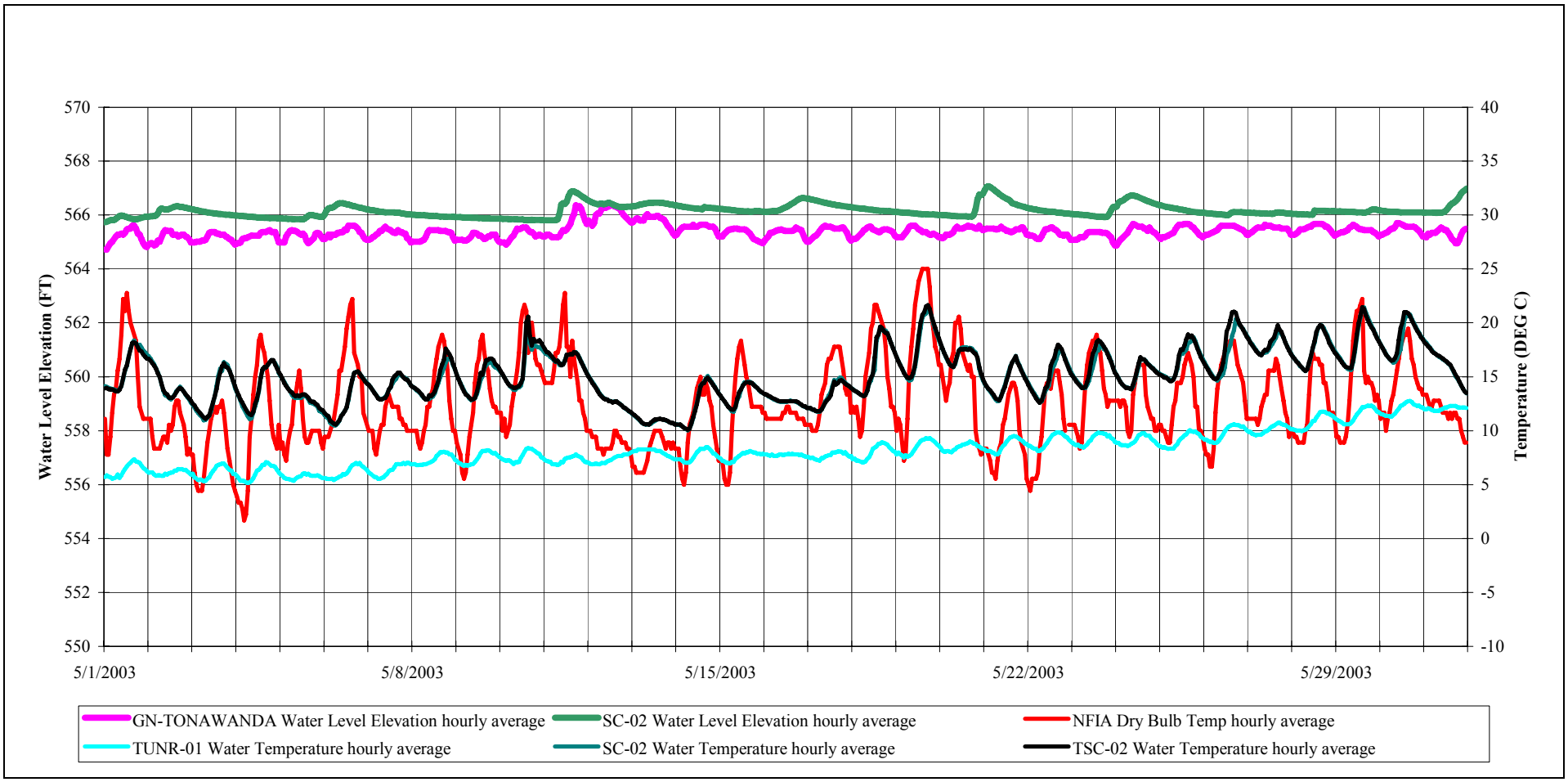

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FIGURE B-147: SPICER CREEK (TSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

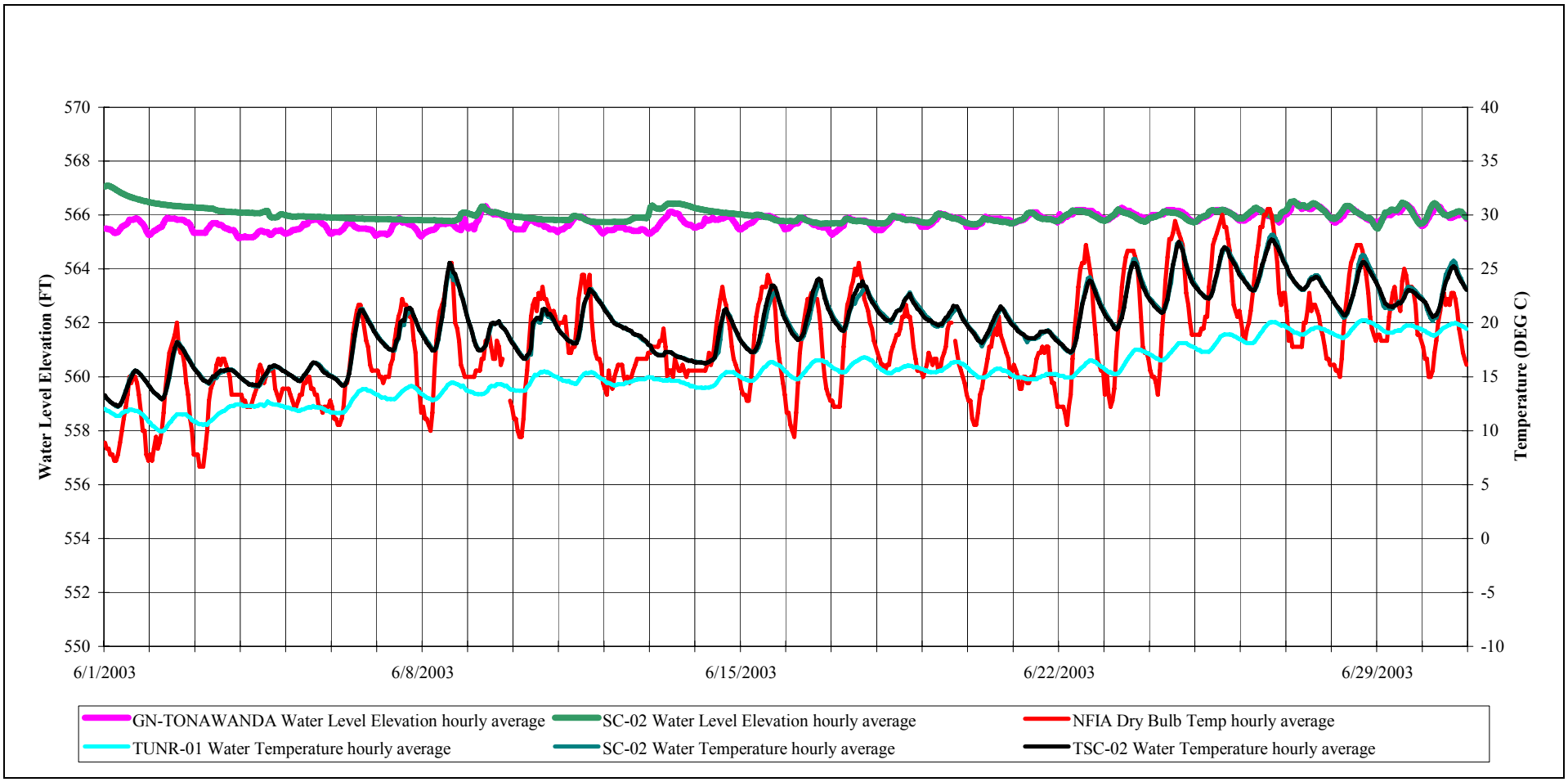

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FIGURE B-148: SPICER CREEK (TSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

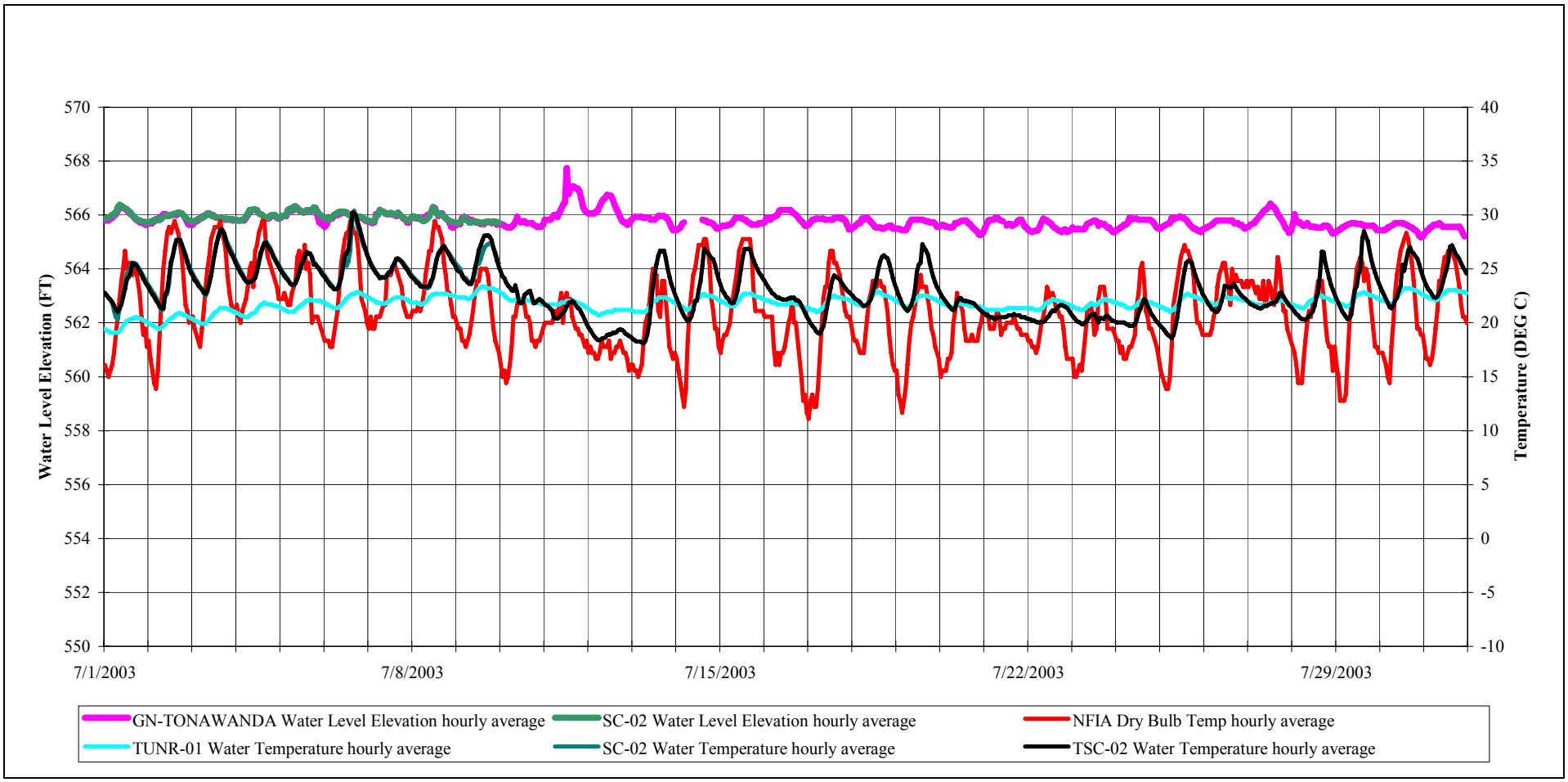

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FIGURE B-149: SPICER CREEK (TSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

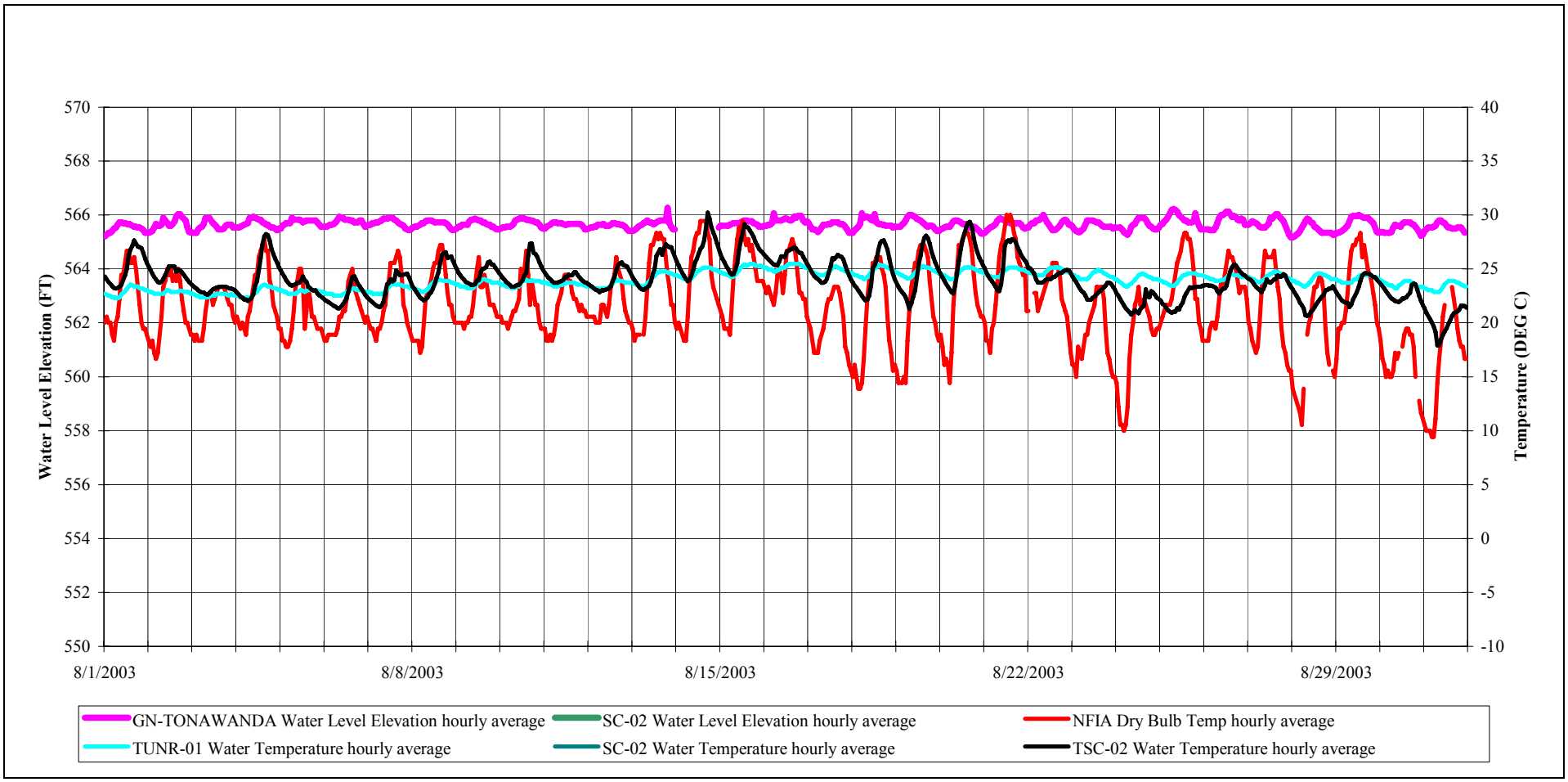

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FIGURE B-150: SPICER CREEK (TSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

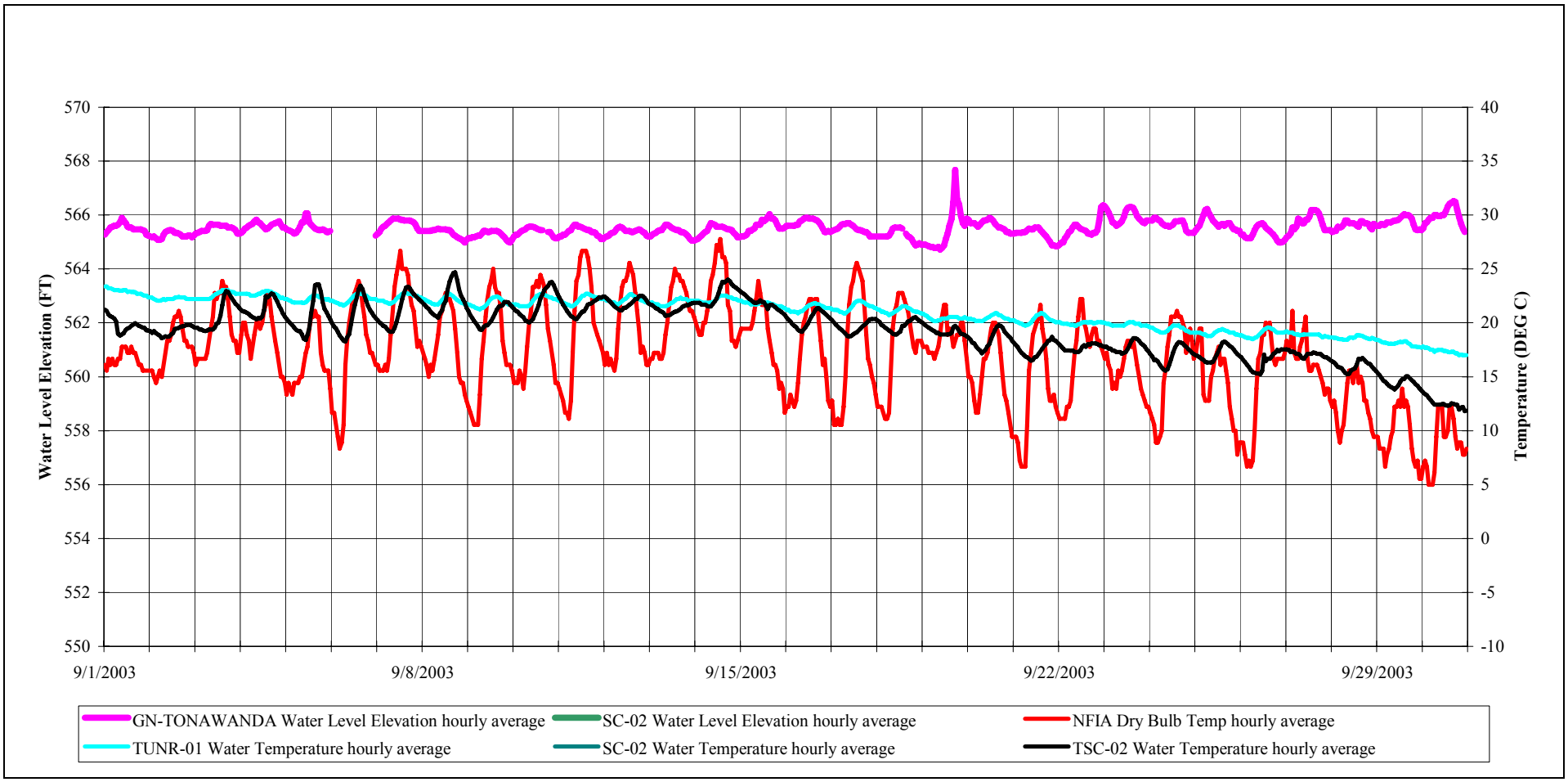

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FIGURE B-151: SPICER CREEK (TSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

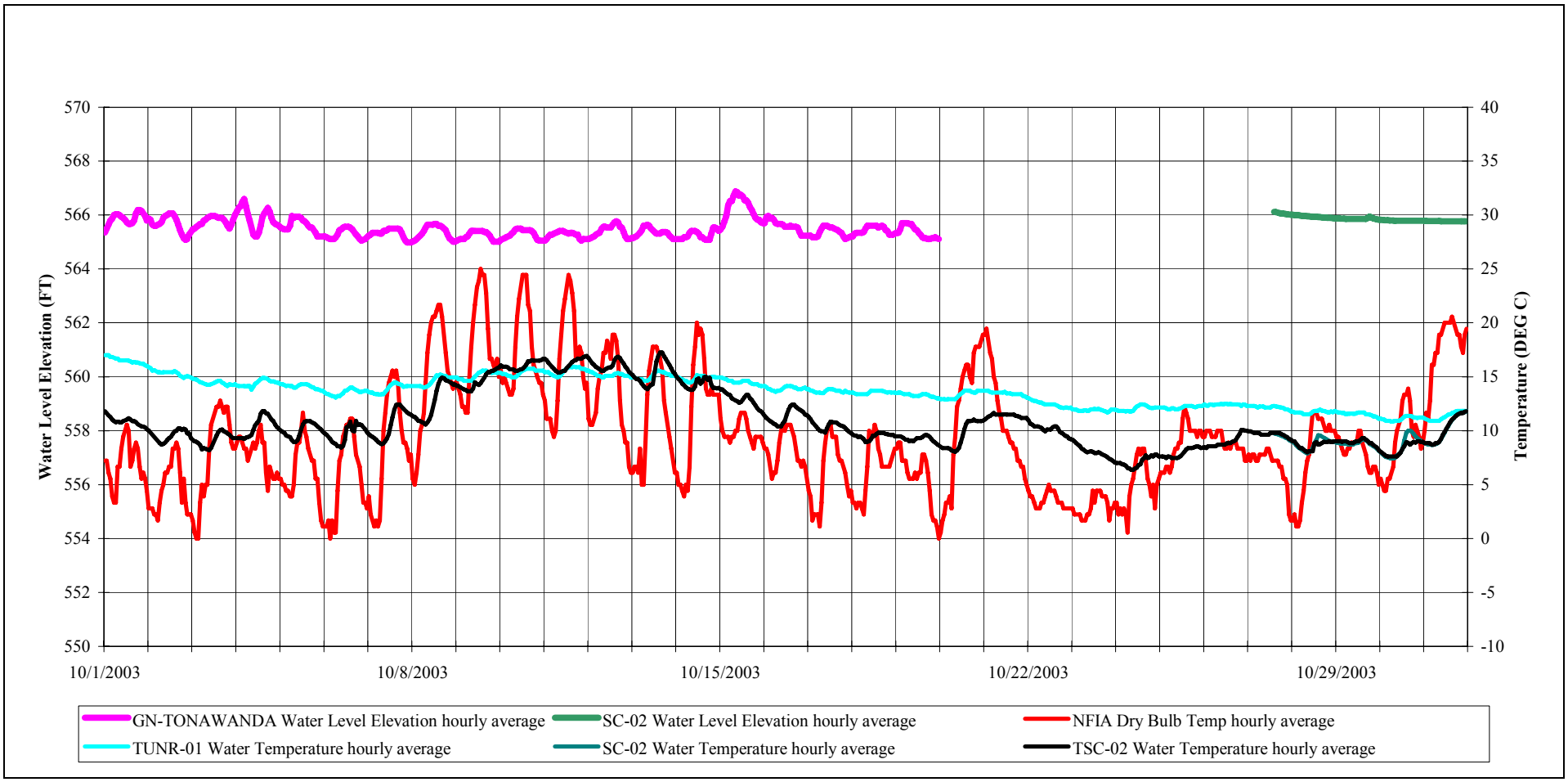

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FIGURE B-152: SPICER CREEK (TSC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

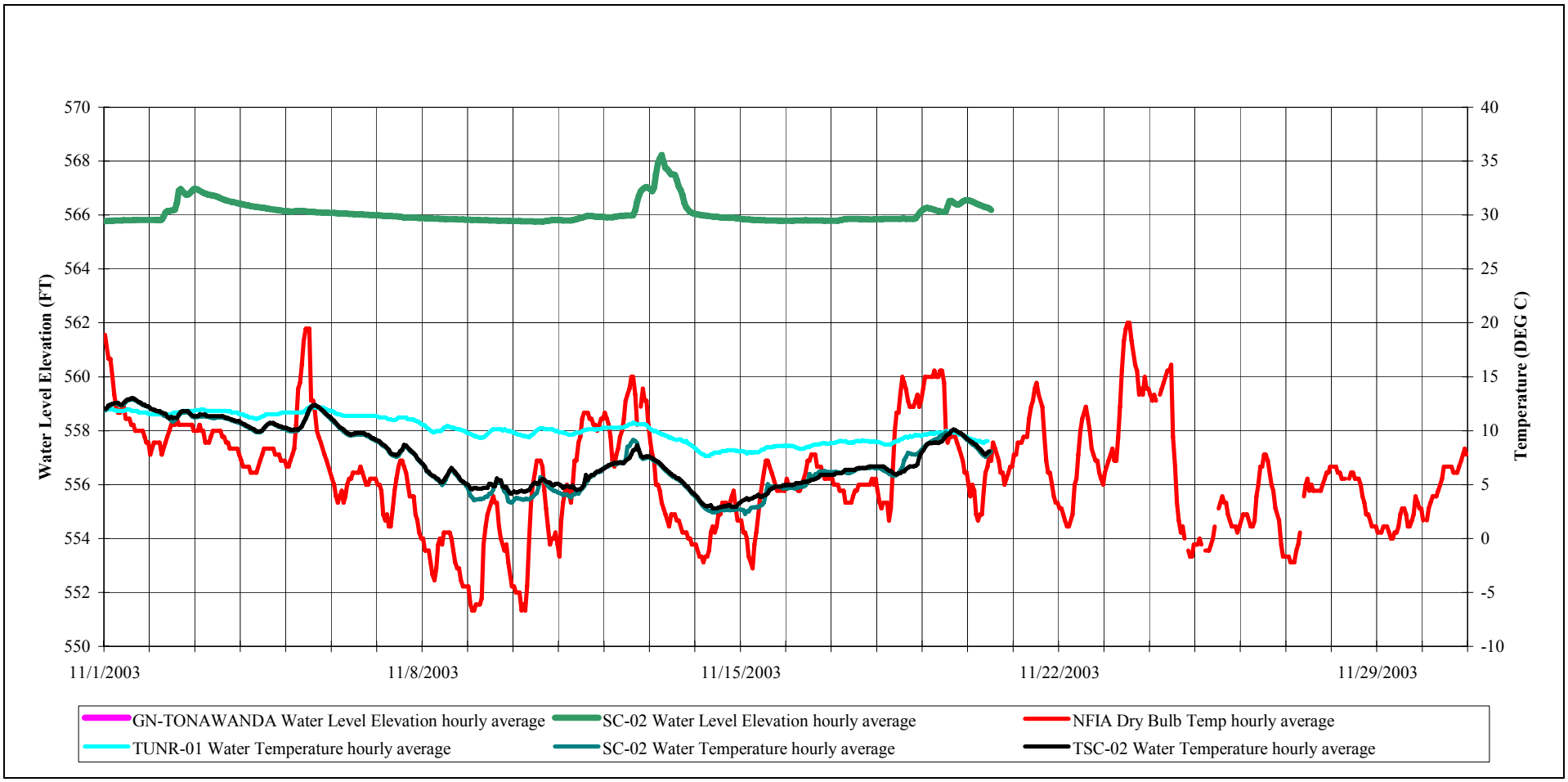

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FIGURE B-153: BIG SIXMILE CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2002

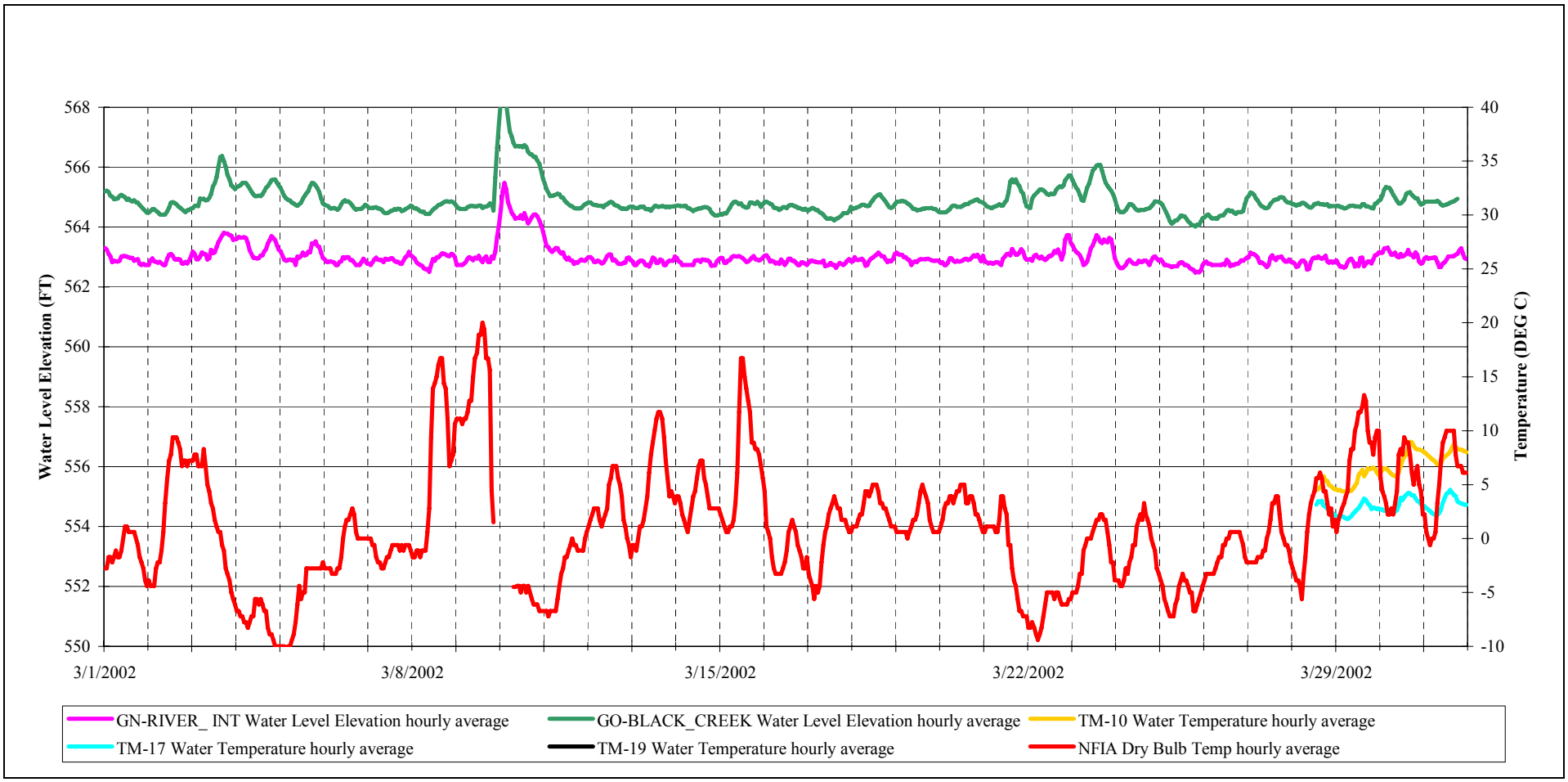

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FIGURE B-154: BIG SIXMILE CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

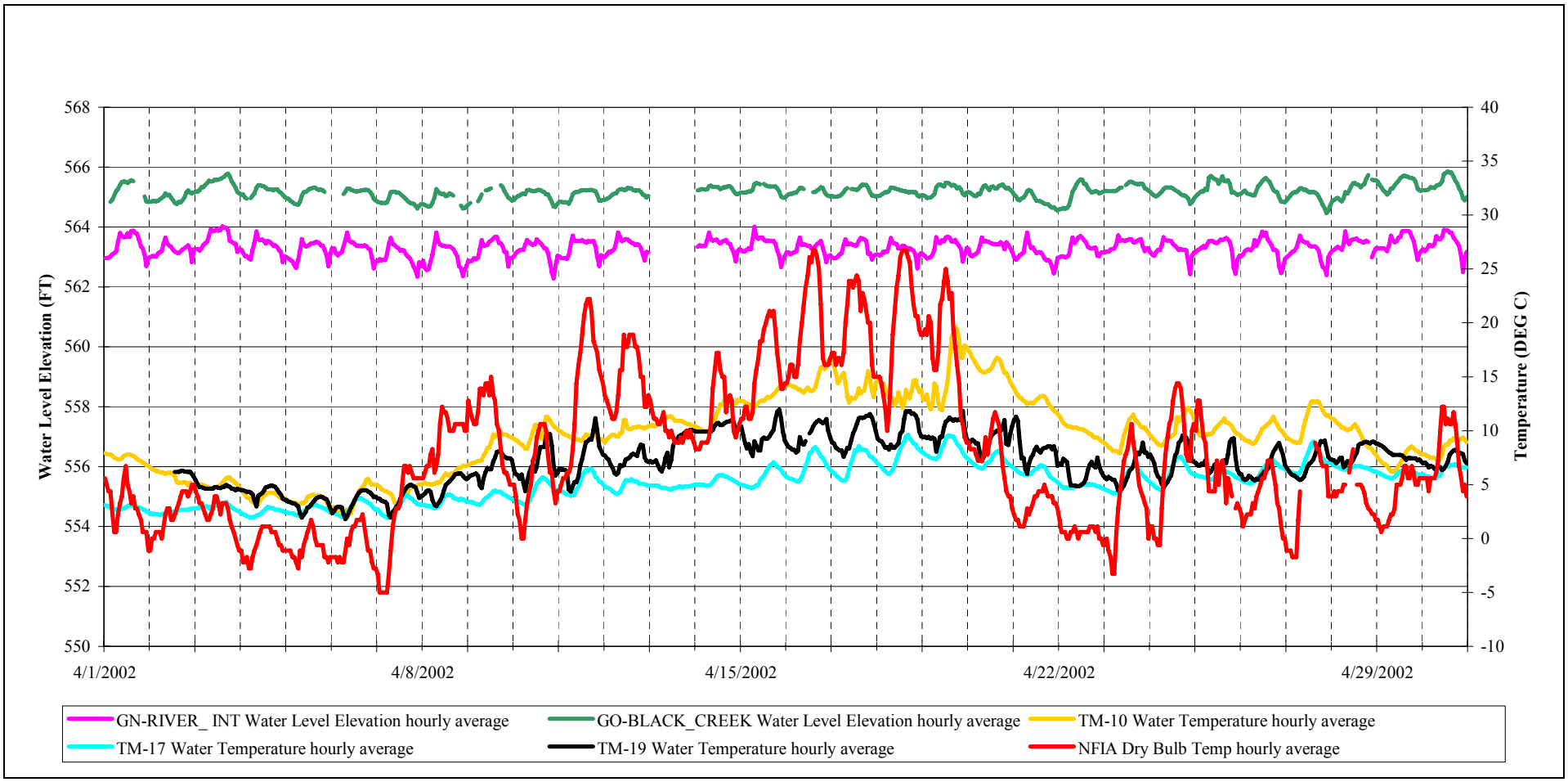

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FIGURE B-155: BIG SIXMILE CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

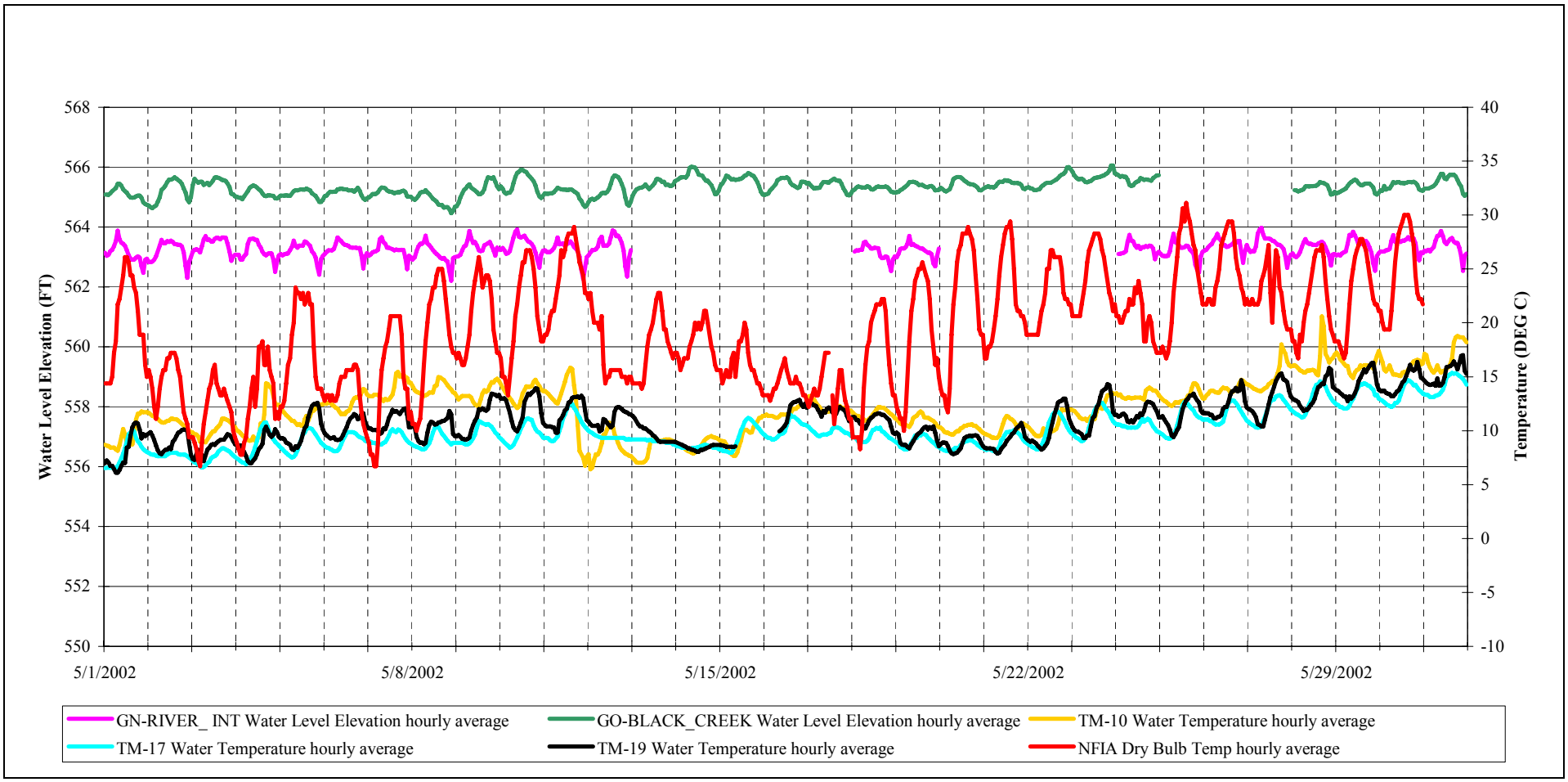

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FIGURE B-156: BIG SIXMILE CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

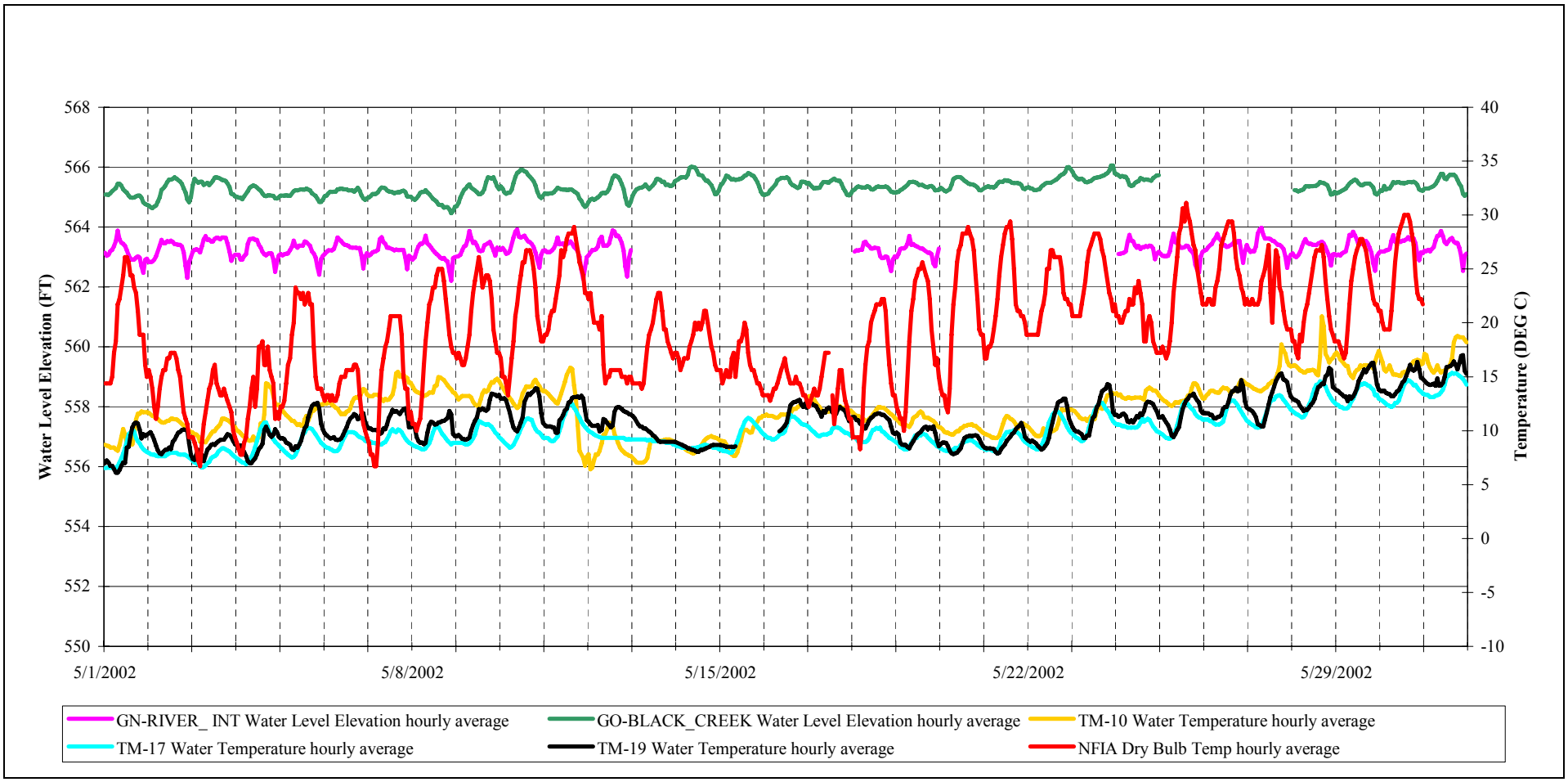

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FIGURE B-157: BIG SIXMILE CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

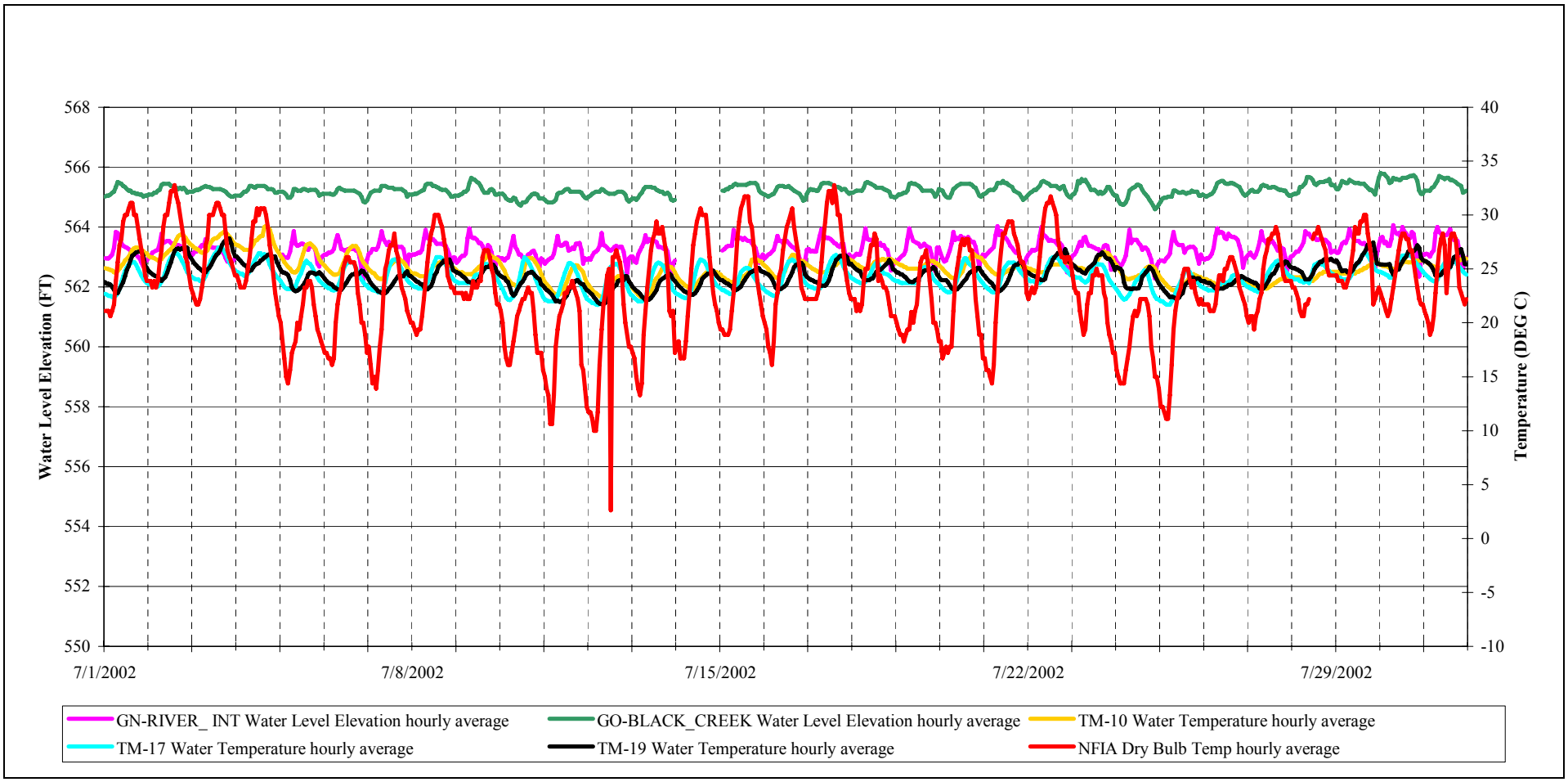

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FIGURE B-158: BIG SIXMILE CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

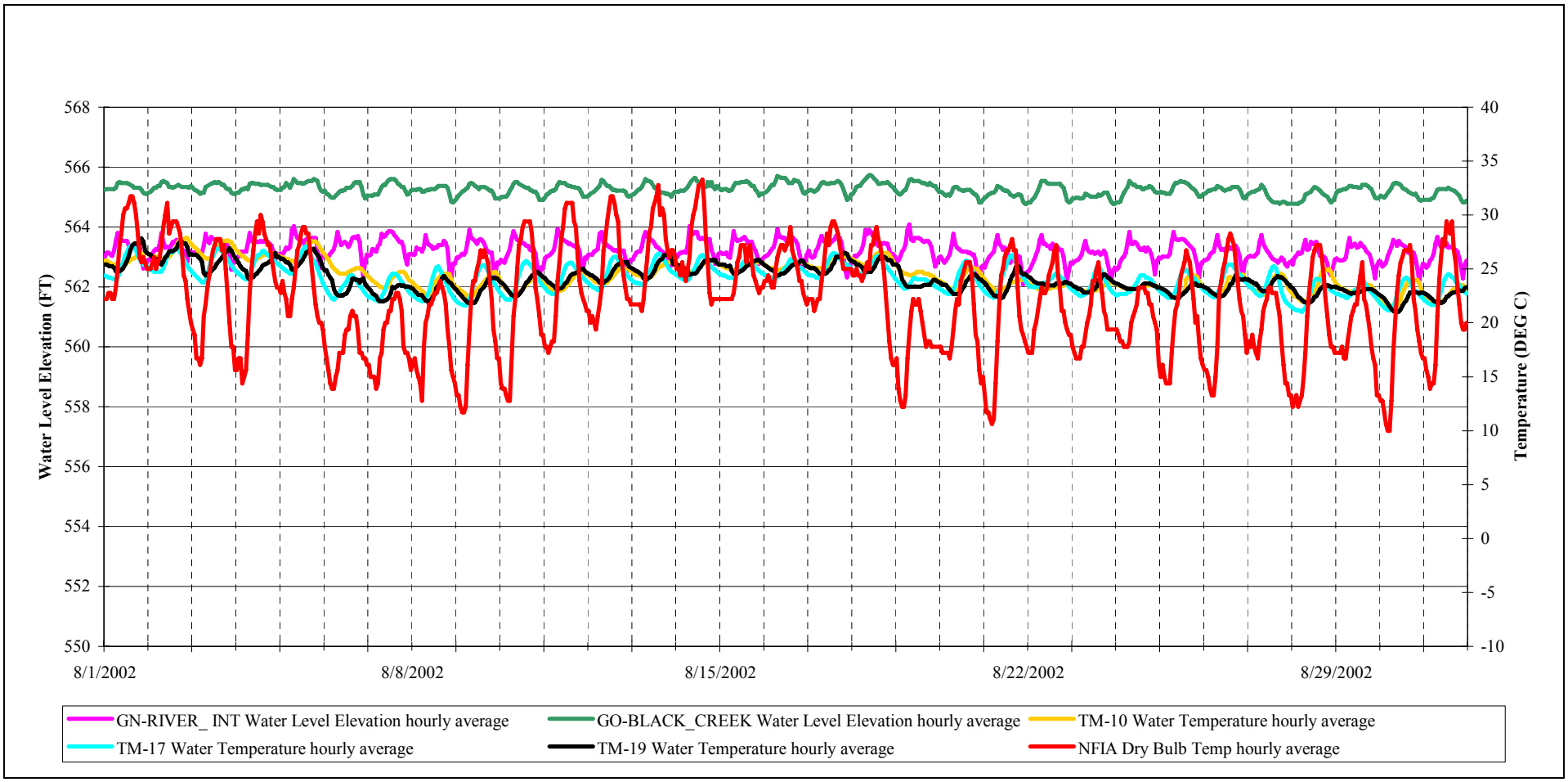

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FIGURE B-159: BIG SIXMILE CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

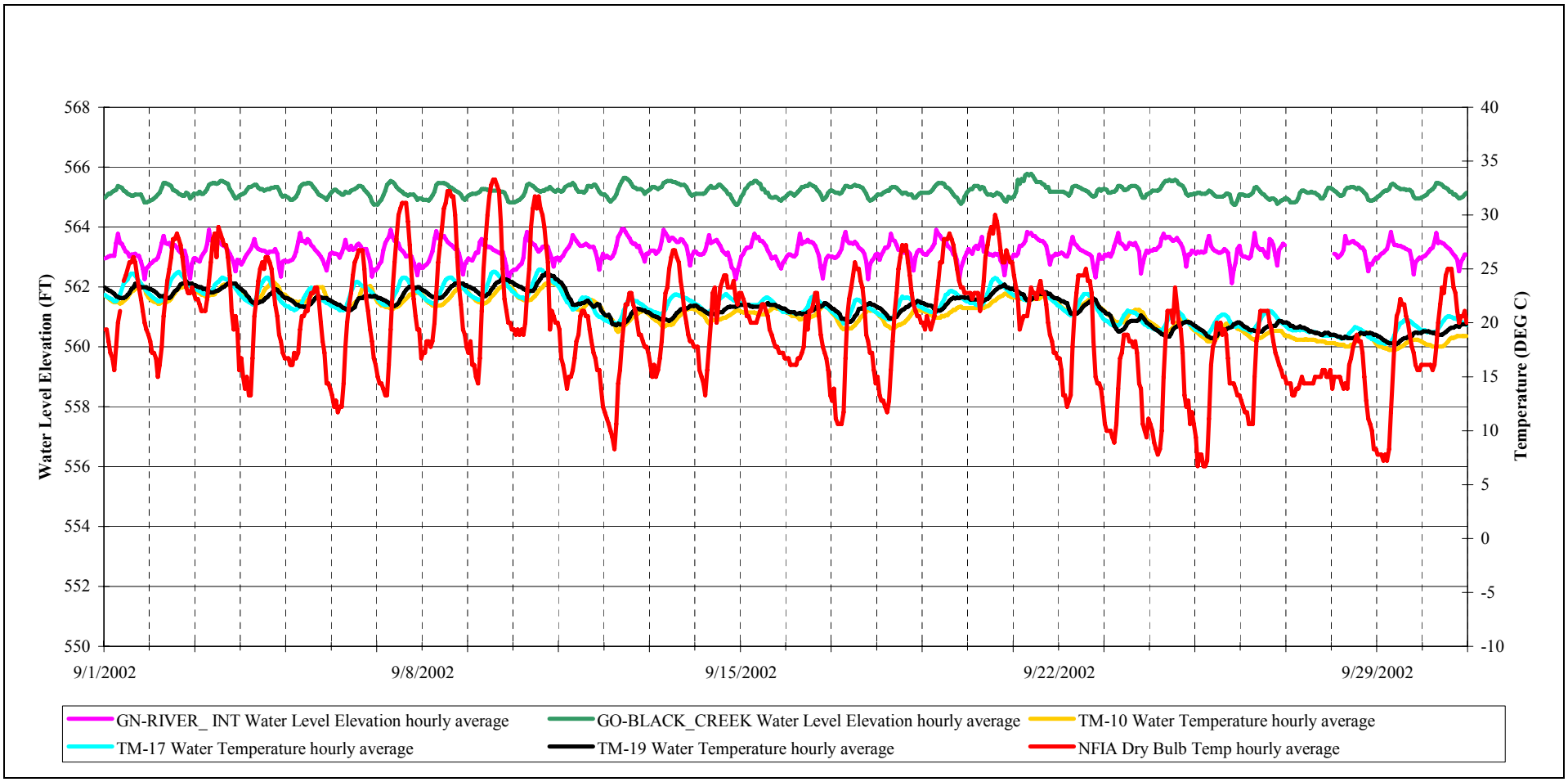

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FIGURE B-160: BIG SIXMILE CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

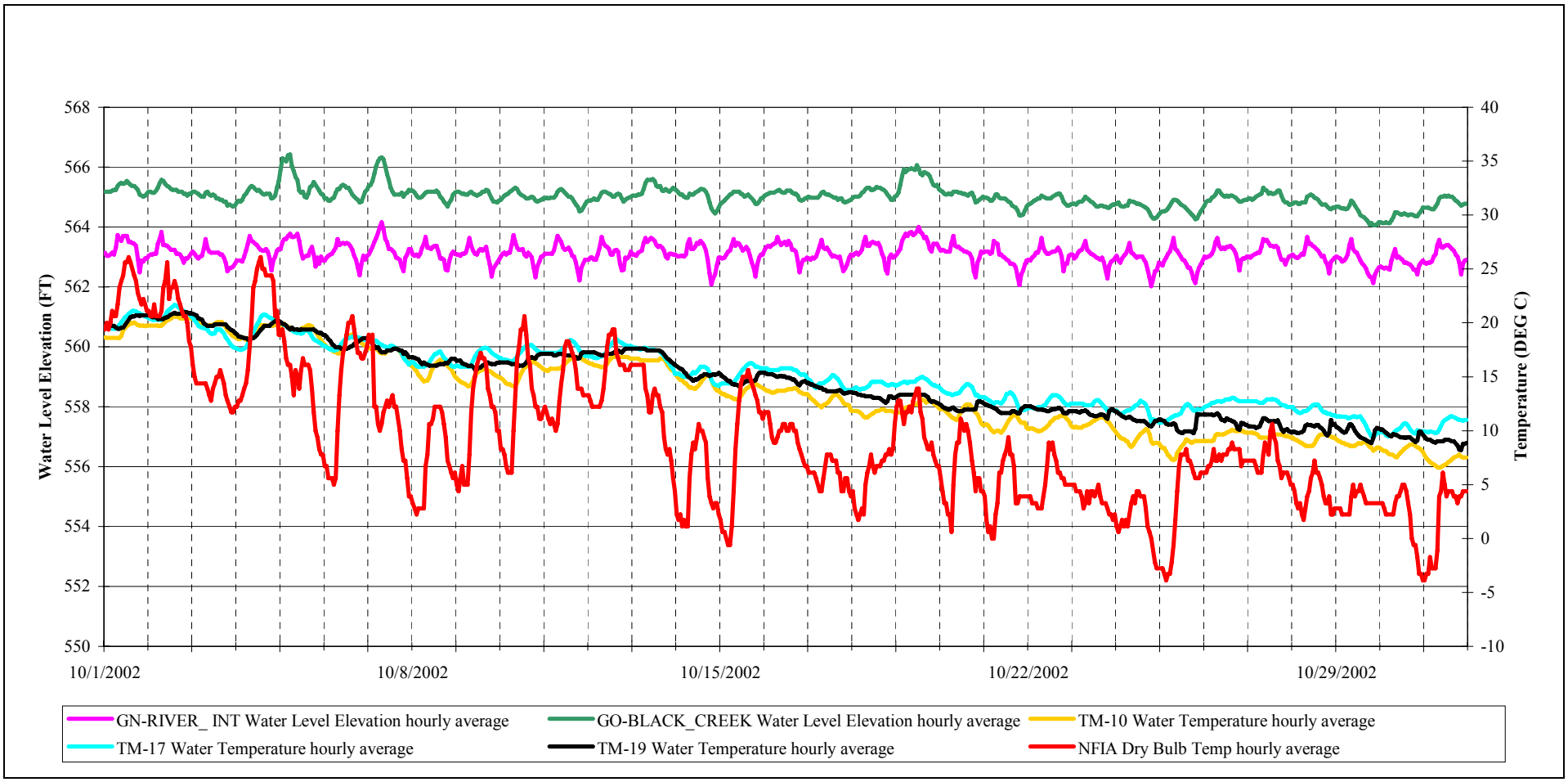

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FIGURE B-161: BIG SIXMILE CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2002

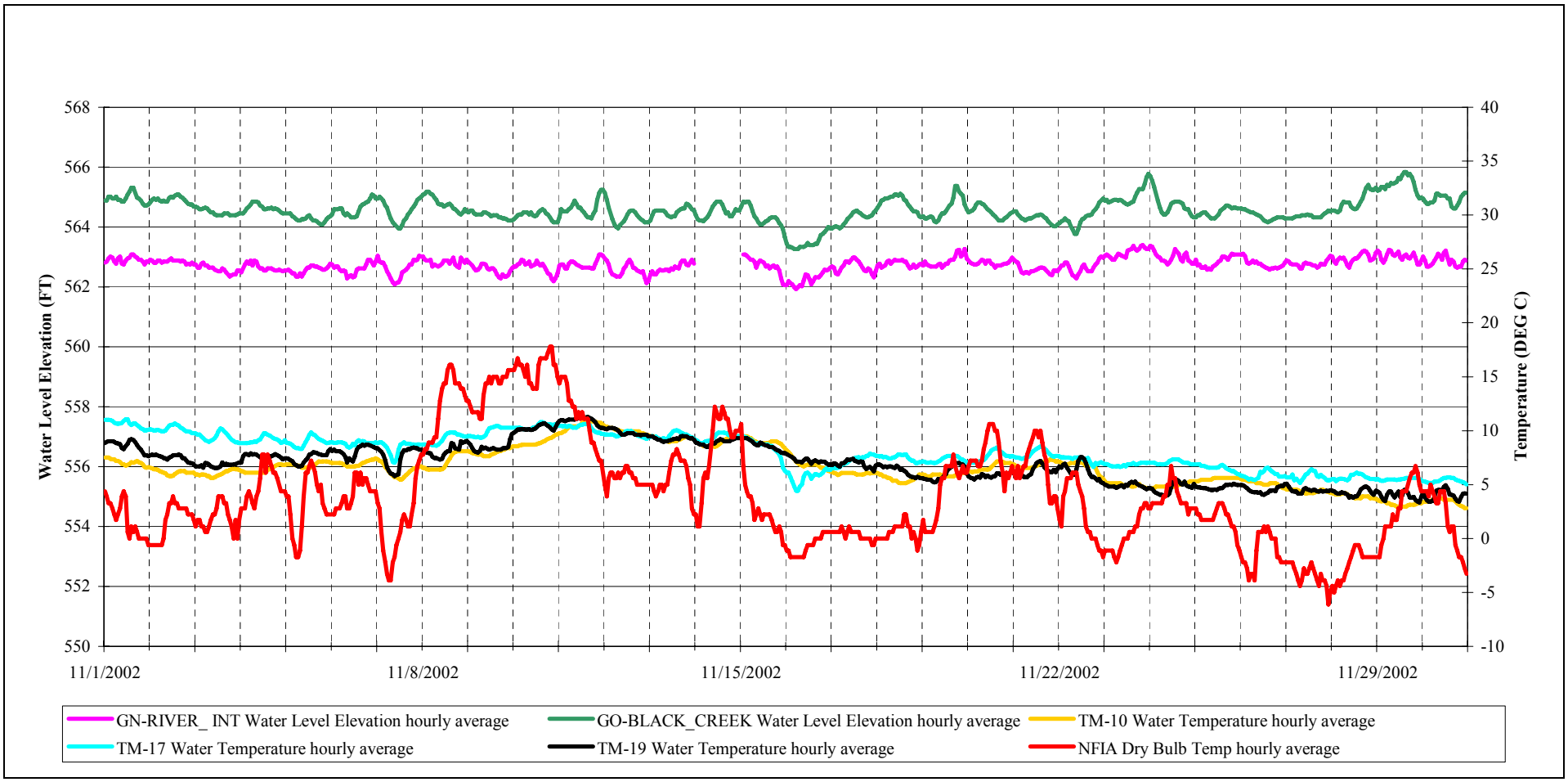

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FIGURE B-162: BIG SIXMILE CREEK (SMC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

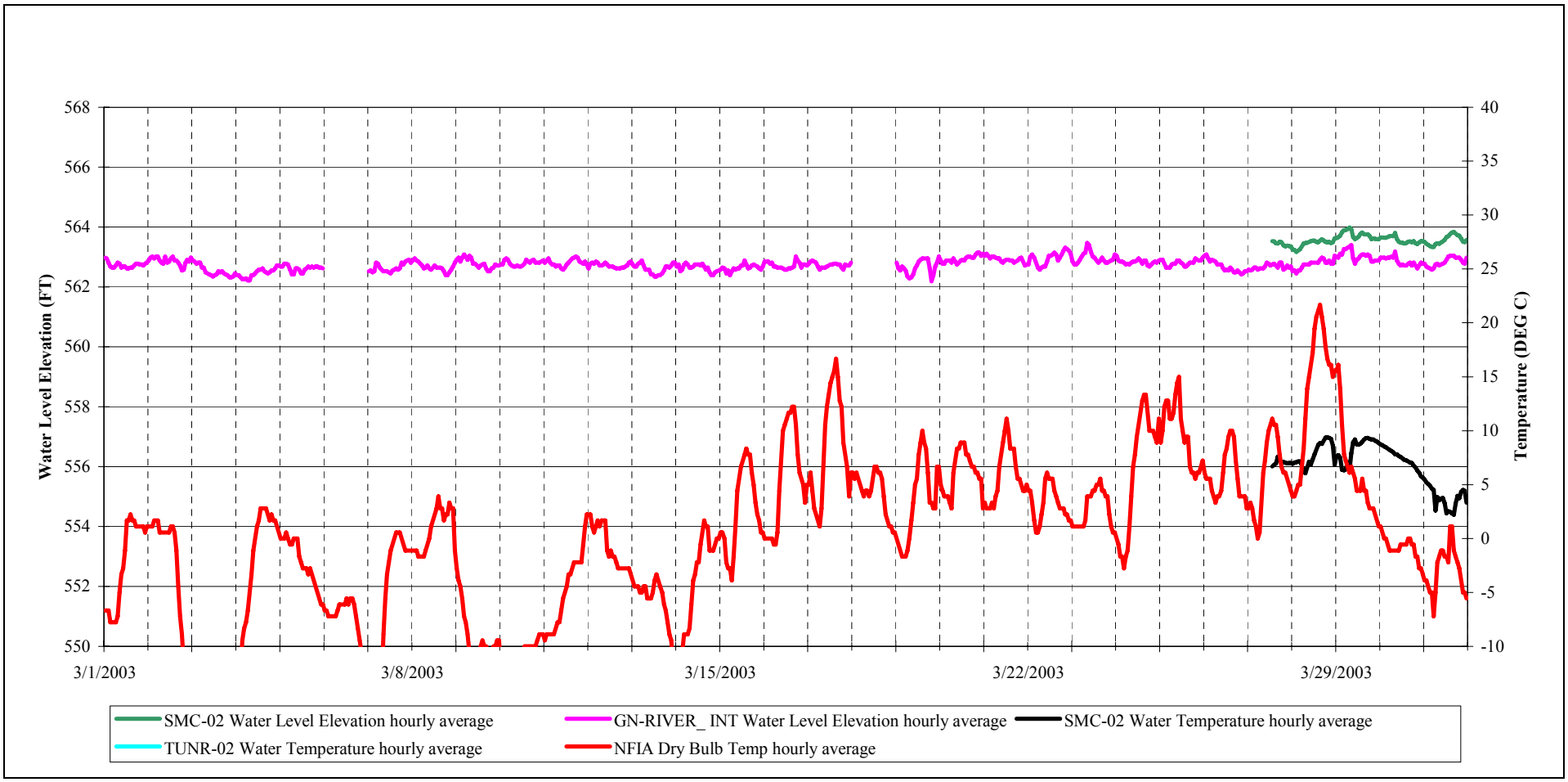

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FIGURE B-163: BIG SIXMILE CREEK (SMC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

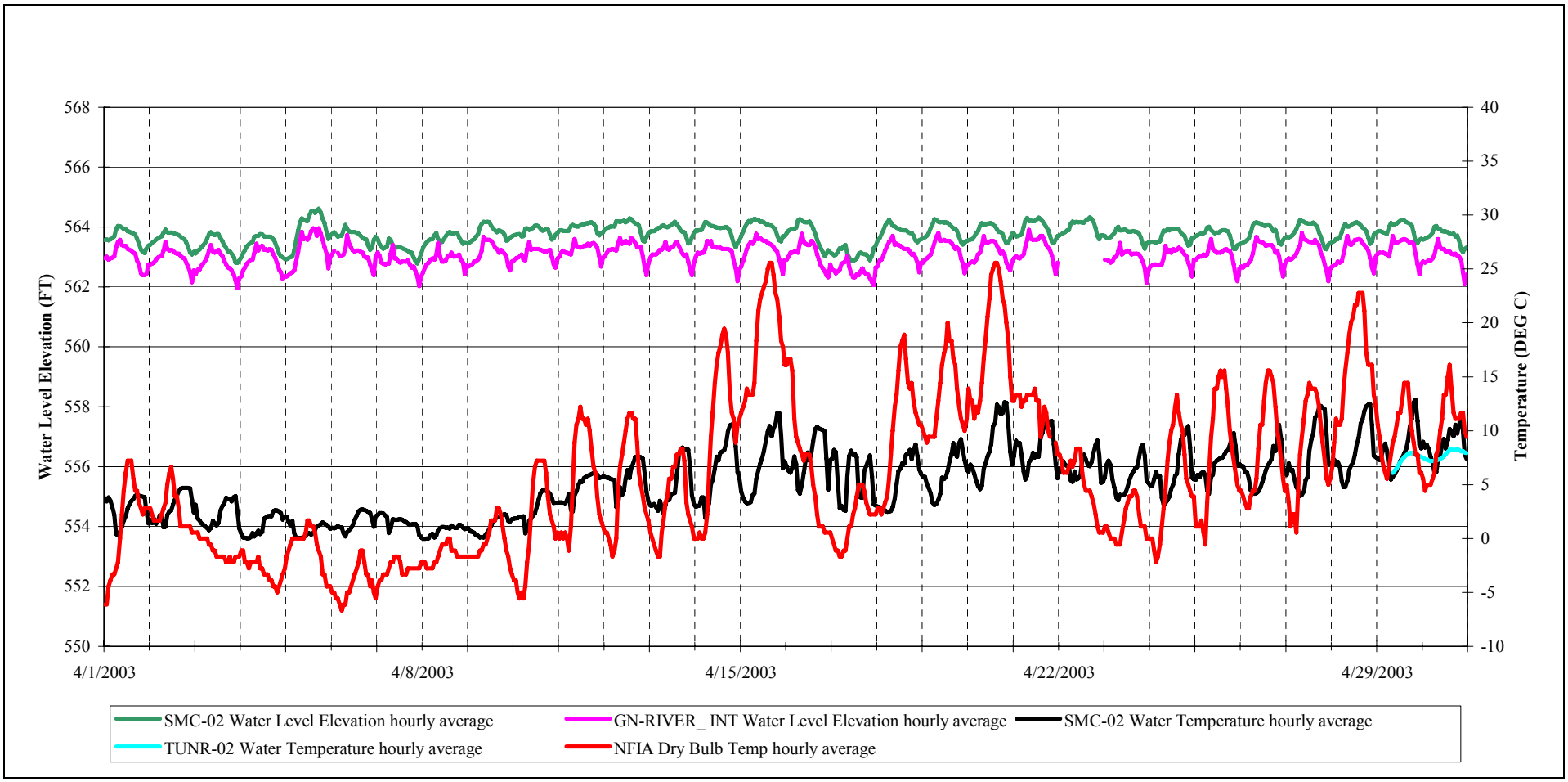

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FIGURE B-164: BIG SIXMILE CREEK (SMC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

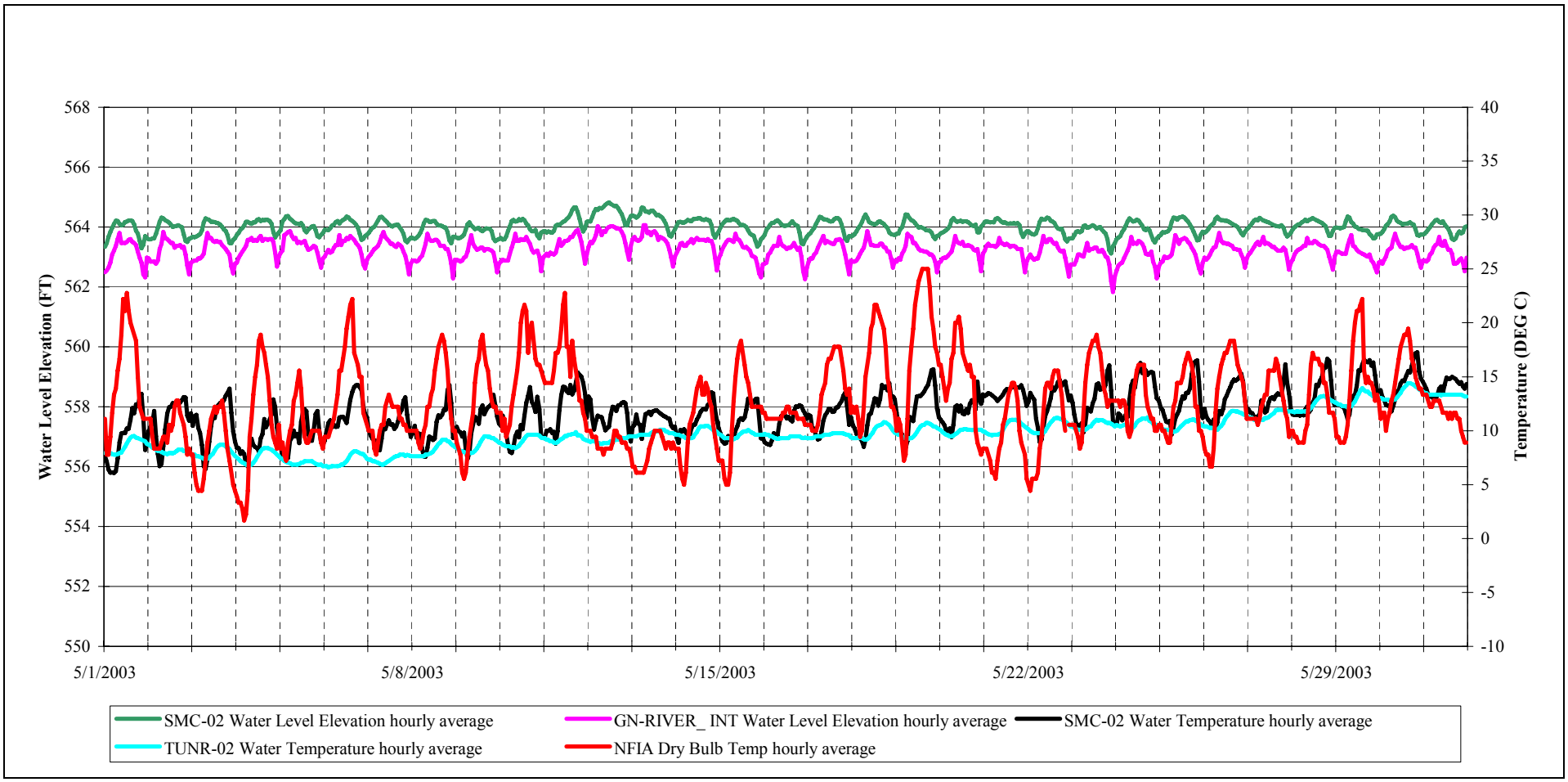

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FIGURE B-165: BIG SIXMILE CREEK (SMC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

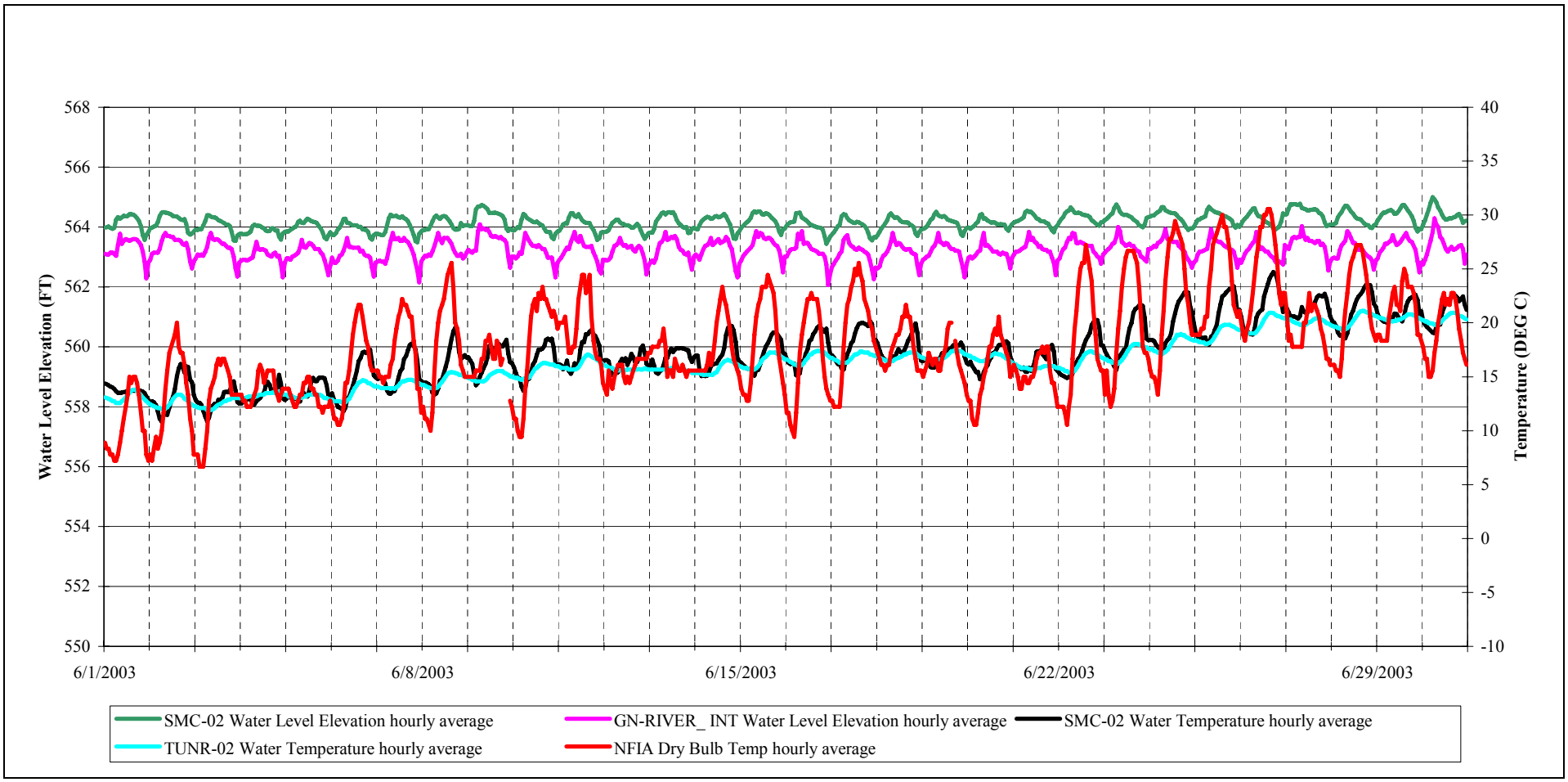

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FIGURE B-166: BIG SIXMILE CREEK (SMC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

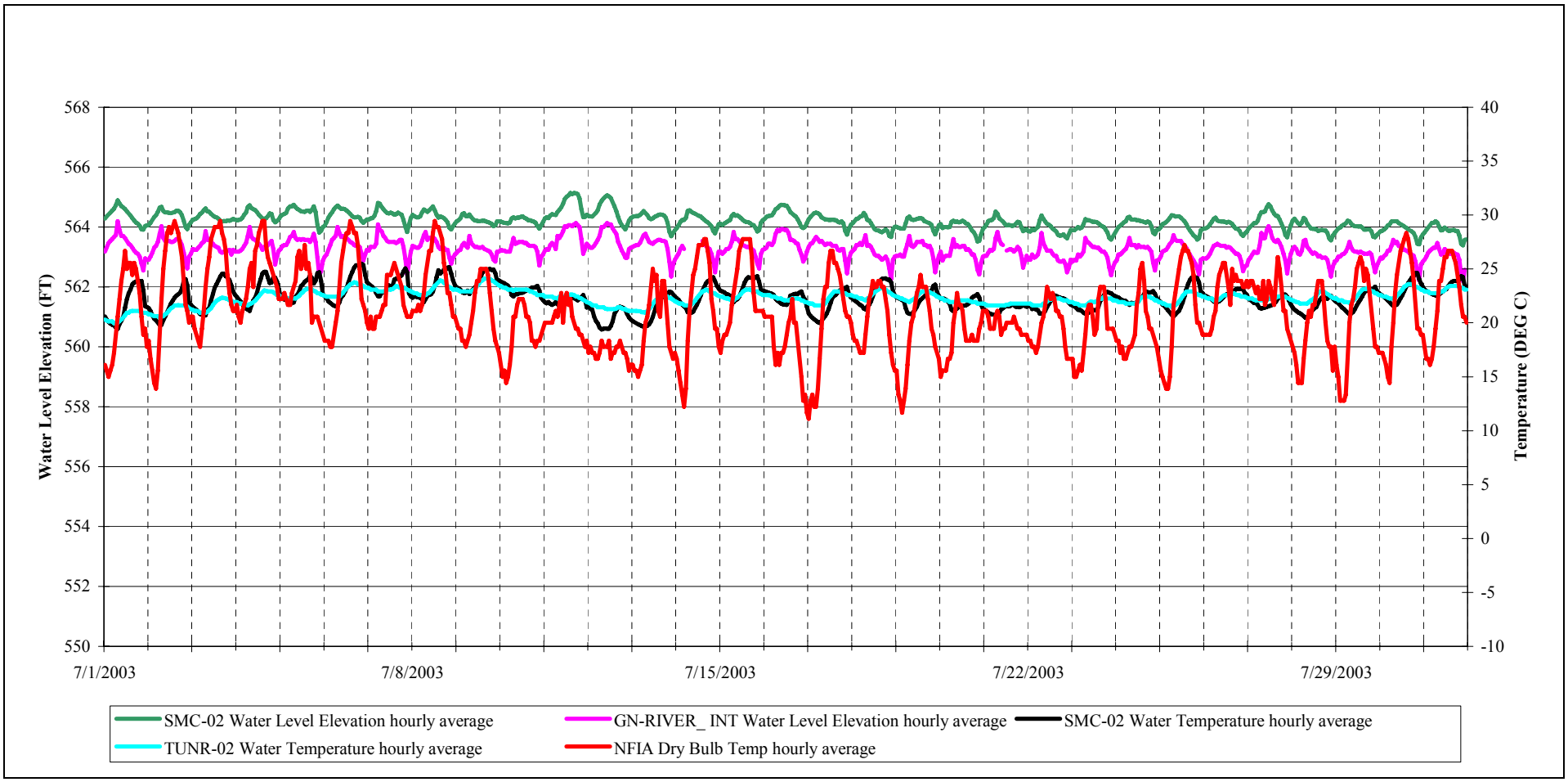

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FIGURE B-167: BIG SIXMILE CREEK (SMC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

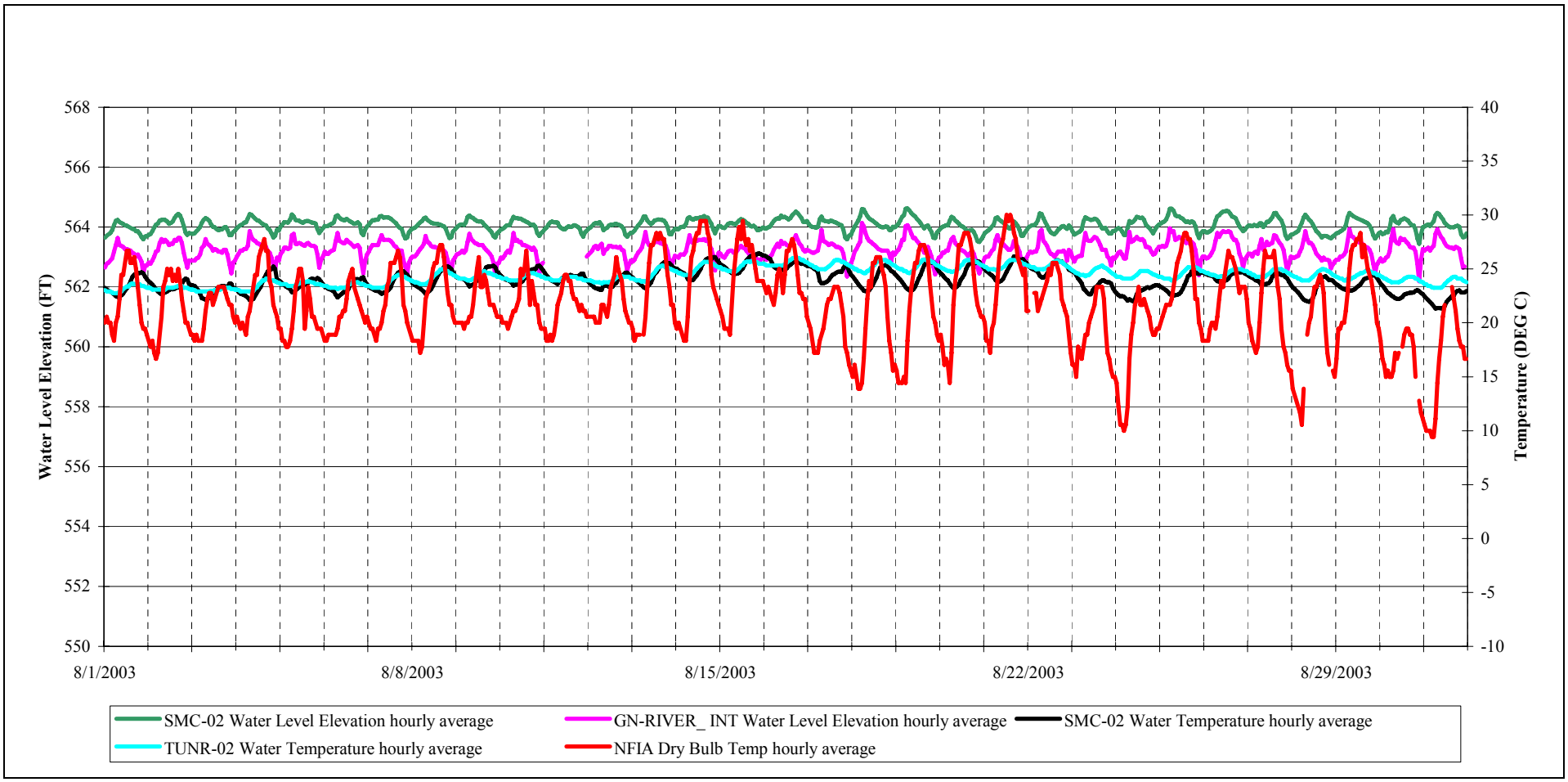

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FIGURE B-168: BIG SIXMILE CREEK (SMC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

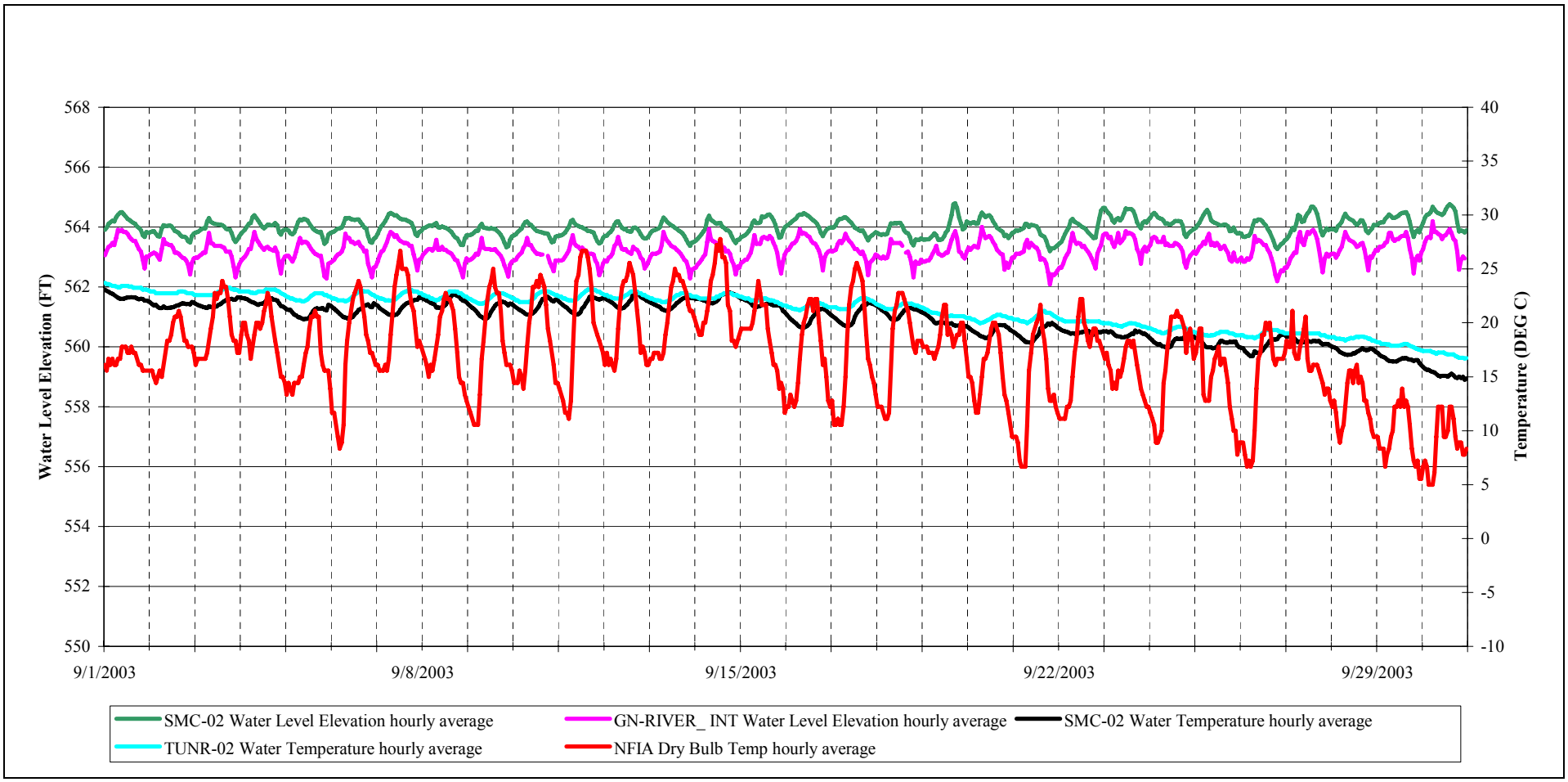

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FIGURE B-169: BIG SIXMILE CREEK (SMC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

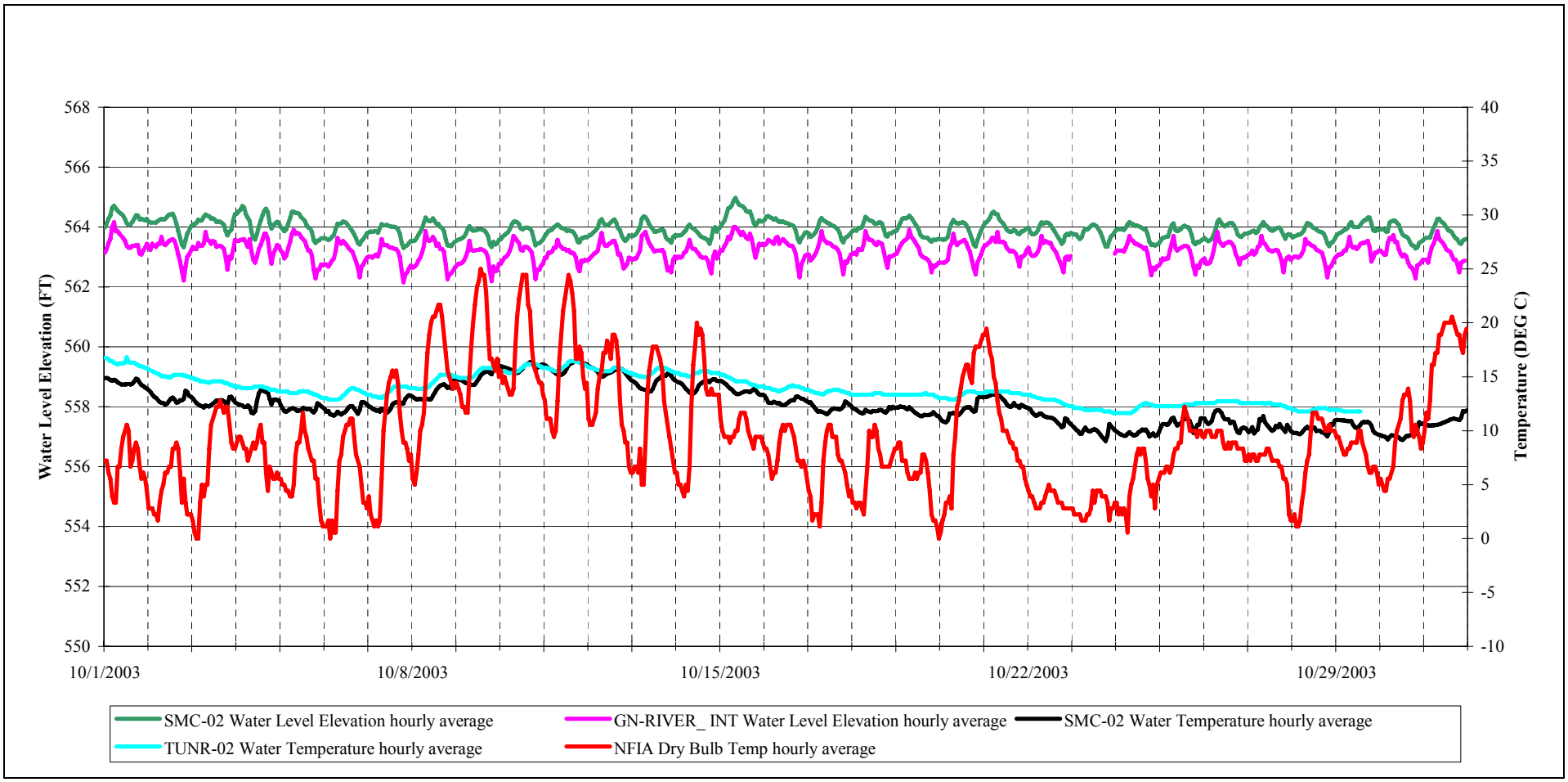

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FIGURE B-170: BIG SIXMILE CREEK (SMC-02)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

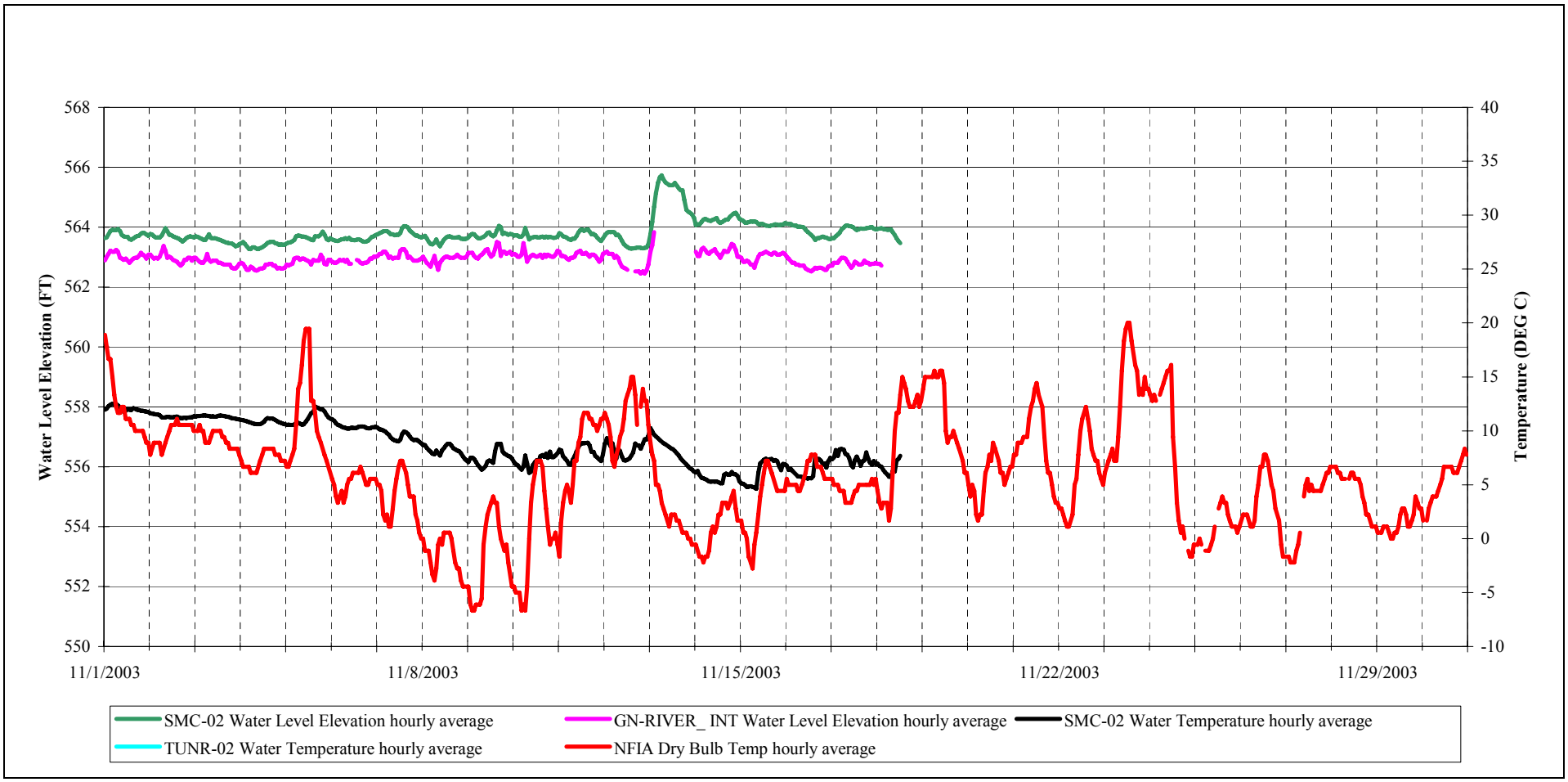

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FIGURE B-171: BIG SIXMILE CREEK (SMC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

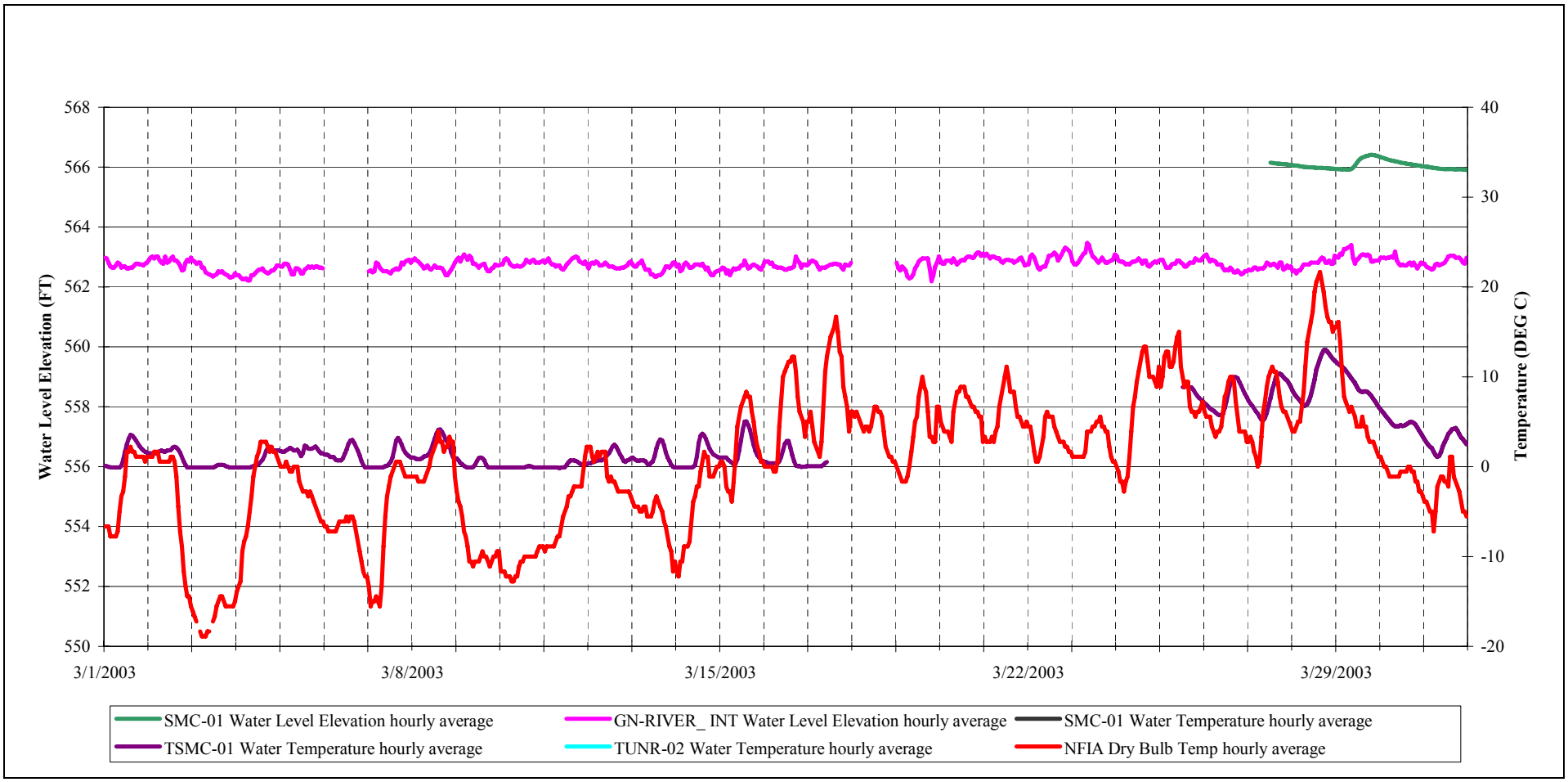

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FIGURE B-172: BIG SIXMILE CREEK (SMC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

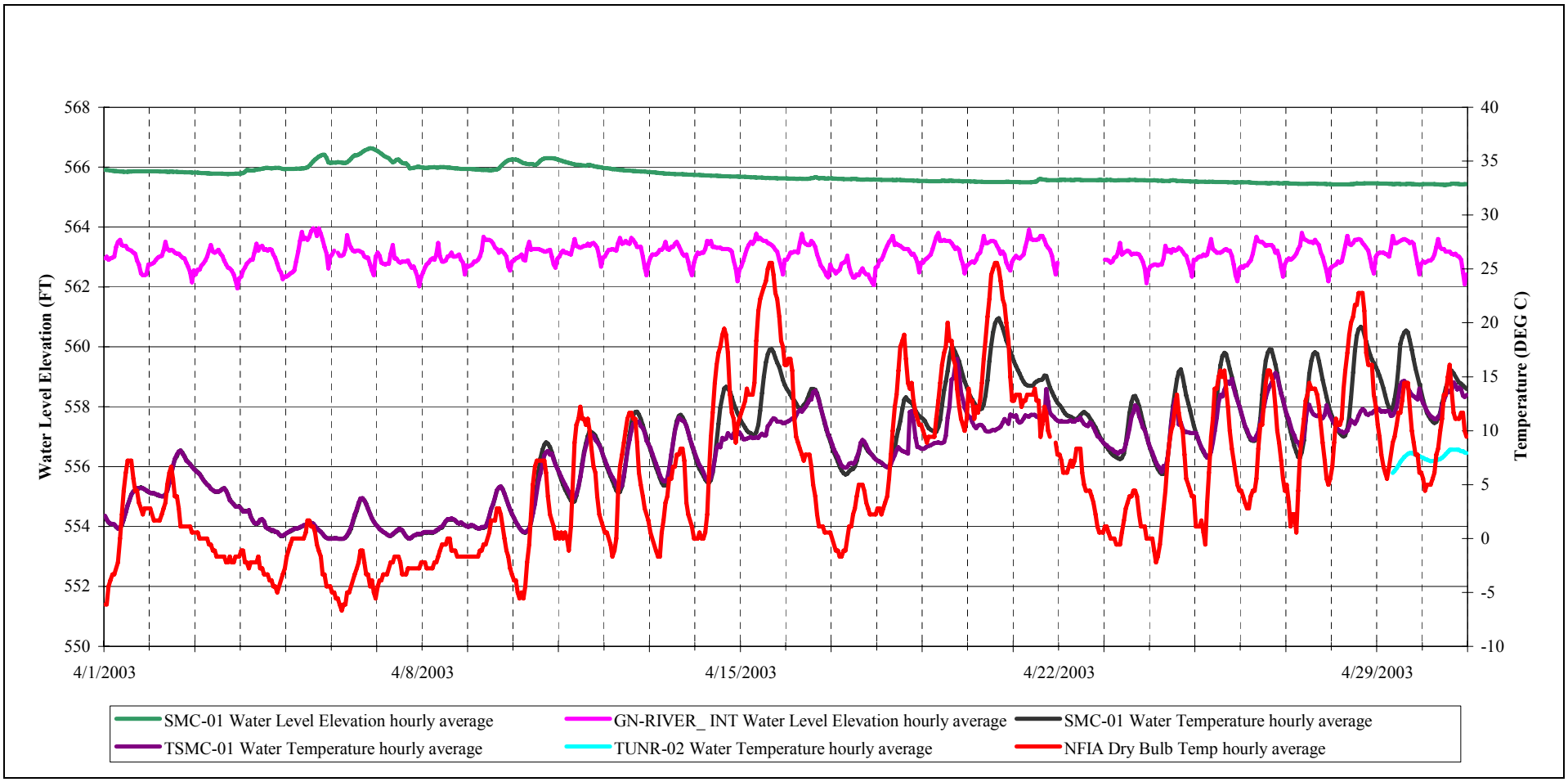

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FIGURE B-173: BIG SIXMILE CREEK (SMC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

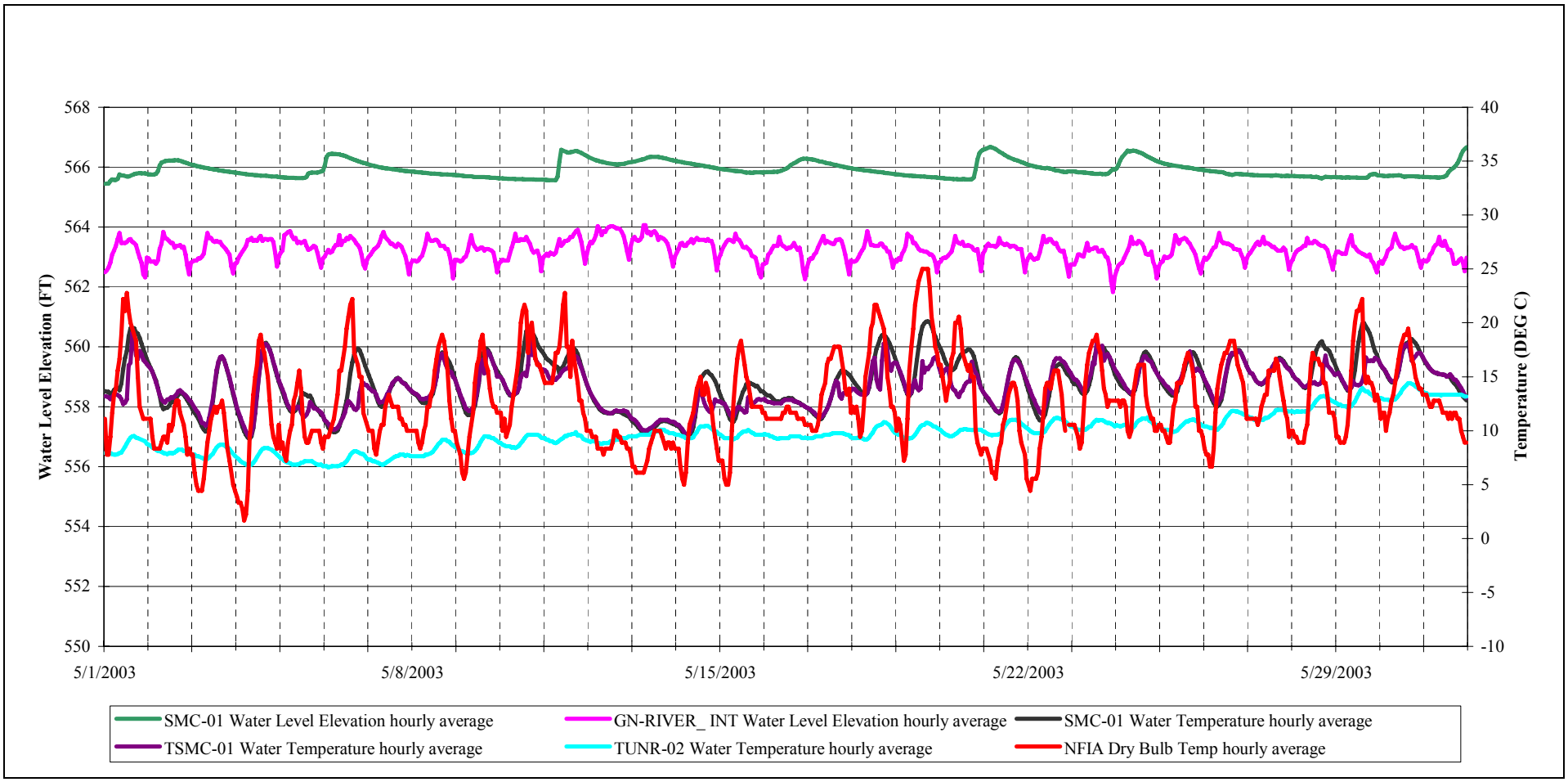

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FIGURE B-174: BIG SIXMILE CREEK (SMC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

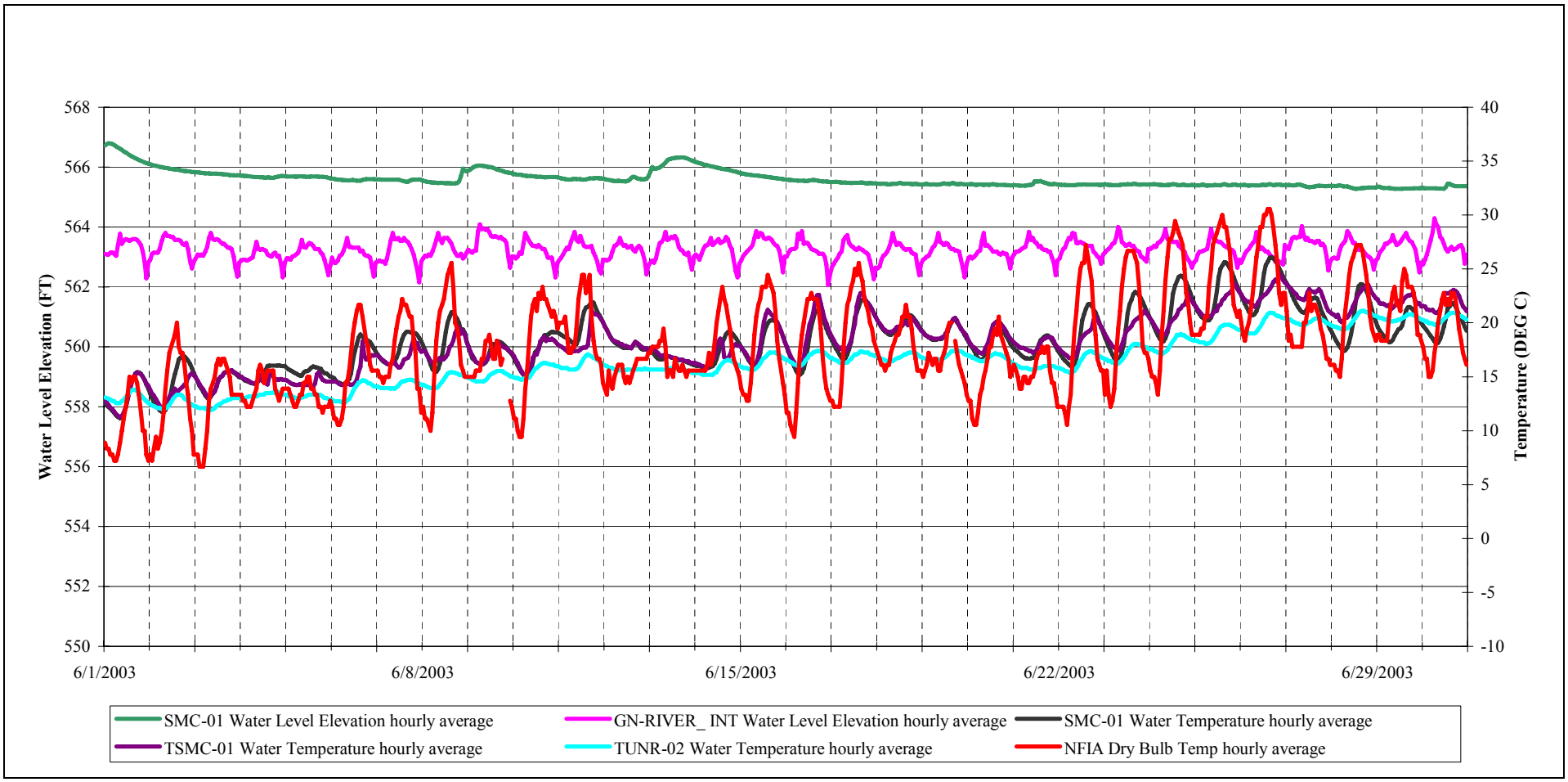

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FIGURE B-175: BIG SIXMILE CREEK (SMC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

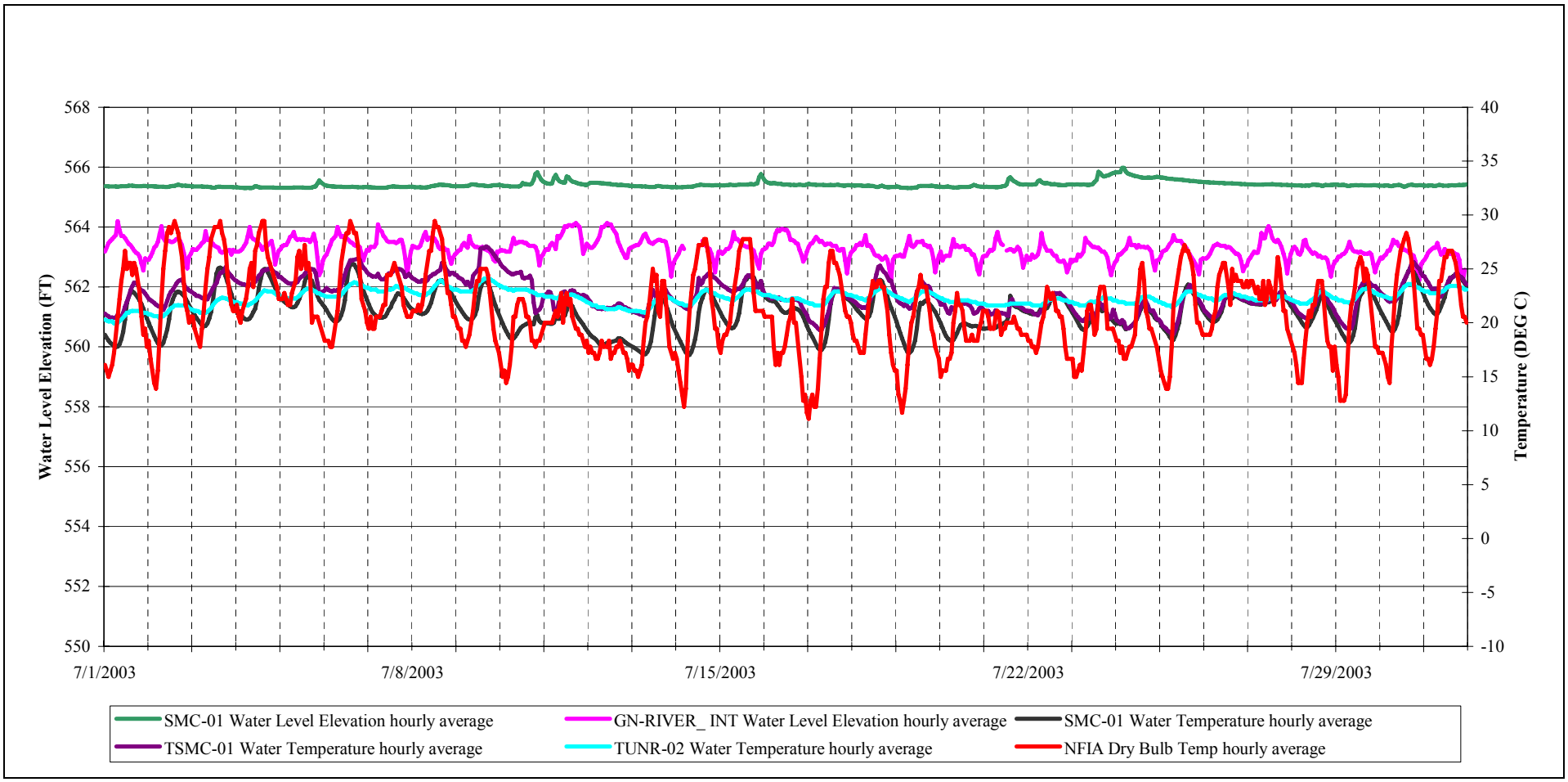

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FIGURE B-176: BIG SIXMILE CREEK (SMC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

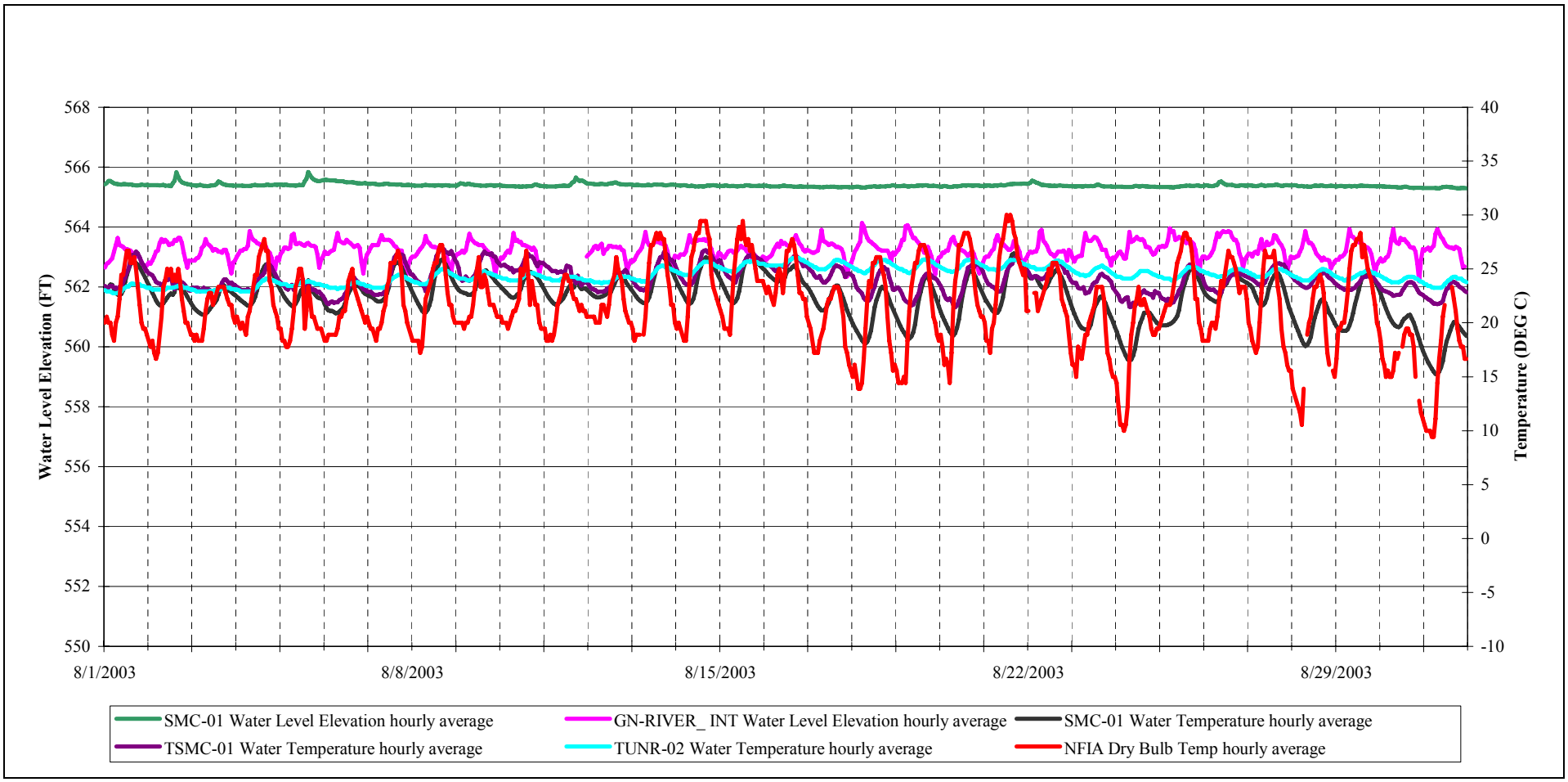

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FIGURE B-177: BIG SIXMILE CREEK (SMC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

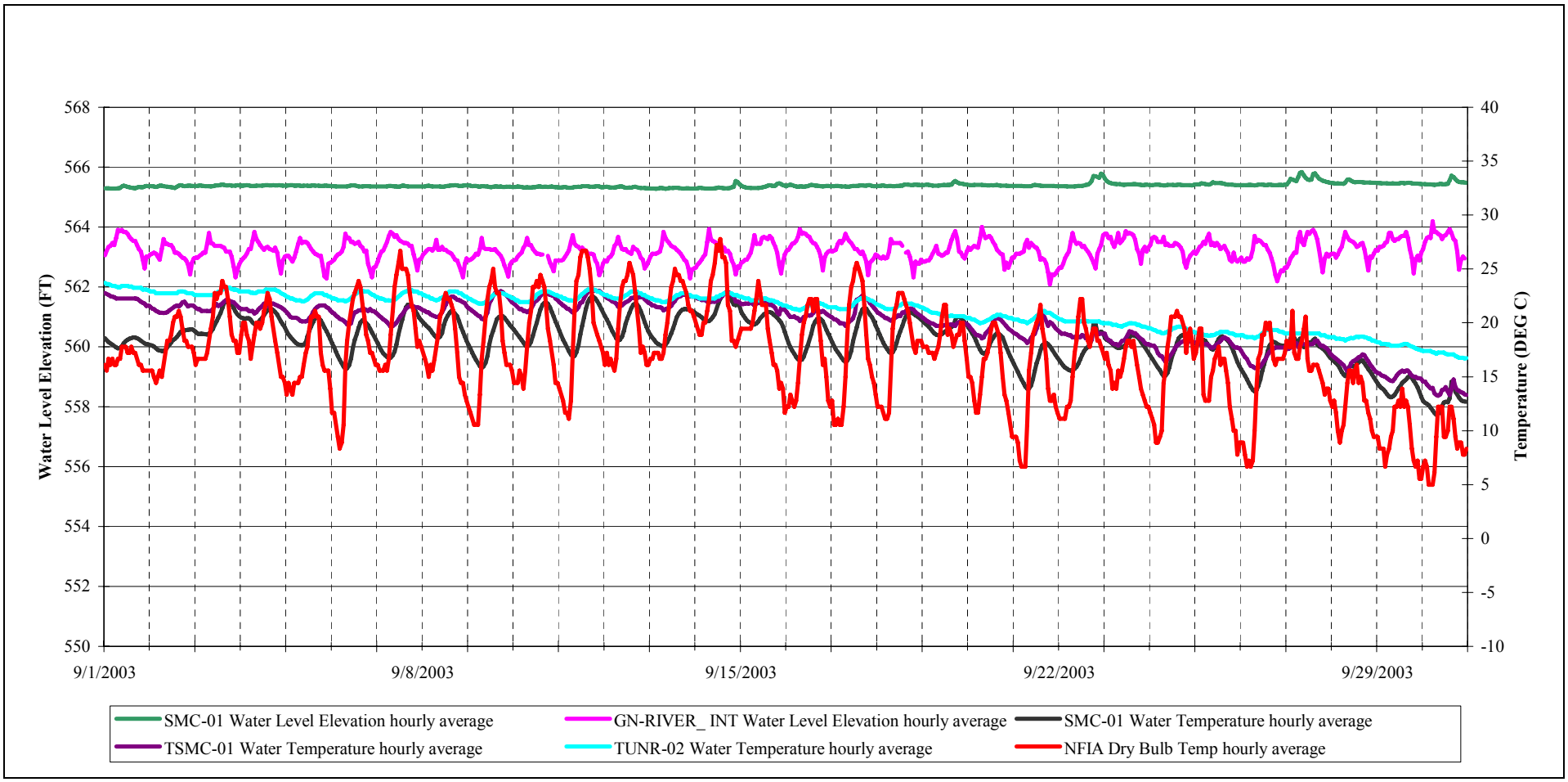

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FIGURE B-178: BIG SIXMILE CREEK (SMC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

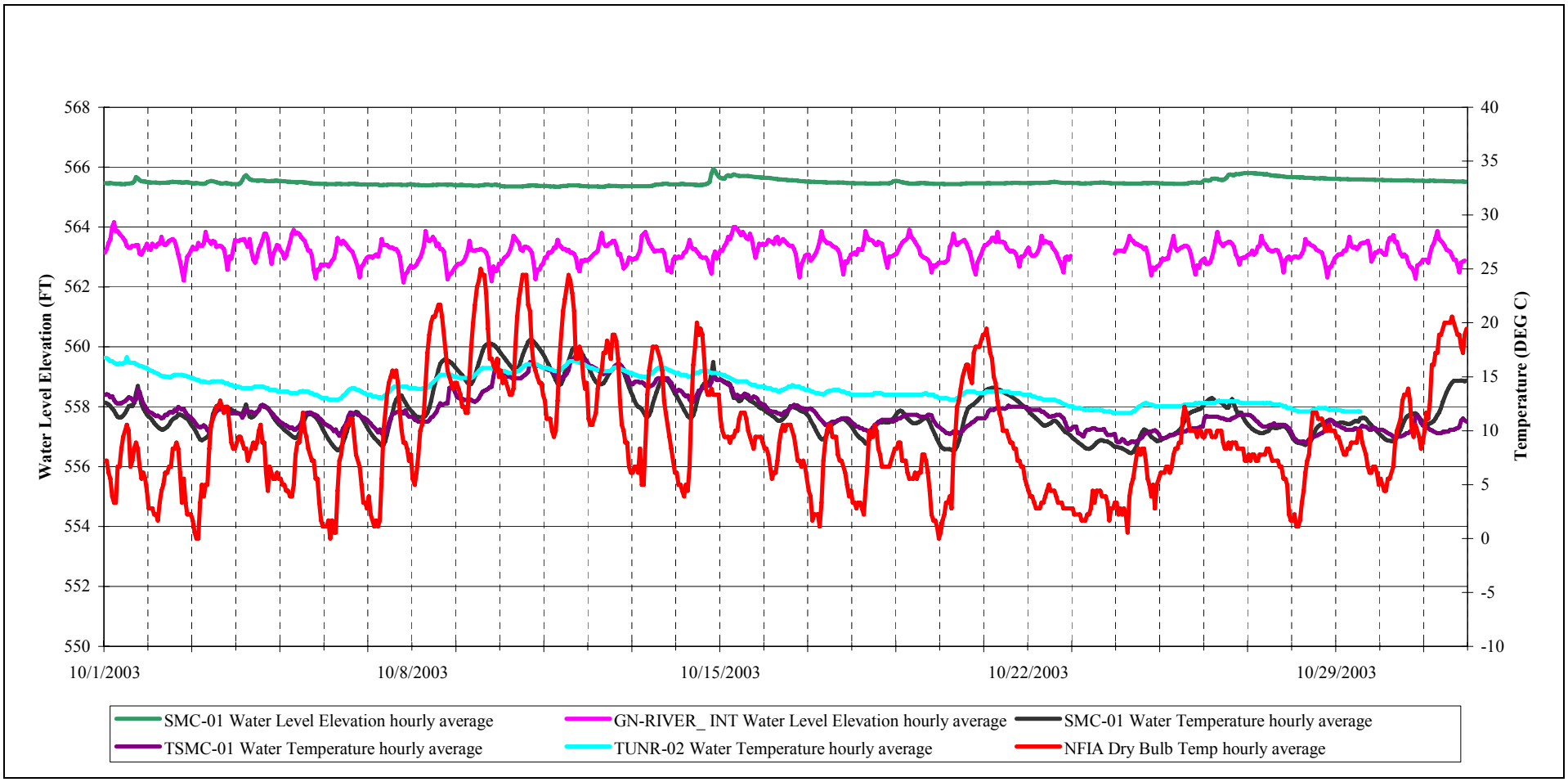

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FIGURE B-179: BIG SIXMILE CREEK (SMC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

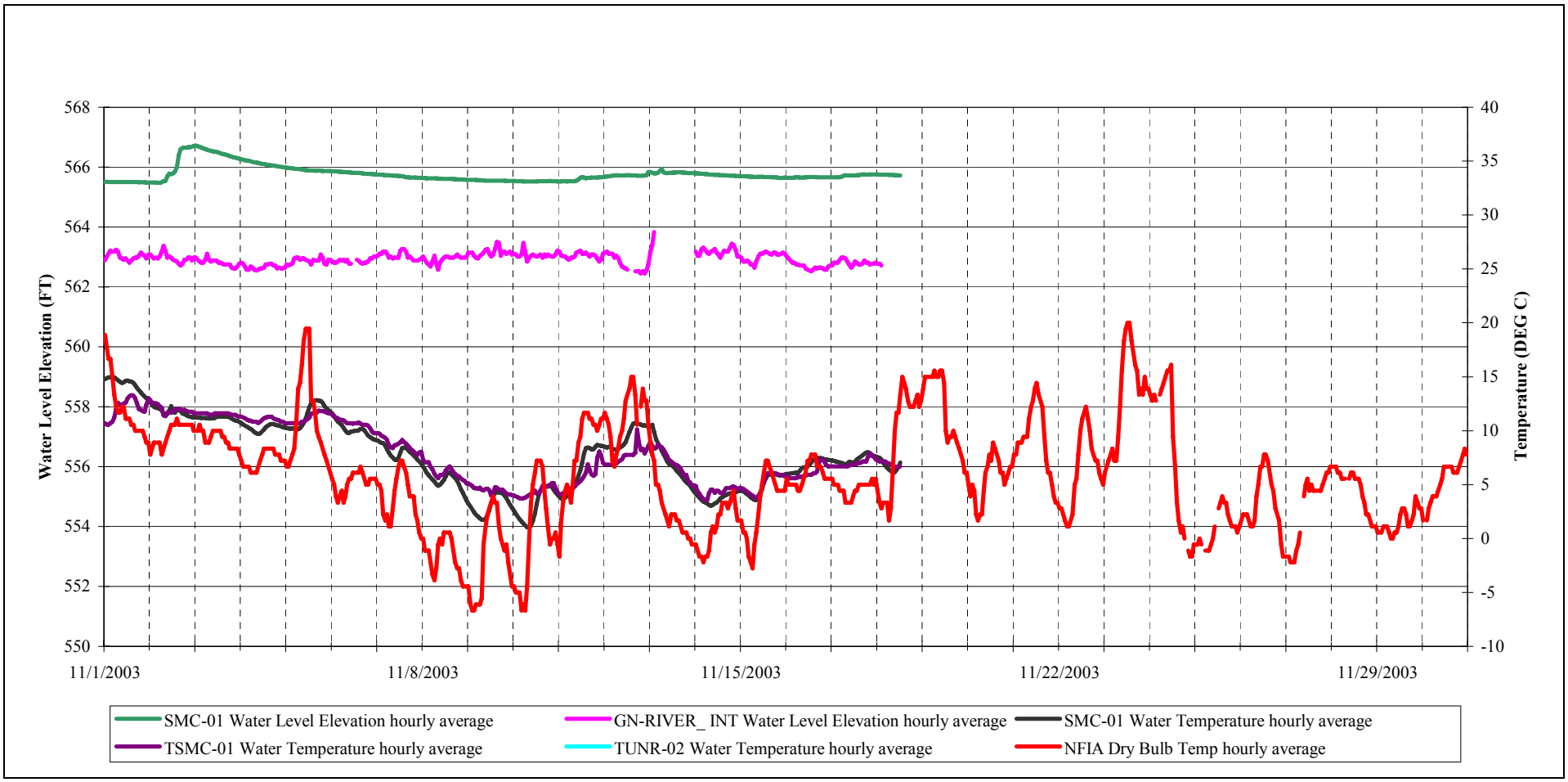

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FIGURE B-180: CAYUGA CREEK (CC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

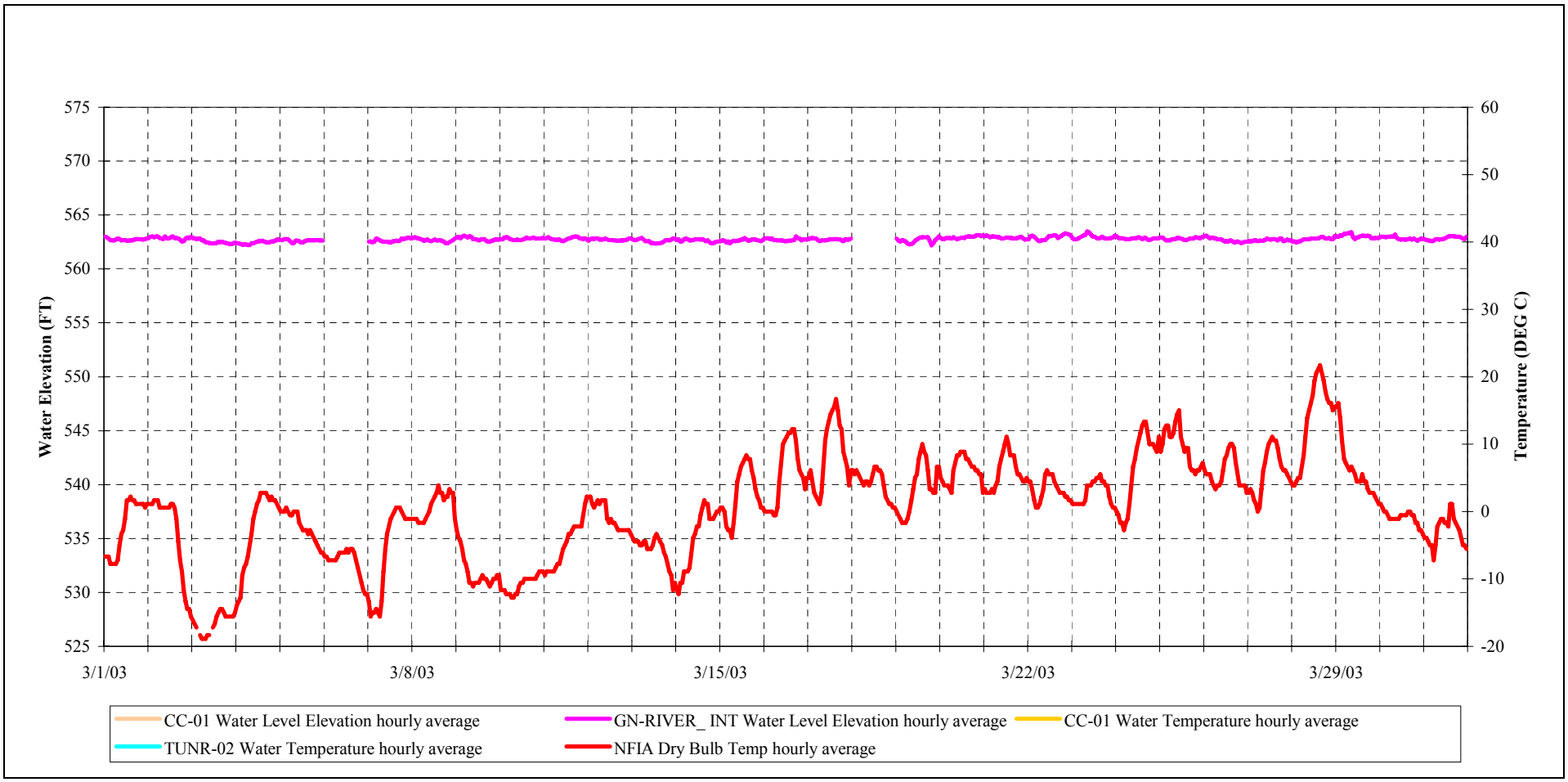

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FIGURE B-181: CAYUGA CREEK (CC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

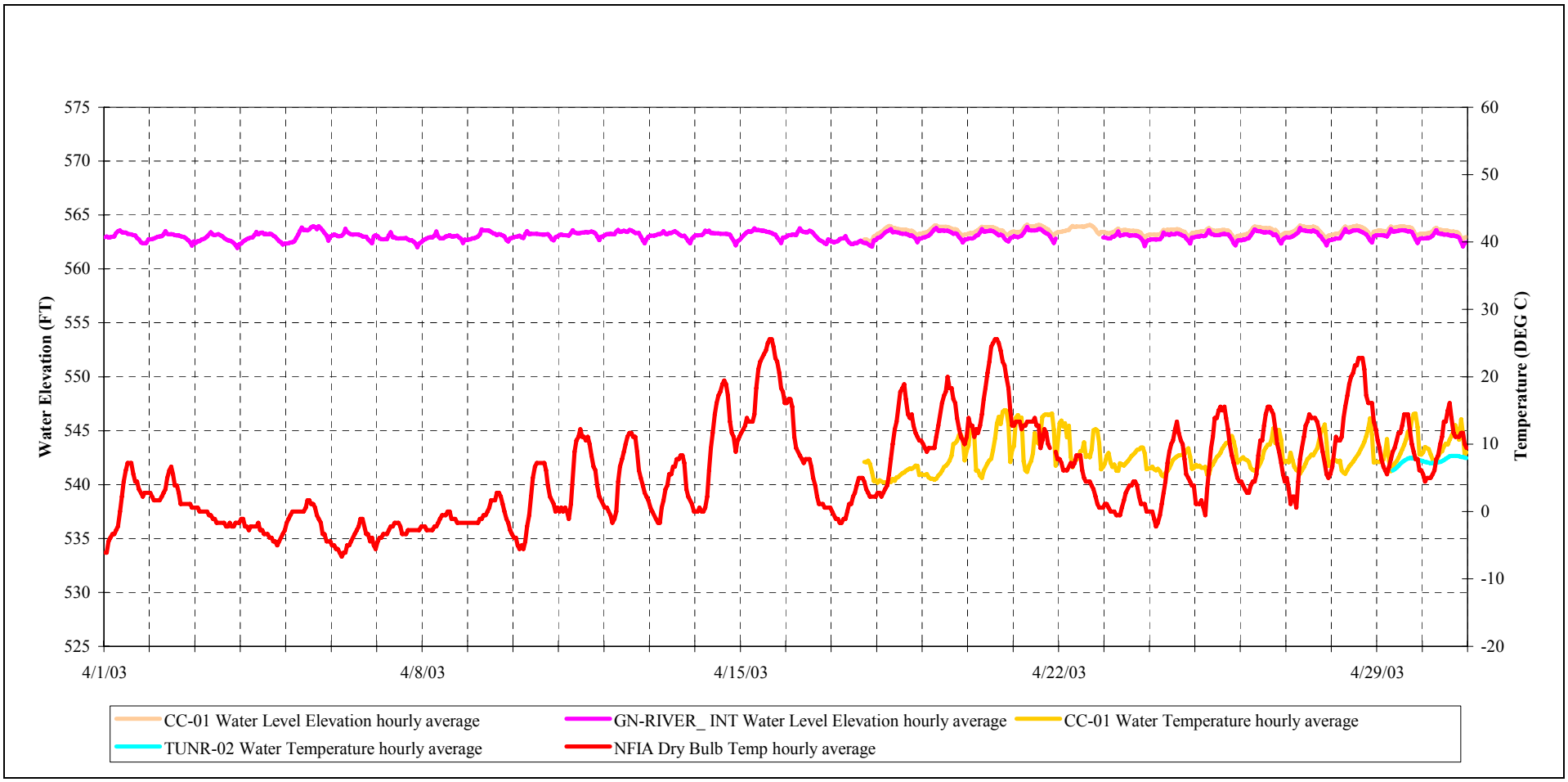

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FIGURE B-182: CAYUGA CREEK (CC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

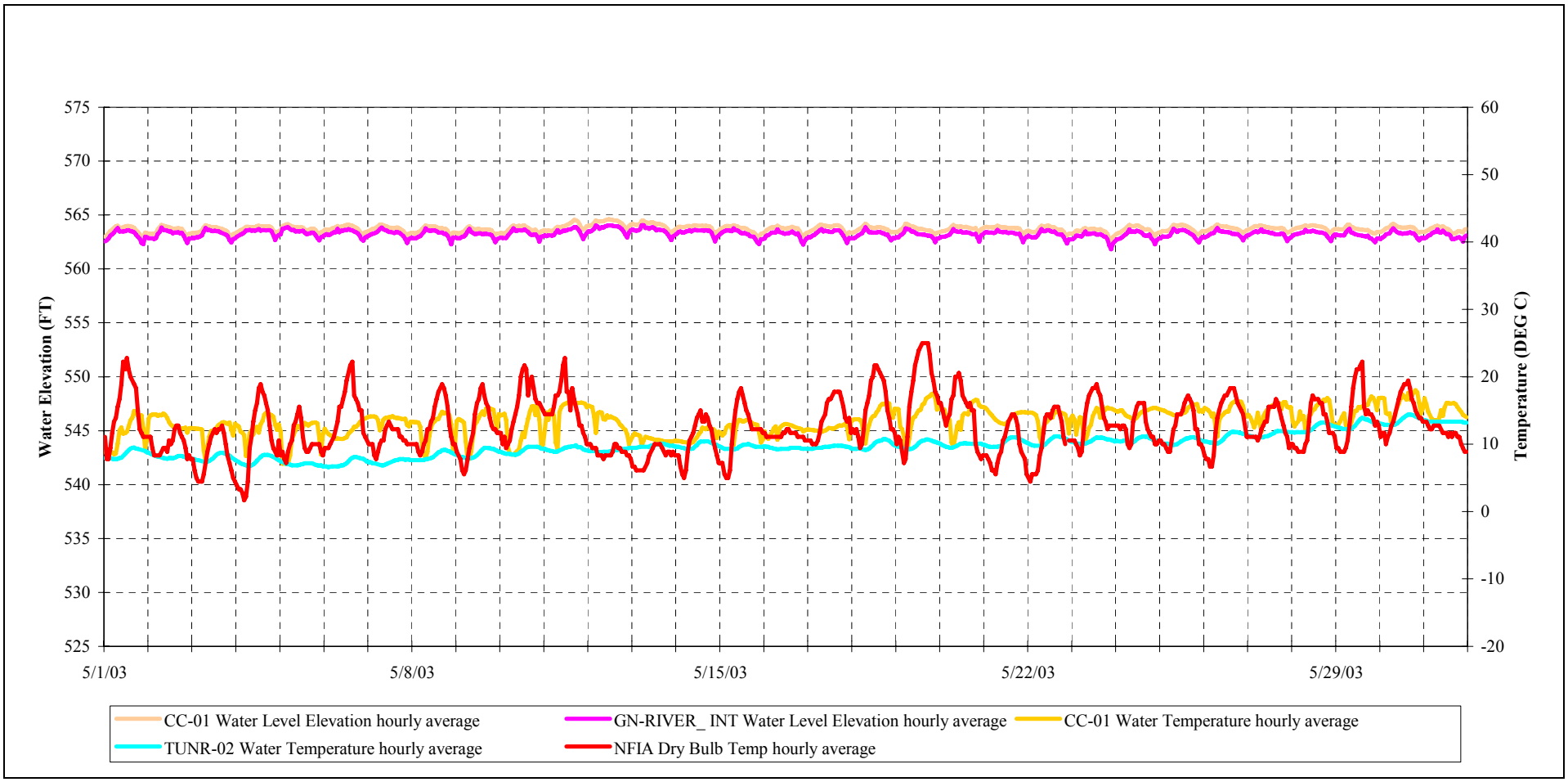

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FIGURE B-183: CAYUGA CREEK (CC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

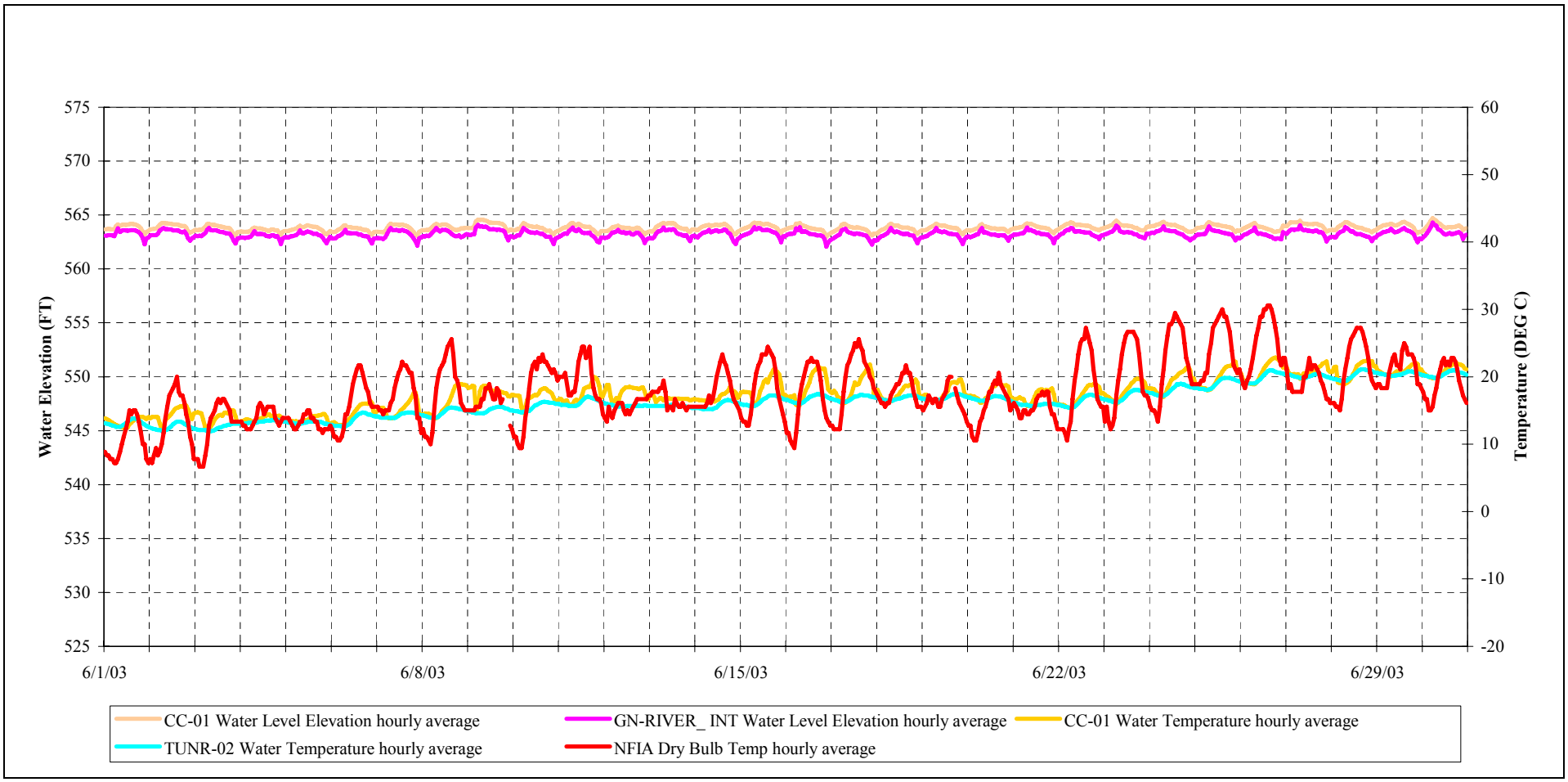

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FIGURE B-184: CAYUGA CREEK (CC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

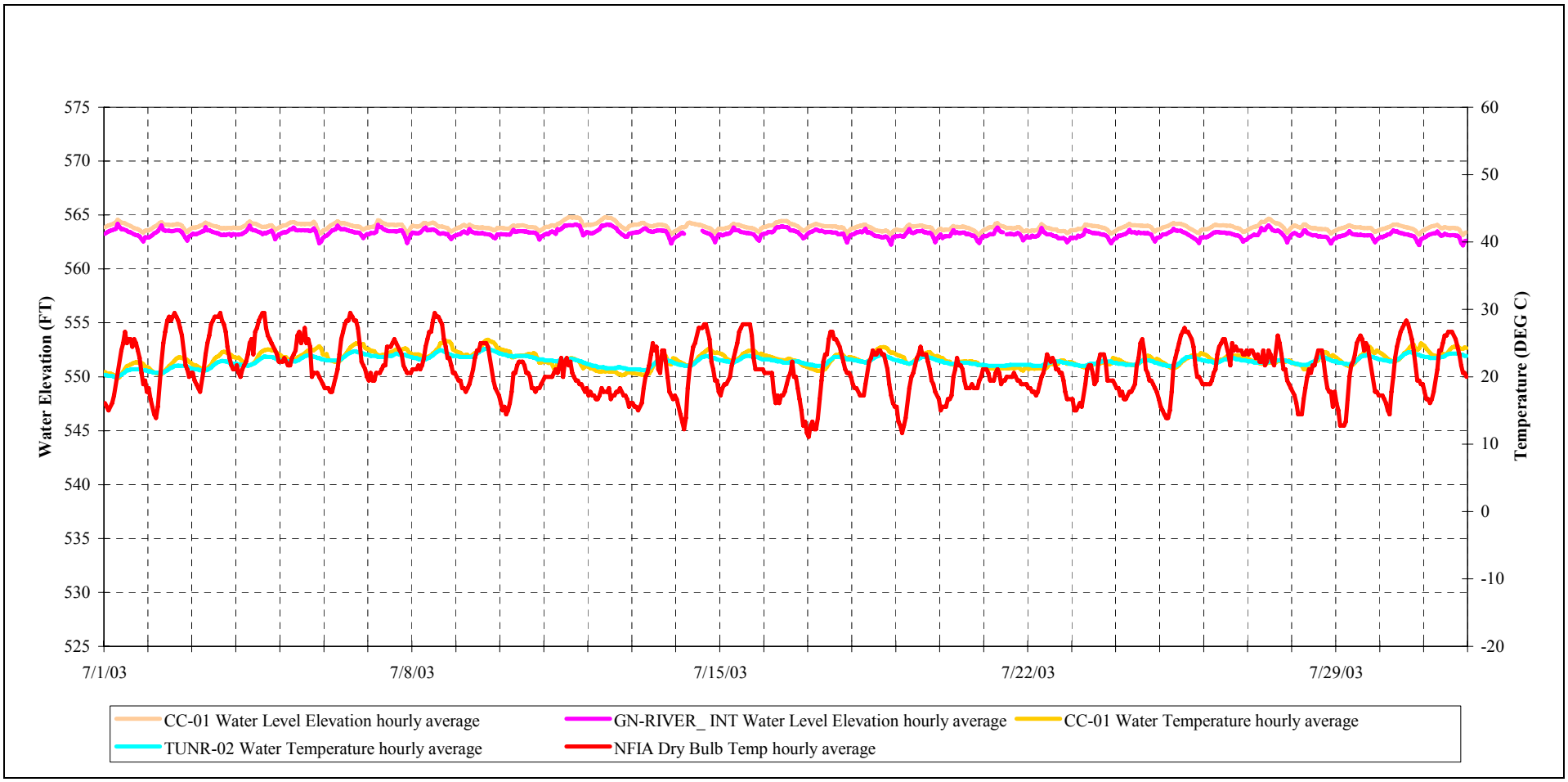

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FIGURE B-185: CAYUGA CREEK (CC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

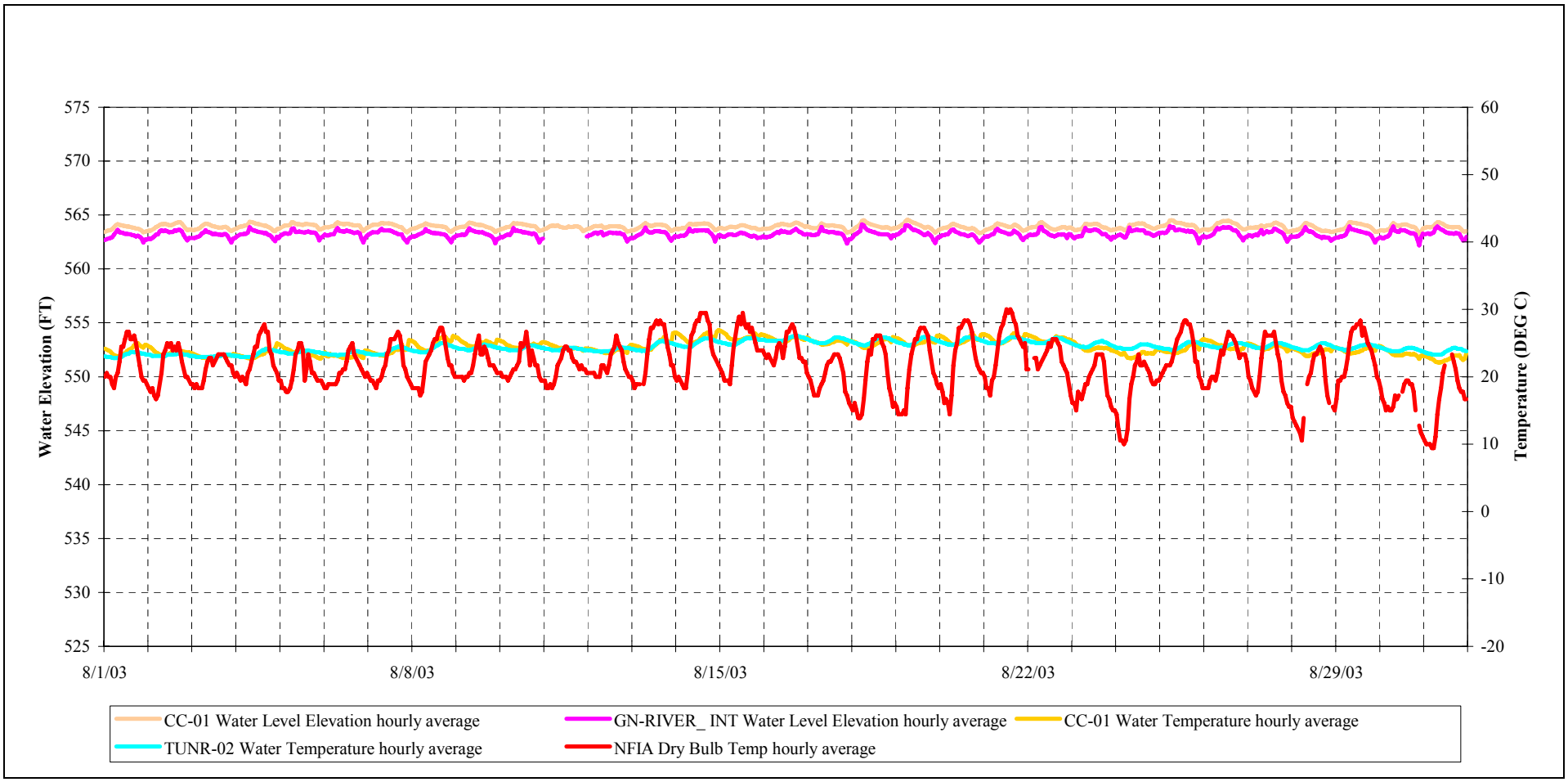

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FIGURE B-186: CAYUGA CREEK (CC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

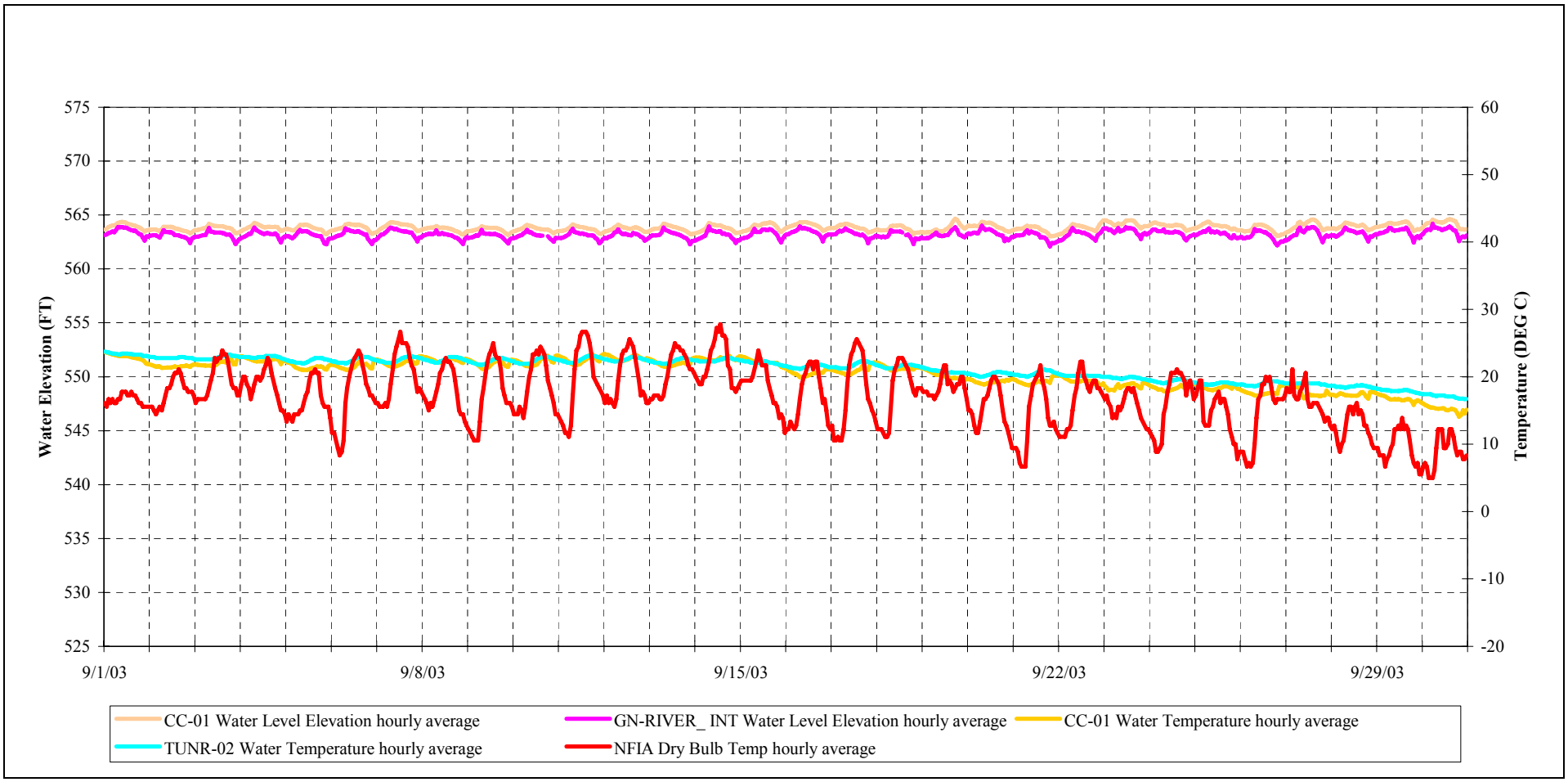

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FIGURE B-187: CAYUGA CREEK (CC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

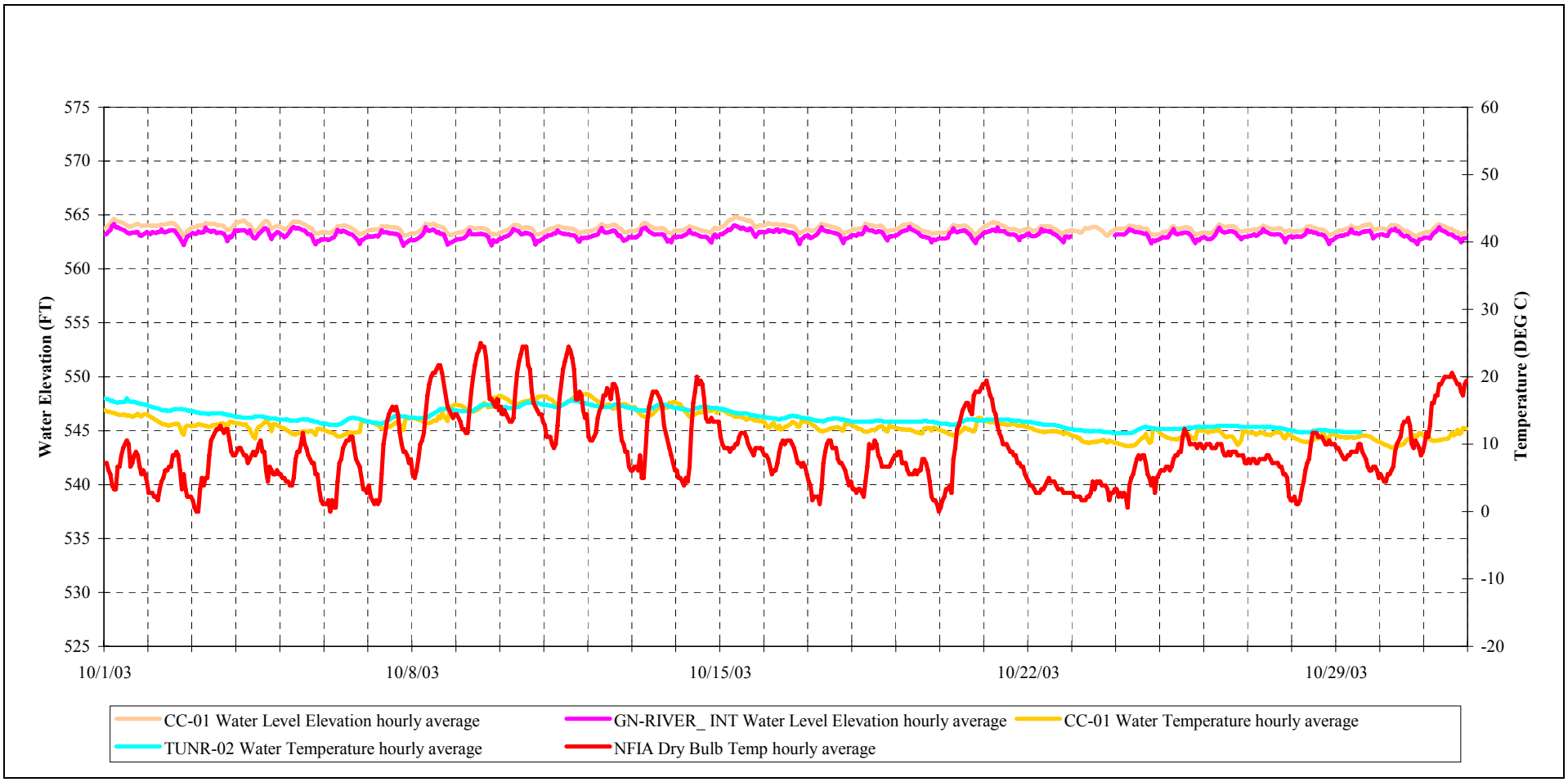

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FIGURE B-188: CAYUGA CREEK (CC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

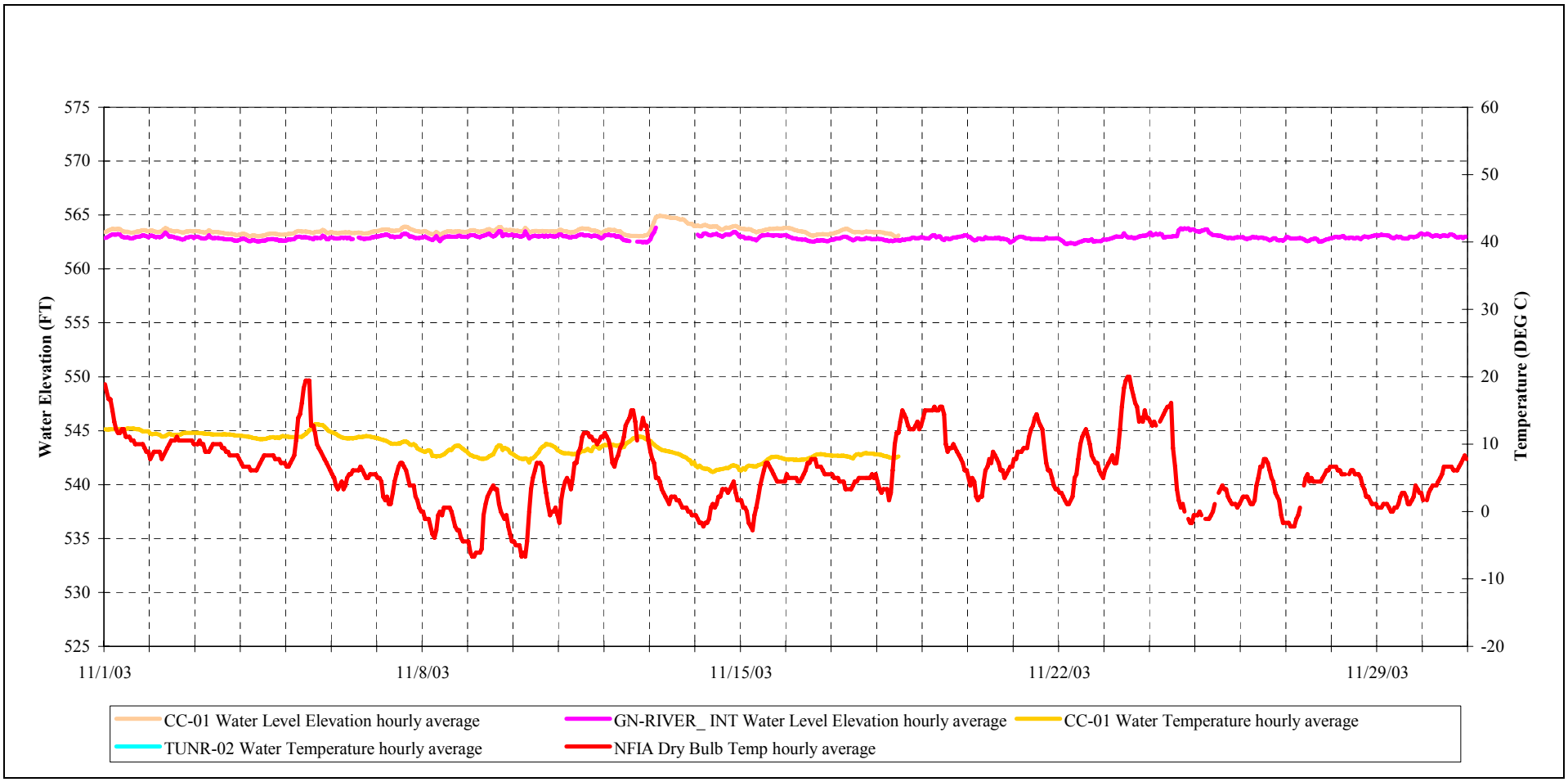

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FIGURE B-189: CAYUGA CREEK (CC-02 AND CC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

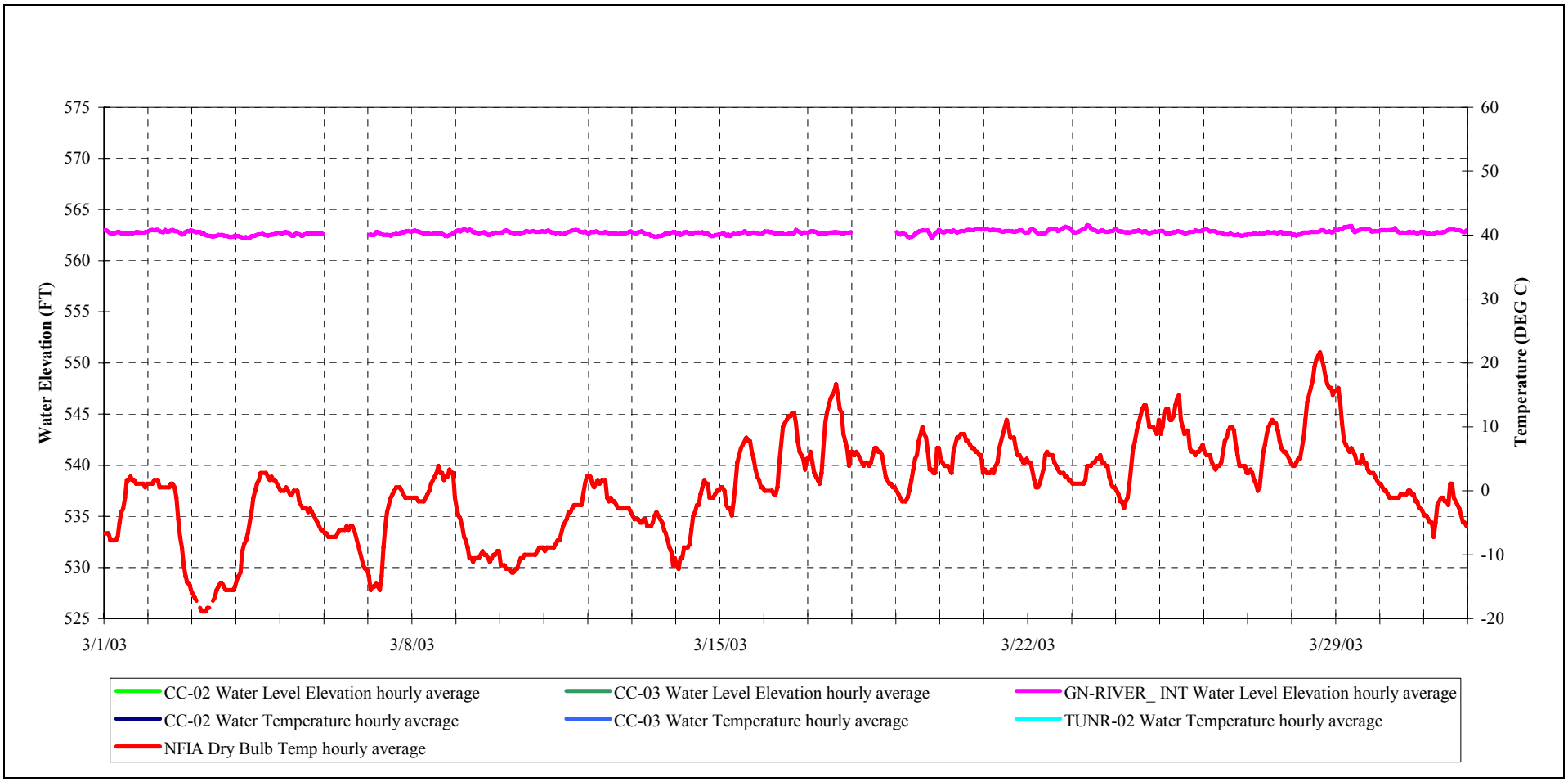

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FIGURE B-190: CAYUGA CREEK (CC-02 AND CC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

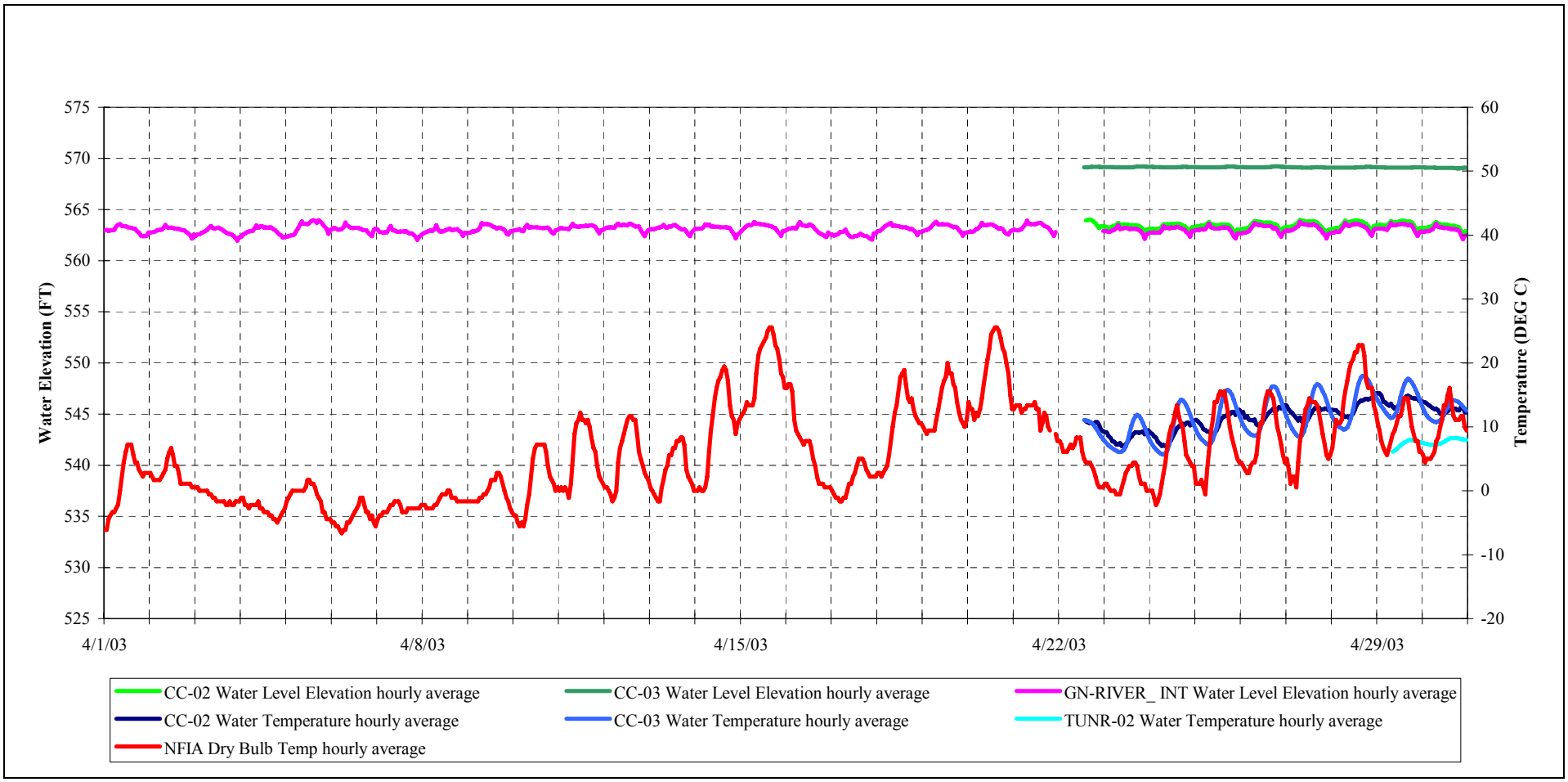

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FIGURE B-191: CAYUGA CREEK (CC-02 AND CC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

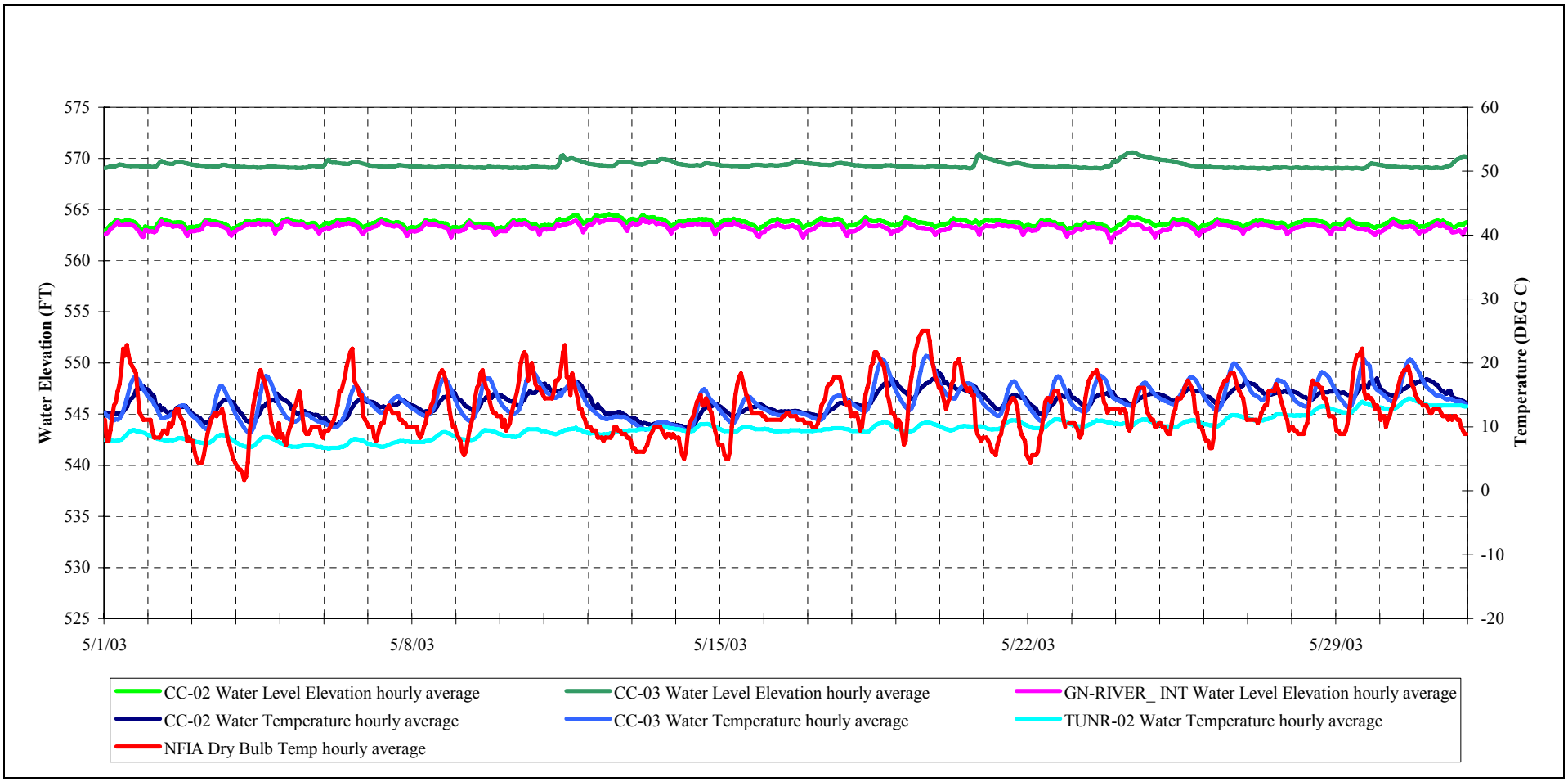

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FIGURE B-192: CAYUGA CREEK (CC-02 AND CC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

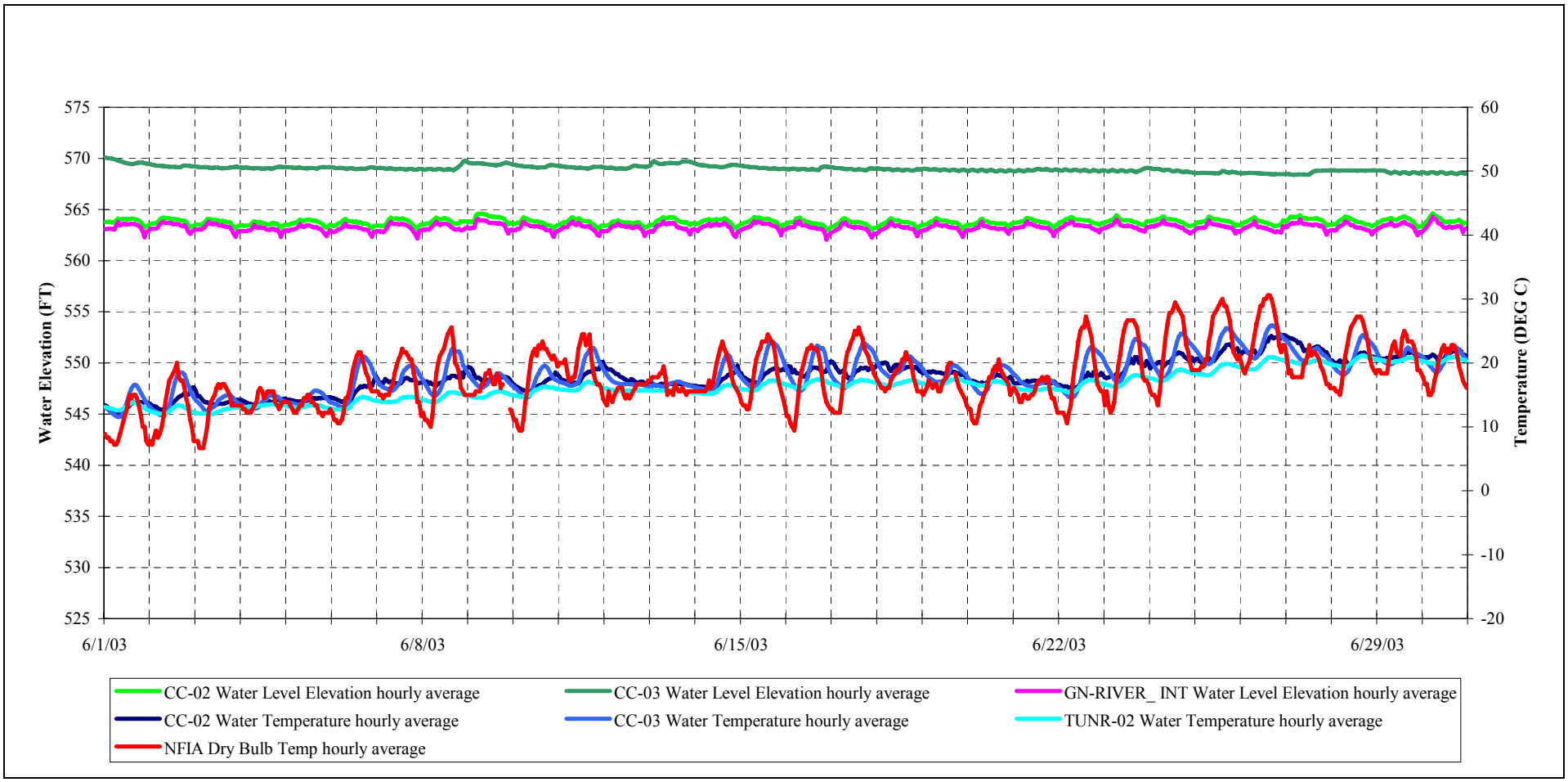

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FIGURE B-193: CAYUGA CREEK (CC-02 AND CC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

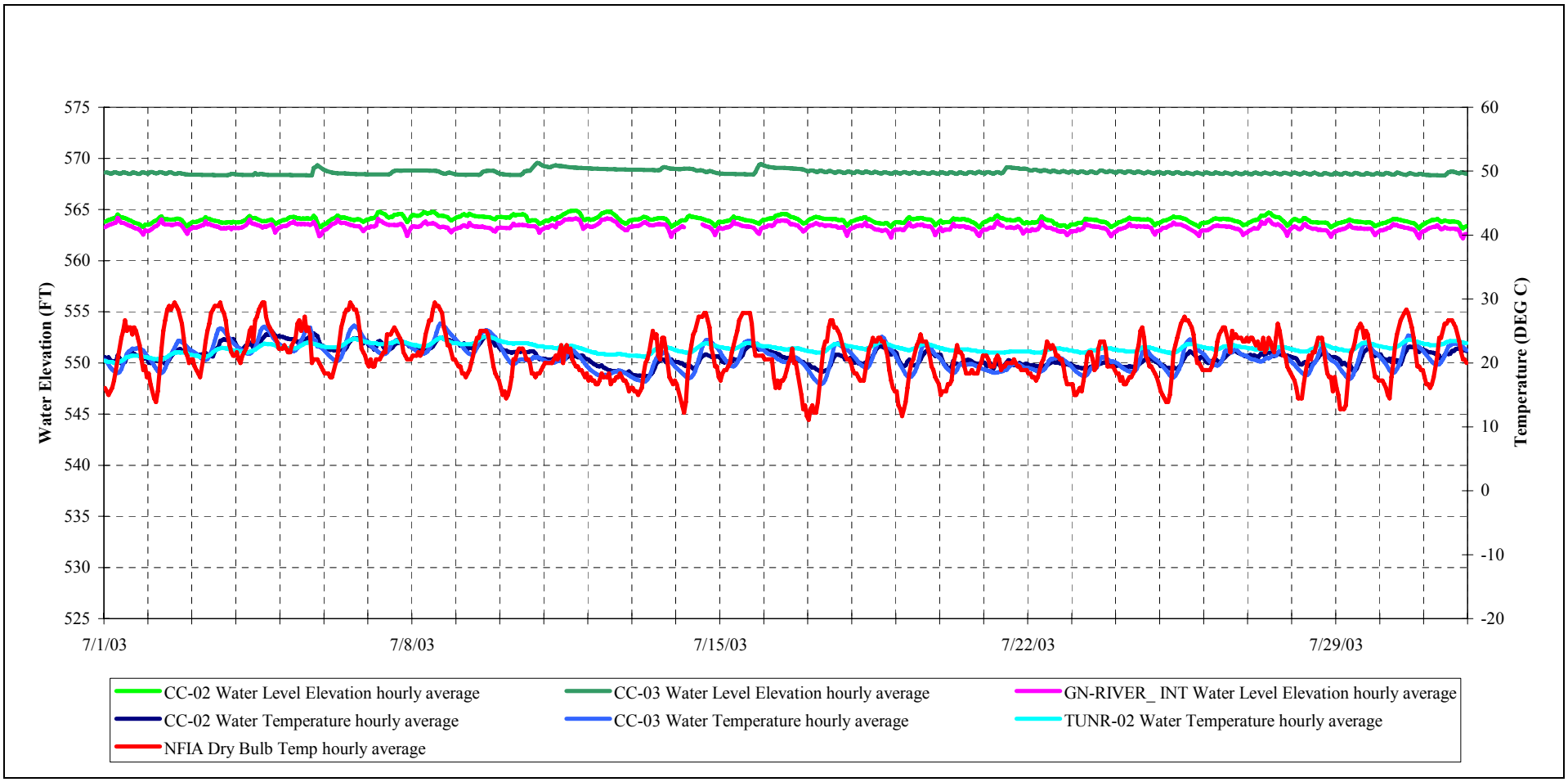

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FIGURE B-194: CAYUGA CREEK (CC-02 AND CC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

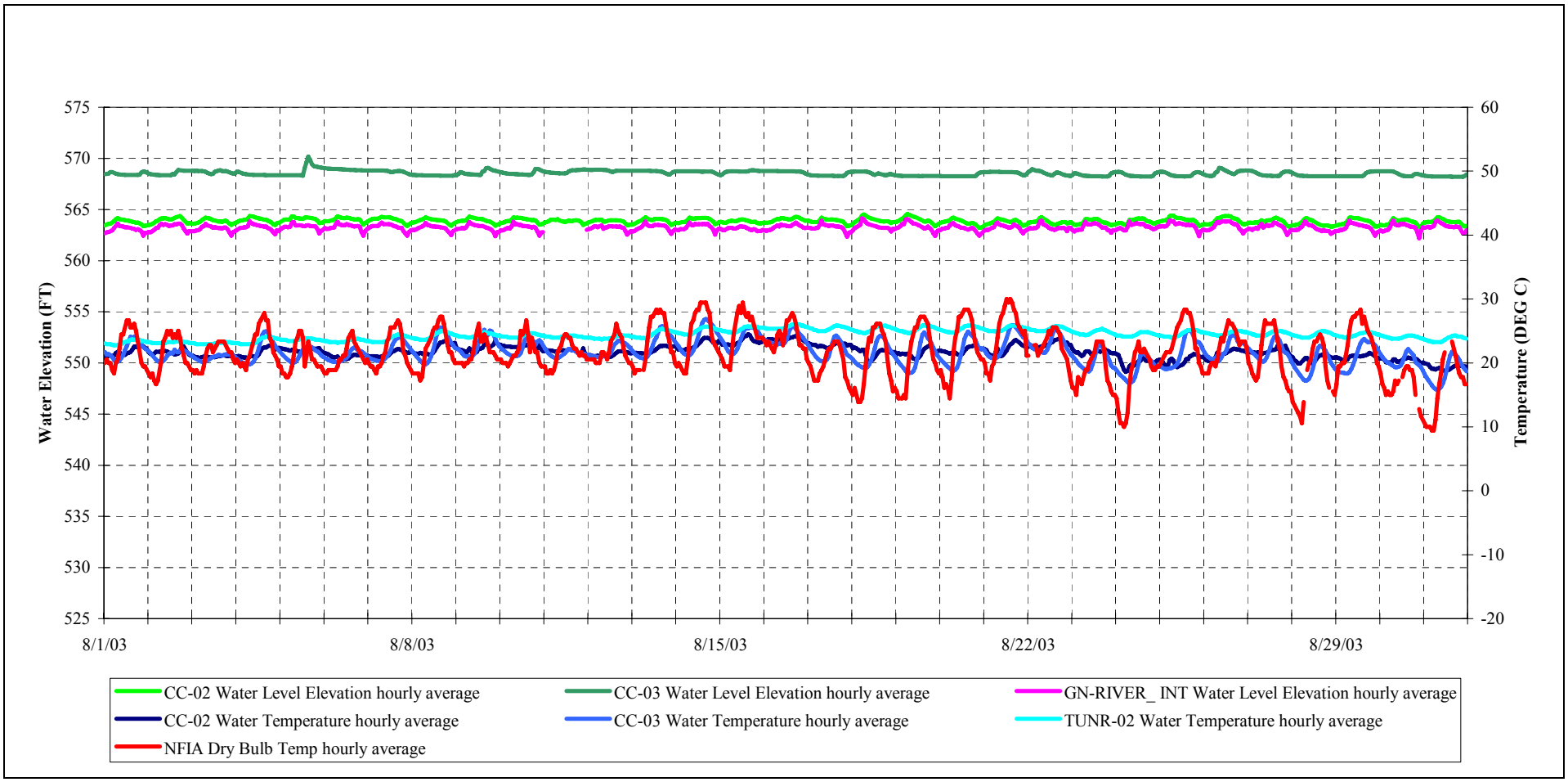

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FIGURE B-195: CAYUGA CREEK (CC-02 AND CC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

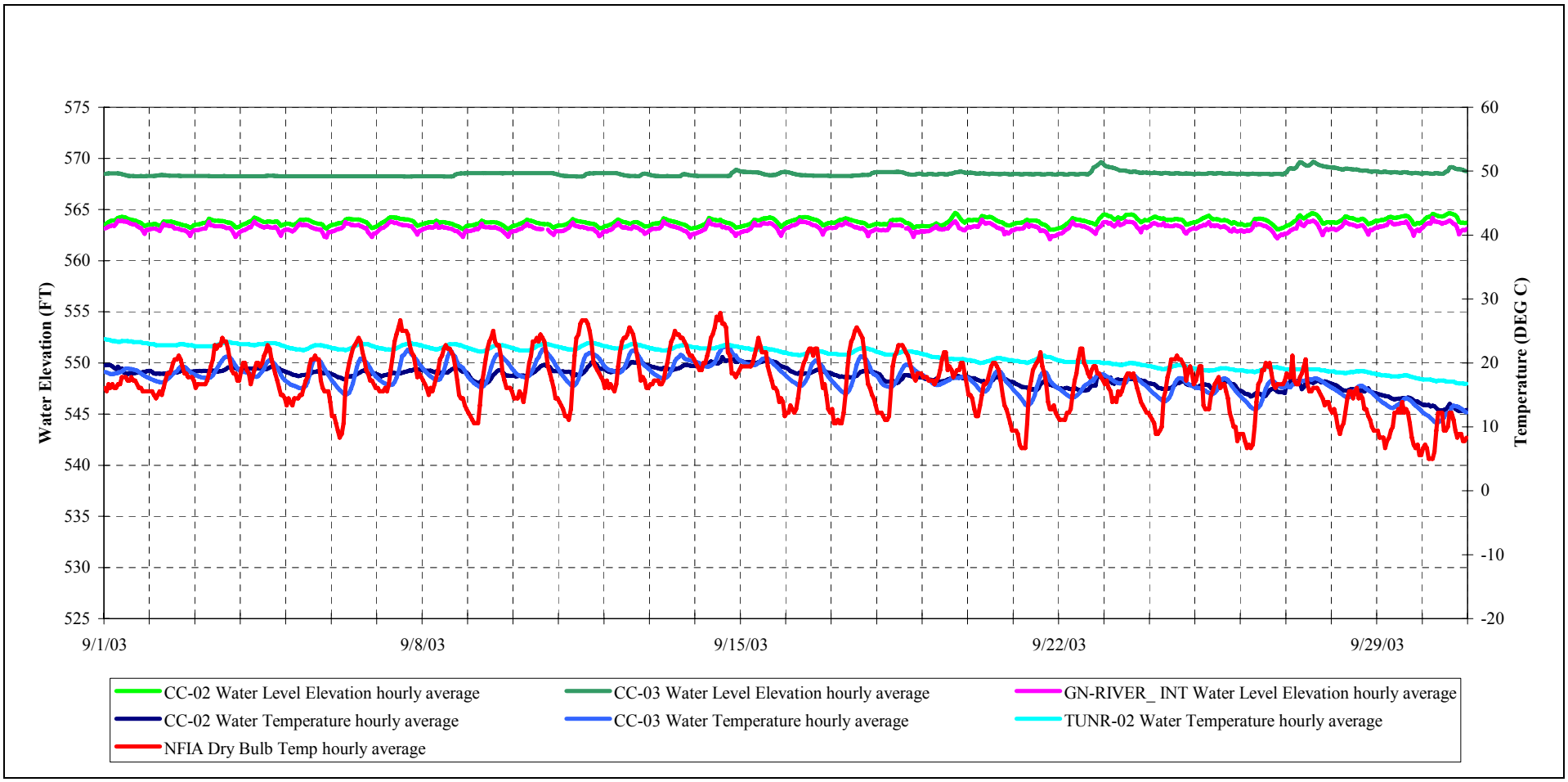

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FIGURE B-196: CAYUGA CREEK (CC-02 AND CC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

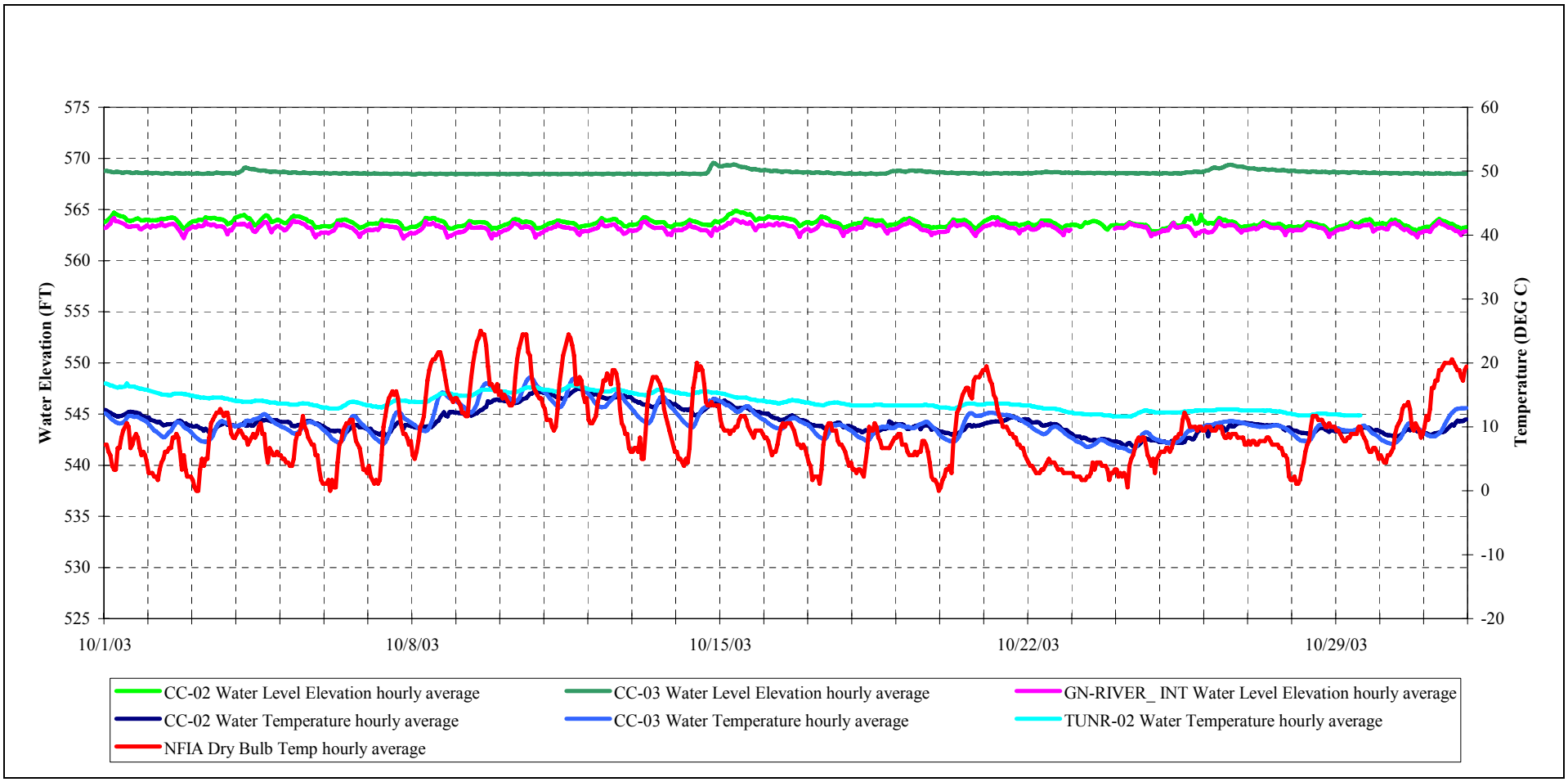

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FIGURE B-197: CAYUGA CREEK (CC-02 AND CC-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

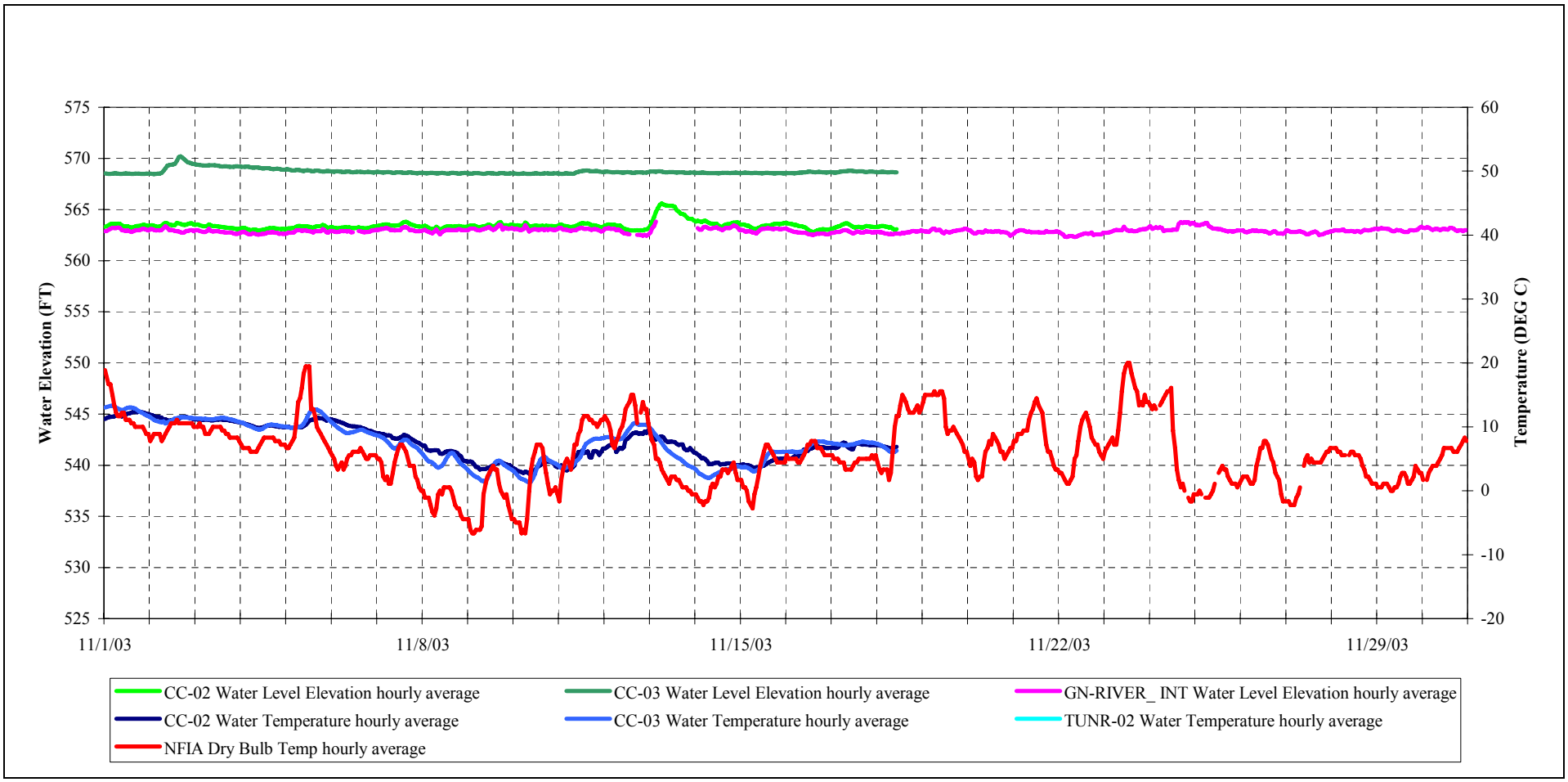

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FIGURE B-198: ELLICOTT CREEK (EC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

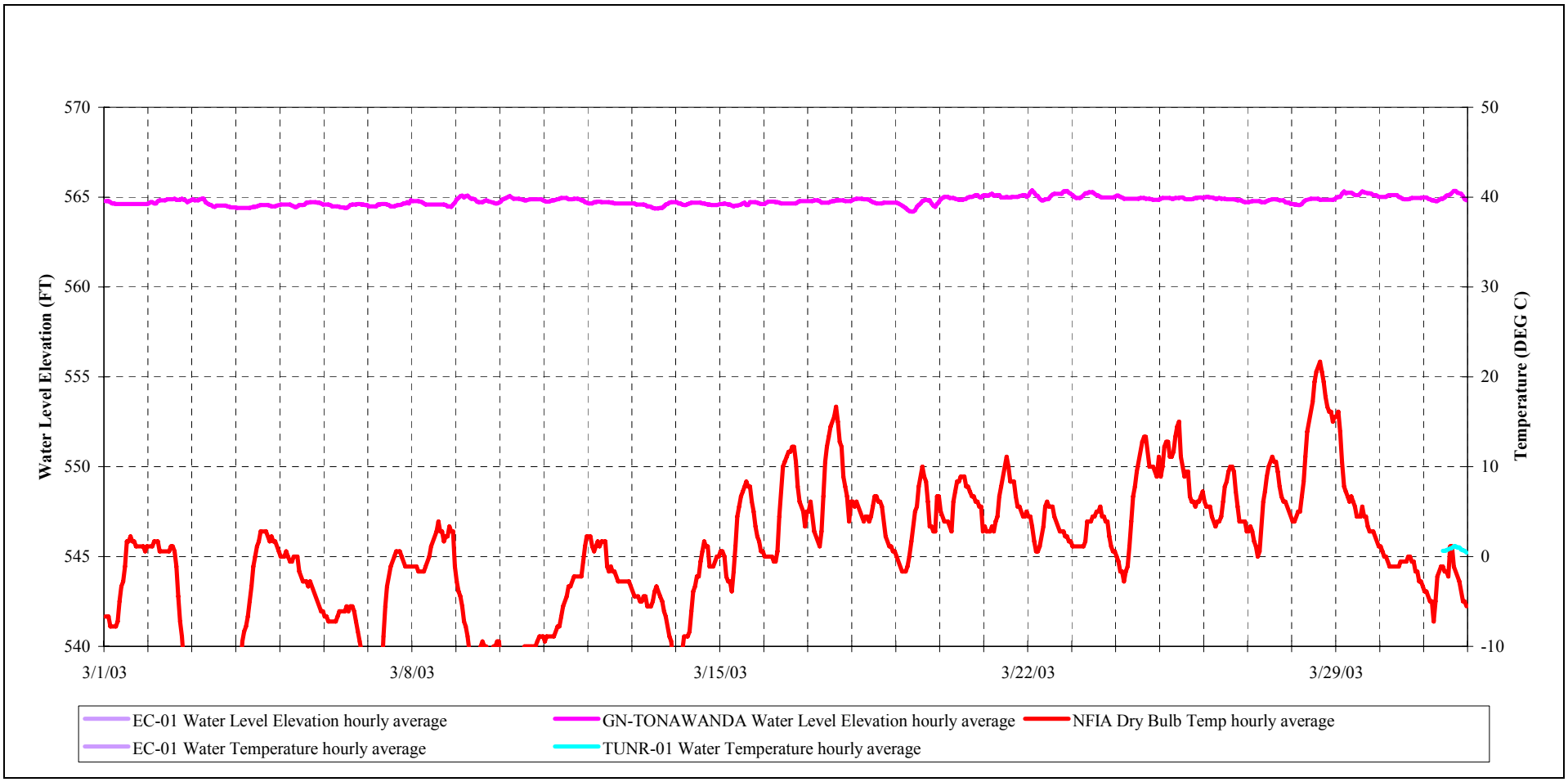

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FIGURE B-199: ELLICOTT CREEK (EC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

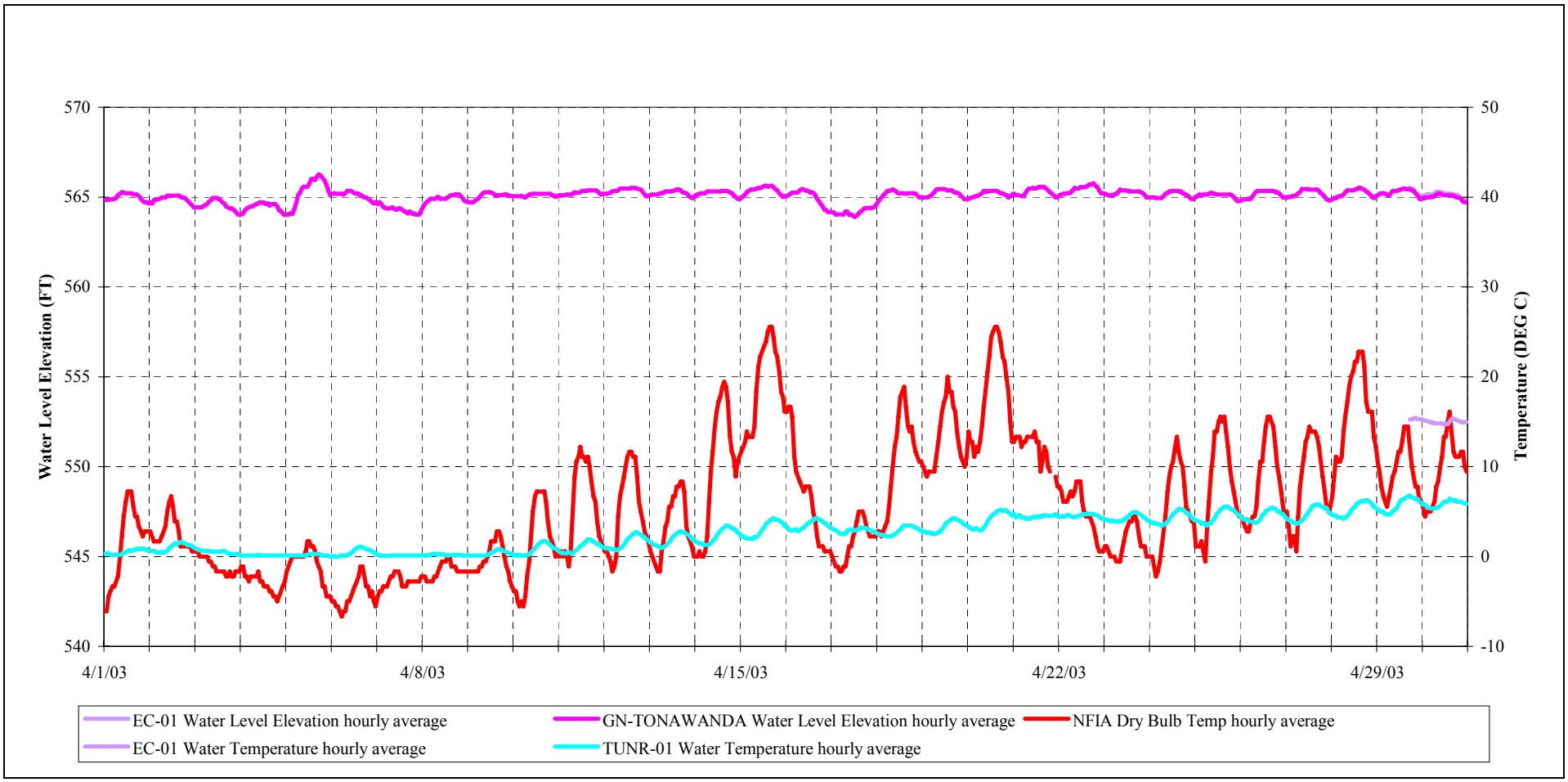

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FIGURE B-200: ELLICOTT CREEK (EC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

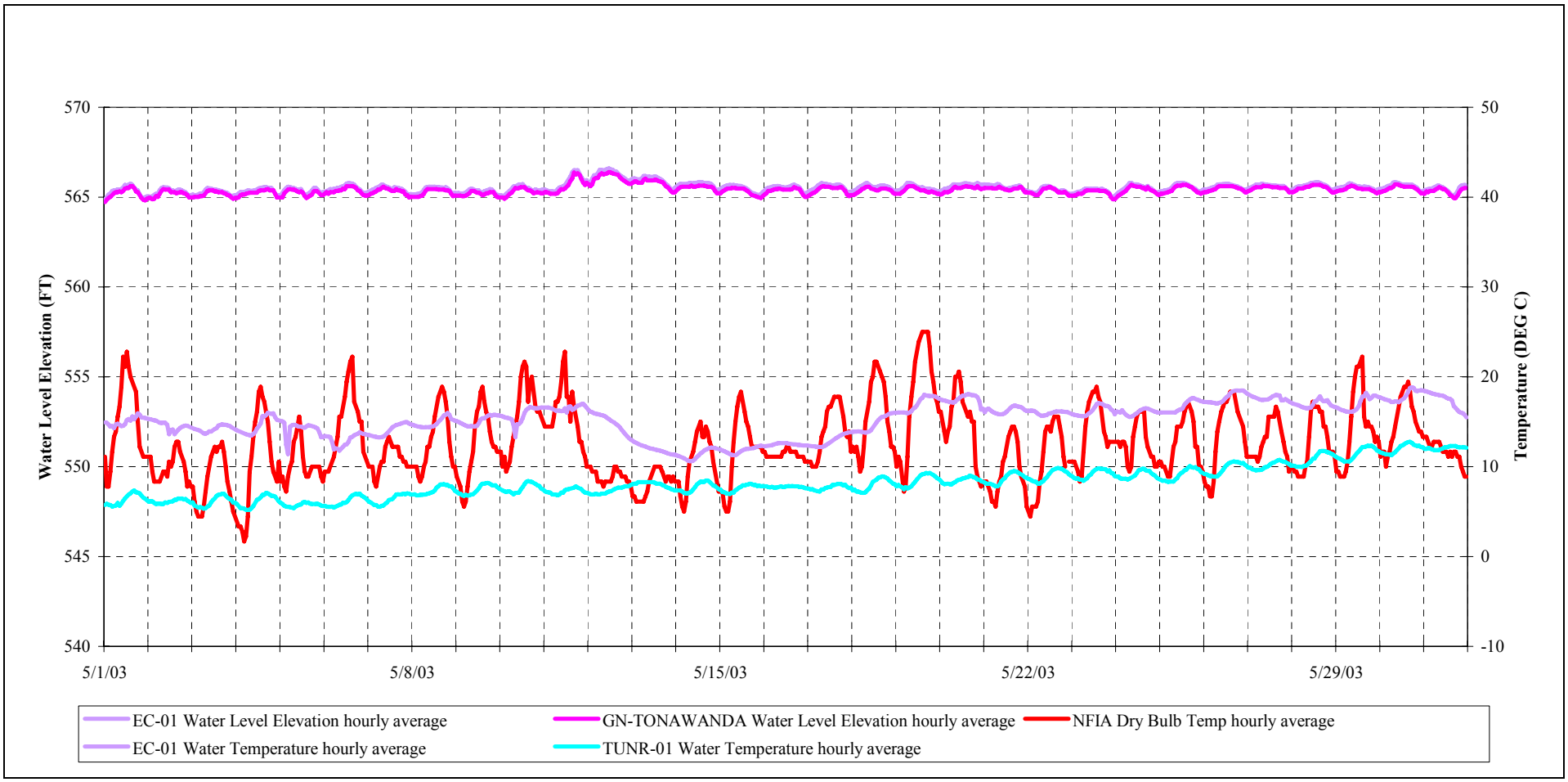

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FIGURE B-201: ELLICOTT CREEK (EC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

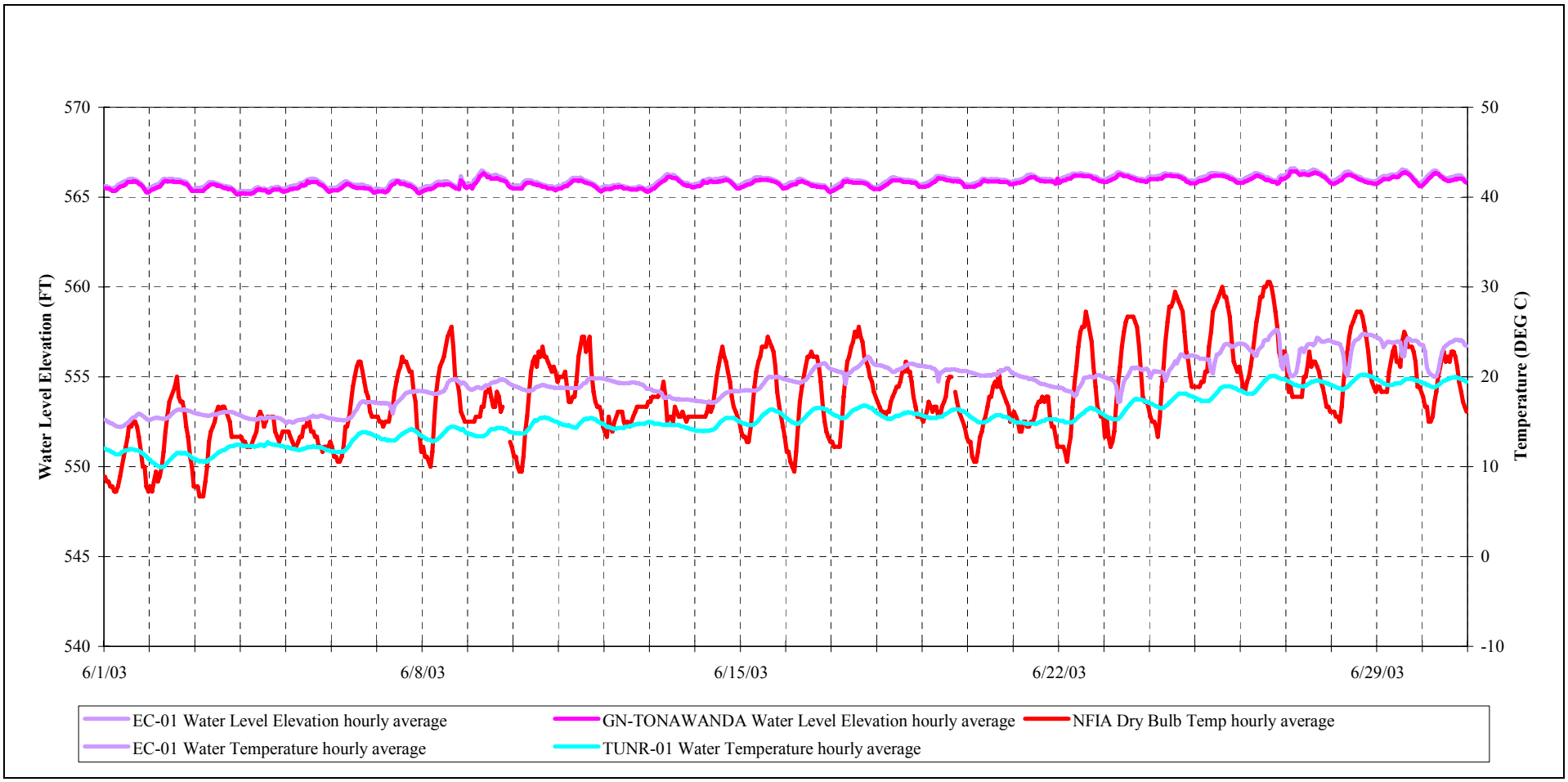

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FIGURE B-202: ELLICOTT CREEK (EC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

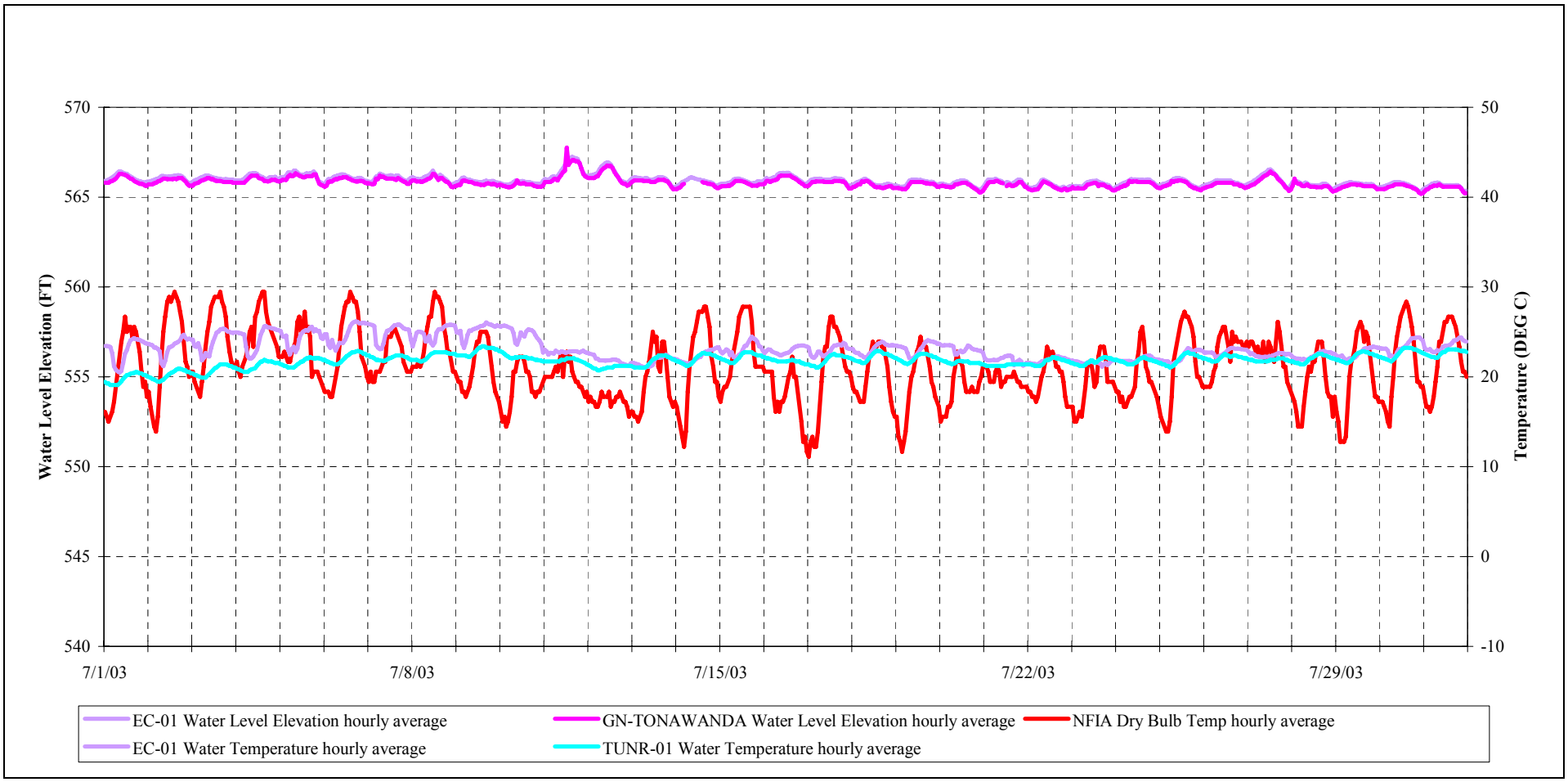

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FIGURE B-203: ELLICOTT CREEK (EC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

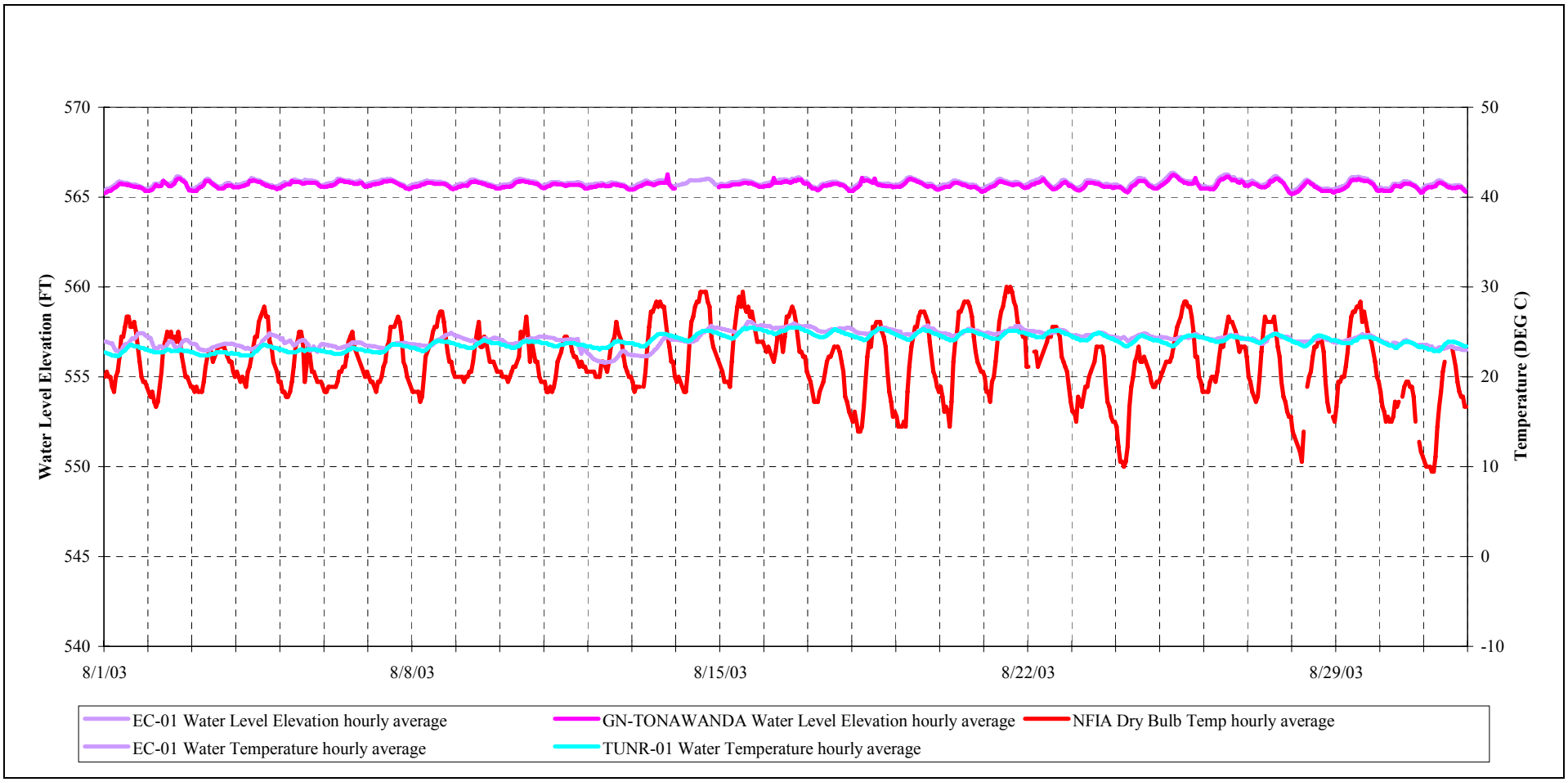

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FIGURE B-204: ELLICOTT CREEK (EC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

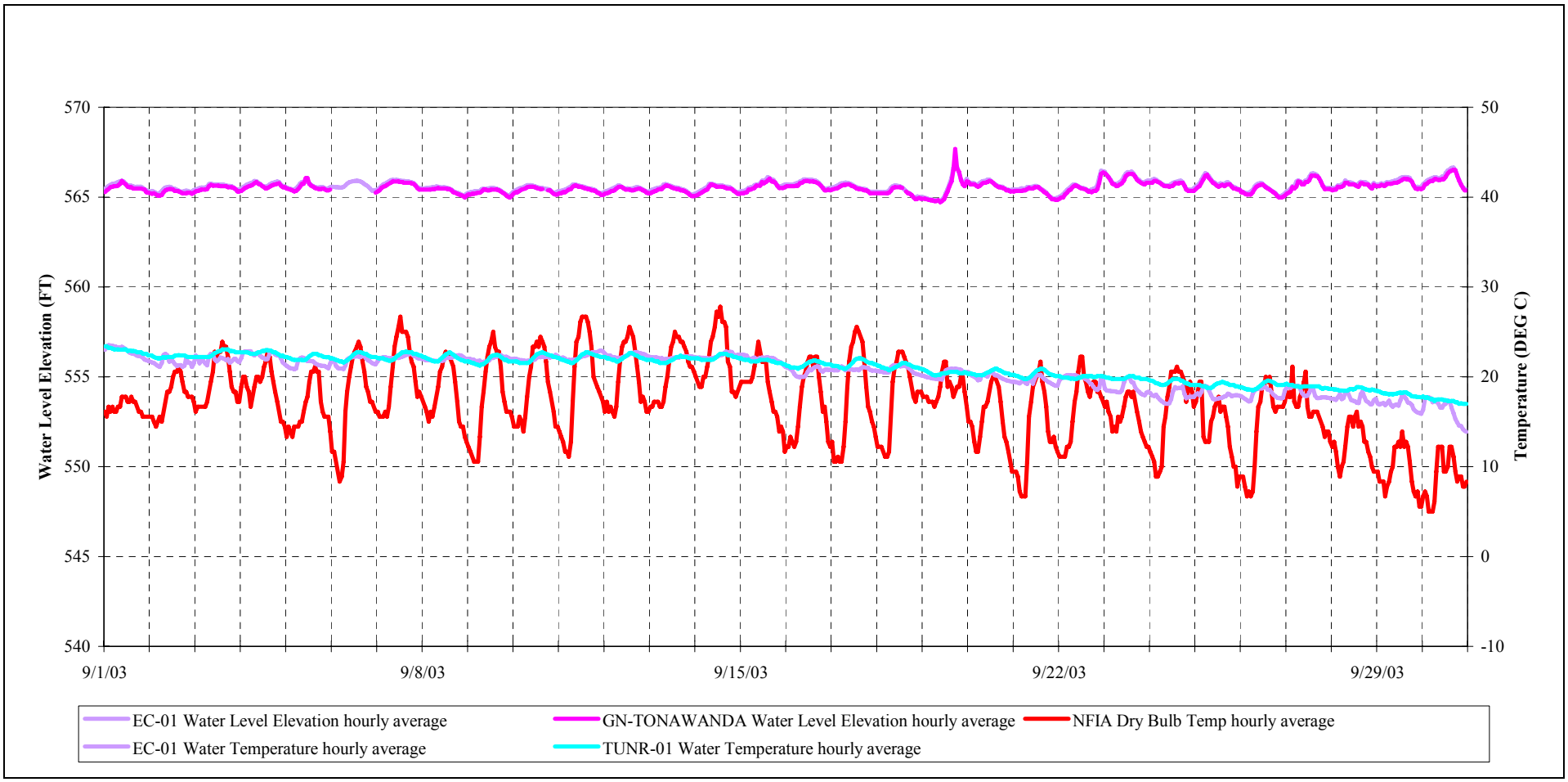

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FIGURE B-205: ELLICOTT CREEK (EC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

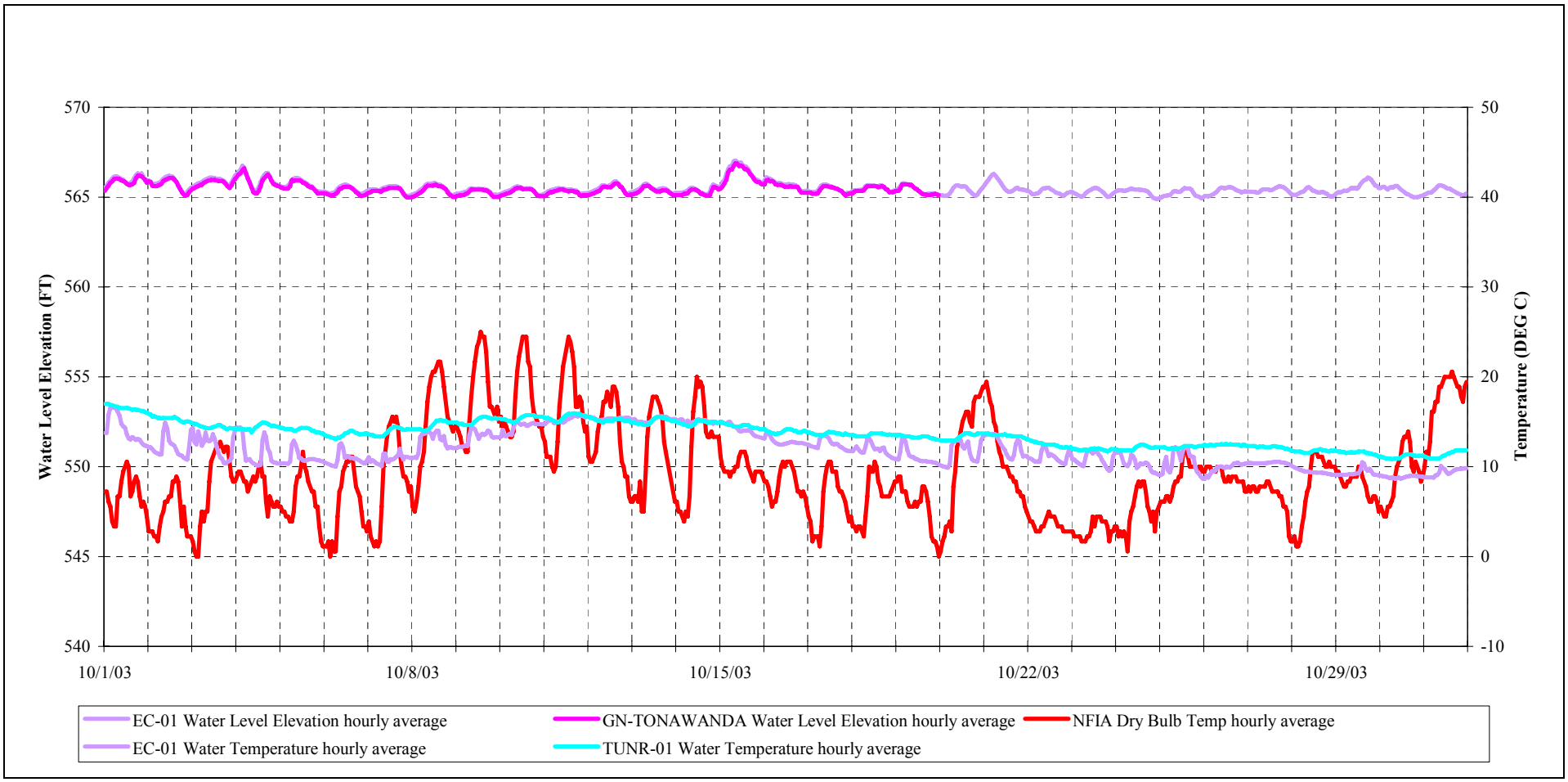

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FIGURE B-206: ELLICOTT CREEK (EC-01)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

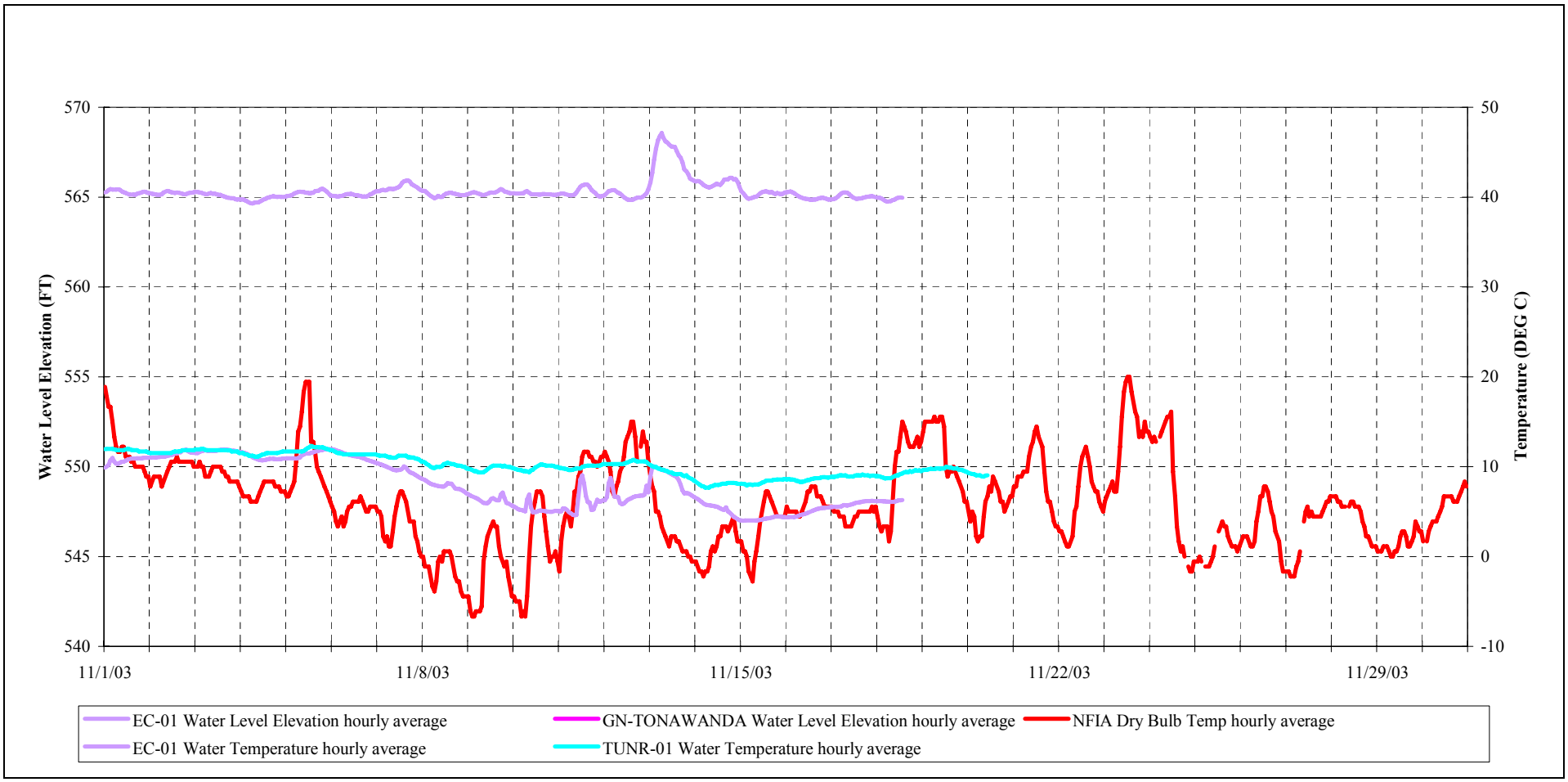

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FIGURE B-207: TONAWANDA/ELLICOTT CREEKS

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

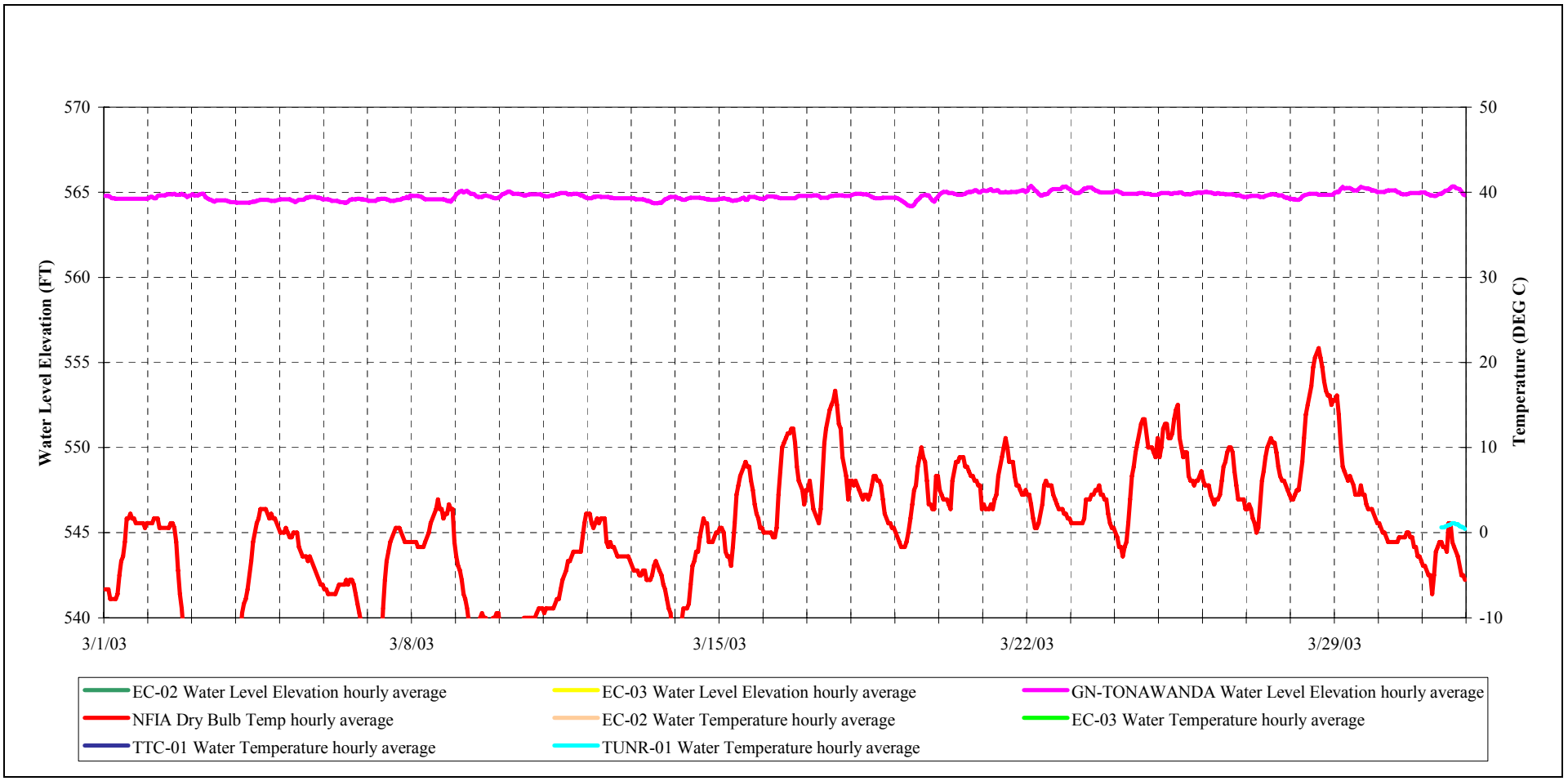

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FIGURE B-208: TONAWANDA/ELLICOTT CREEKS

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

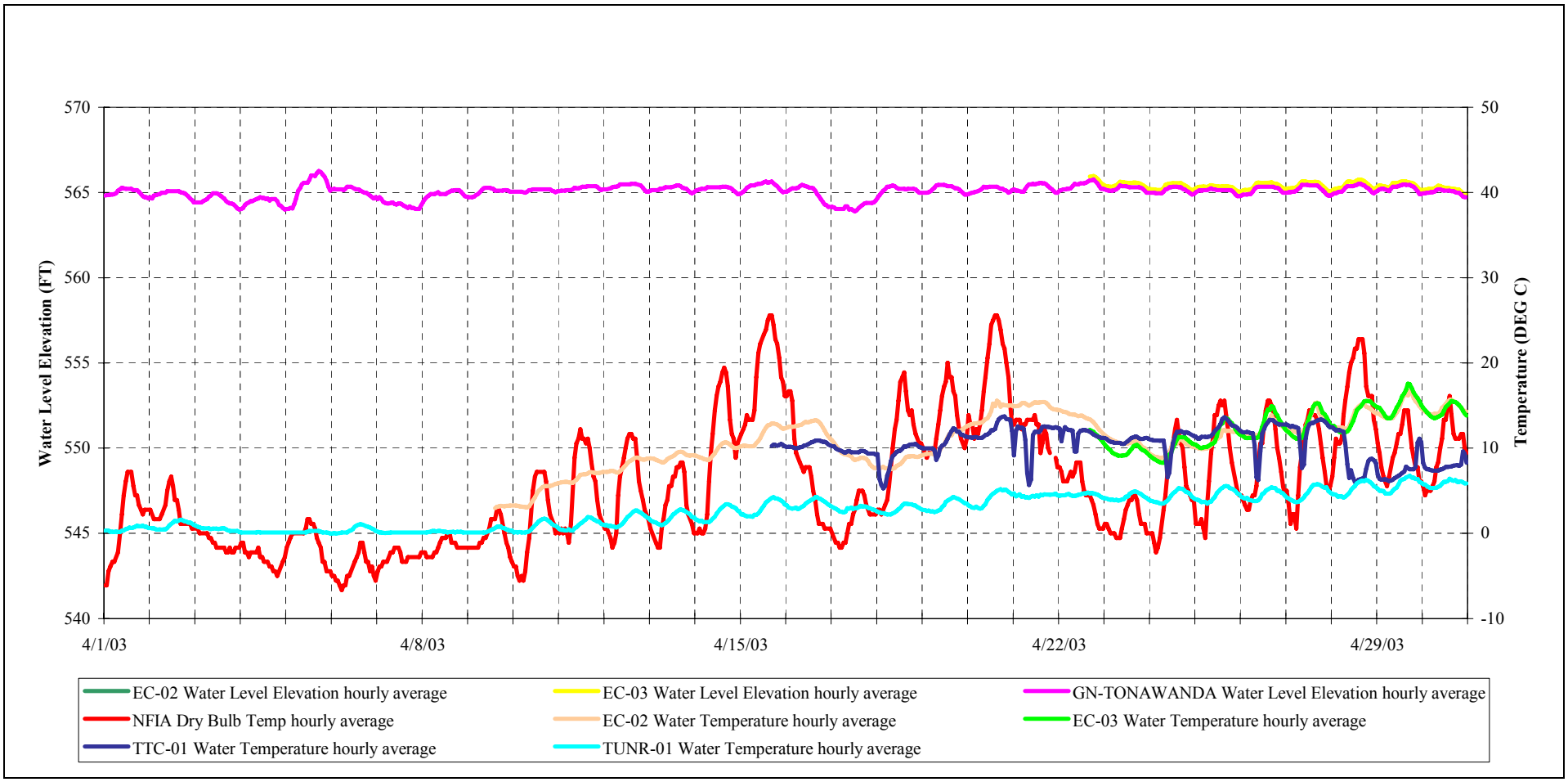

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FIGURE B-209: TONAWANDA/ELLICOTT CREEKS

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

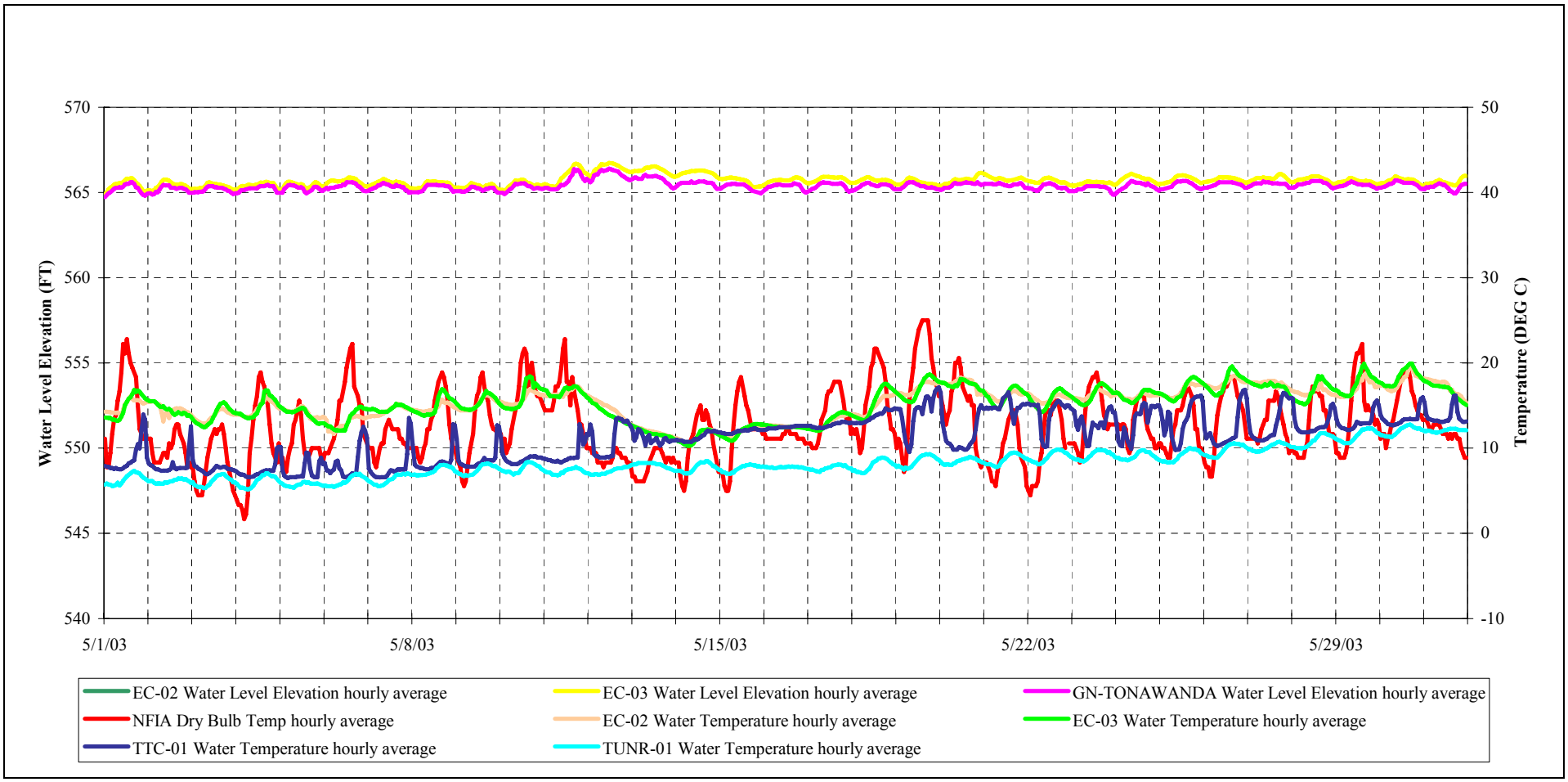

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FIGURE B-210: TONAWANDA/ELLICOTT CREEKS

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

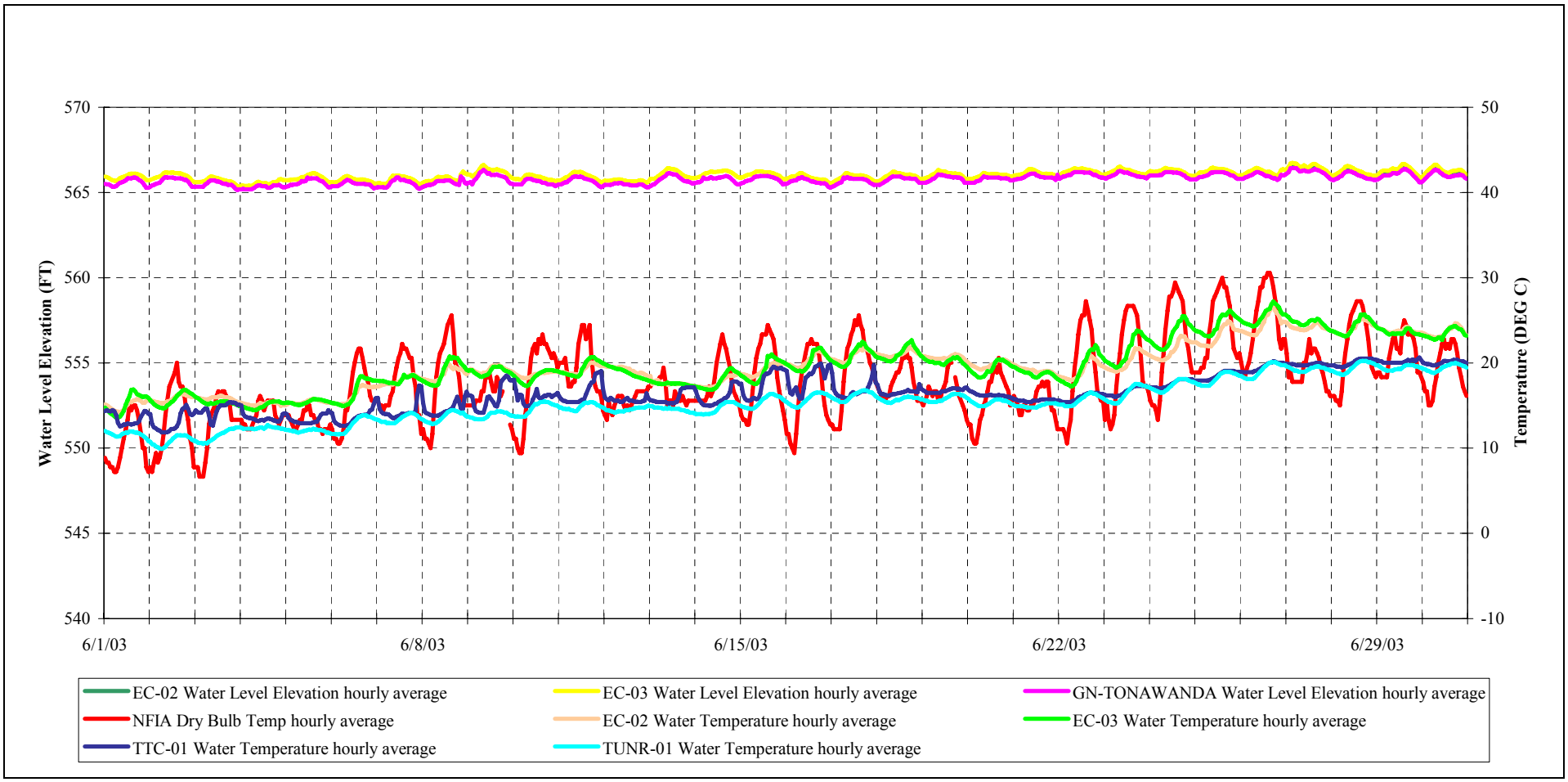

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FIGURE B-211: TONAWANDA/ELLICOTT CREEKS

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

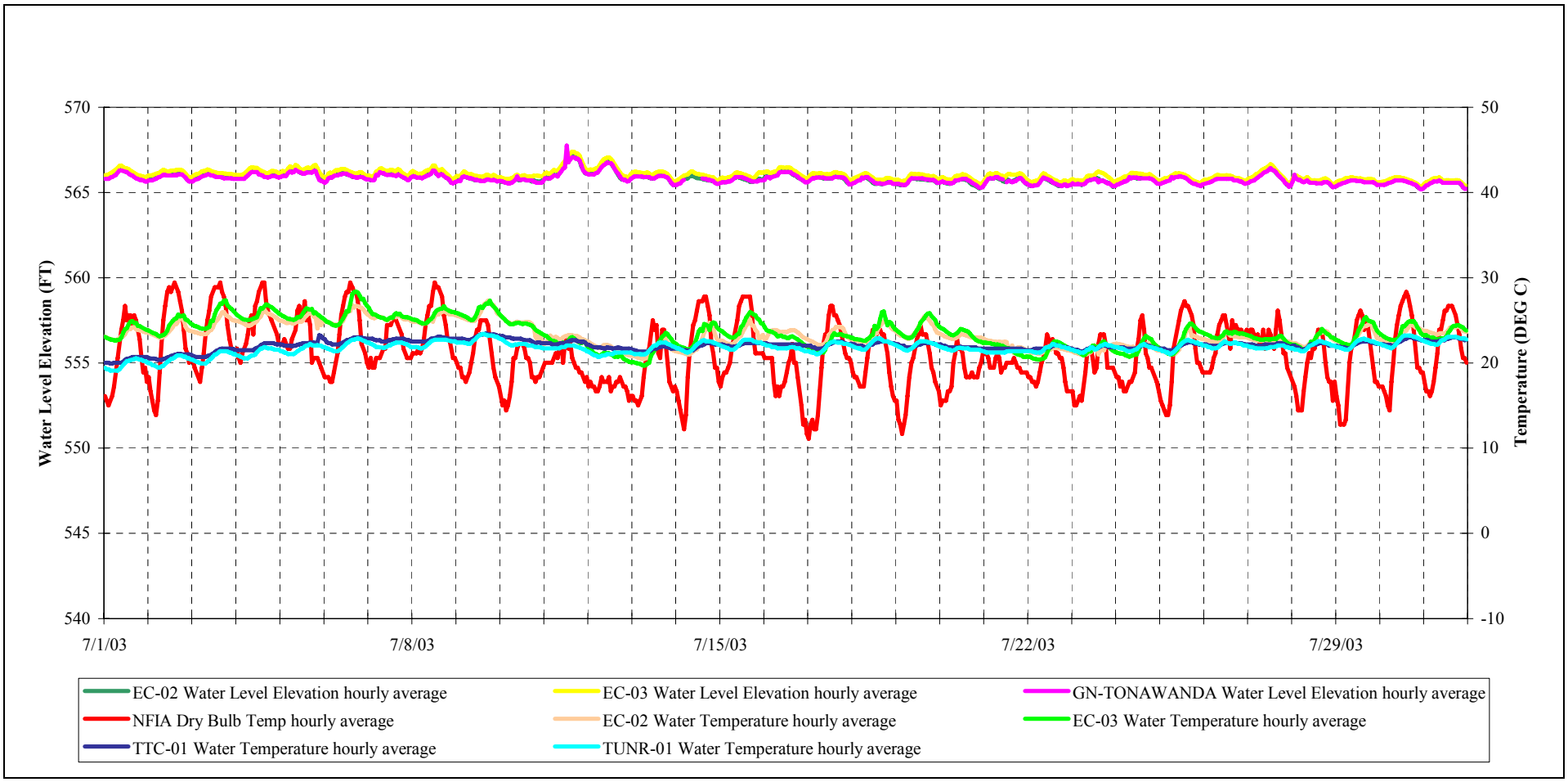

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FIGURE B-212: TONAWANDA/ELLICOTT CREEKS

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

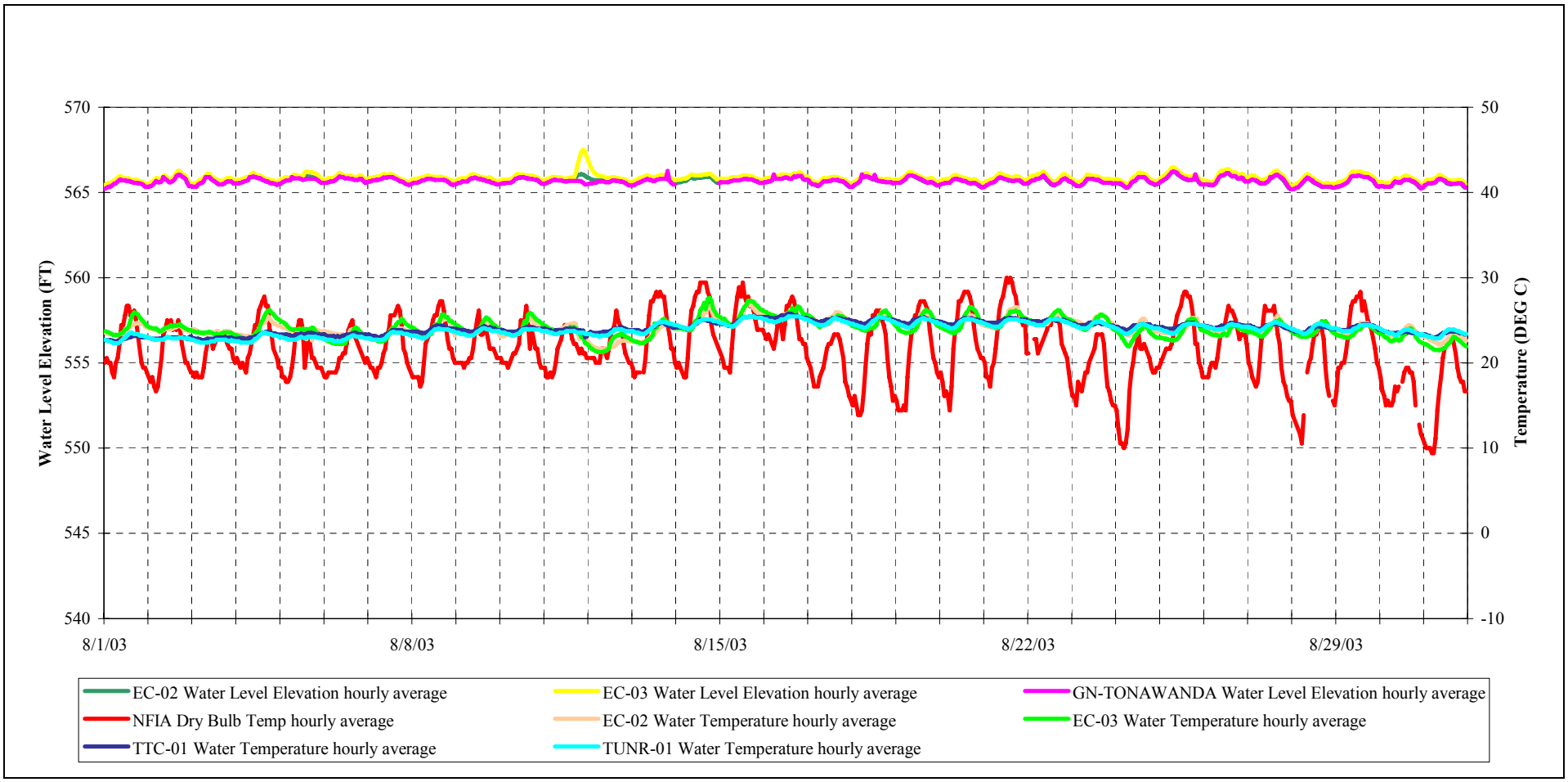

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FIGURE B-213: TONAWANDA/ELLICOTT CREEKS

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

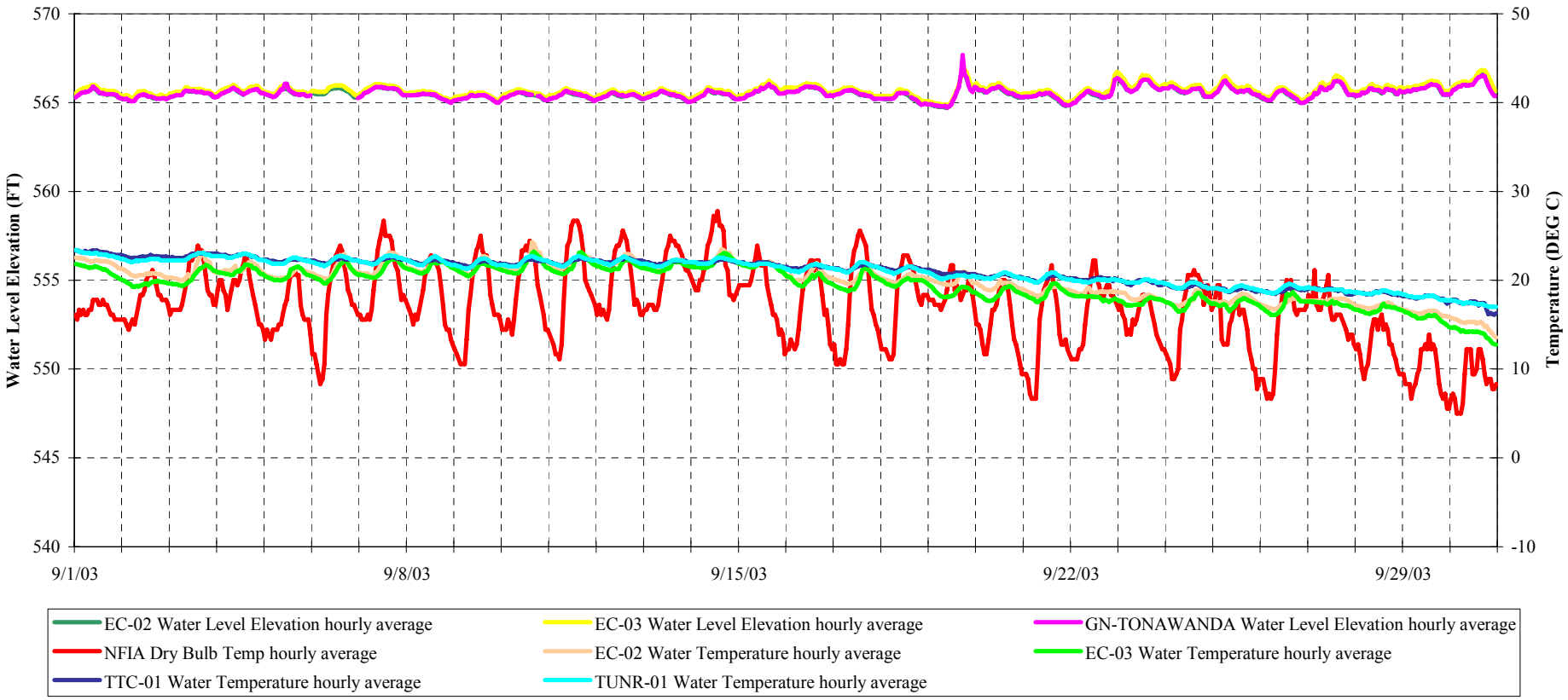

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FIGURE B-214: TONAWANDA/ELLICOTT CREEKS

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

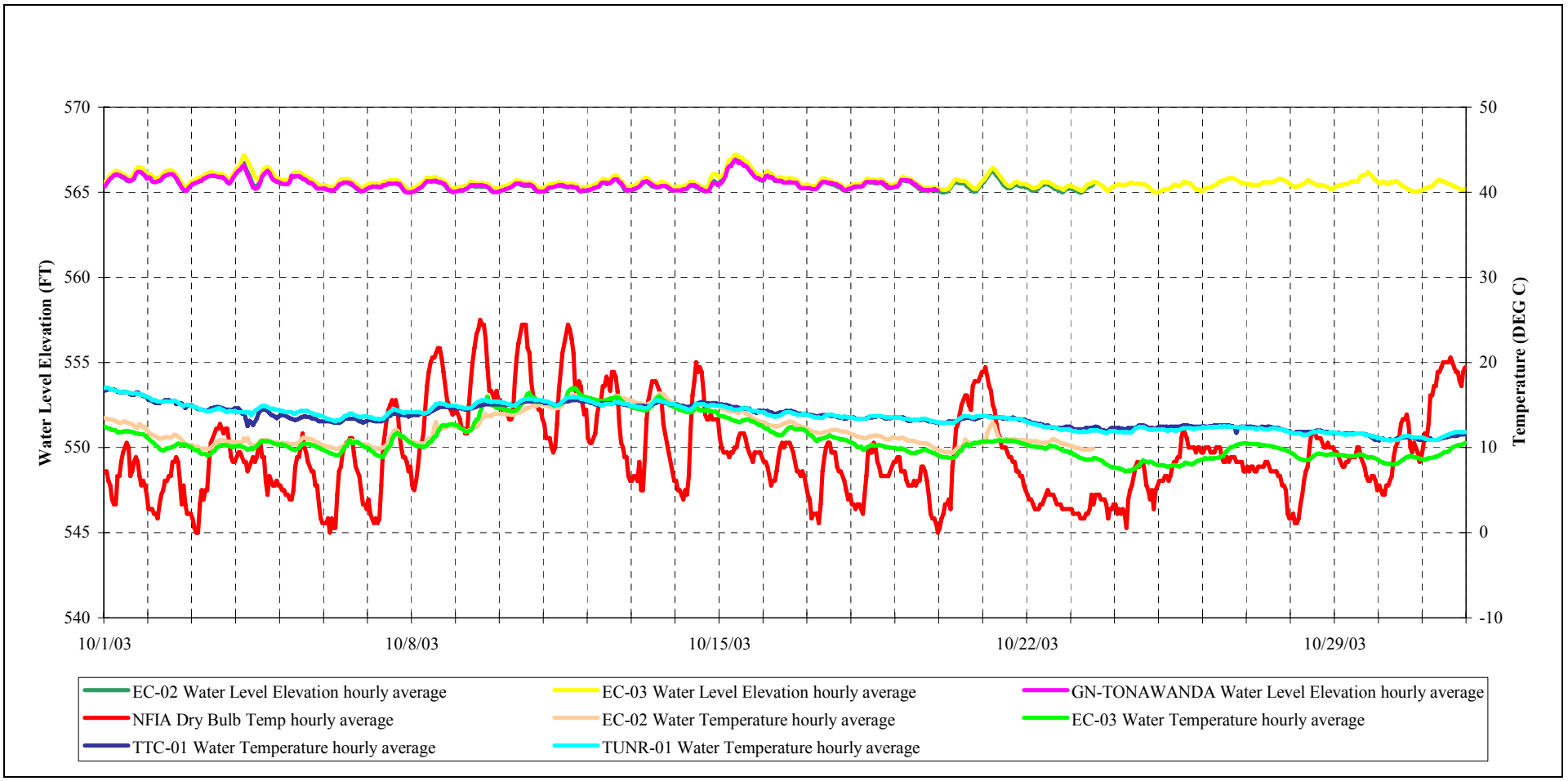

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FIGURE B-215: TONAWANDA/ELLICOTT CREEKS

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

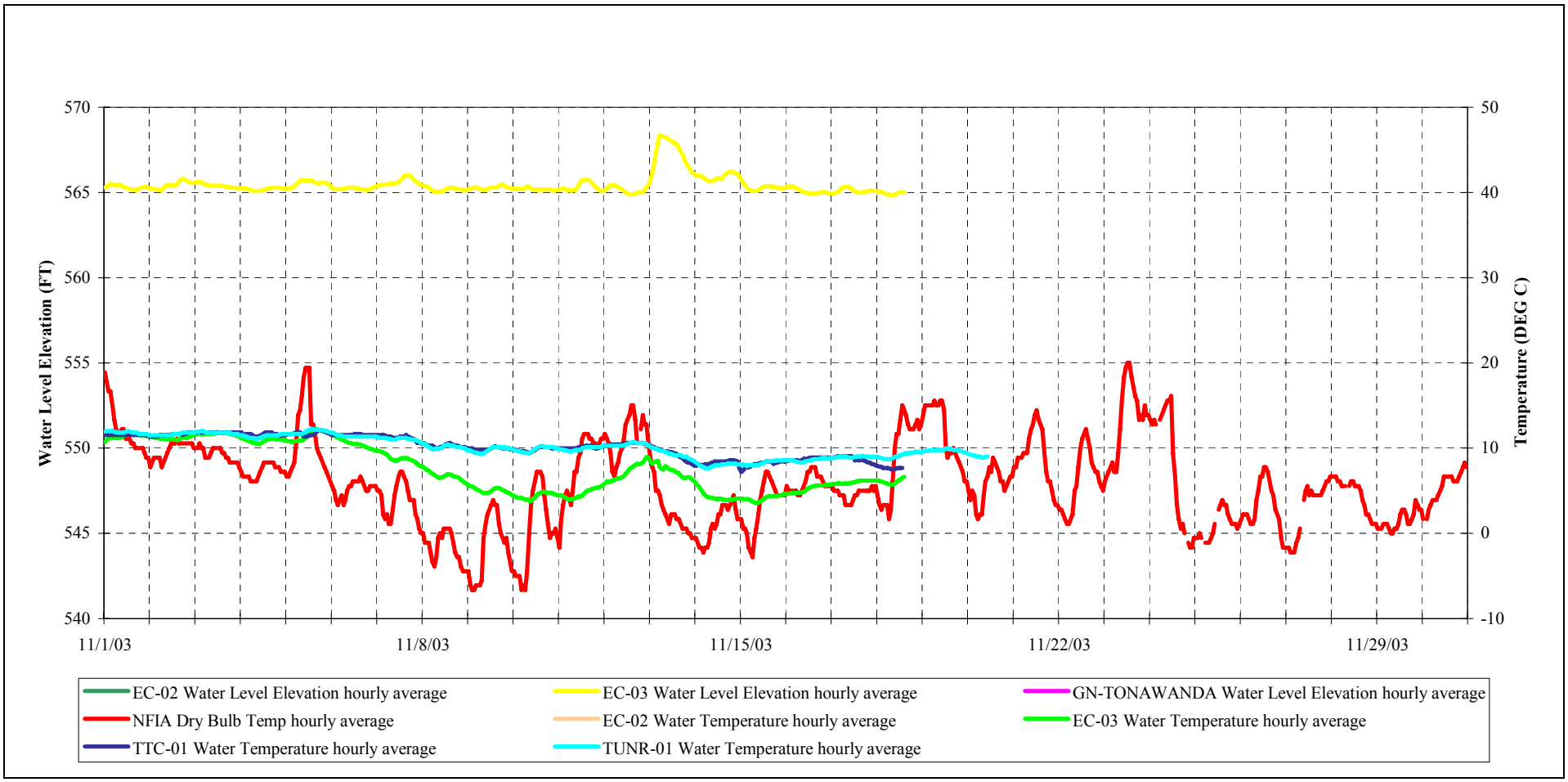

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FIGURE B-216: FISH CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

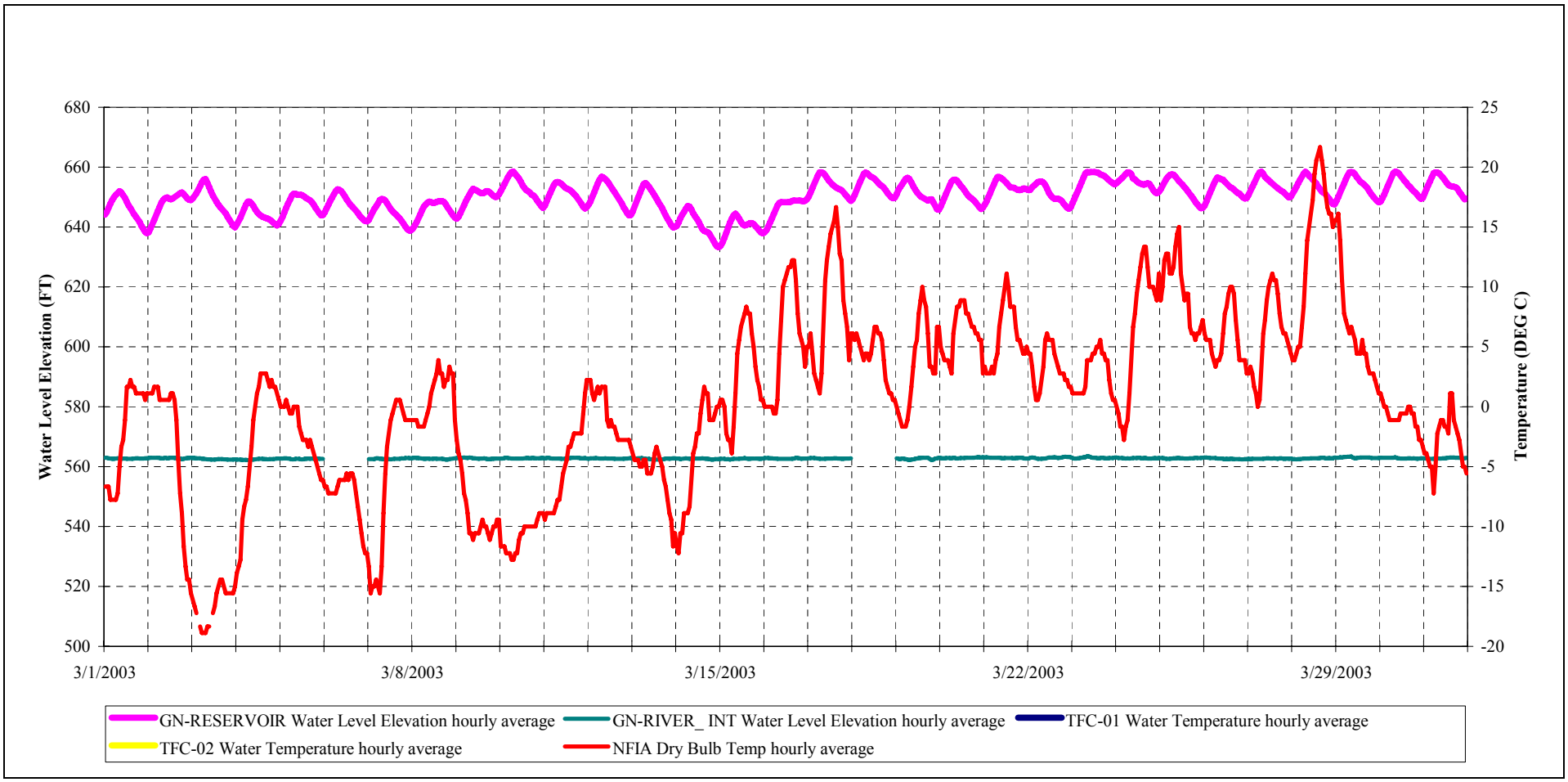

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FIGURE B-217: FISH CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

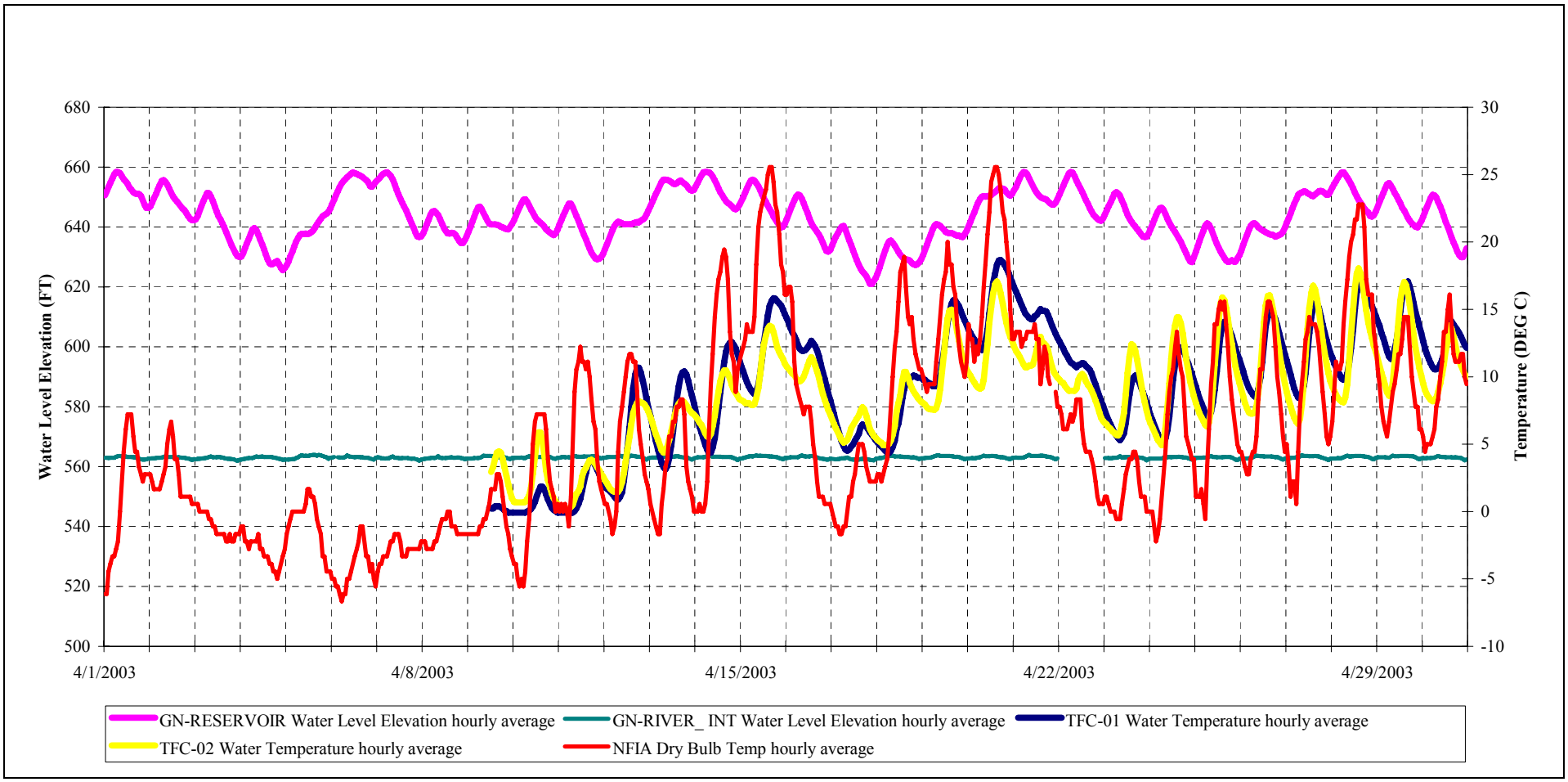

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FIGURE B-218: FISH CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

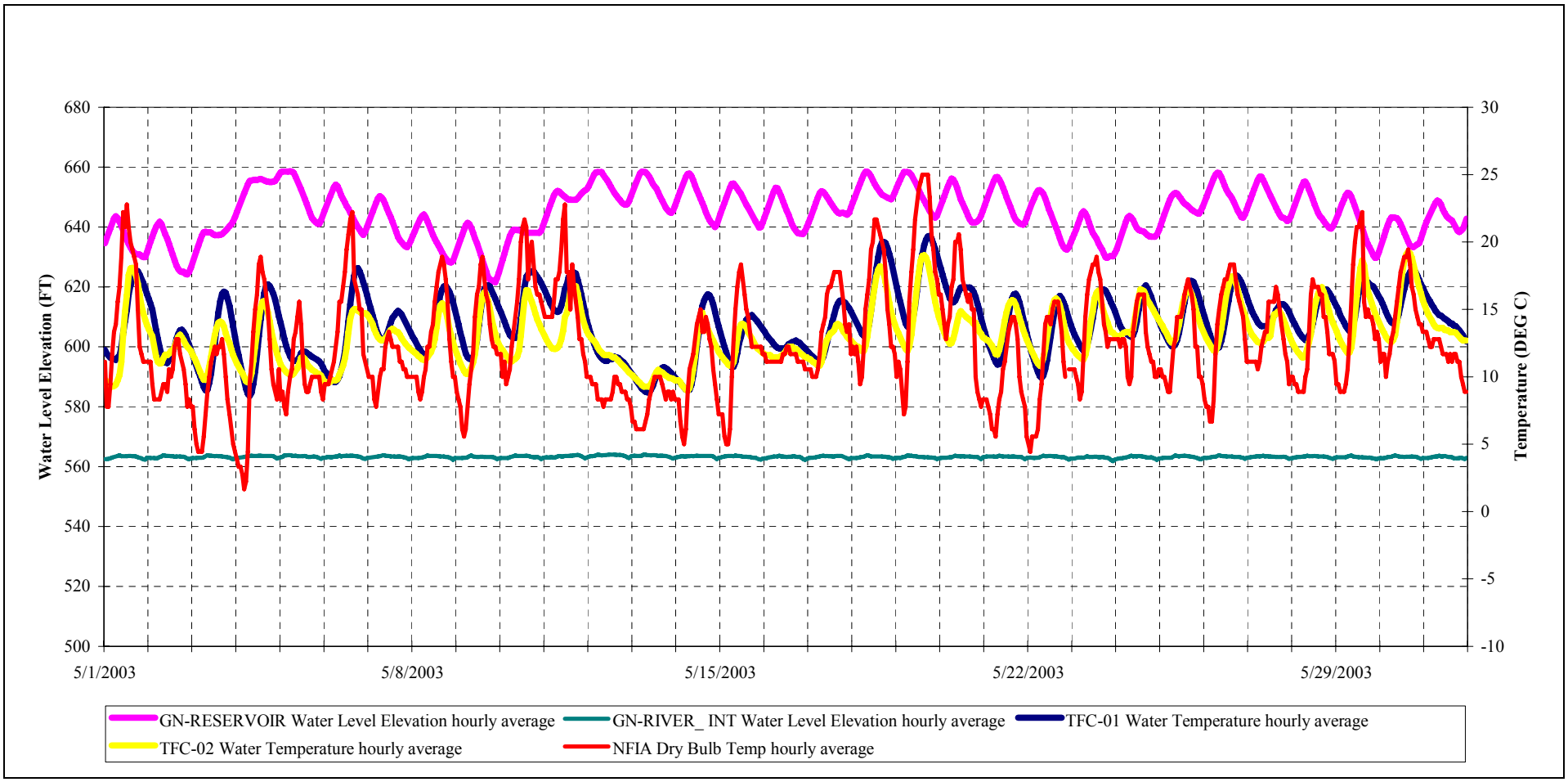

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FIGURE B-219: FISH CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

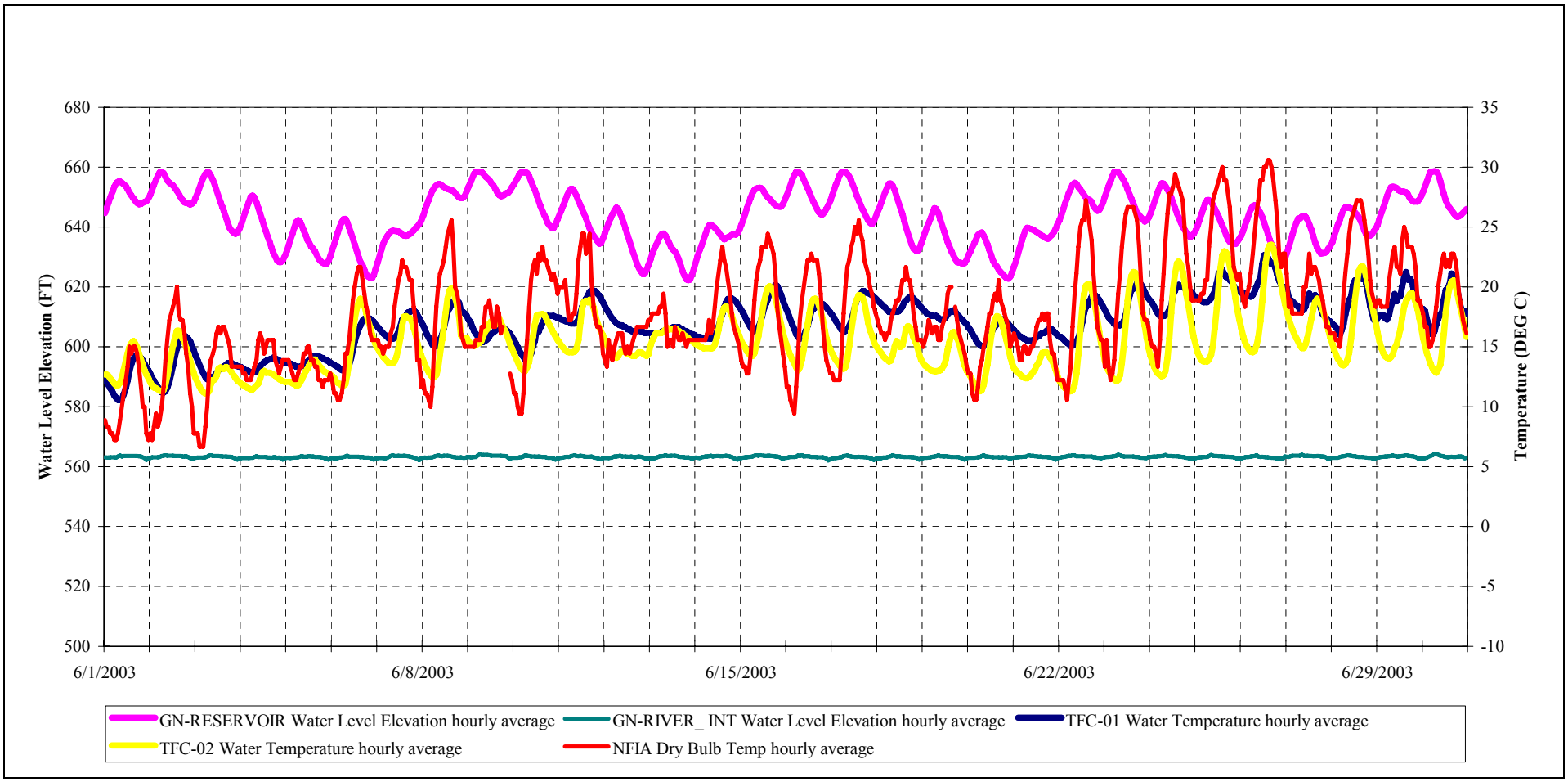

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FIGURE B-220: FISH CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

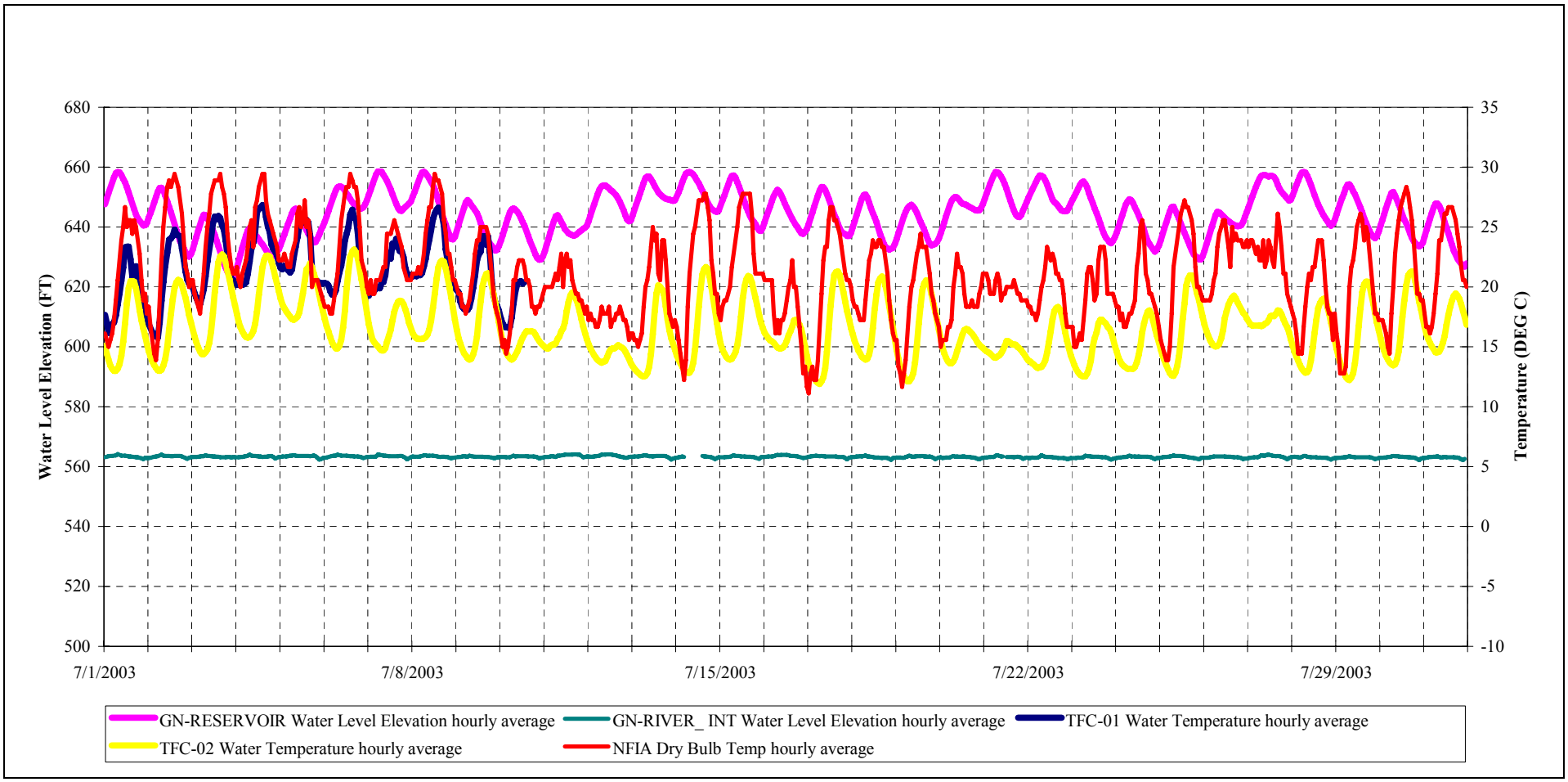

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FIGURE B-221: FISH CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

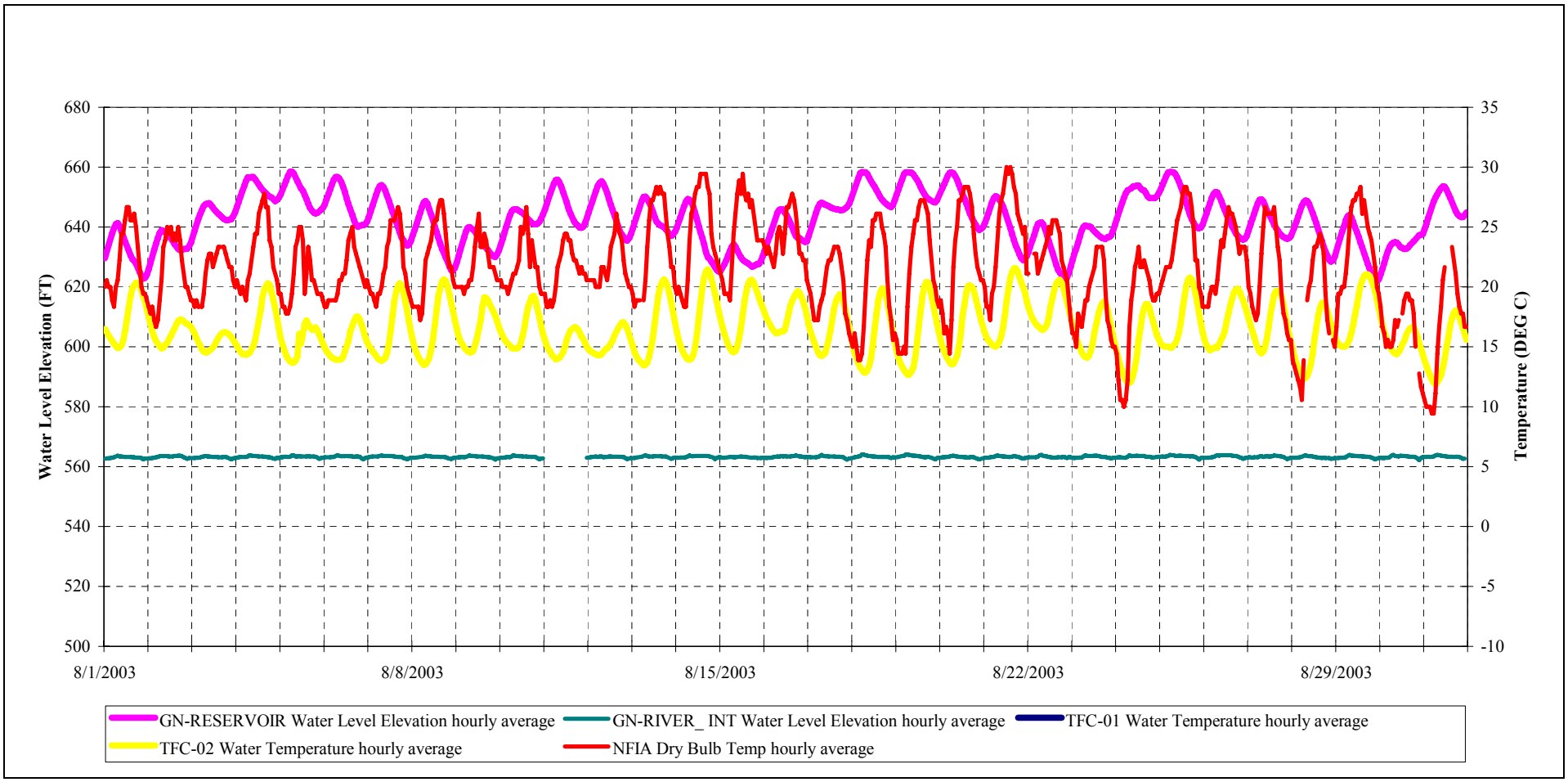

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FIGURE B-222: FISH CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

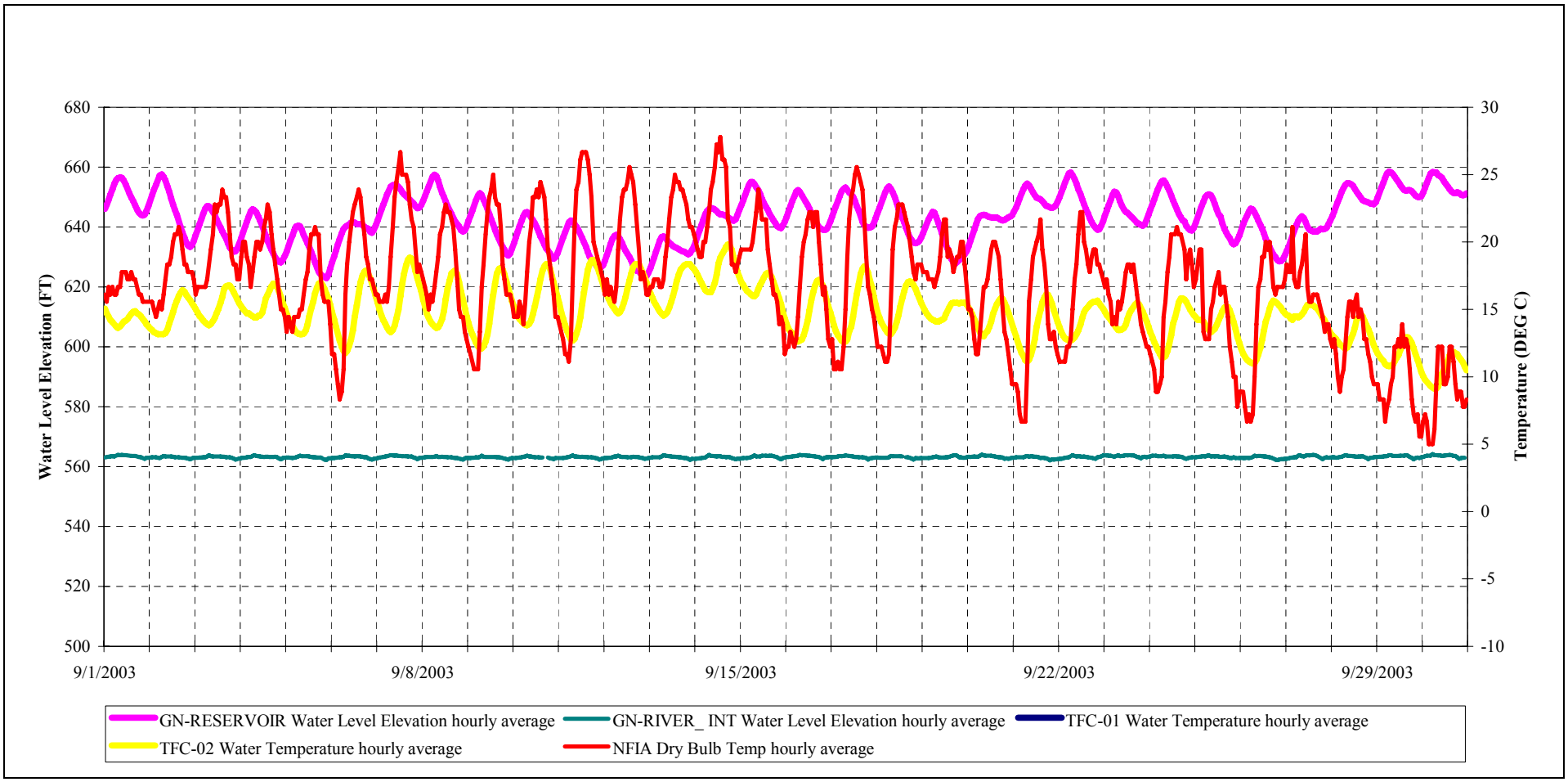

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FIGURE B-223: FISH CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

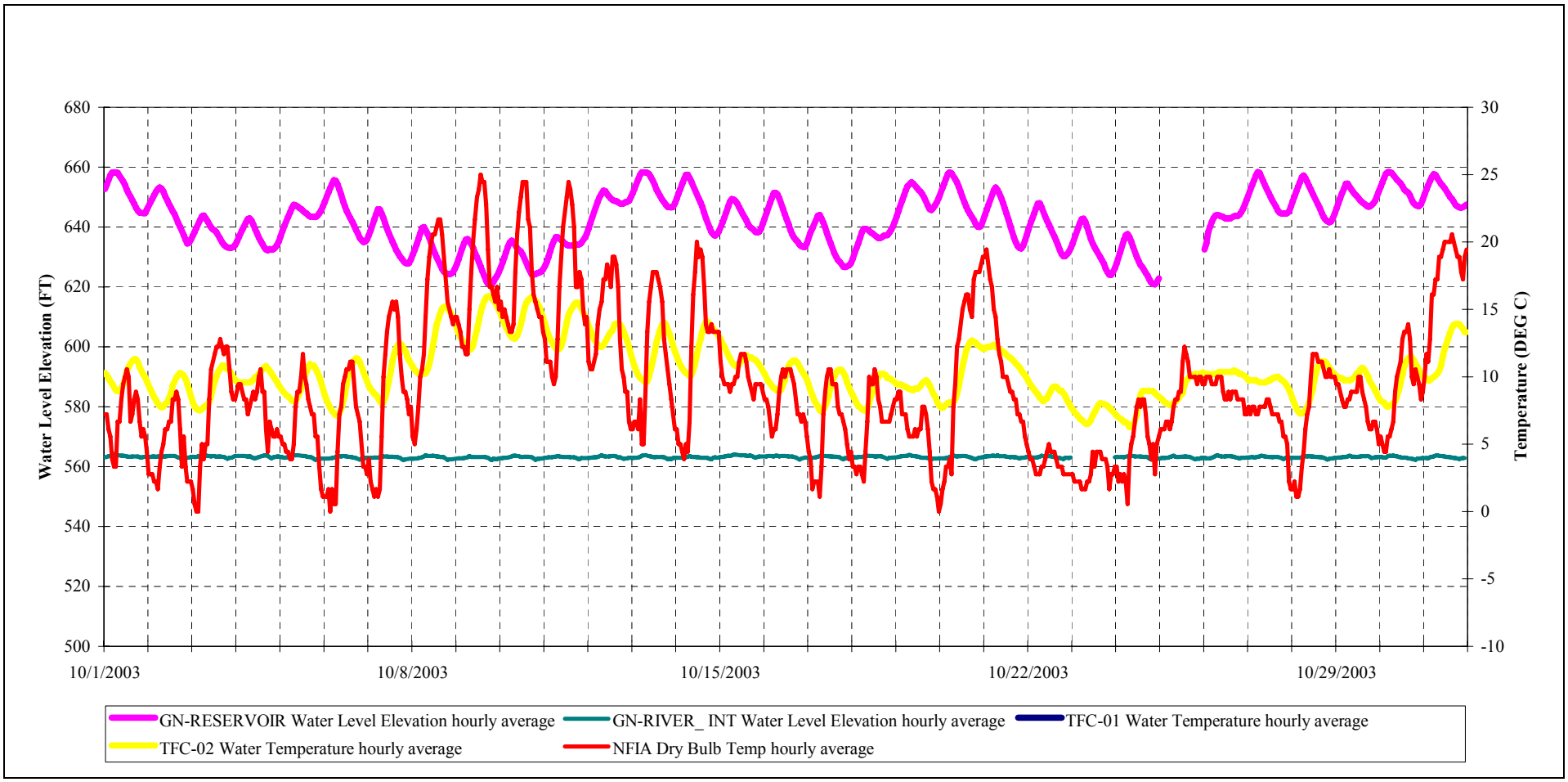

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FIGURE B-224: FISH CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

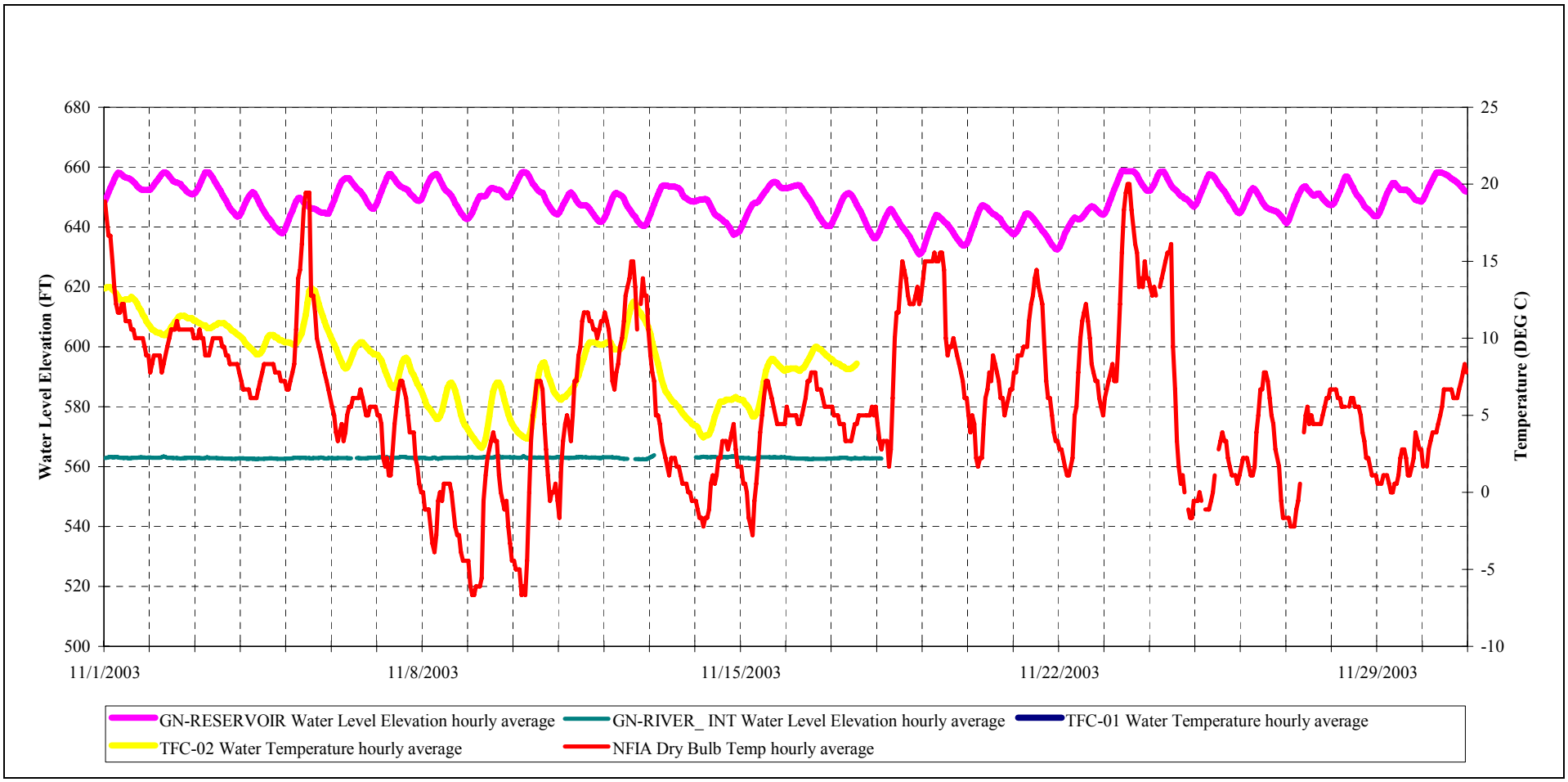

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FIGURE B-225: GILL CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

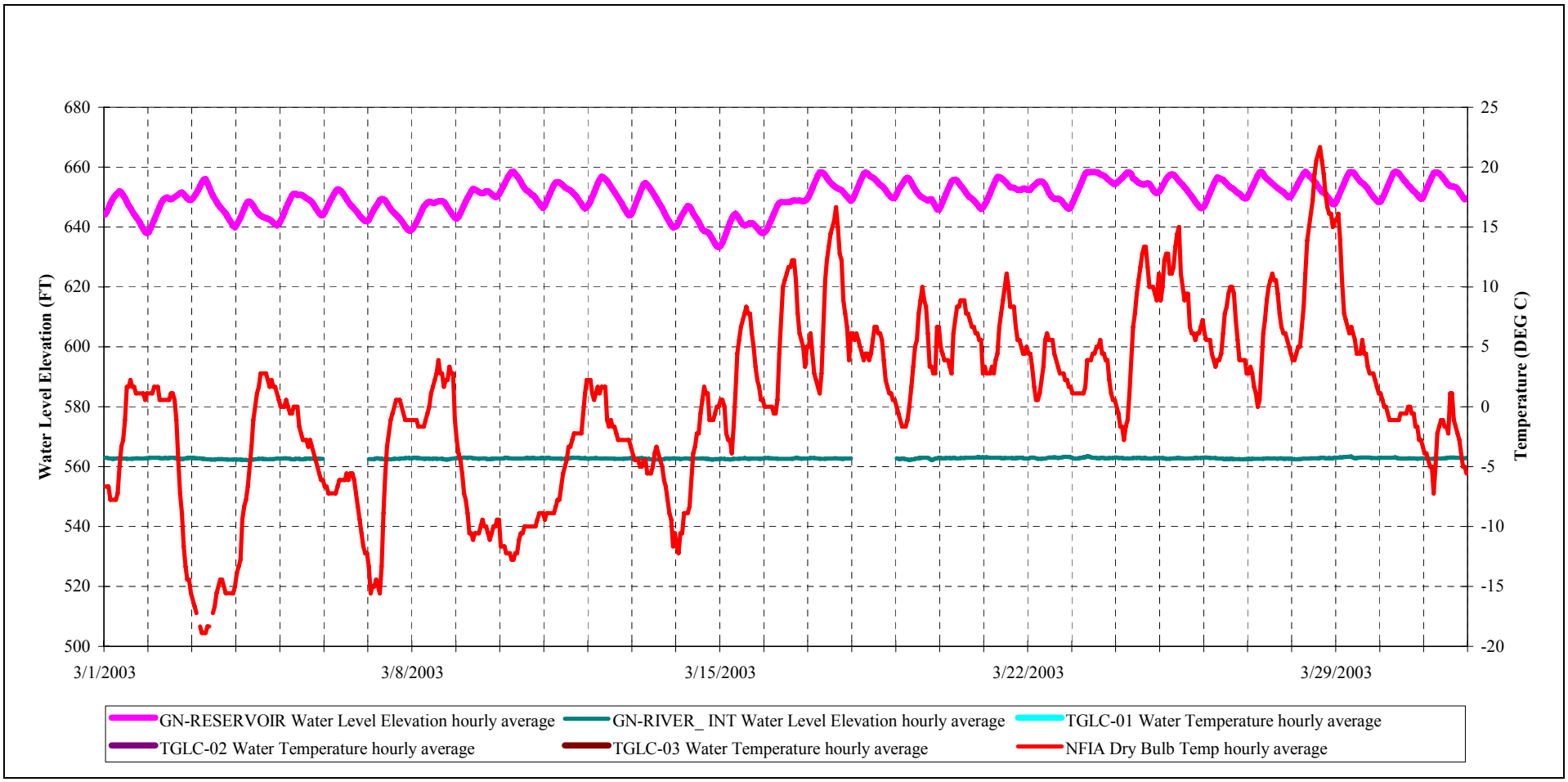

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FIGURE B-226: GILL CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

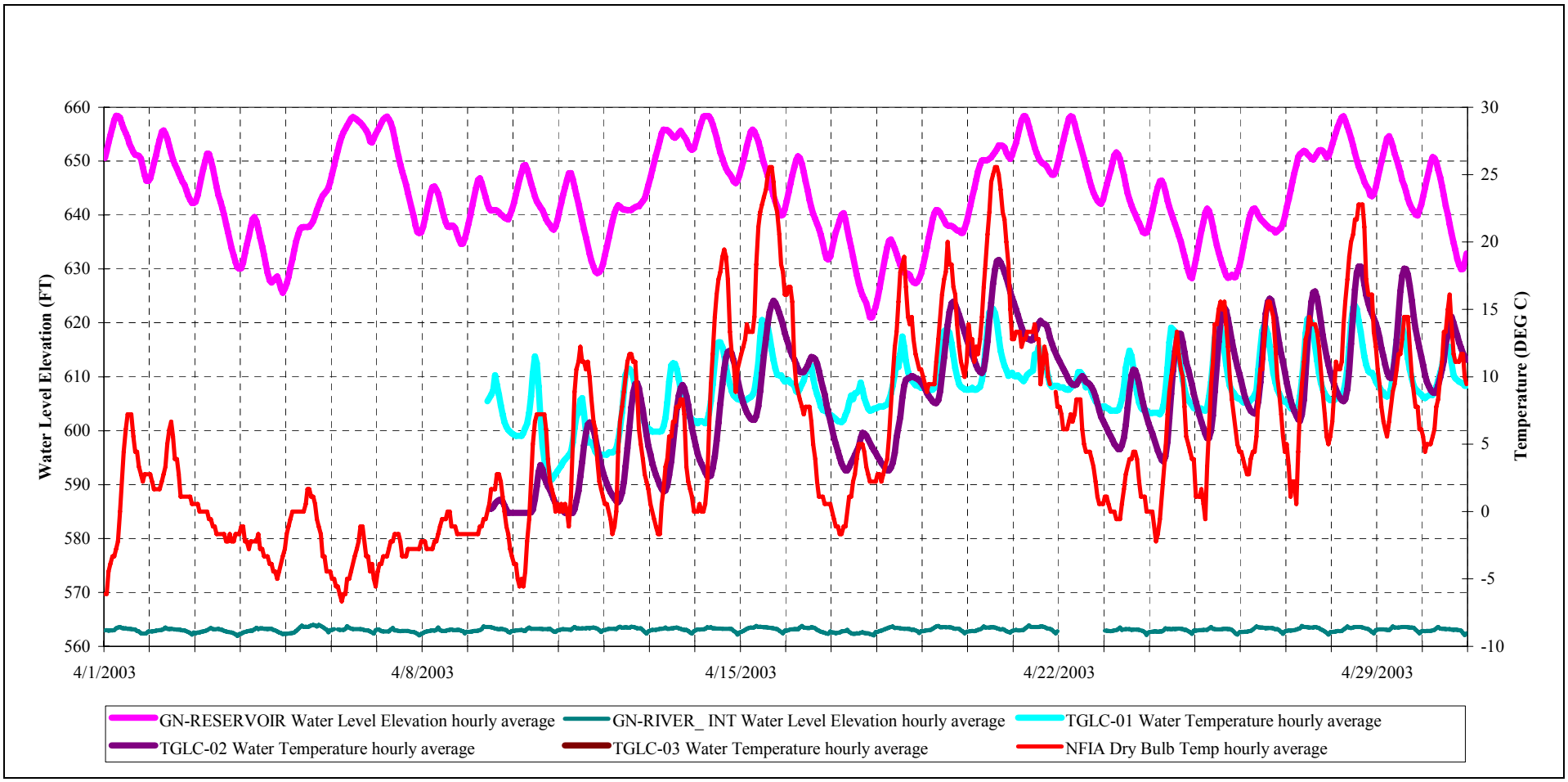

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FIGURE B-227: GILL CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

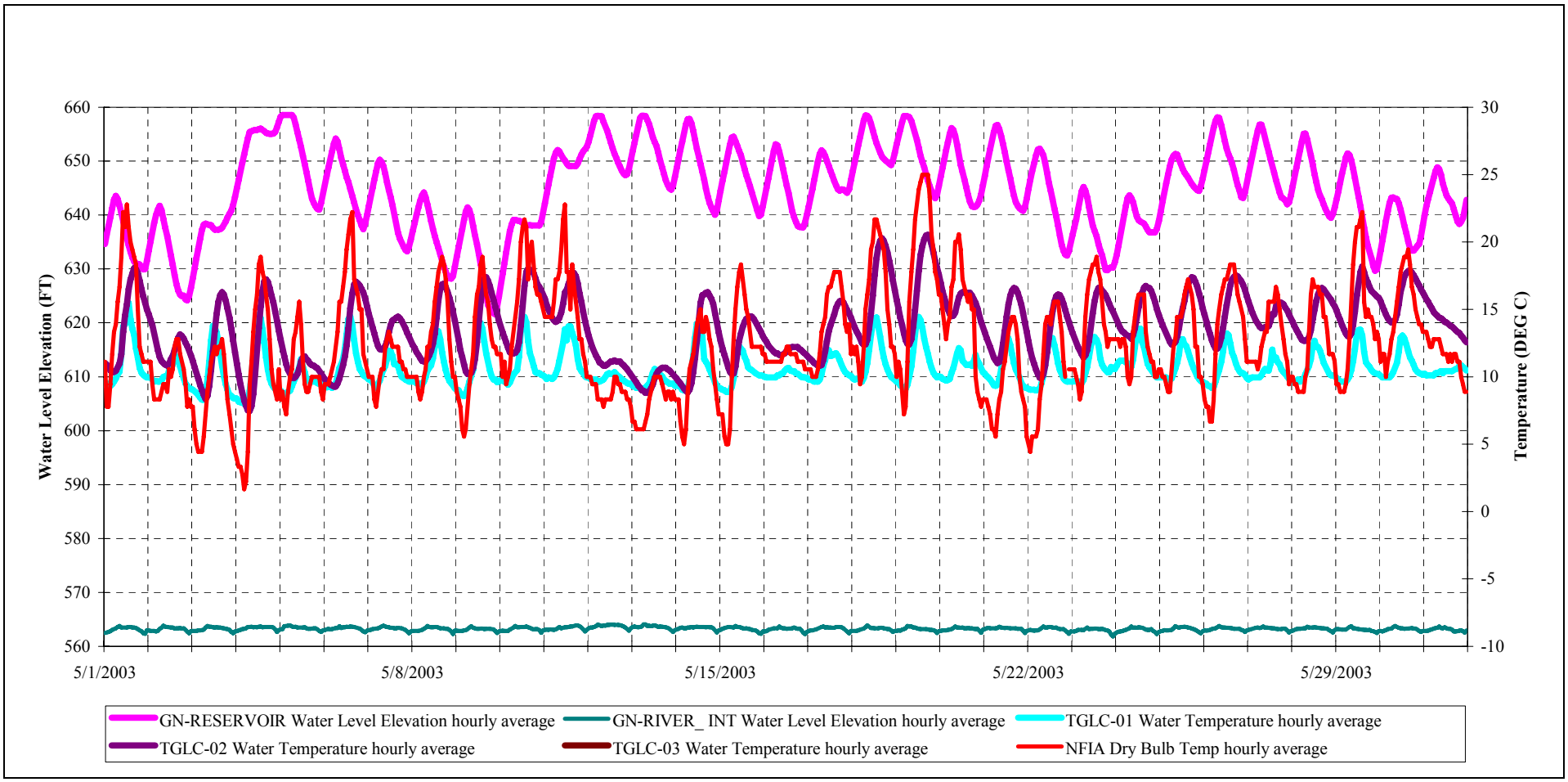

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FIGURE B-228: GILL CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

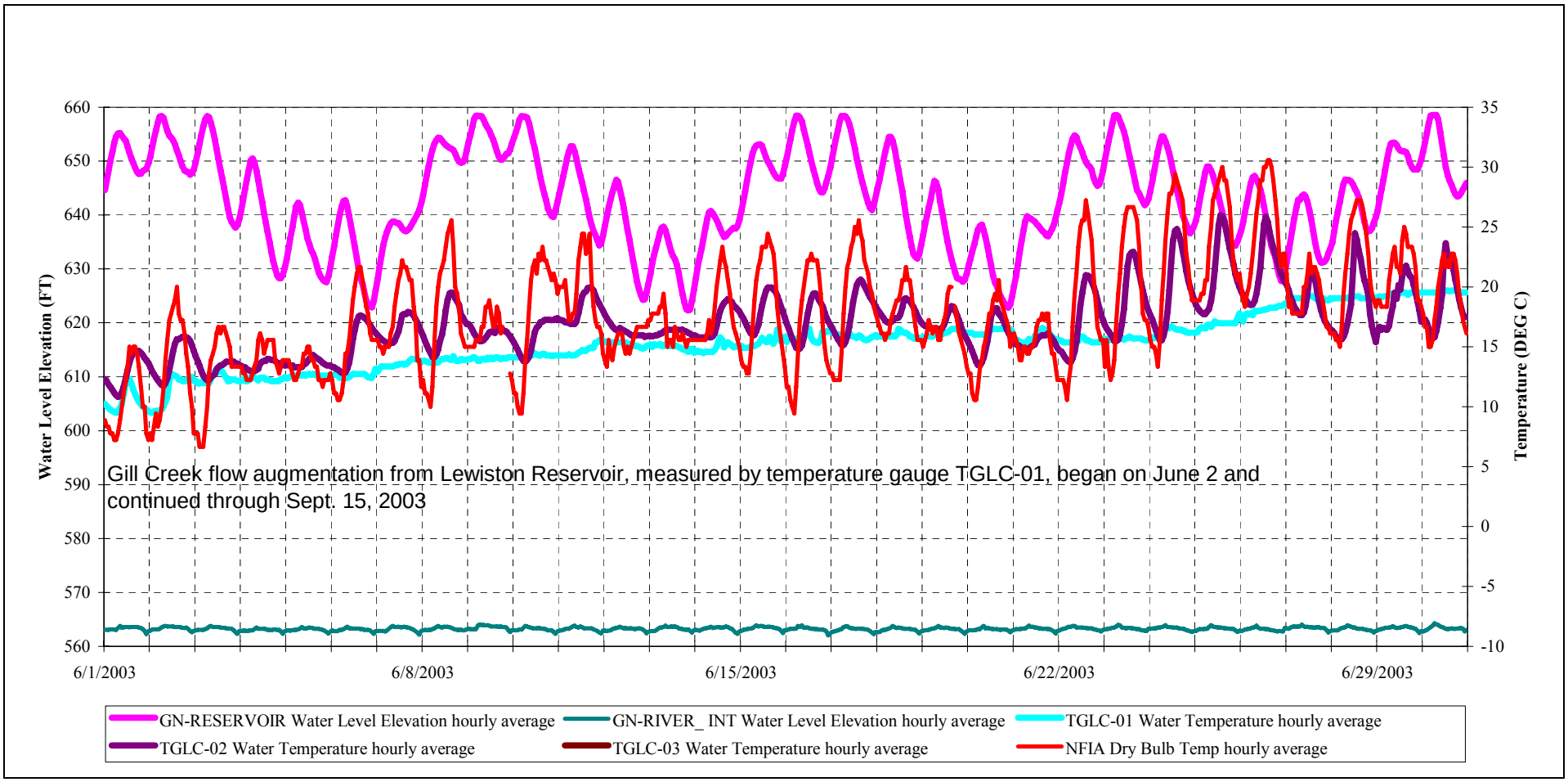

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FIGURE B-229: GILL CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

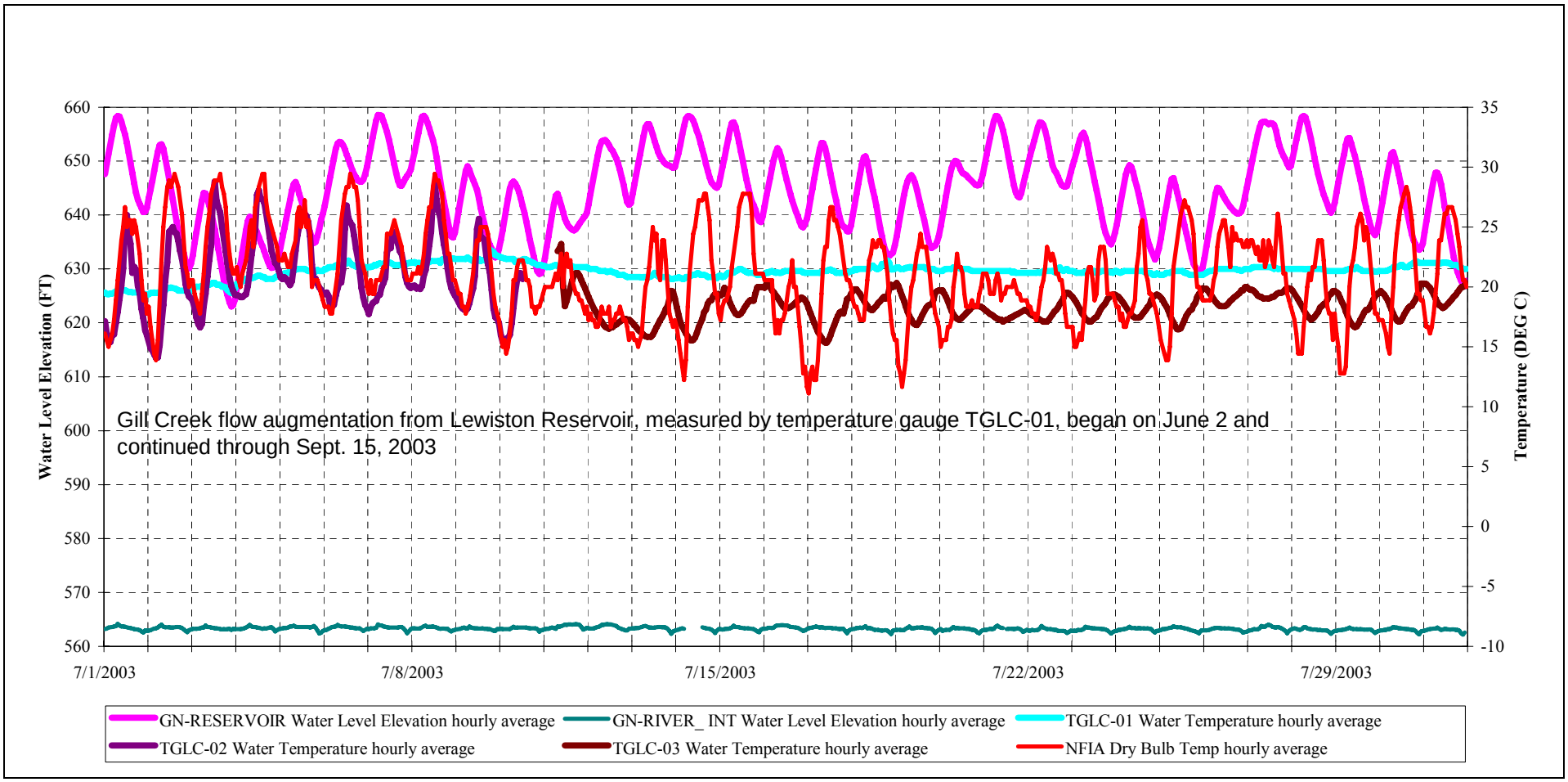

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FIGURE B-230: GILL CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

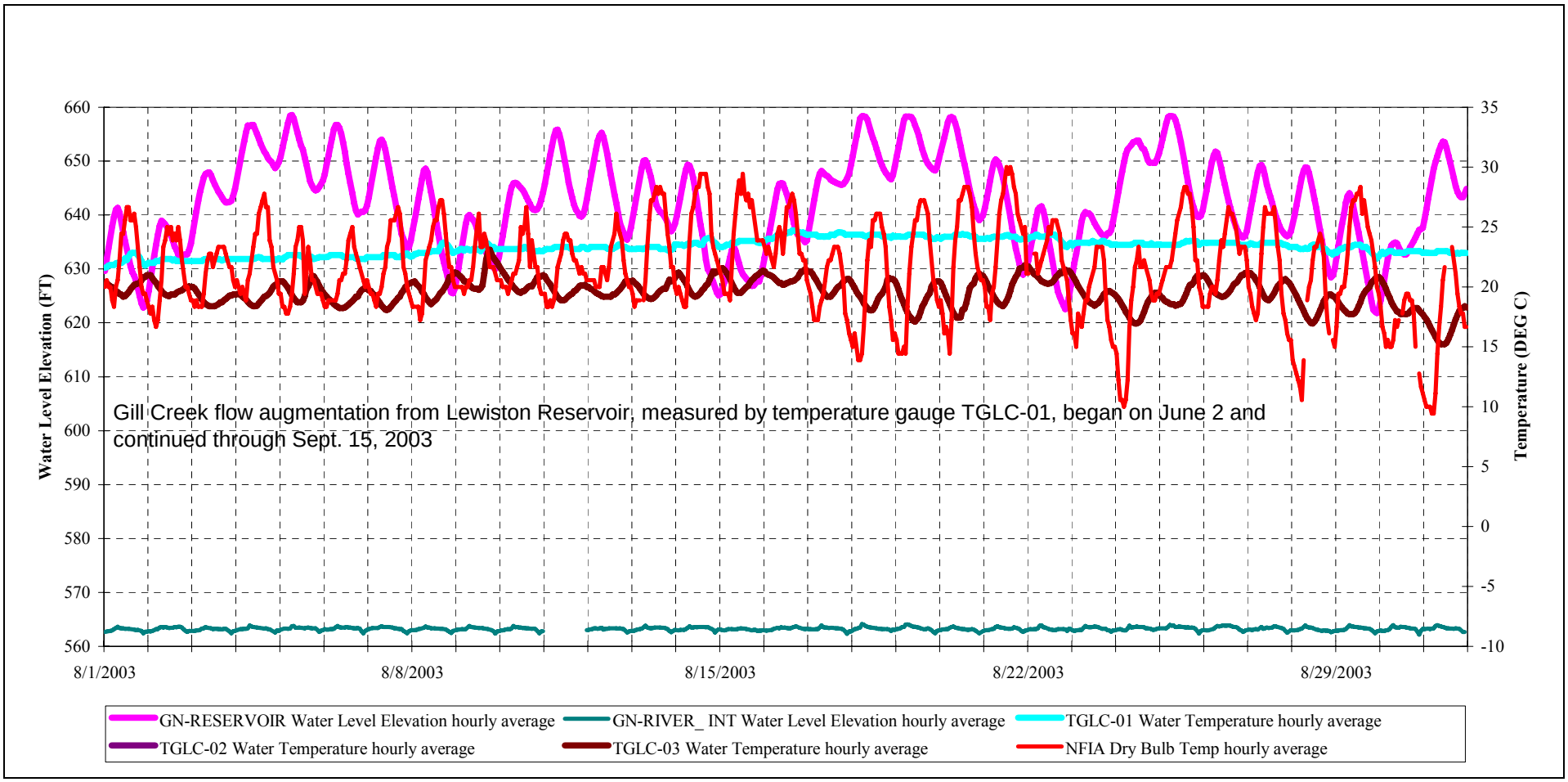

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FIGURE B-231: GILL CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

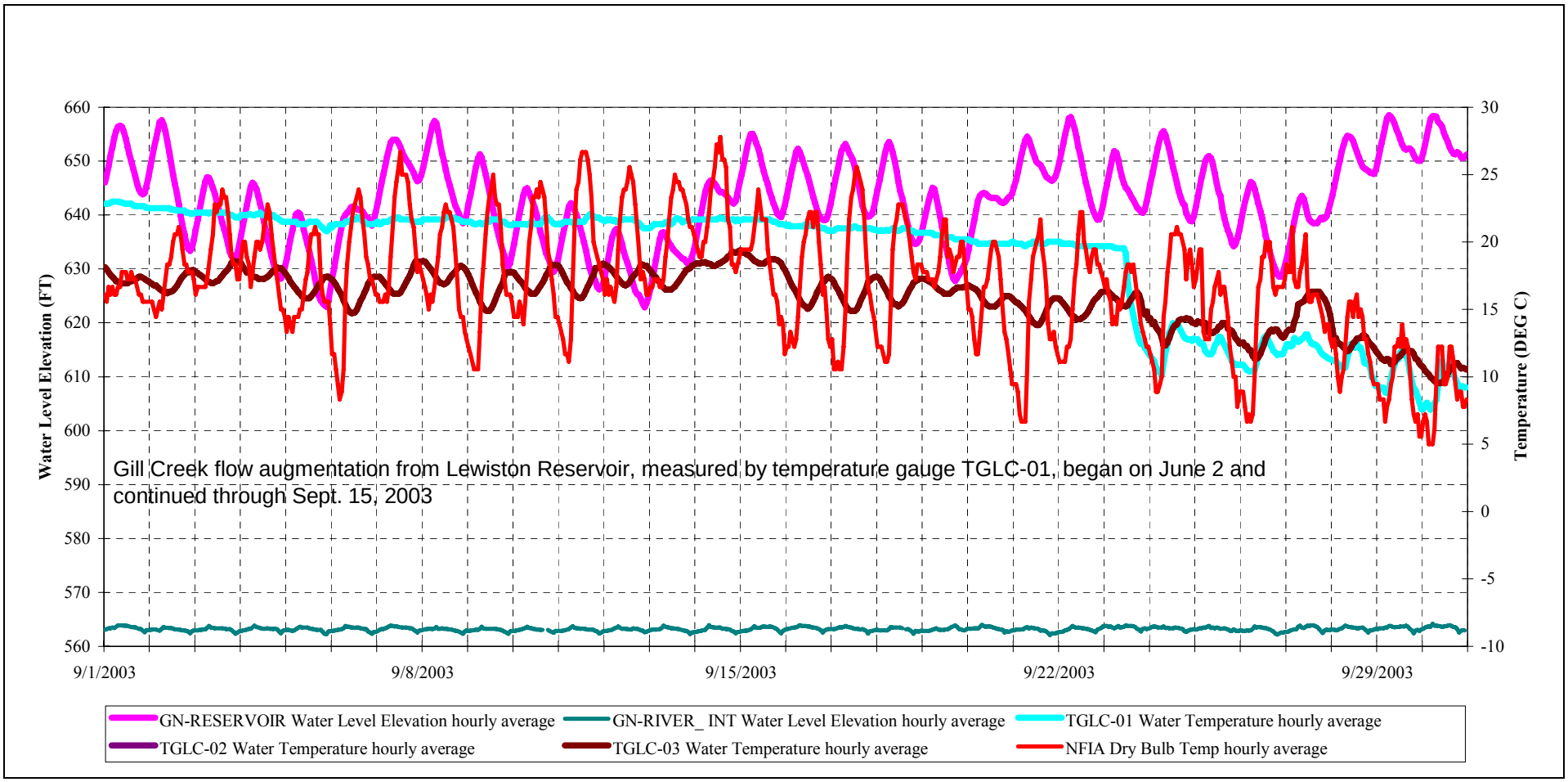

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FIGURE B-232: GILL CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

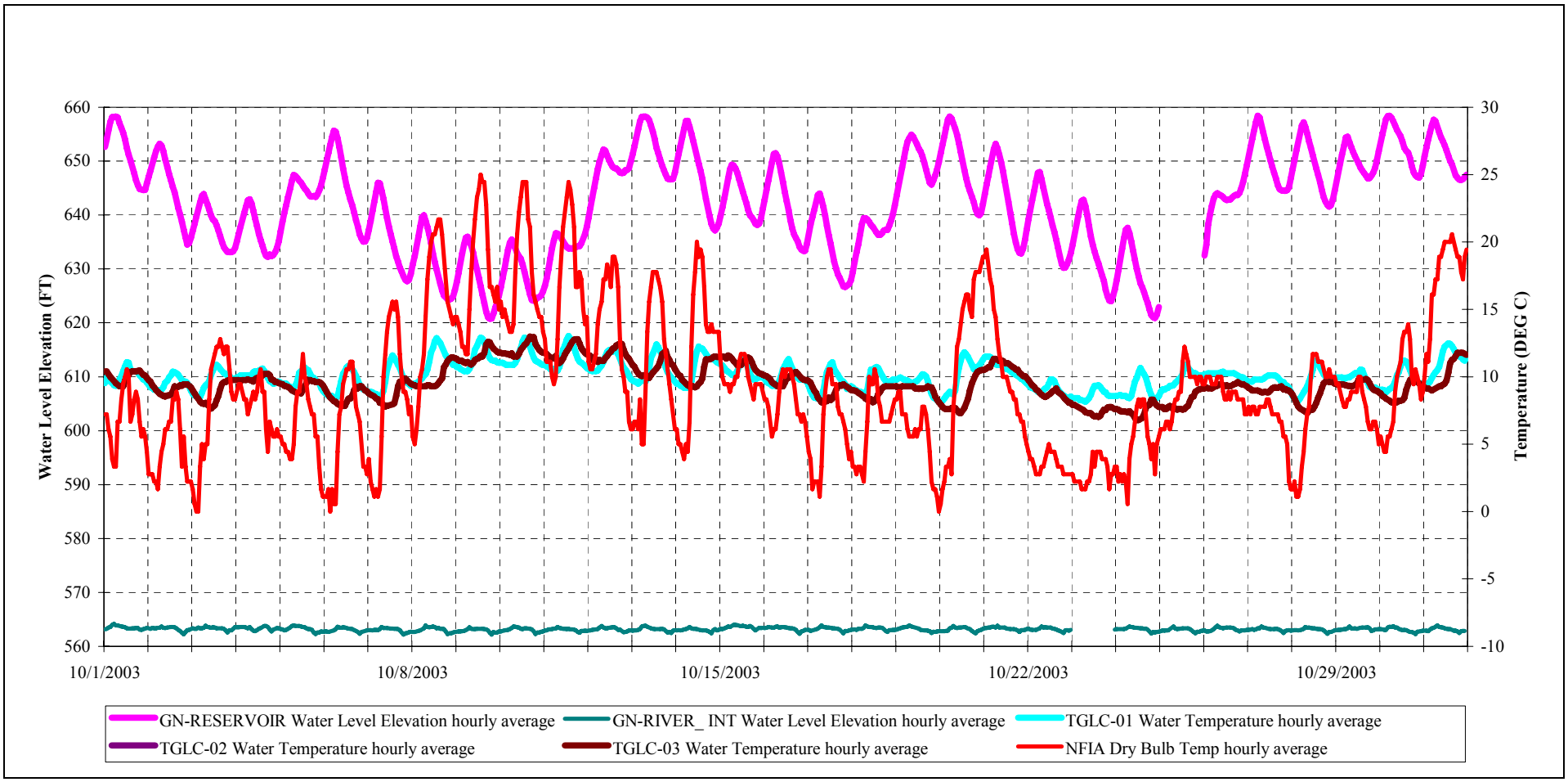

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FIGURE B-233: GILL CREEK

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

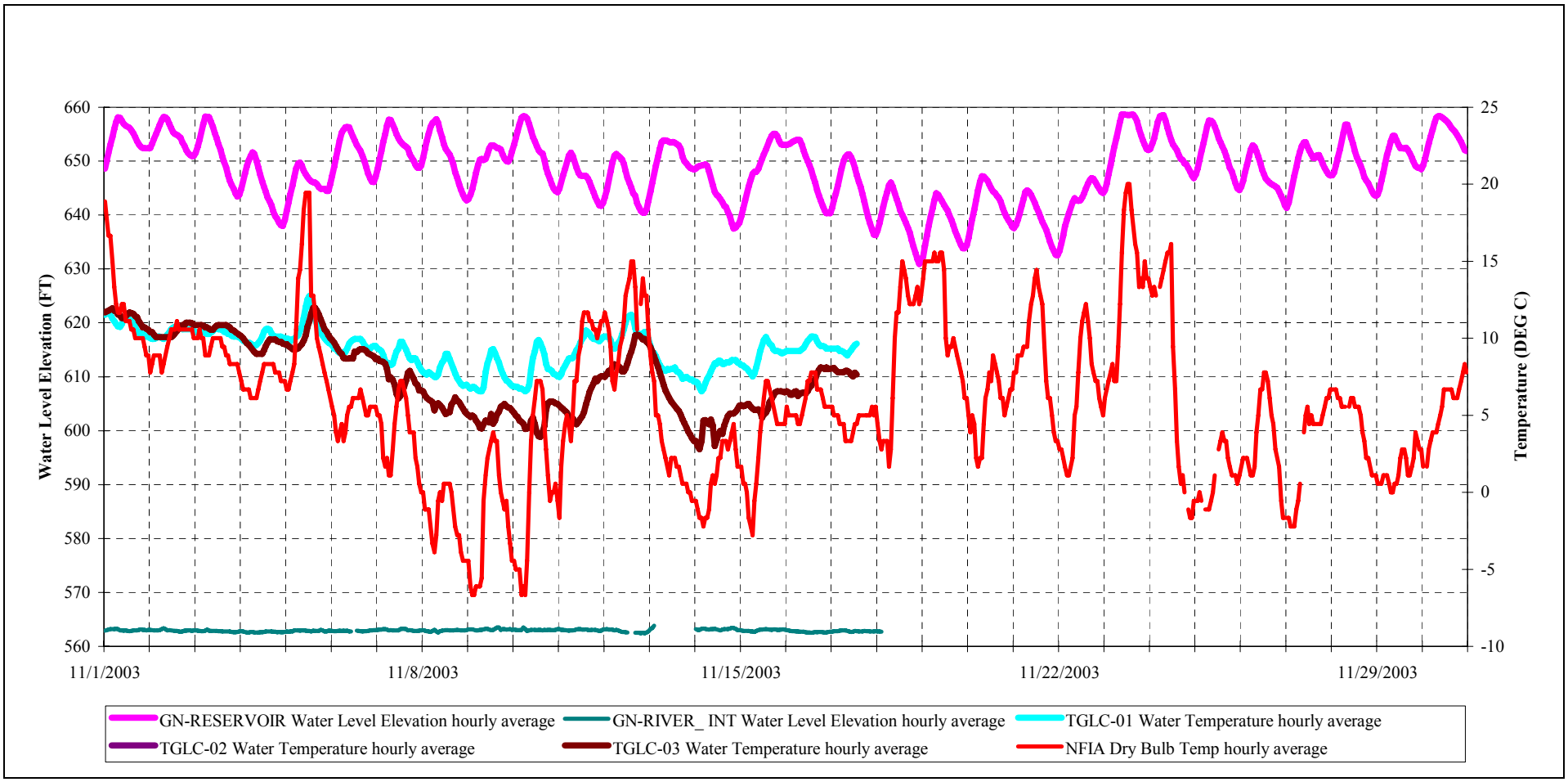

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FIGURE B-234: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

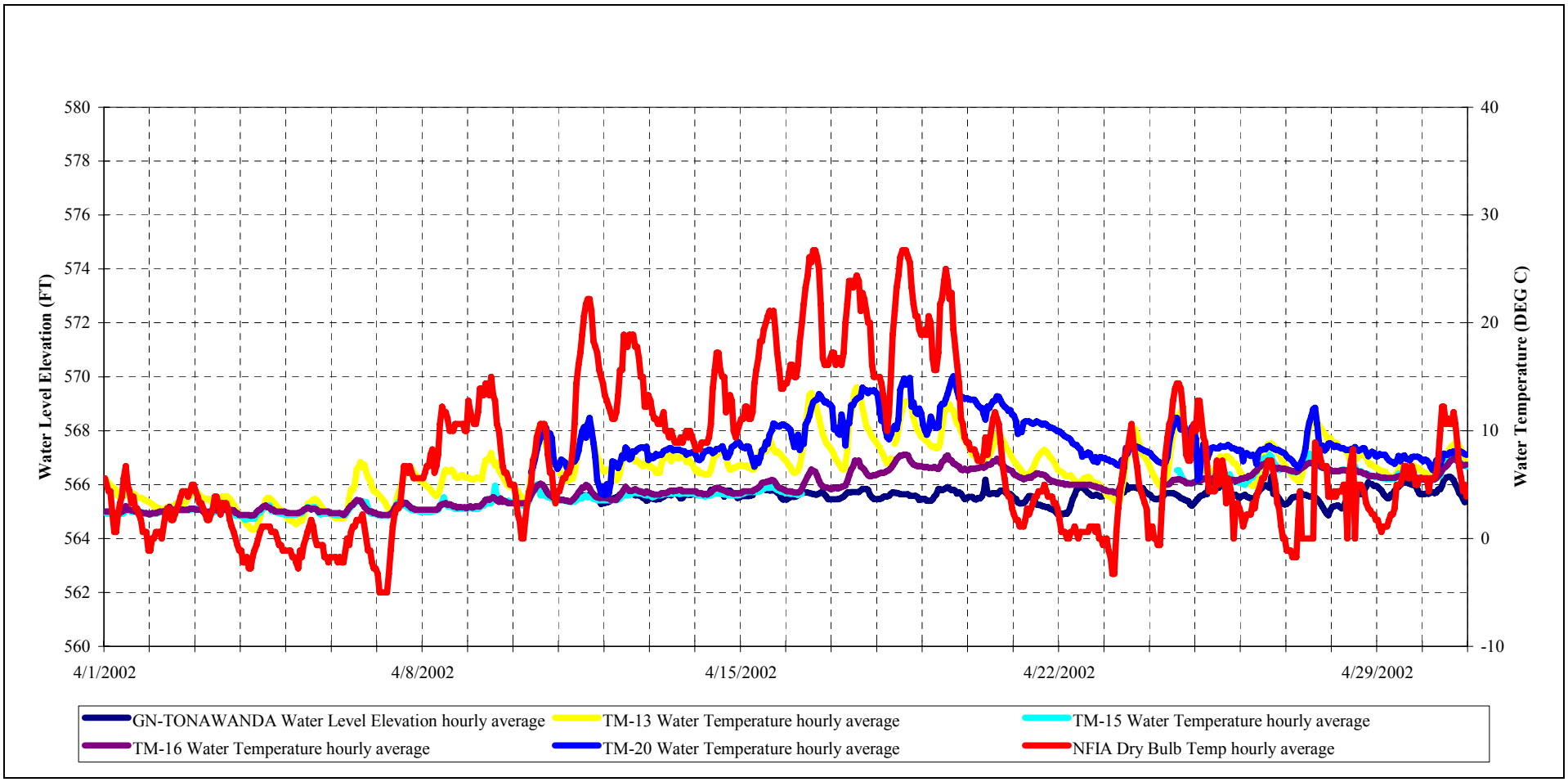

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FIGURE B-235: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

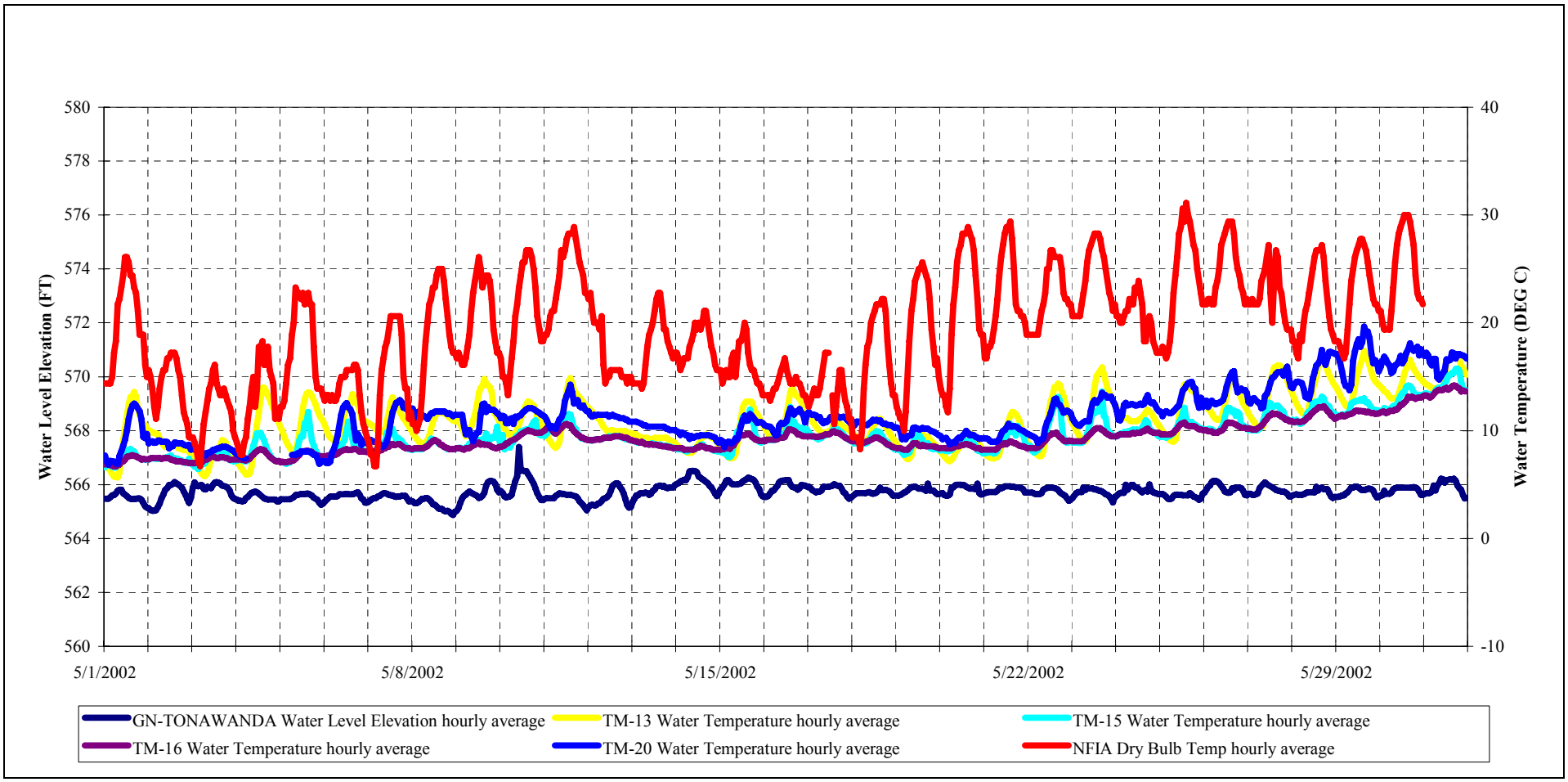

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FIGURE B-236: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

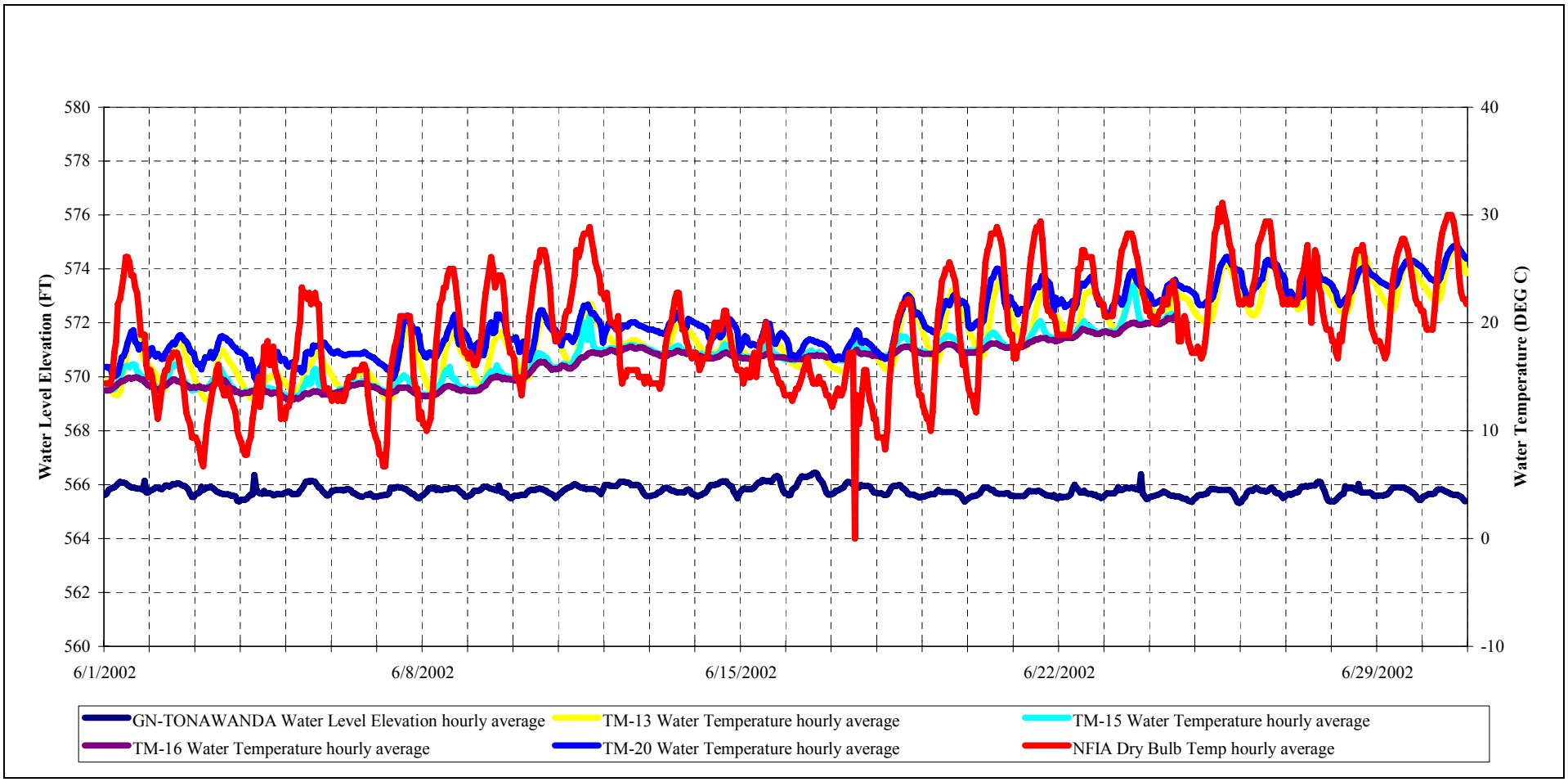

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FIGURE B-237: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

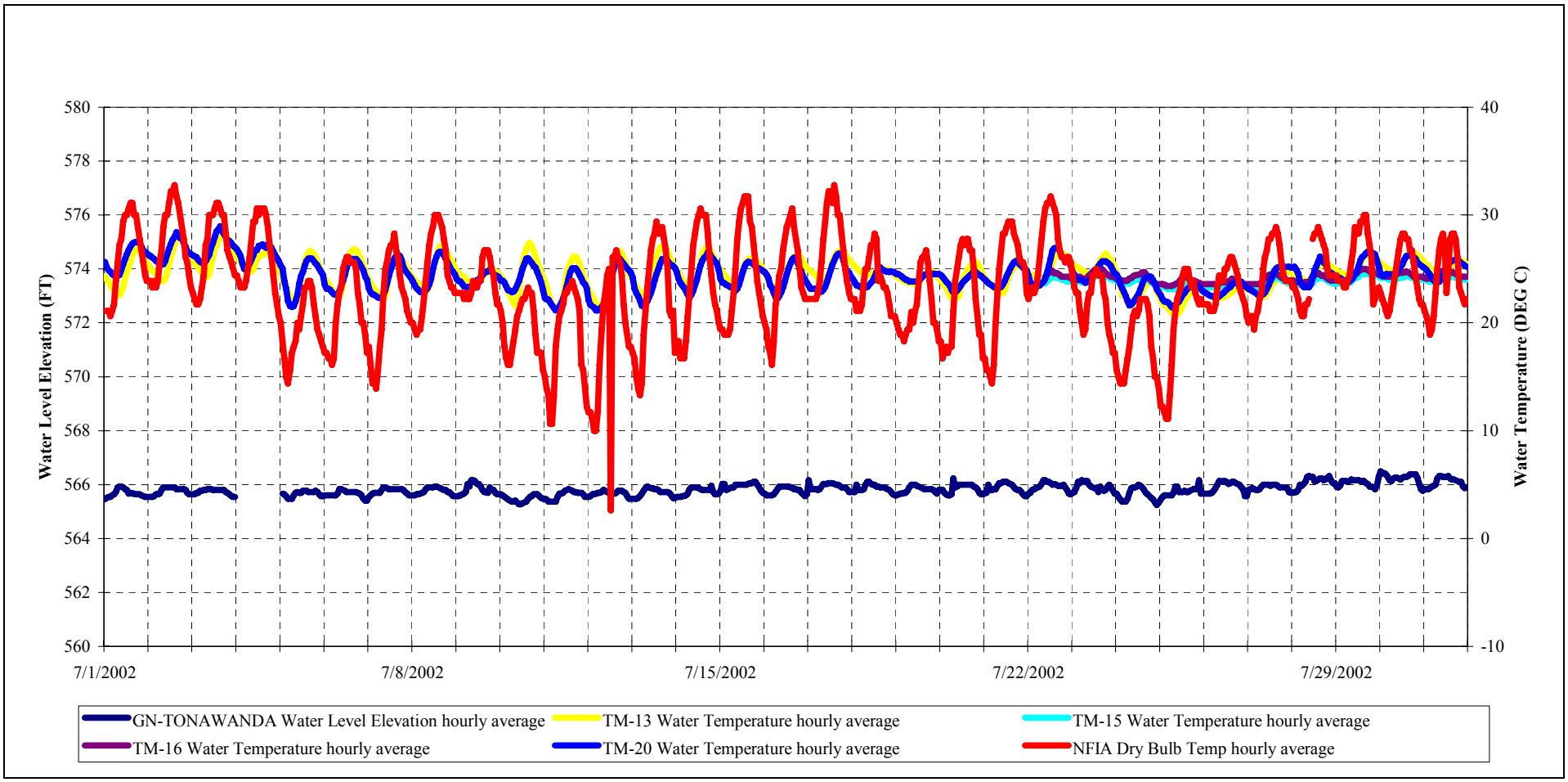

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FIGURE B-238: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

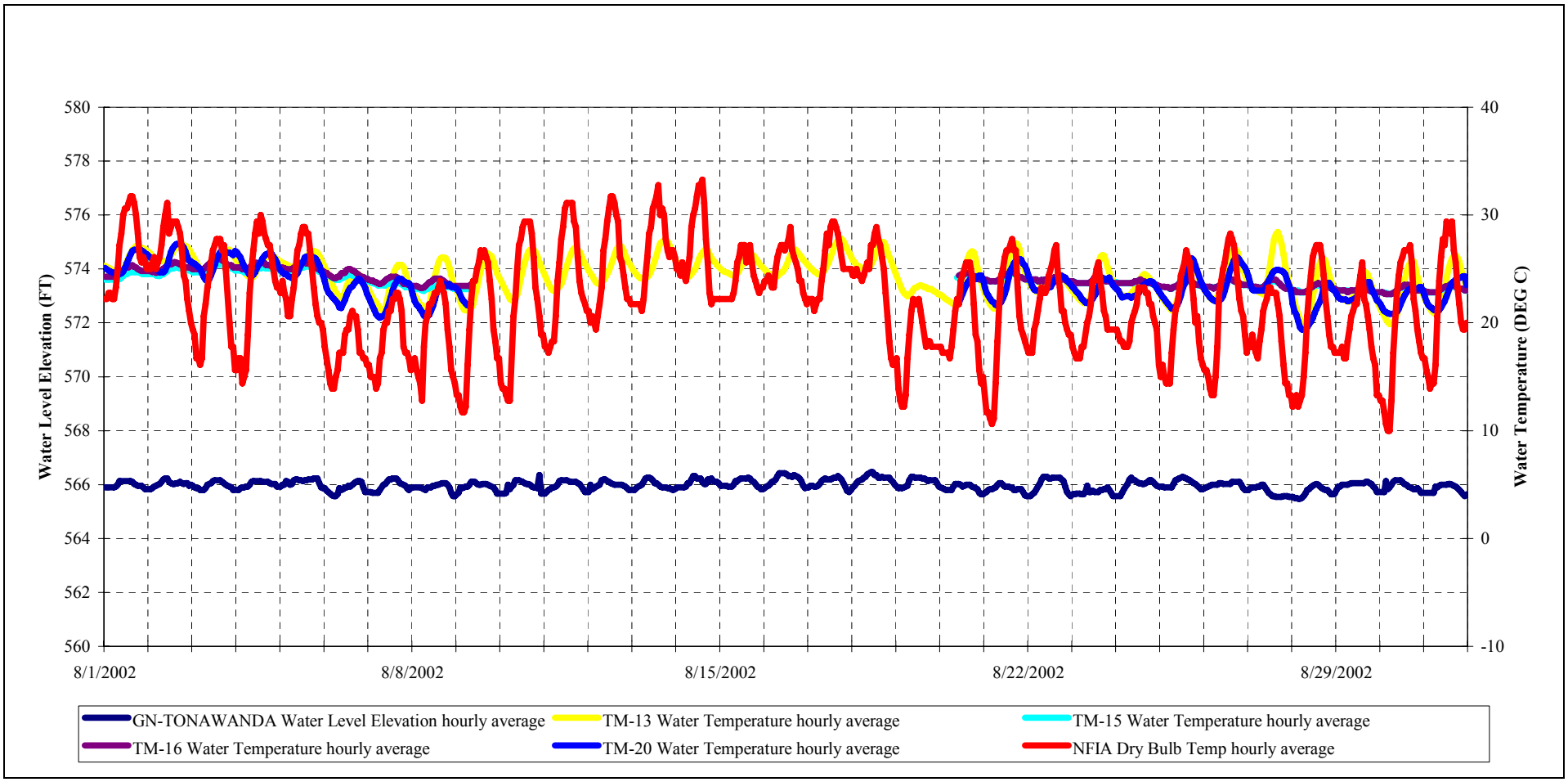

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FIGURE B-239: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

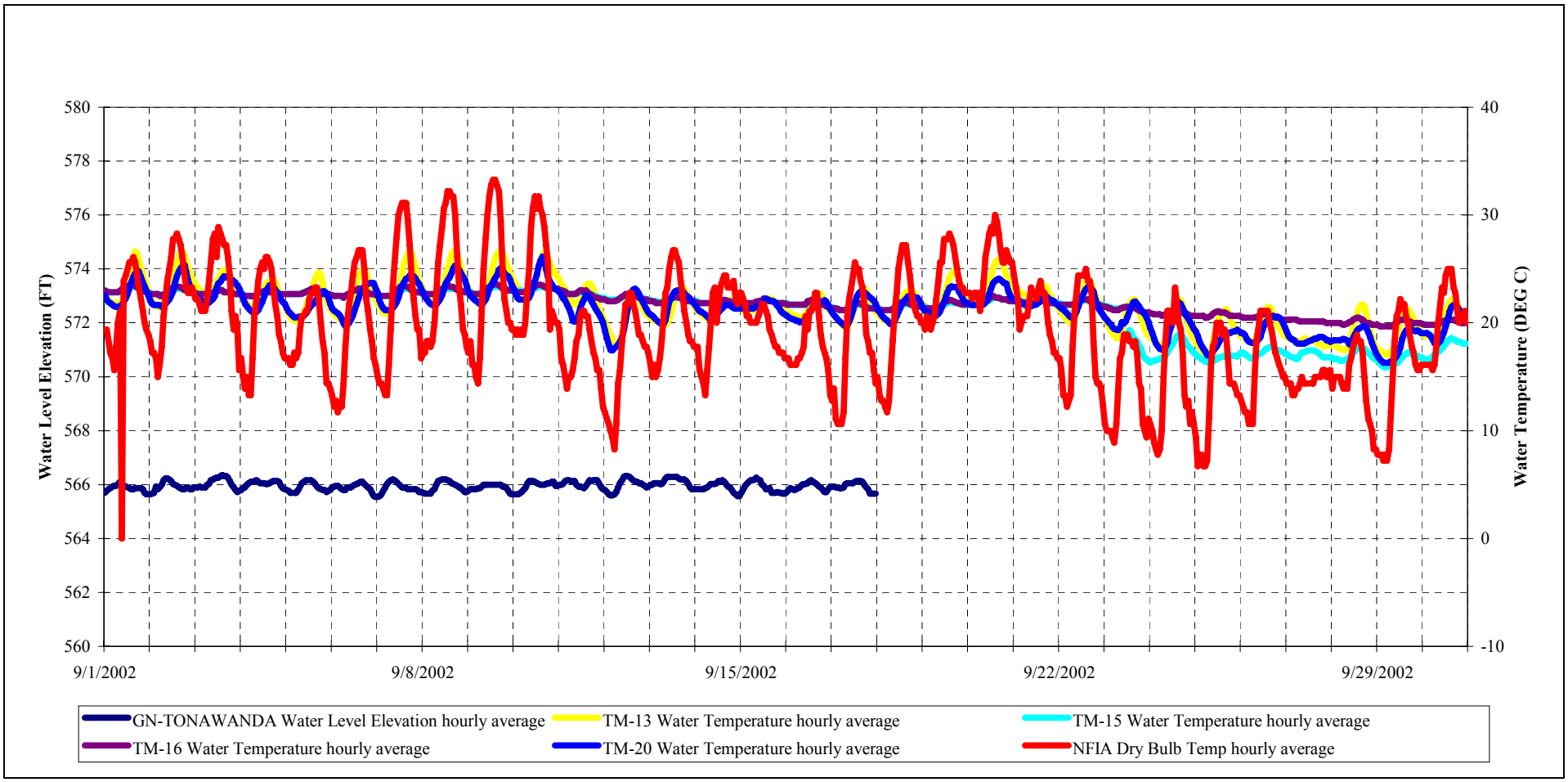

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FIGURE B-240: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

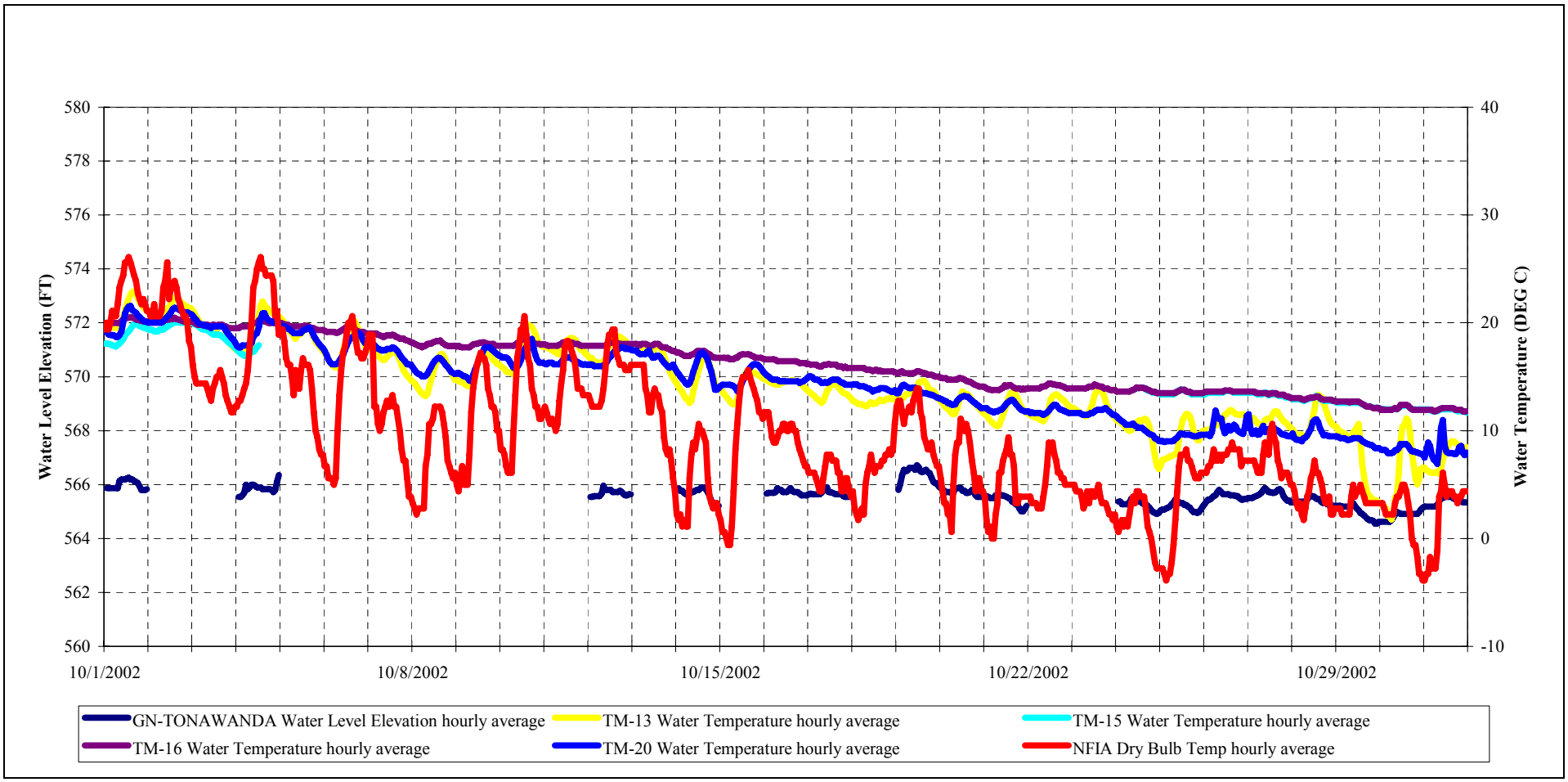

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FIGURE B-241: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

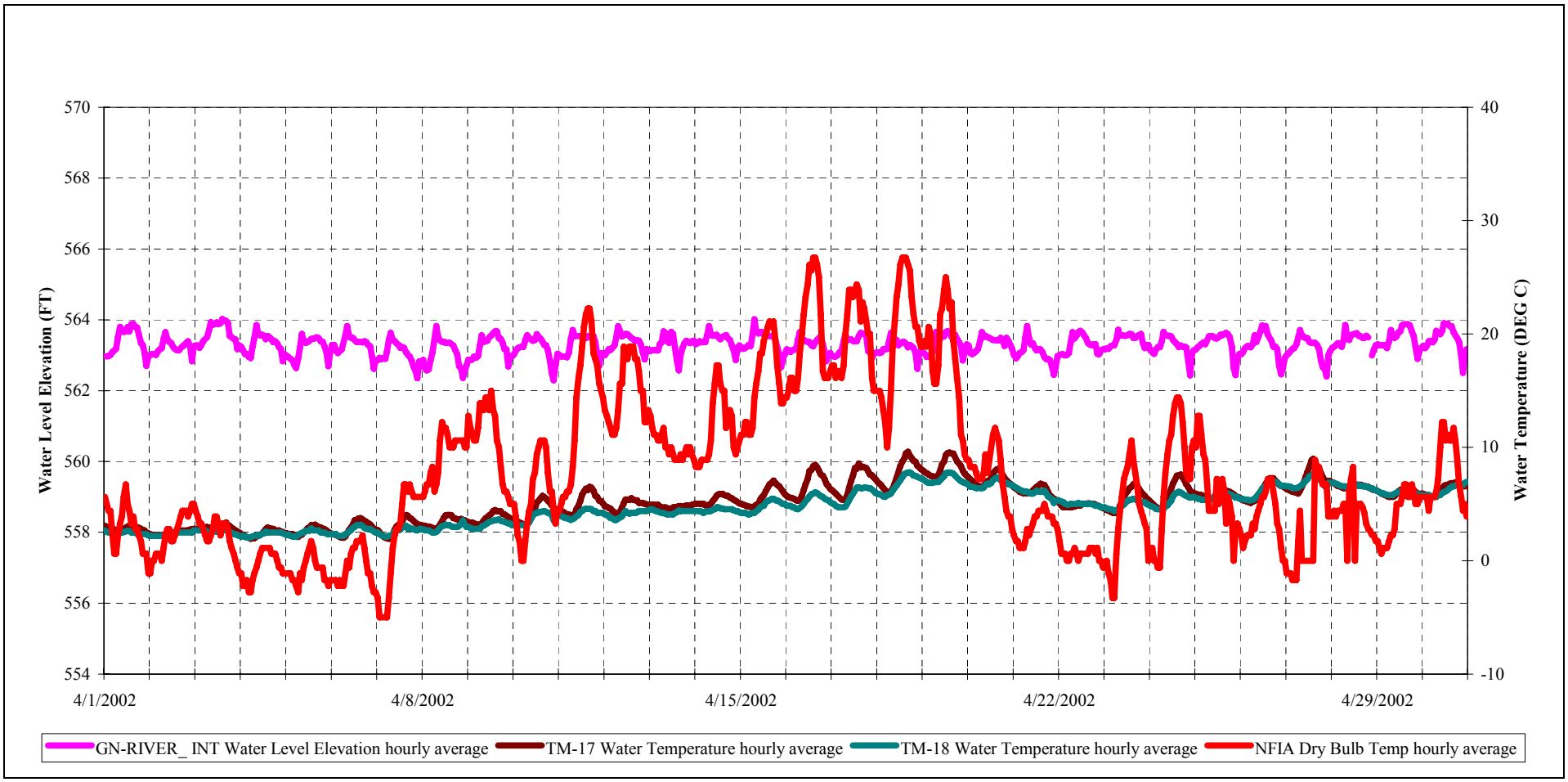

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FIGURE B-242: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

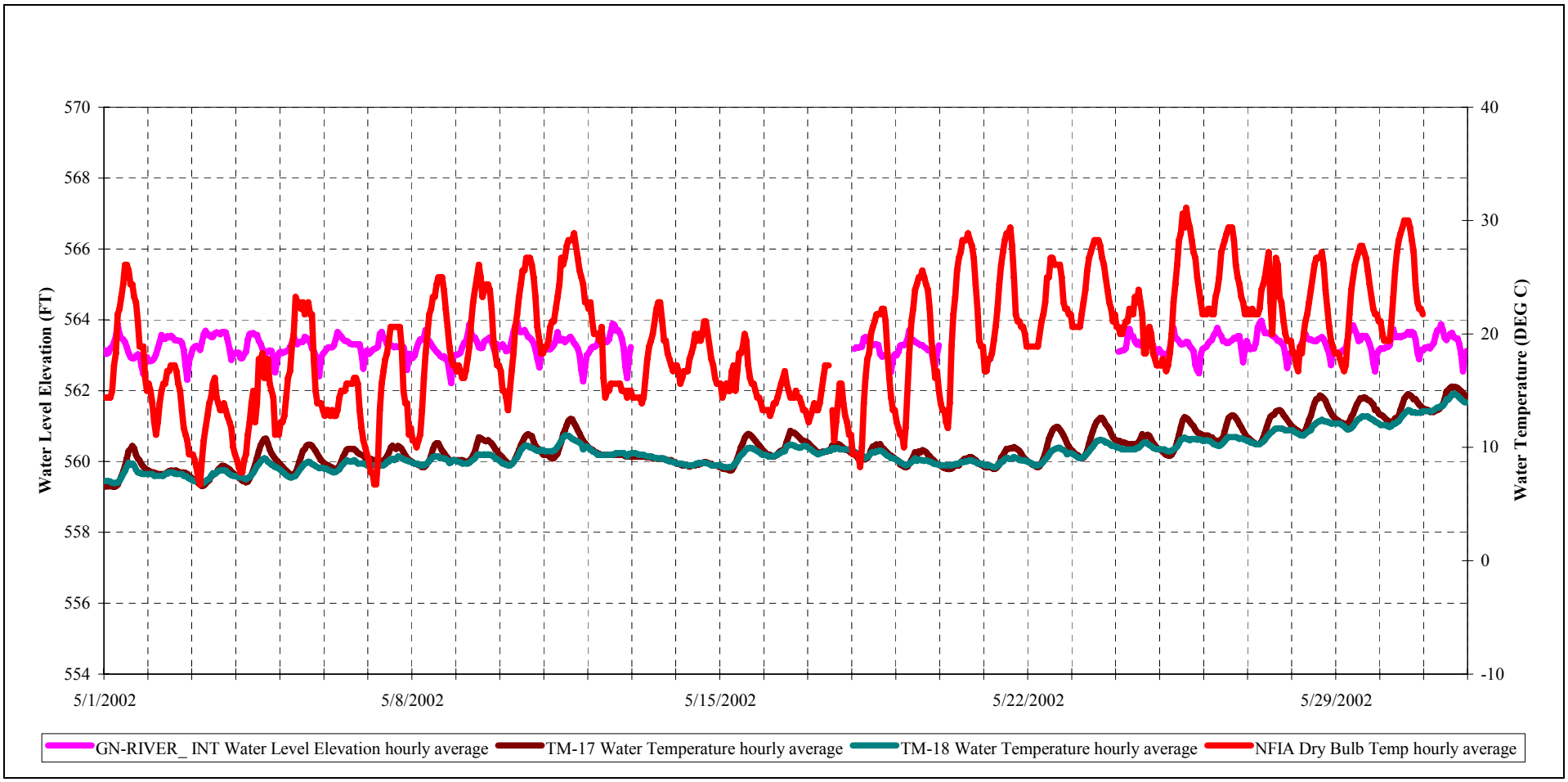

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FIGURE B-243: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

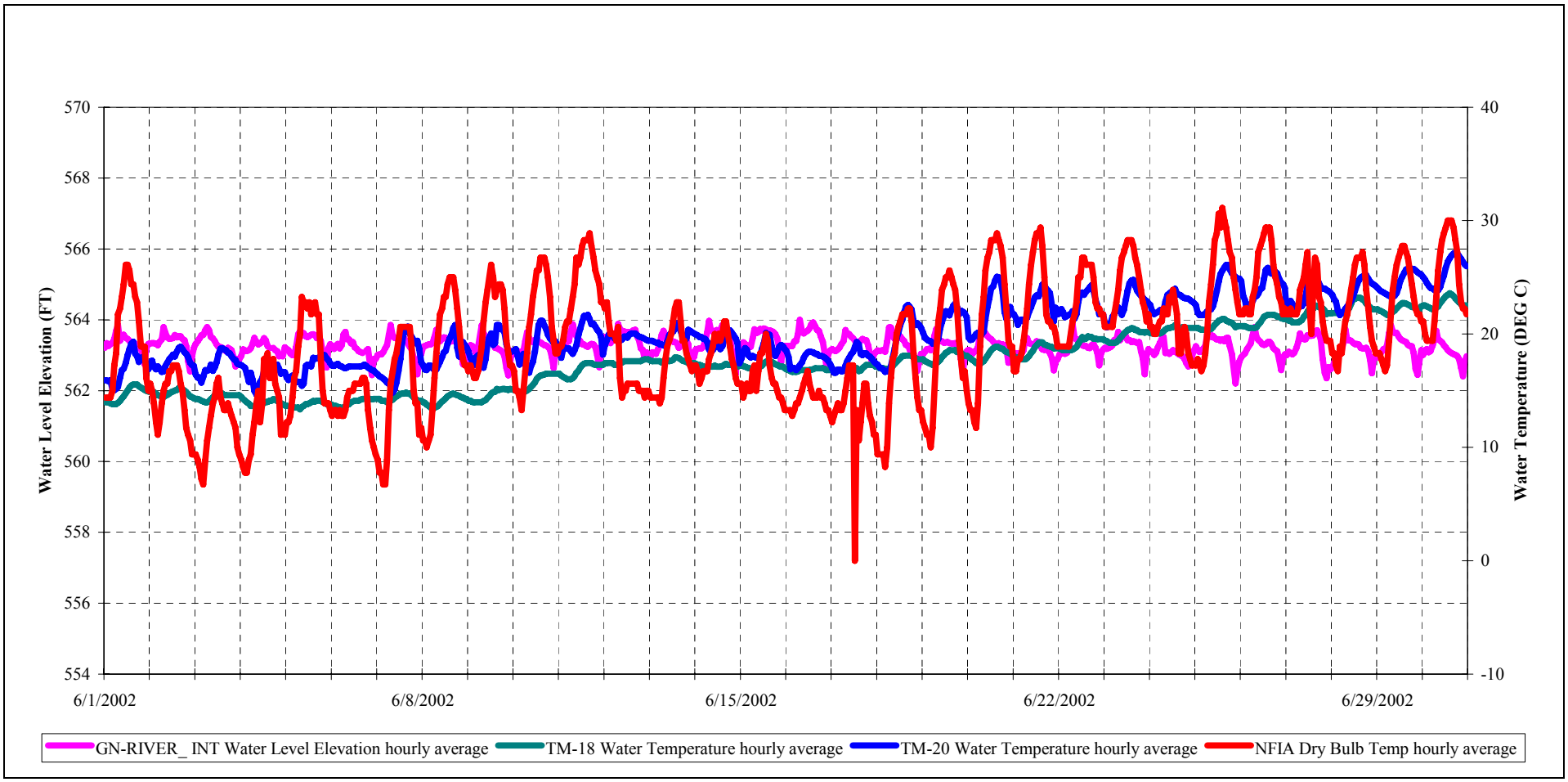

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FIGURE B-244: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

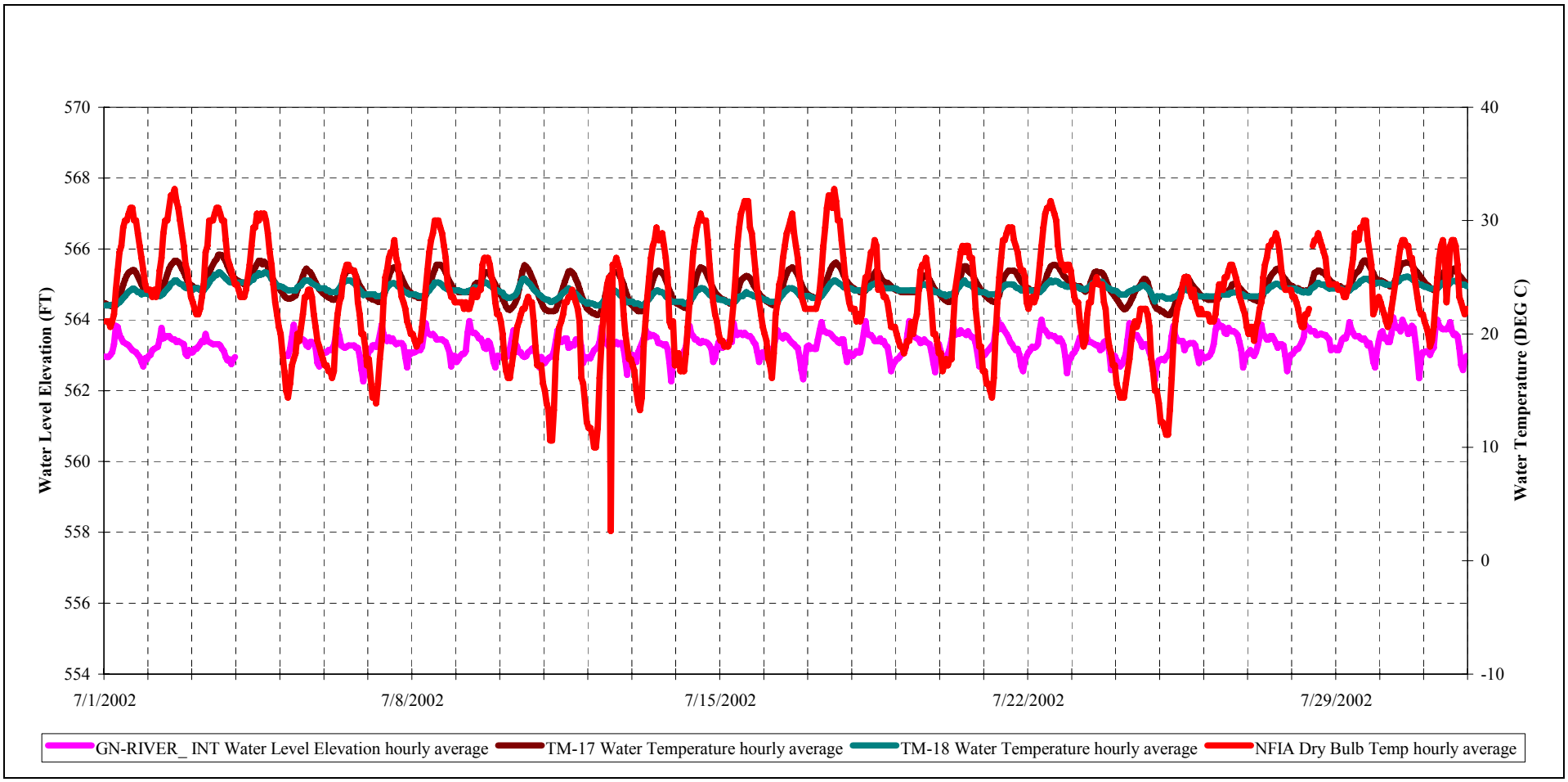

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FIGURE B-245: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

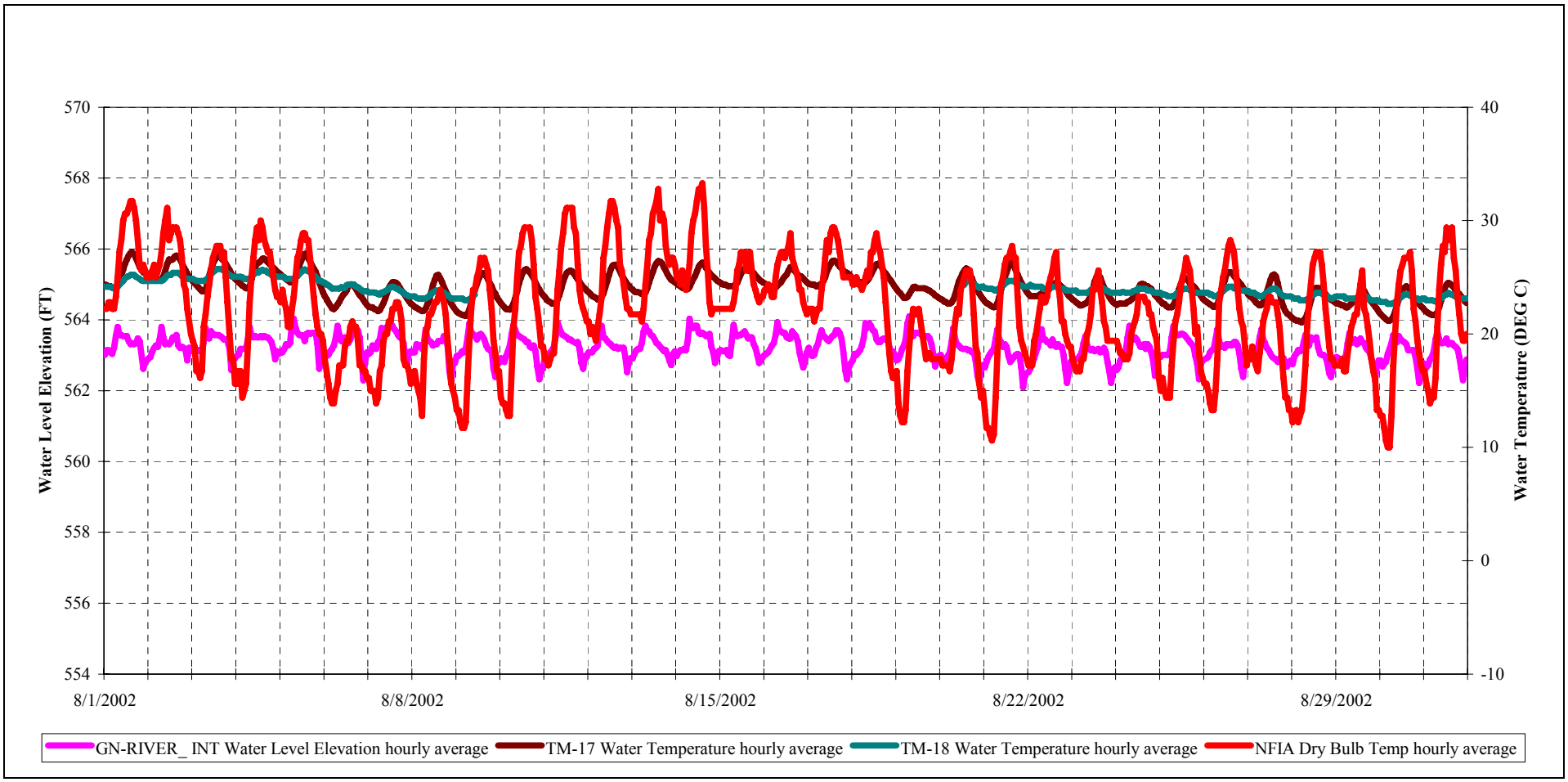

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FIGURE B-246: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

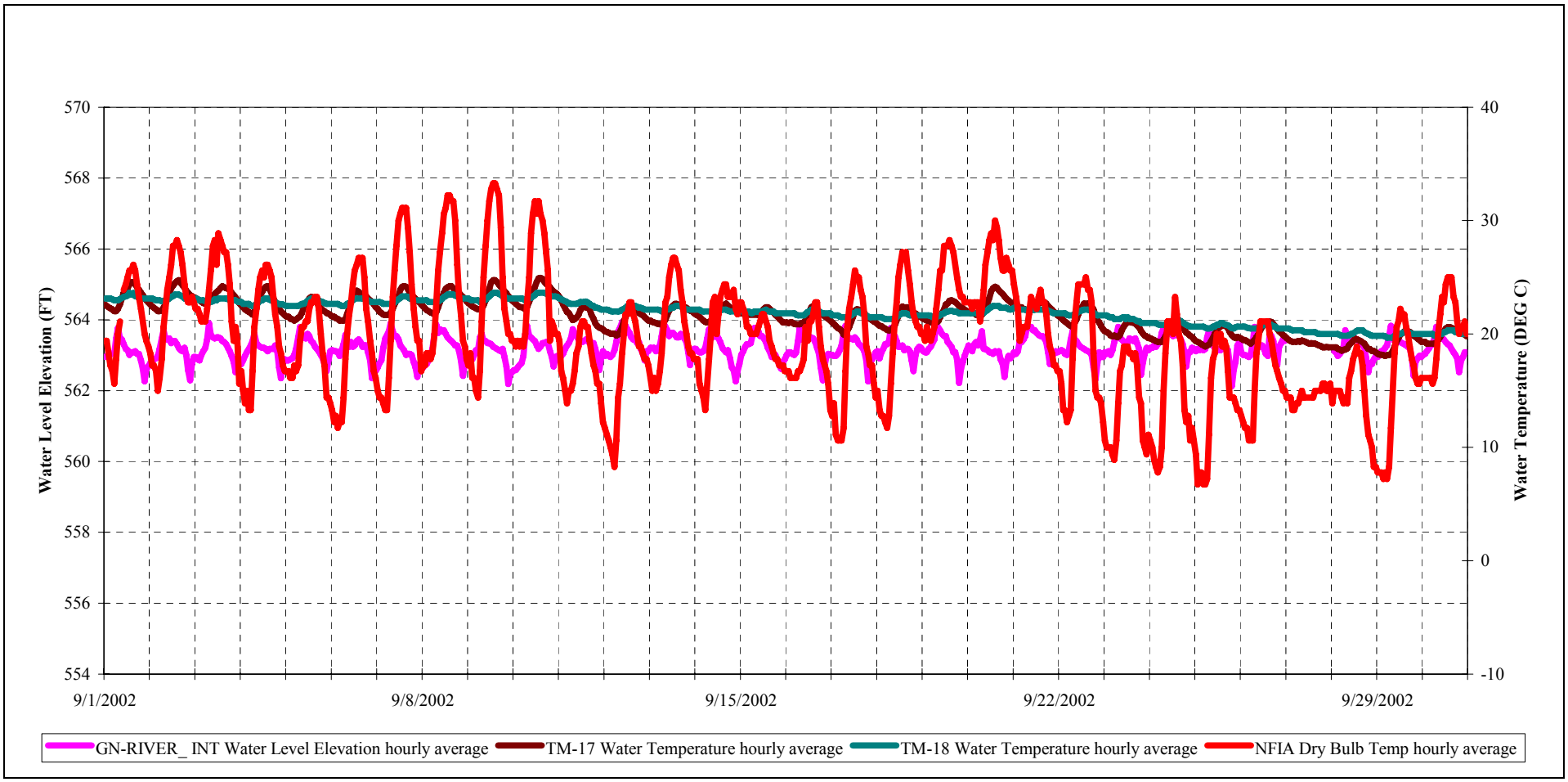

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FIGURE B-247: UPPER NIAGARA – MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

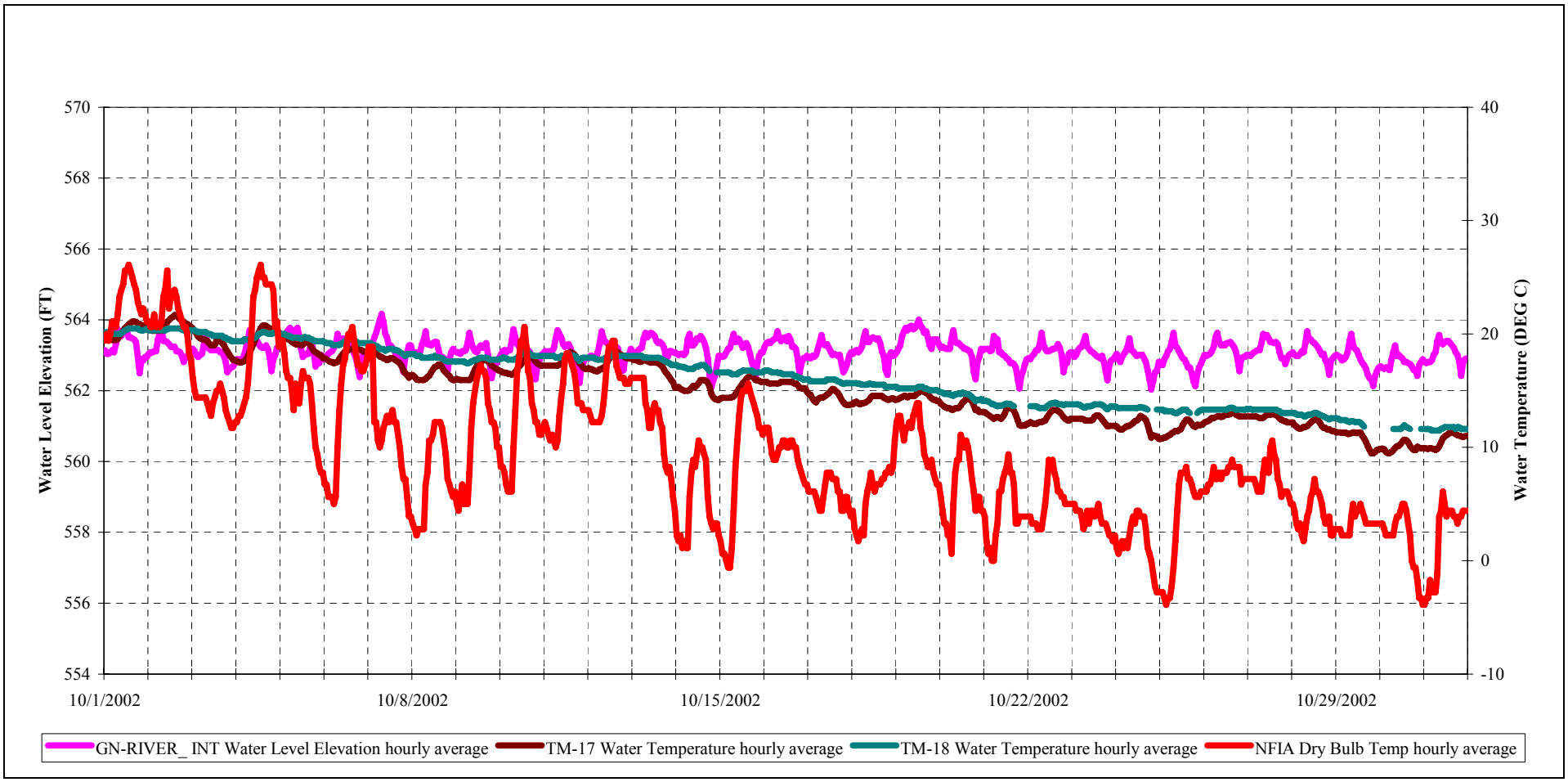

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FIGURE B-248: UPPER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

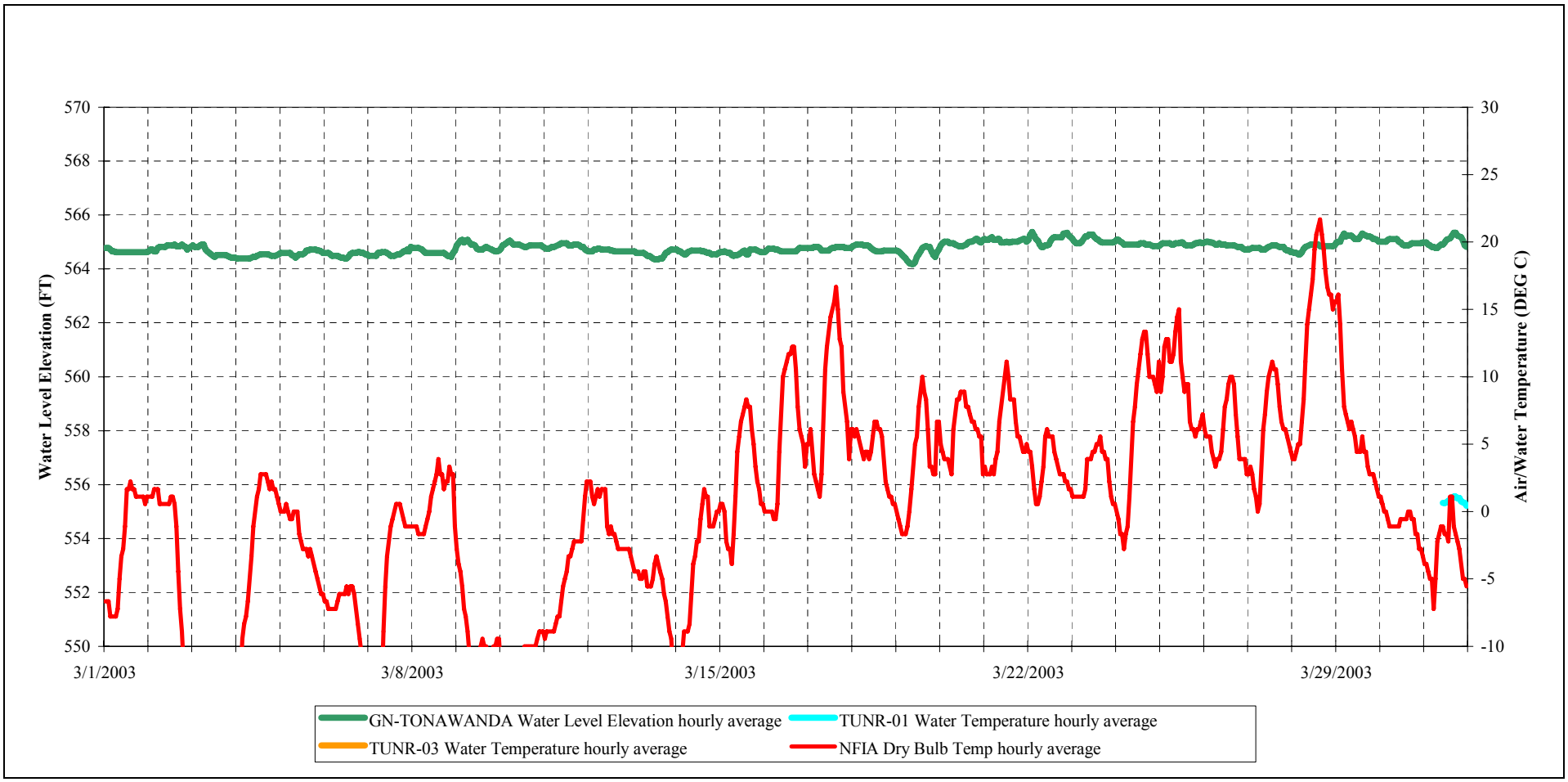

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FIGURE B-249: UPPER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

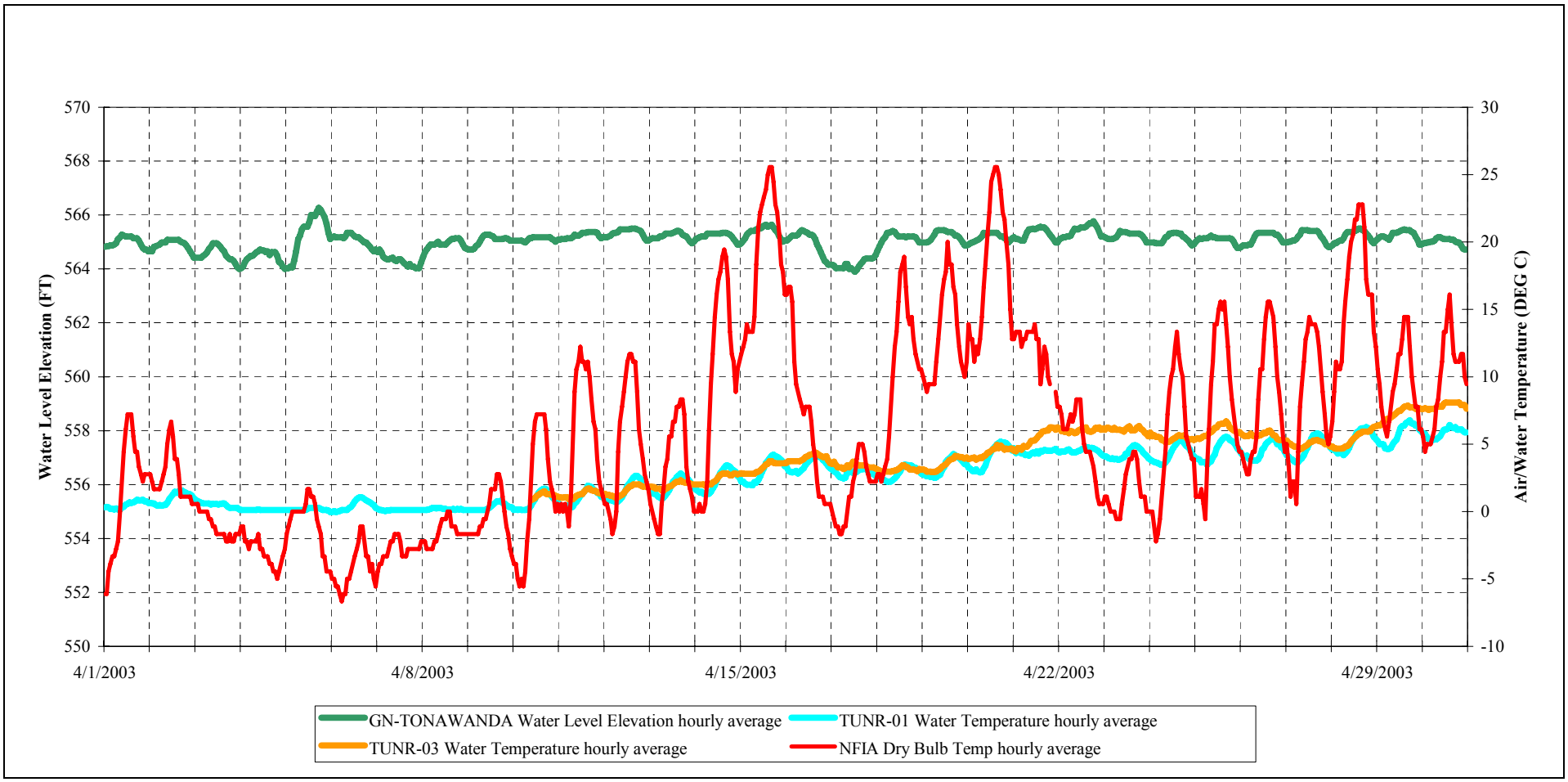

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FIGURE B-250: UPPER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

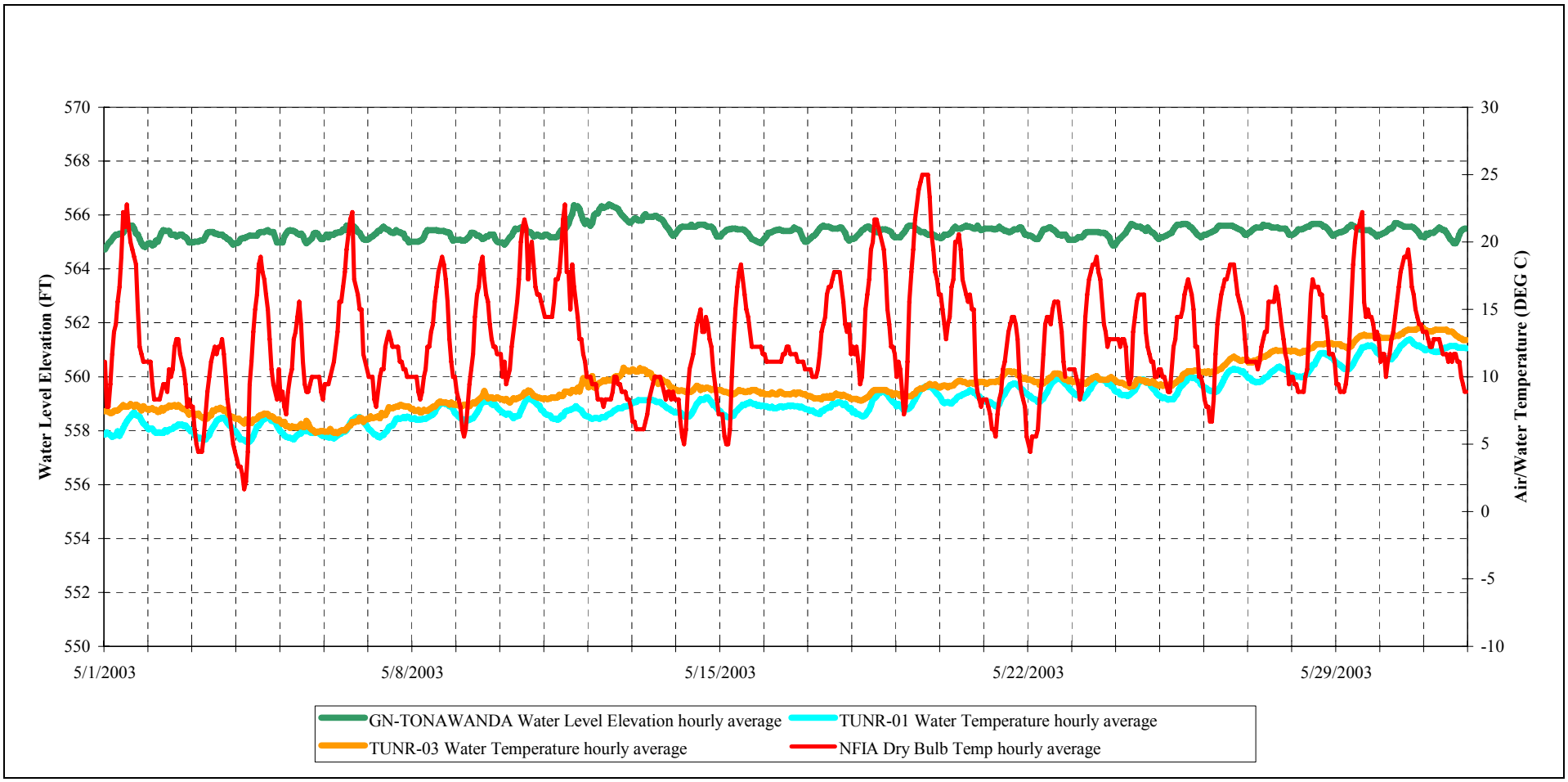

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FIGURE B-251: UPPER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

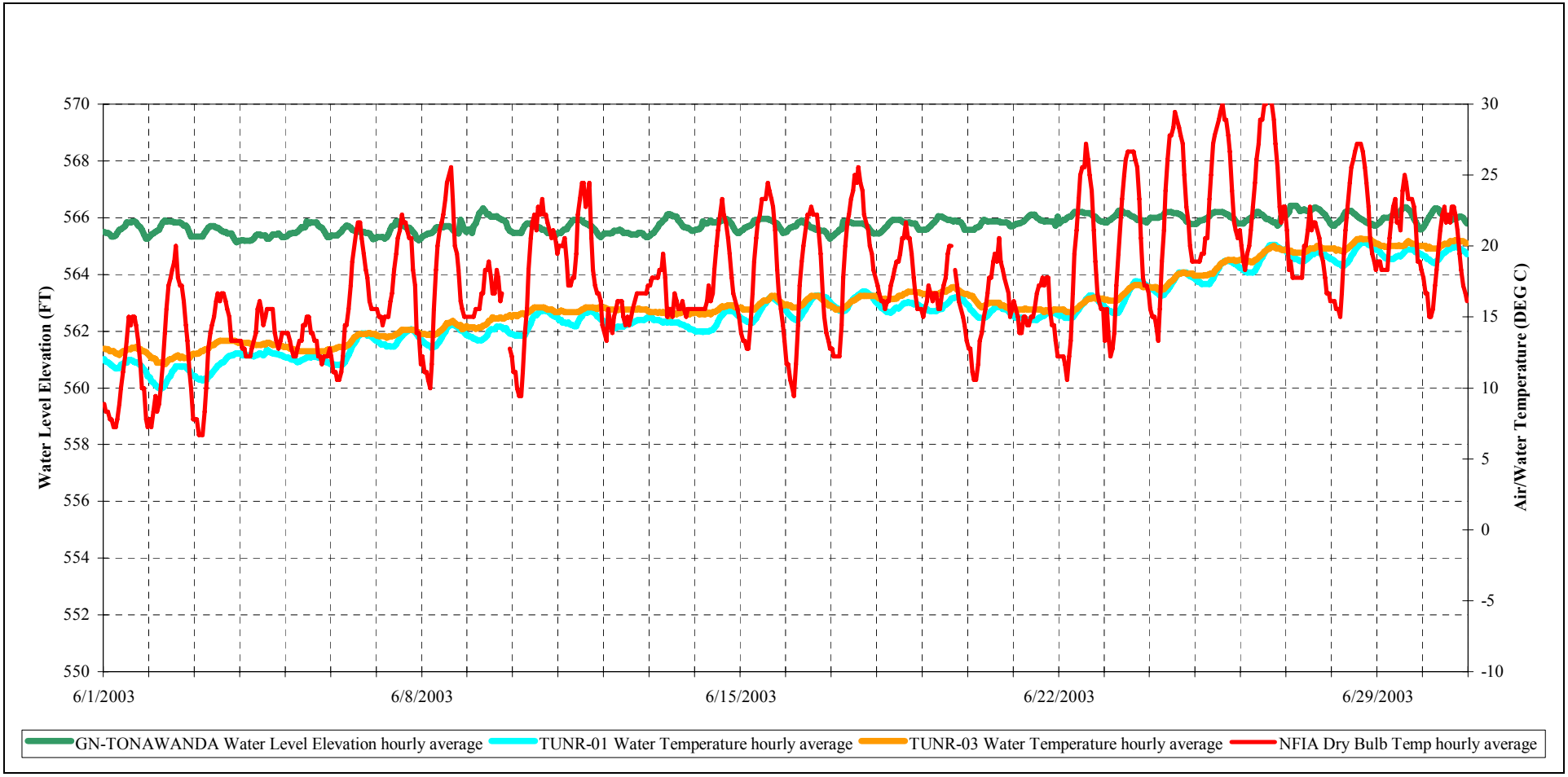

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FIGURE B-252: UPPER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

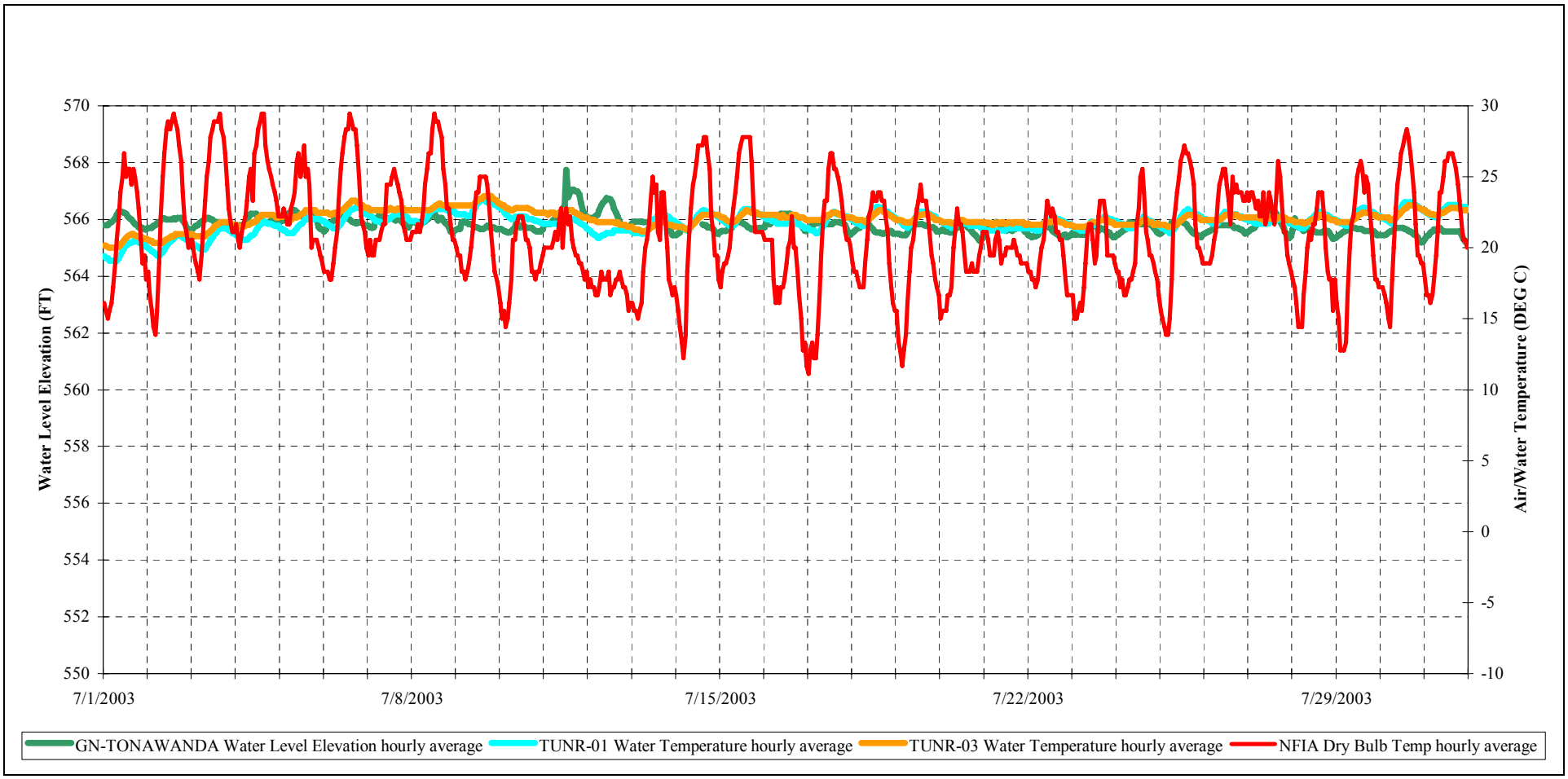

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FIGURE B-253: UPPER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

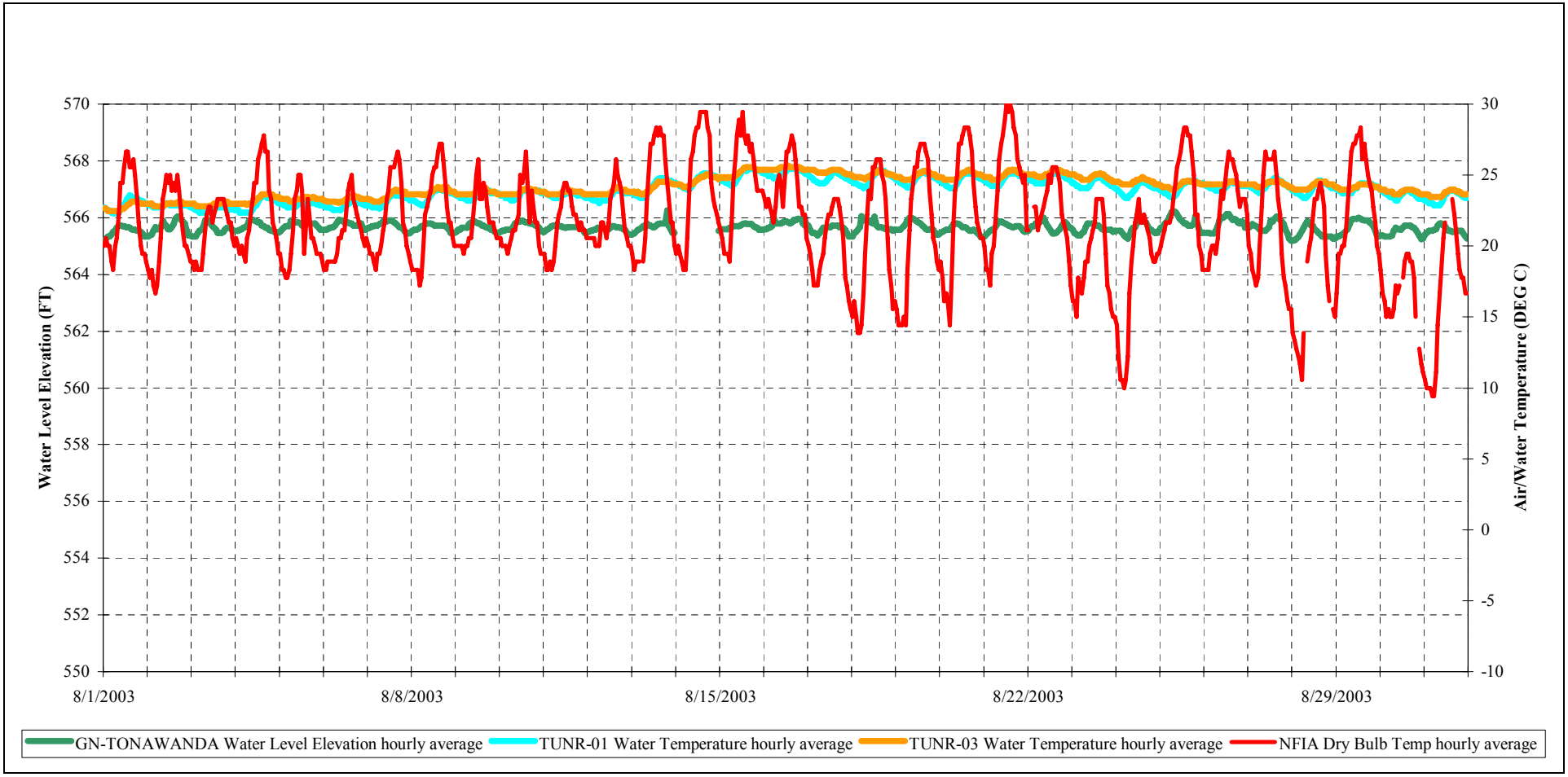

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FIGURE B-254: UPPER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

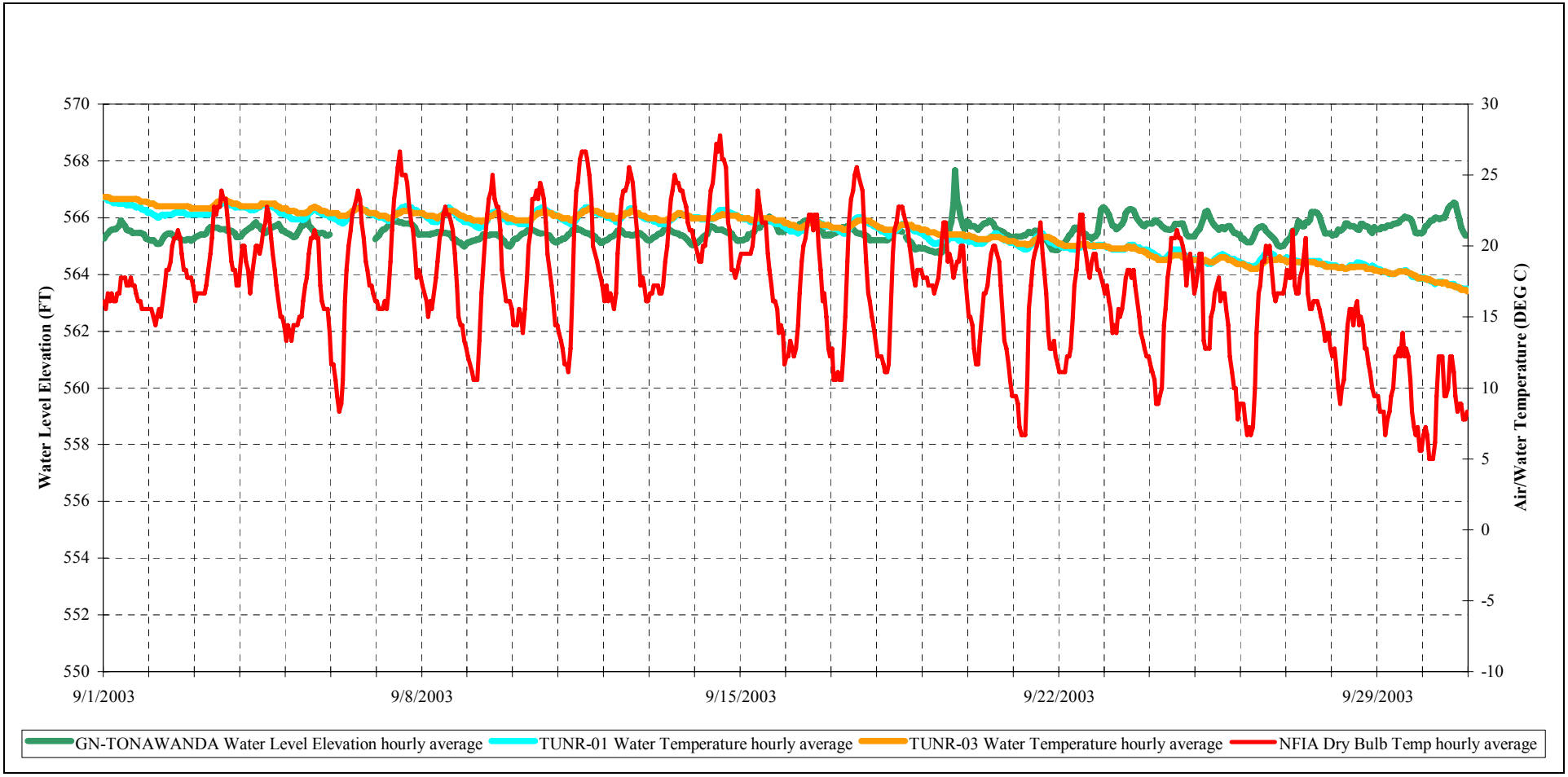

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FIGURE B-255: UPPER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

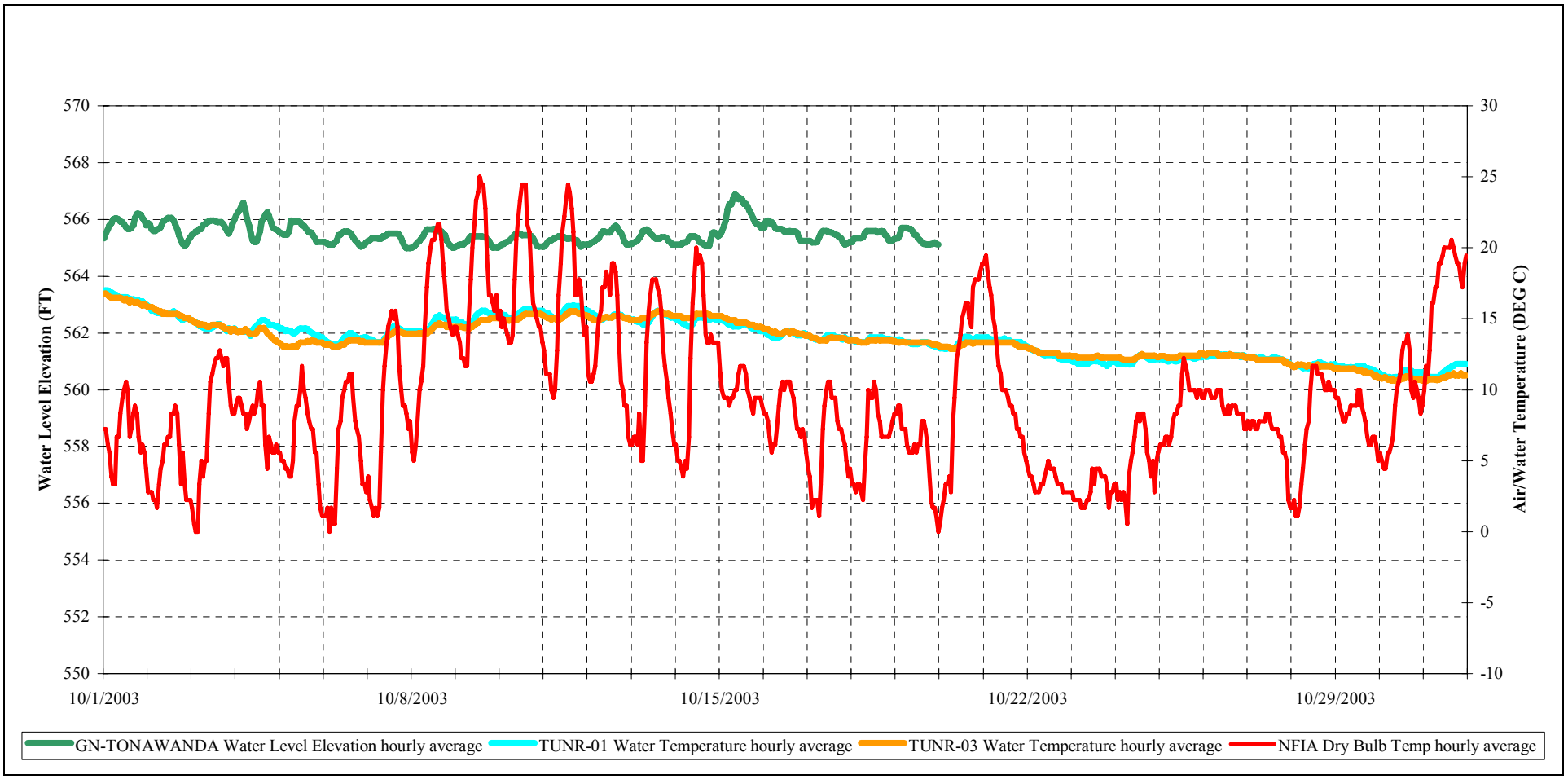

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FIGURE B-256: UPPER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

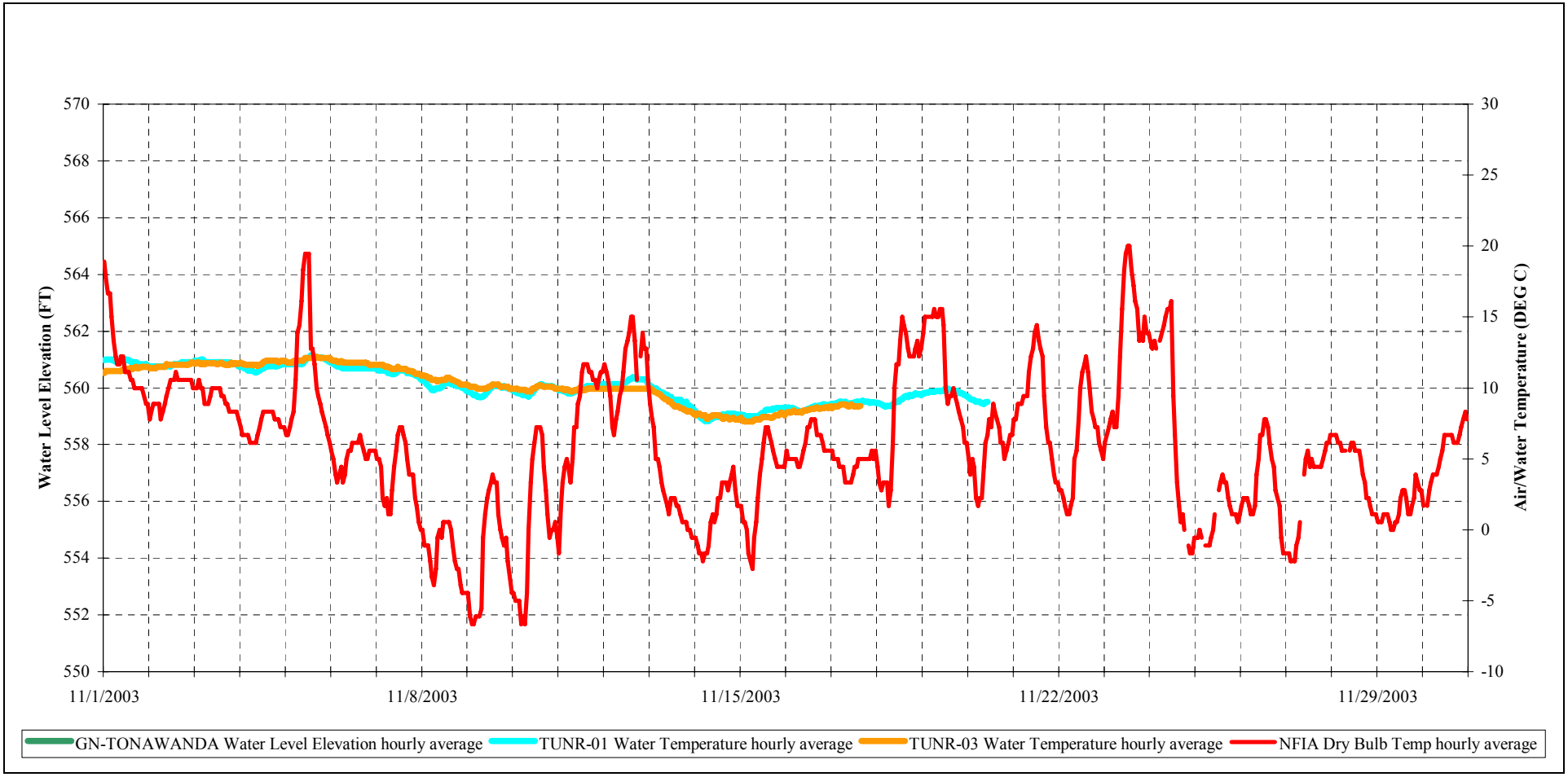

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FIGURE B-257: UPPER MAIN CHANNEL (TUNR-02 AND TUNR-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

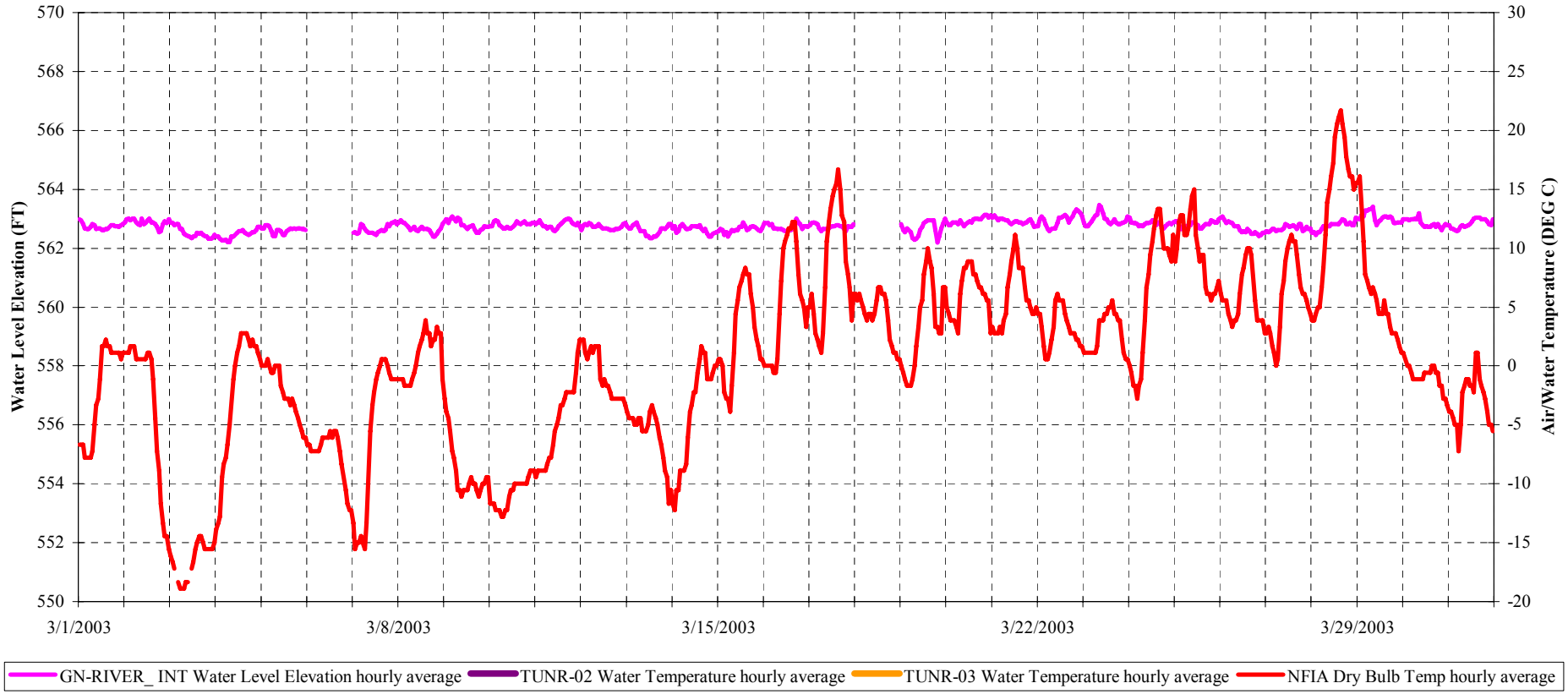

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FIGURE B-258: UPPER MAIN CHANNEL (TUNR-02 AND TUNR-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

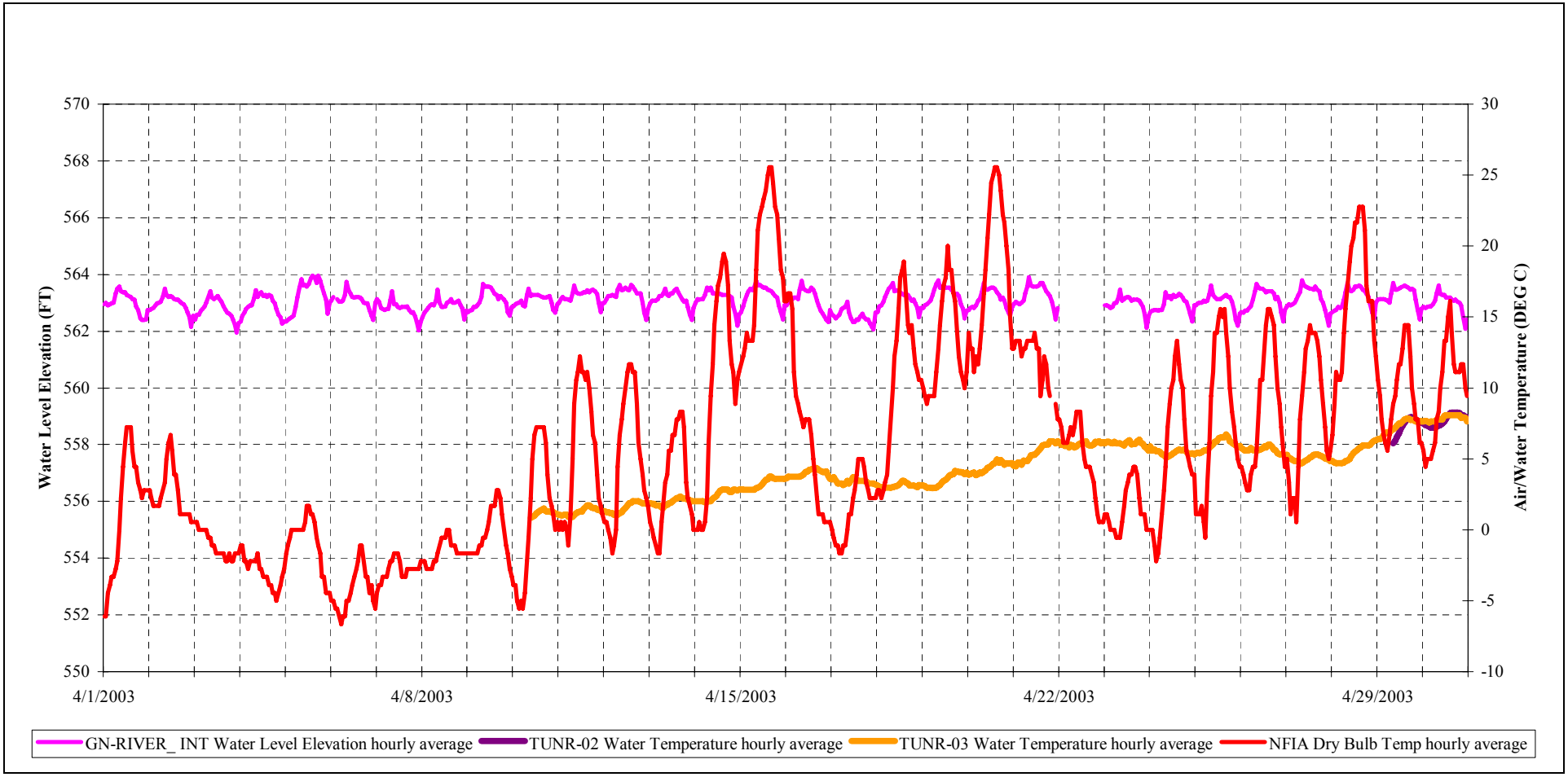

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FIGURE B-259: UPPER MAIN CHANNEL (TUNR-02 AND TUNR-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

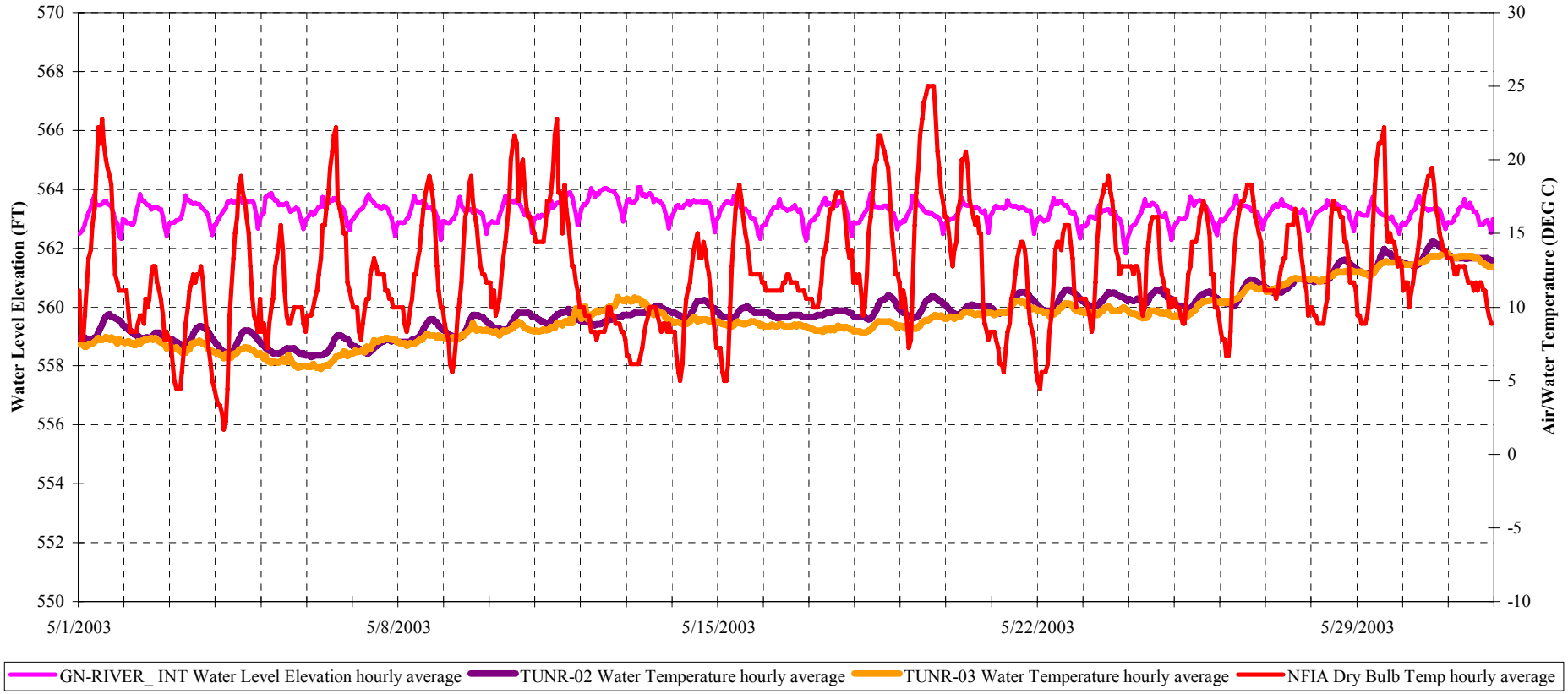

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FIGURE B-260: UPPER MAIN CHANNEL (TUNR-02 AND TUNR-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

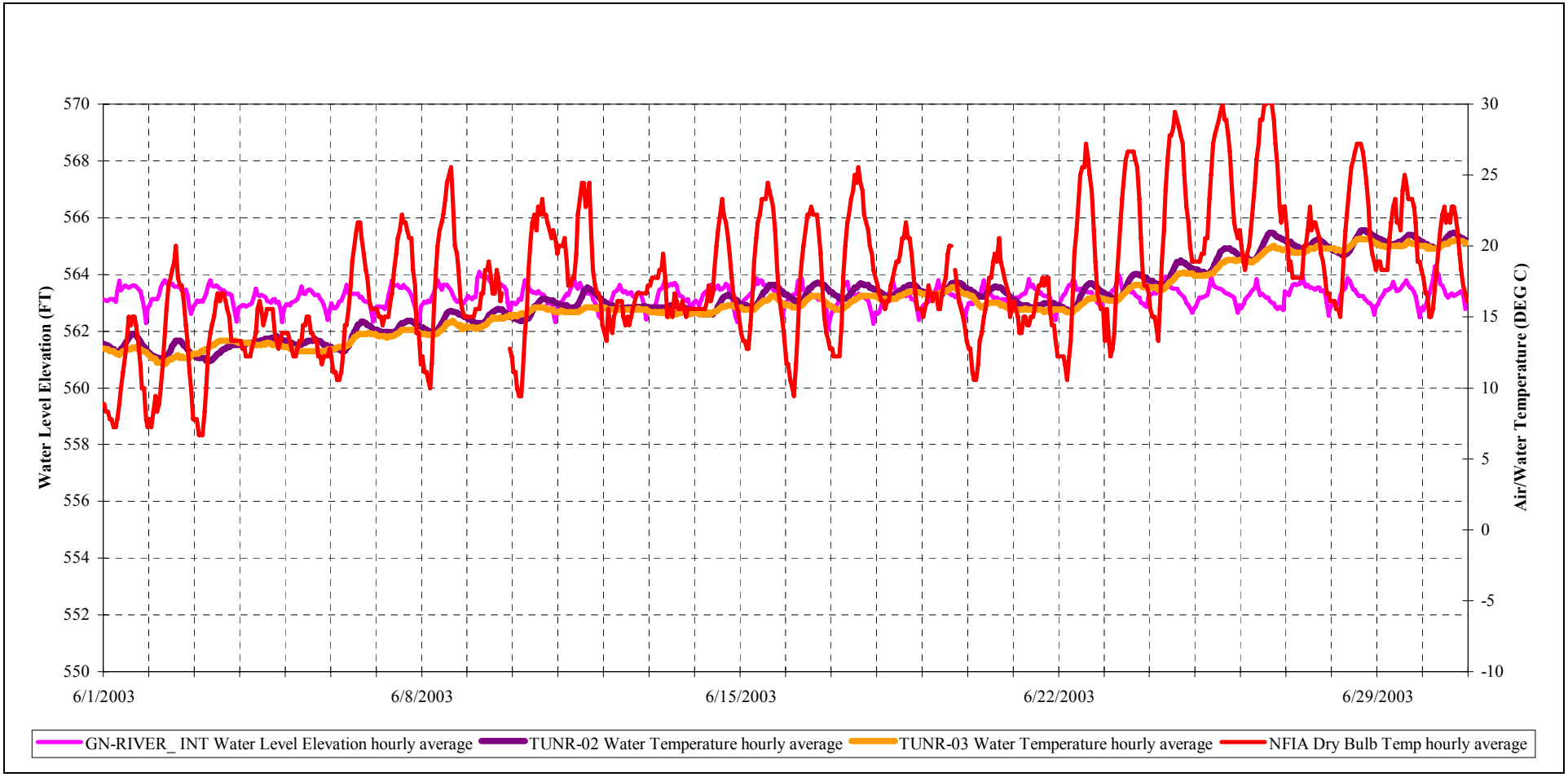

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FIGURE B-261: UPPER MAIN CHANNEL (TUNR-02 AND TUNR-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

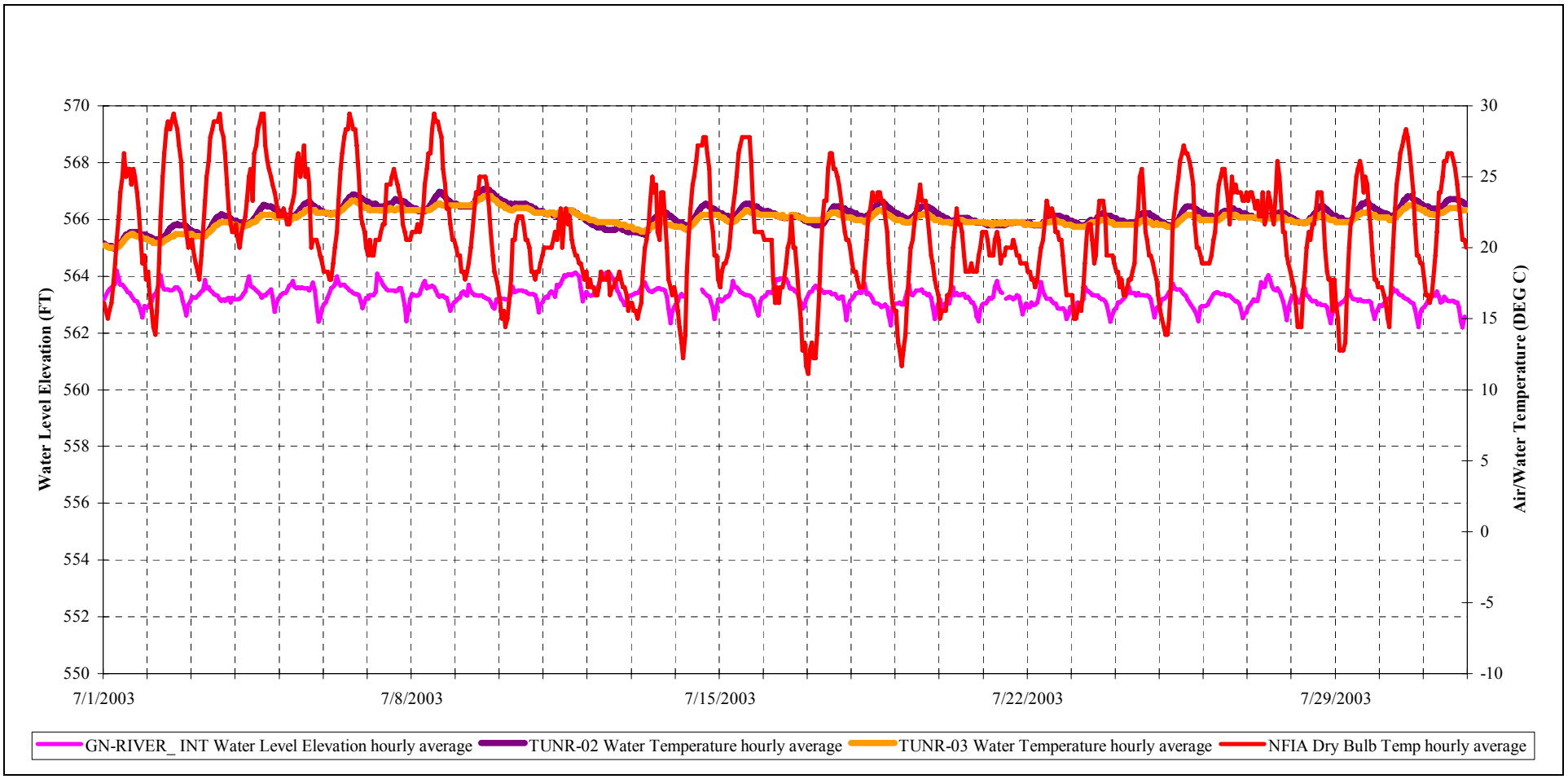

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FIGURE B-262: UPPER MAIN CHANNEL (TUNR-02 AND TUNR-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

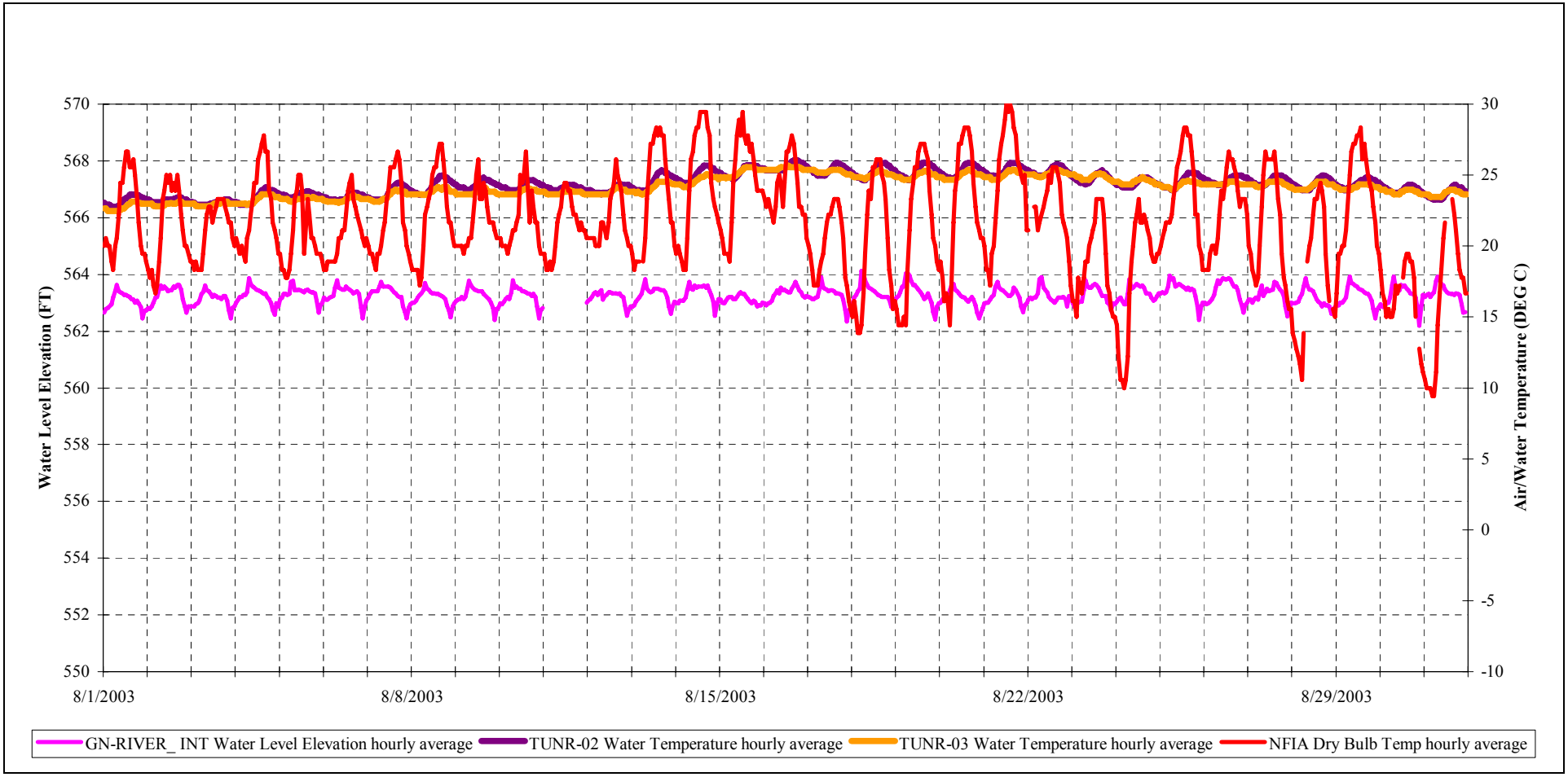

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FIGURE B-263: UPPER MAIN CHANNEL (TUNR-02 AND TUNR-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

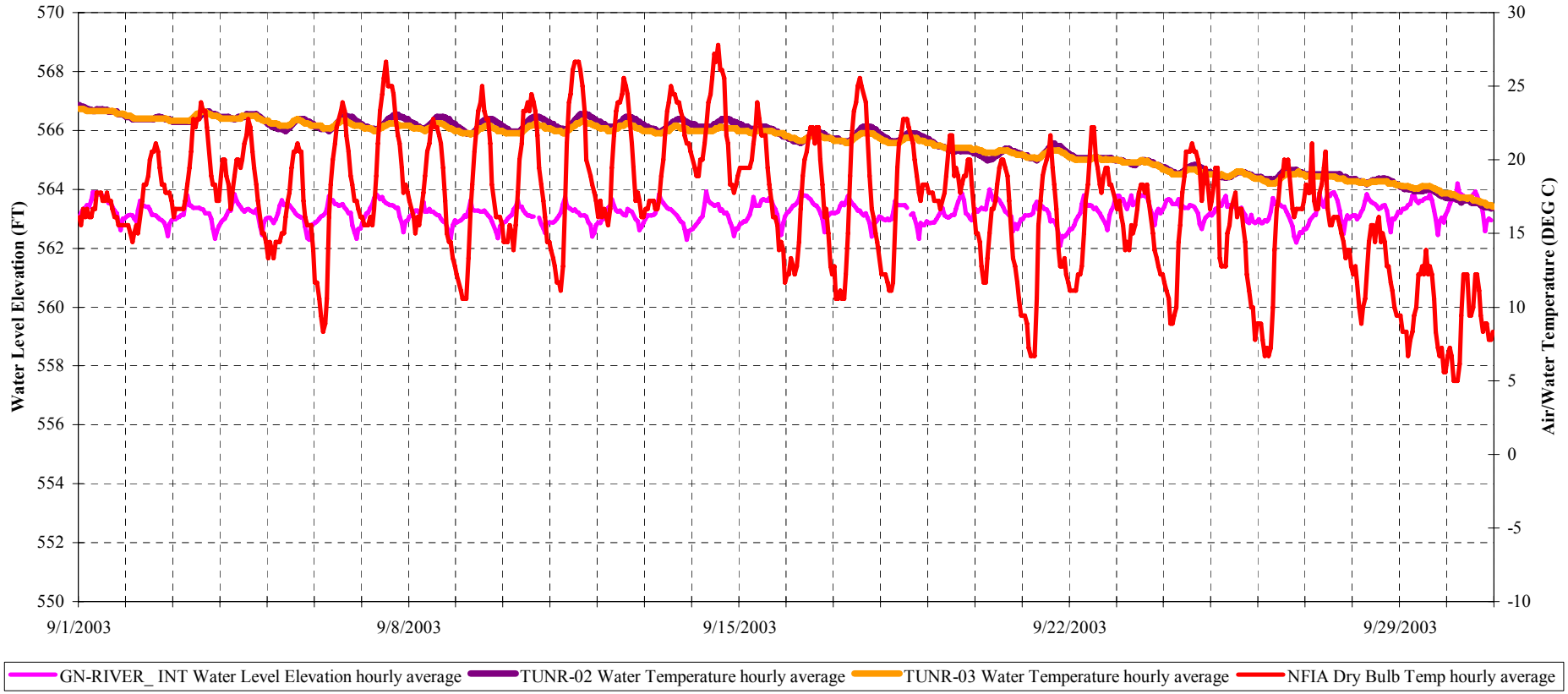

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FIGURE B-264: UPPER MAIN CHANNEL (TUNR-02 AND TUNR-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

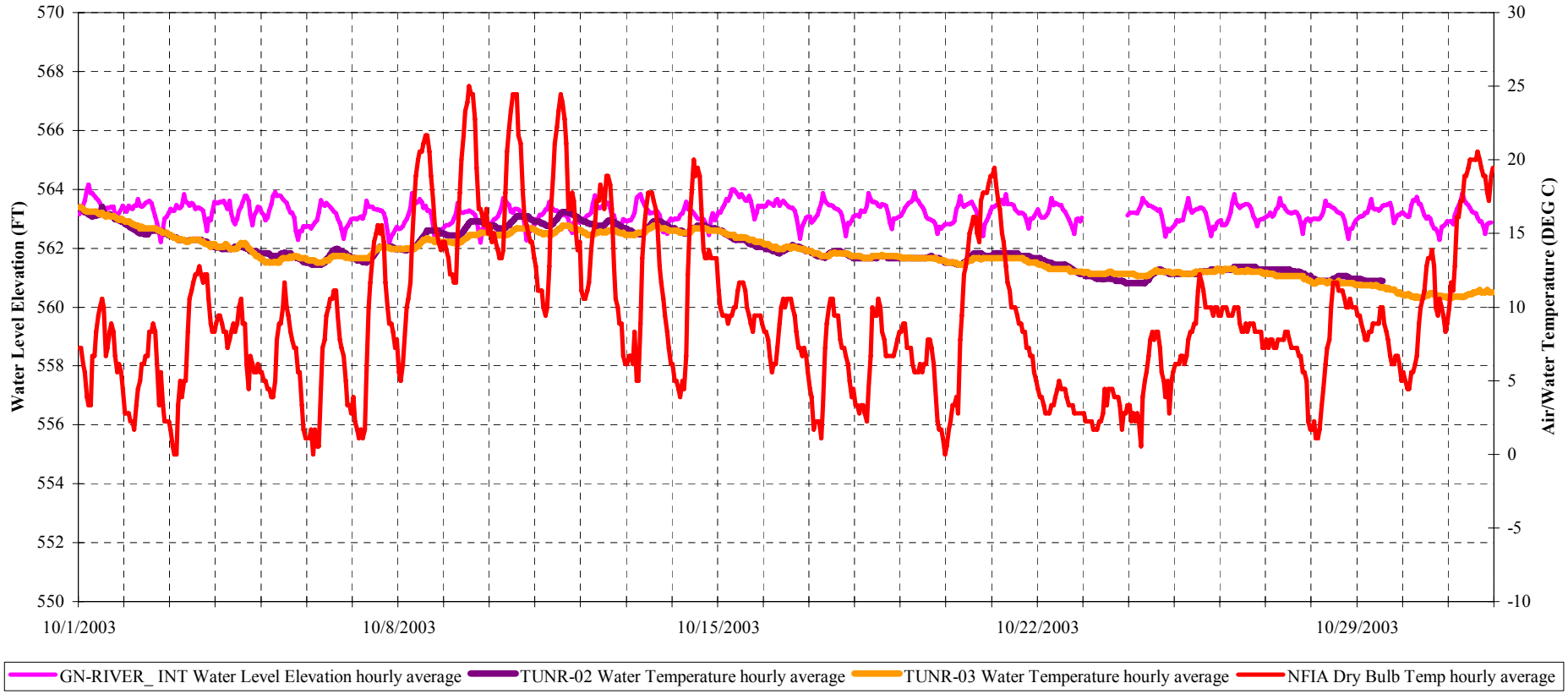

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FIGURE B-265: UPPER MAIN CHANNEL (TUNR-02 AND TUNR-03)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

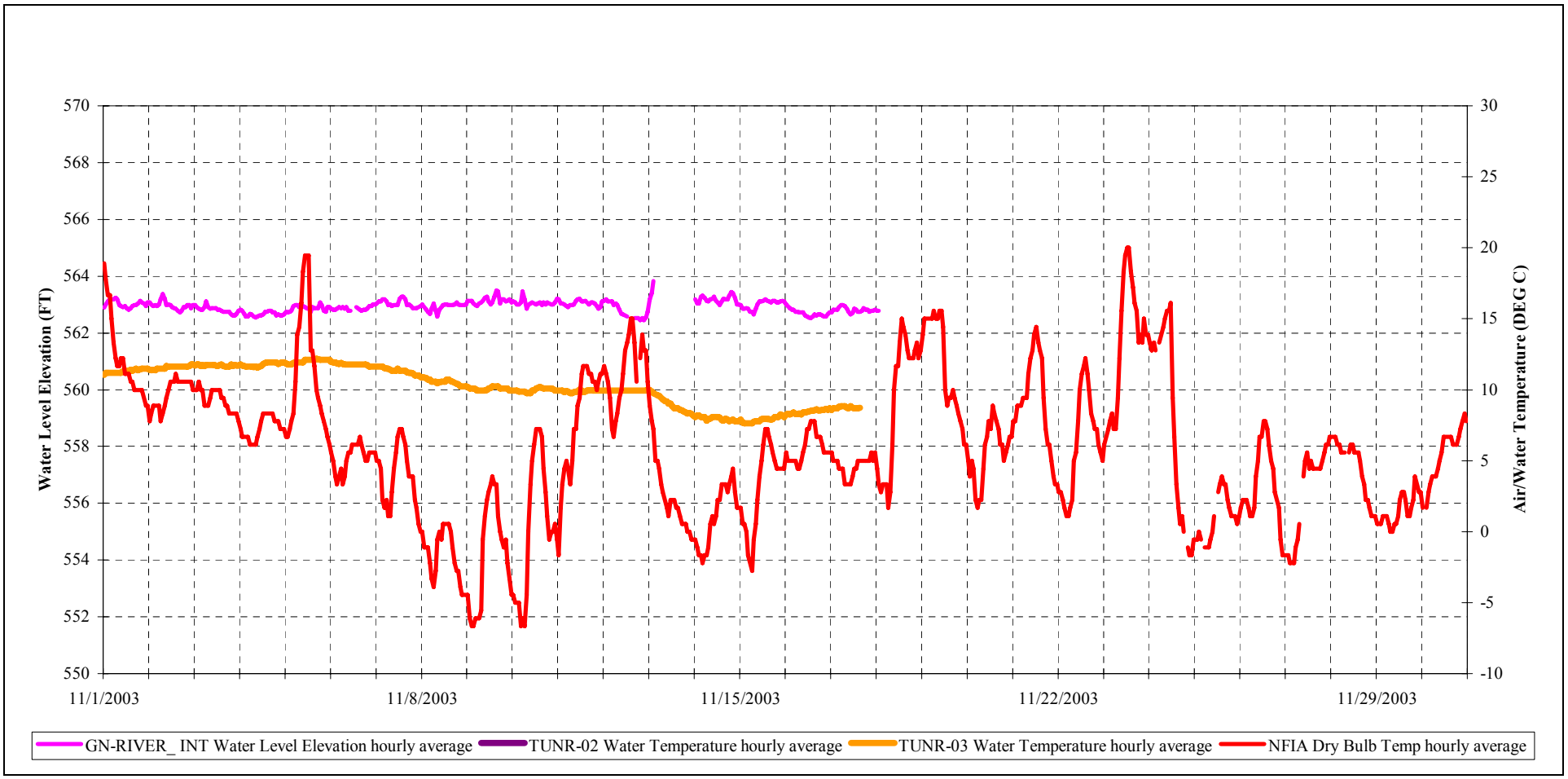

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FIGURE B-266: UPPER MAIN CHANNEL (TUNR-03 AND TUNR-04)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

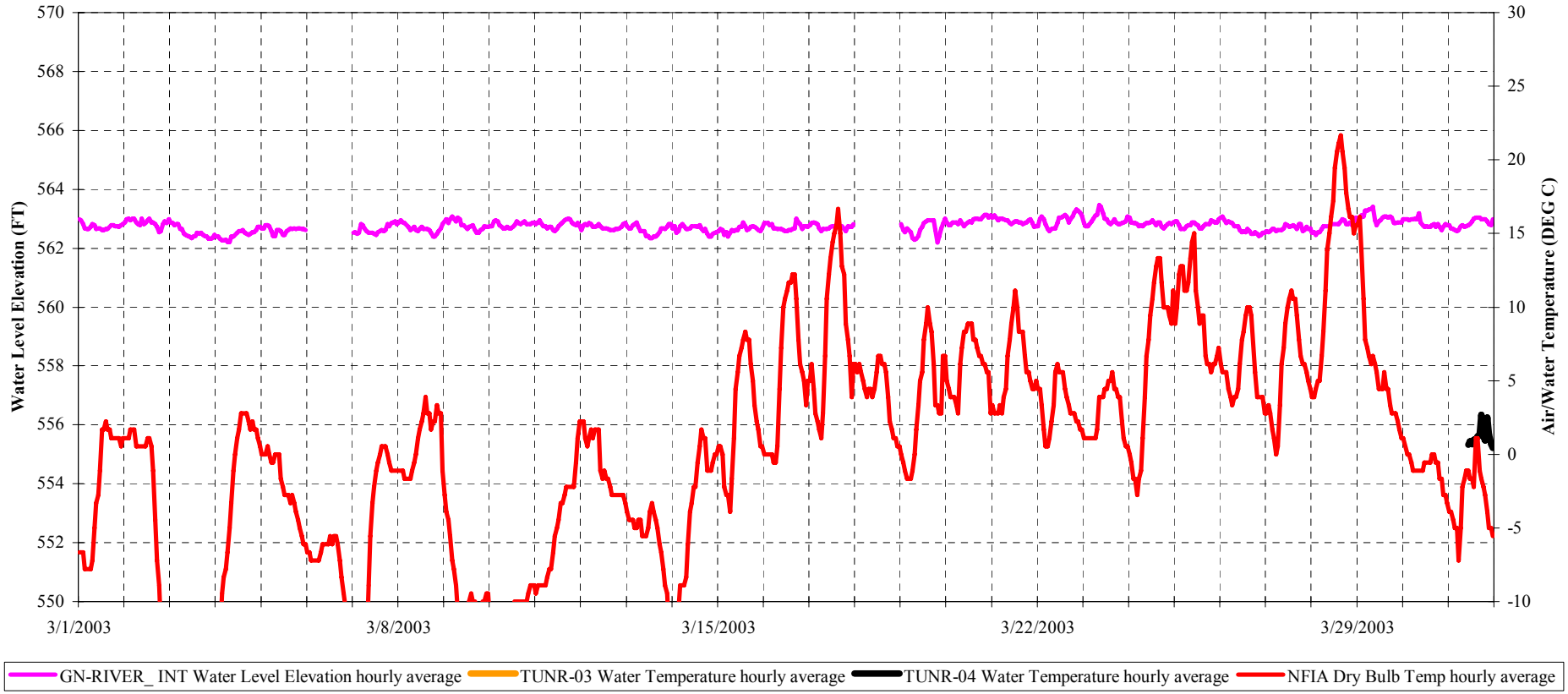

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FIGURE B-267: UPPER MAIN CHANNEL (TUNR-03 AND TUNR-04)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

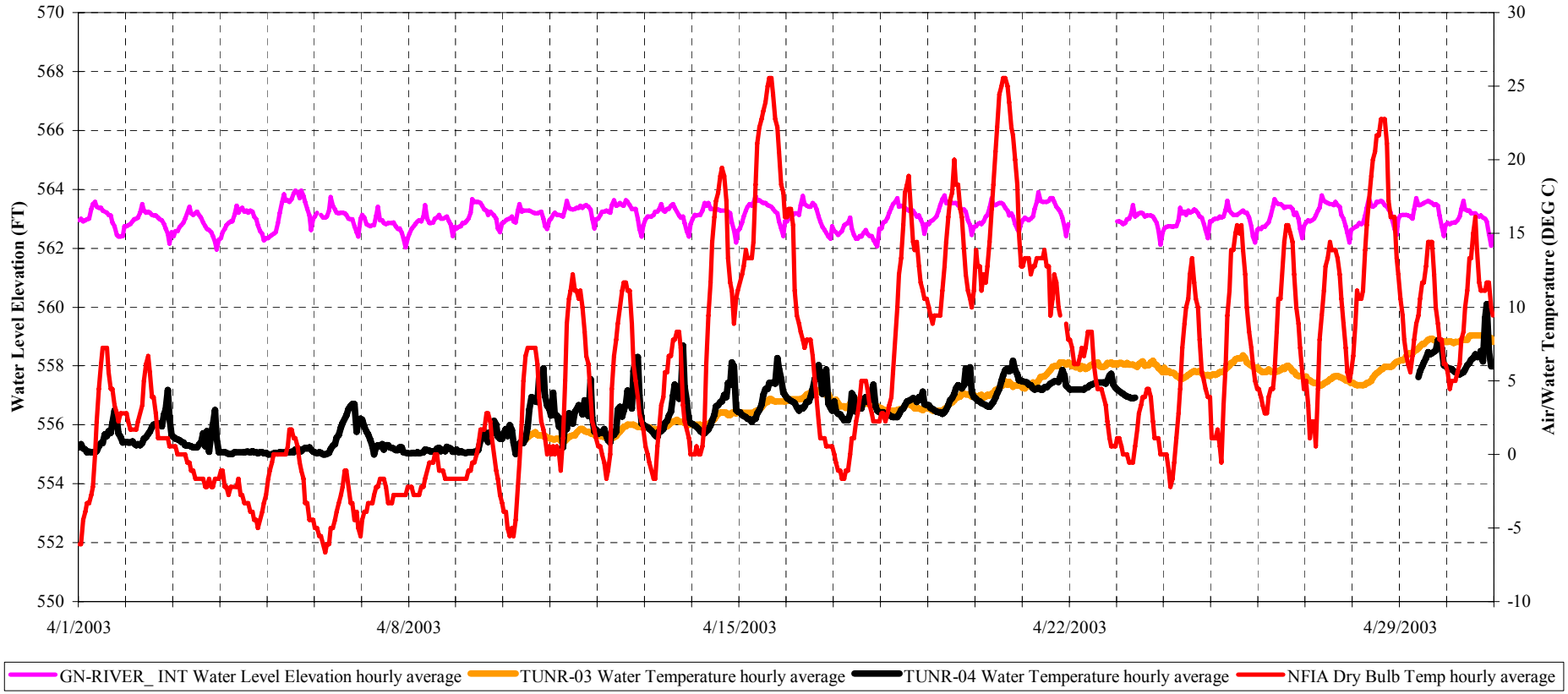

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FIGURE B-268: UPPER MAIN CHANNEL (TUNR-03 AND TUNR-04)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

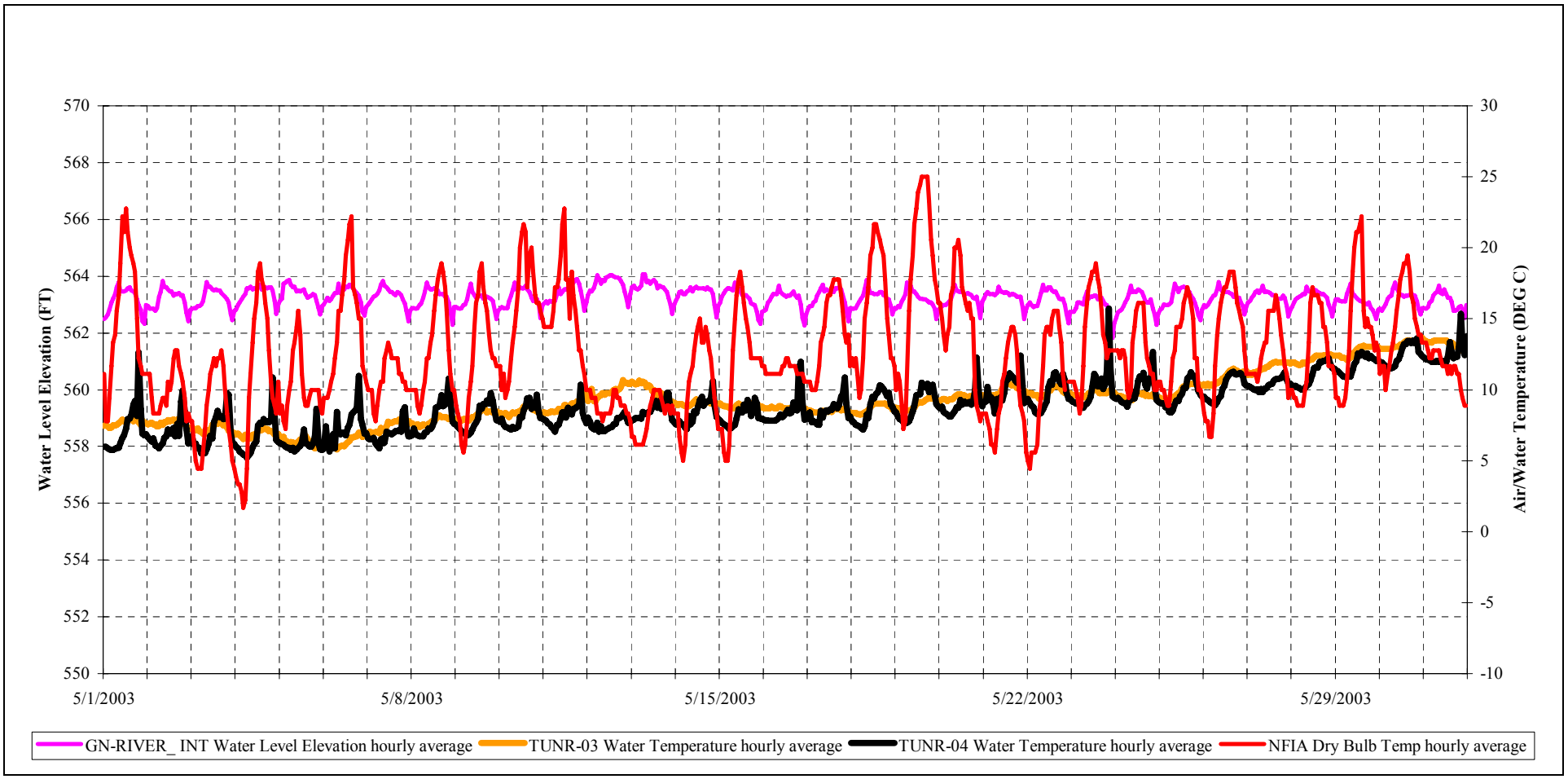

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FIGURE B-269: UPPER MAIN CHANNEL (TUNR-03 AND TUNR-04)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

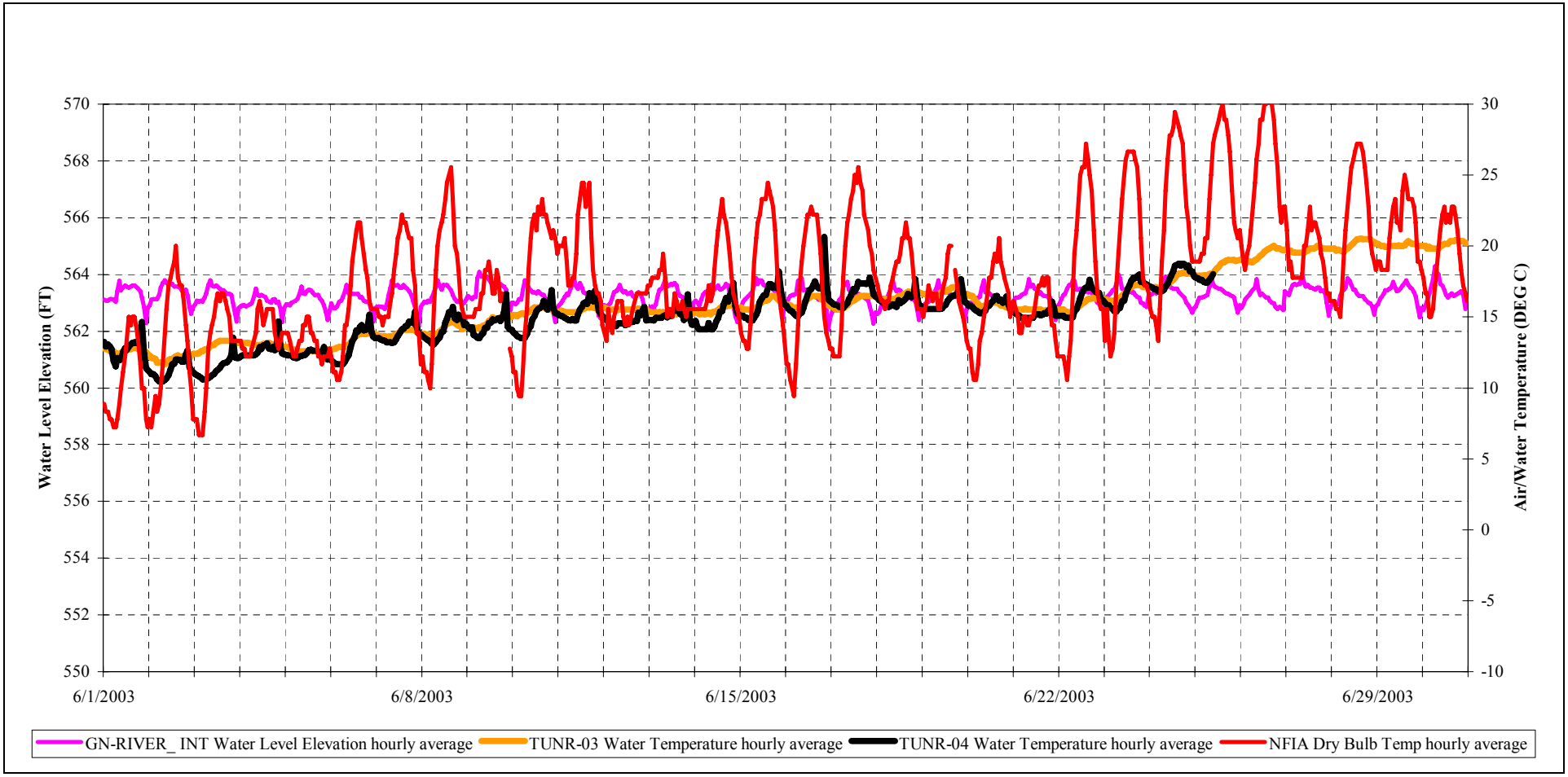

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FIGURE B-270: UPPER MAIN CHANNEL (TUNR-03 AND TUNR-04)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

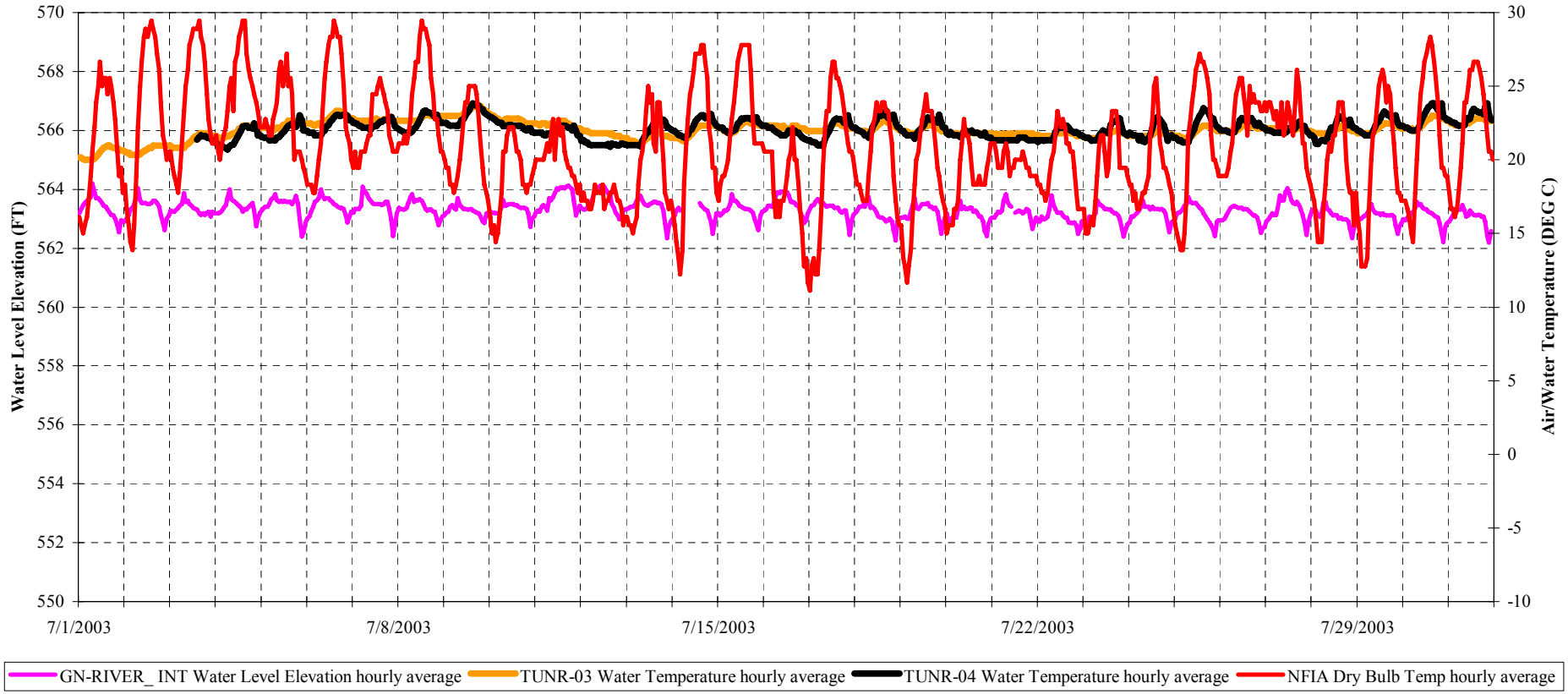

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FIGURE B-271: UPPER MAIN CHANNEL (TUNR-03 AND TUNR-04)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

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FIGURE B-272: UPPER MAIN CHANNEL (TUNR-03 AND TUNR-04)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

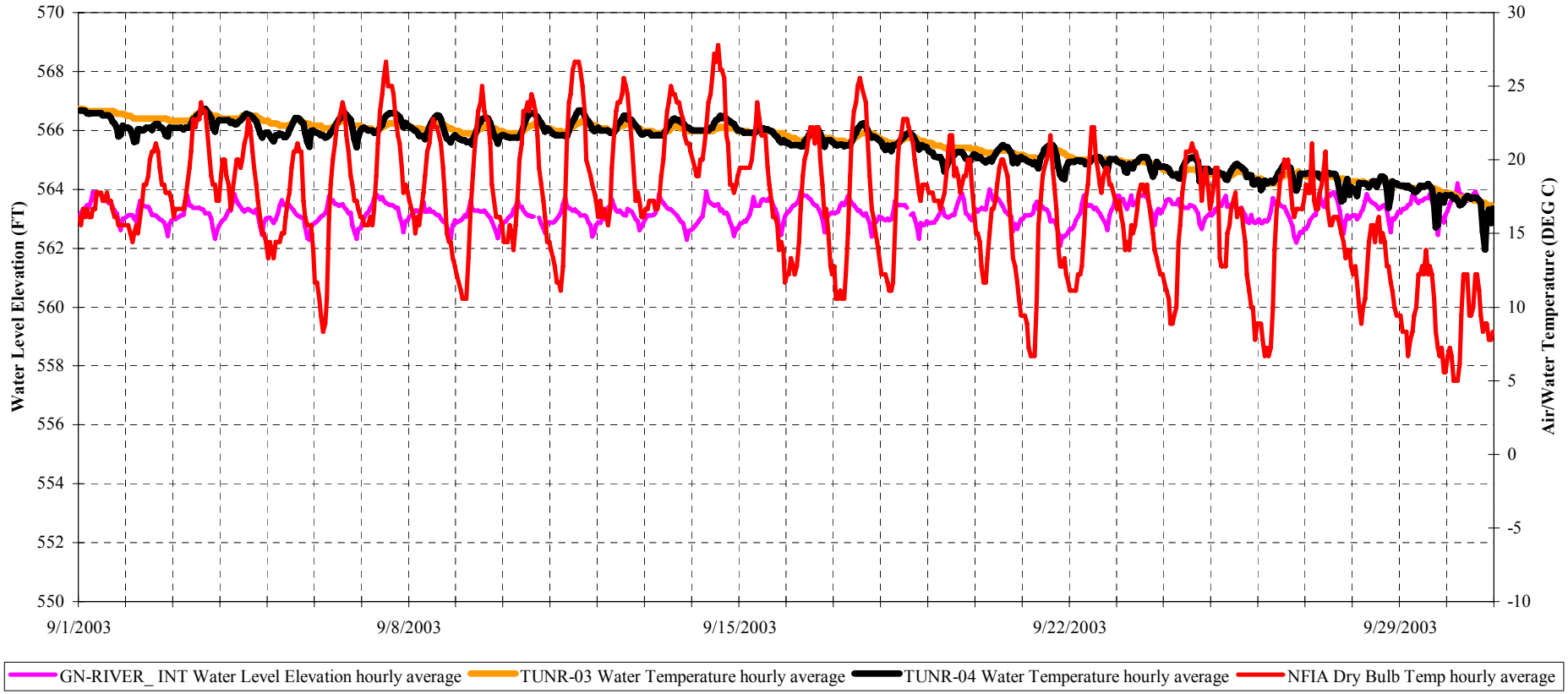

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FIGURE B-273: UPPER MAIN CHANNEL (TUNR-03 AND TUNR-04)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

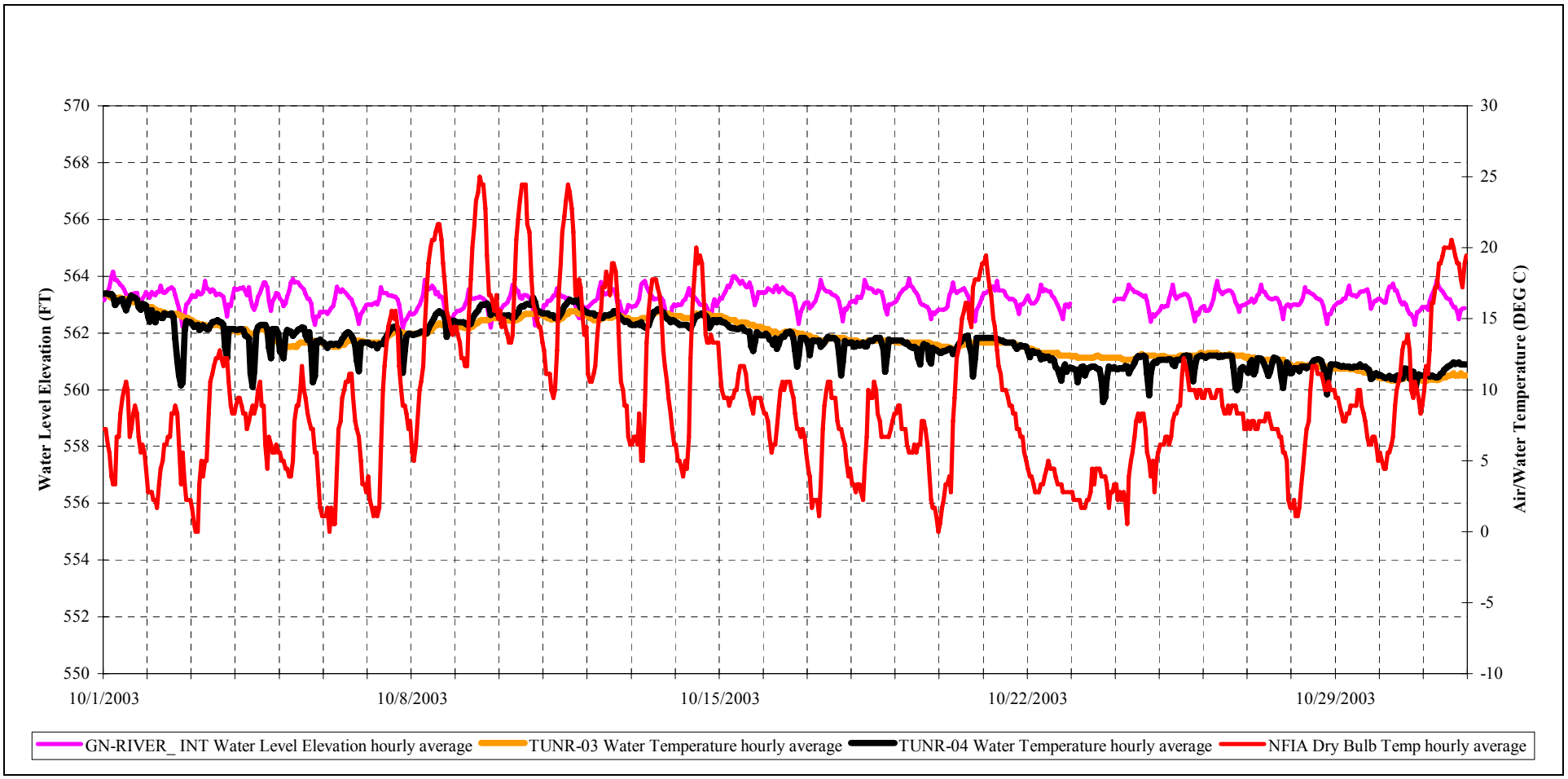

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FIGURE B-274: UPPER MAIN CHANNEL (TUNR-03 AND TUNR-04)

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

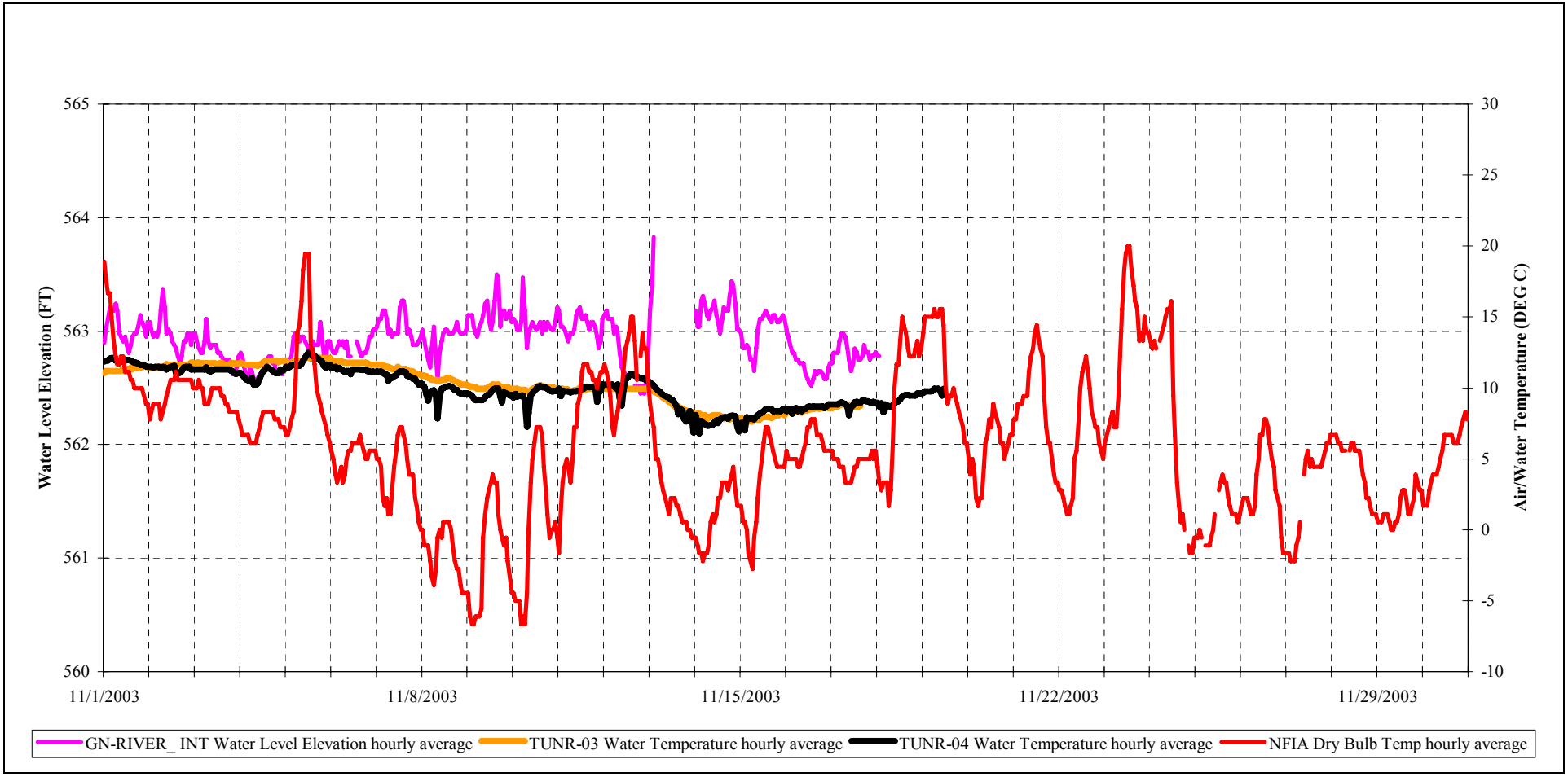

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FIGURE B-275: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2002

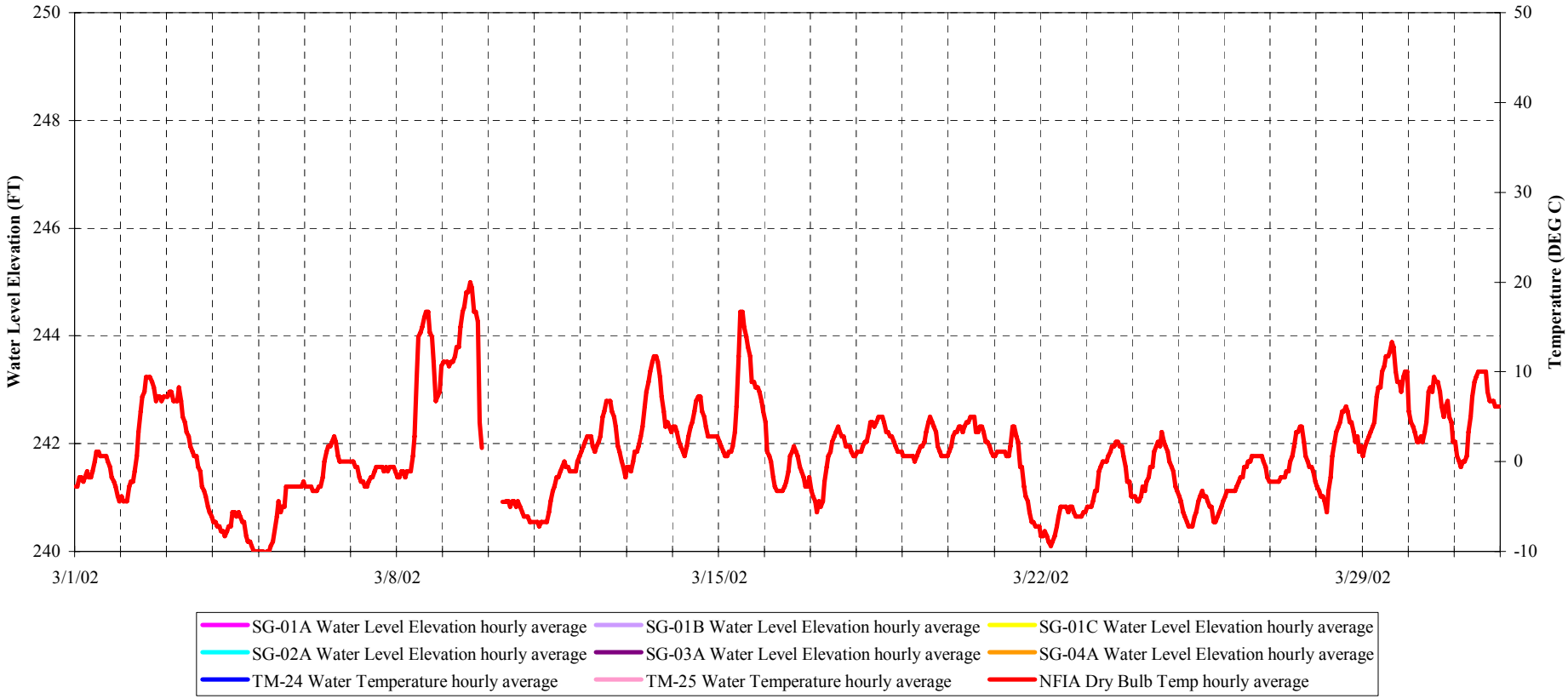

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FIGURE B-276: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2002

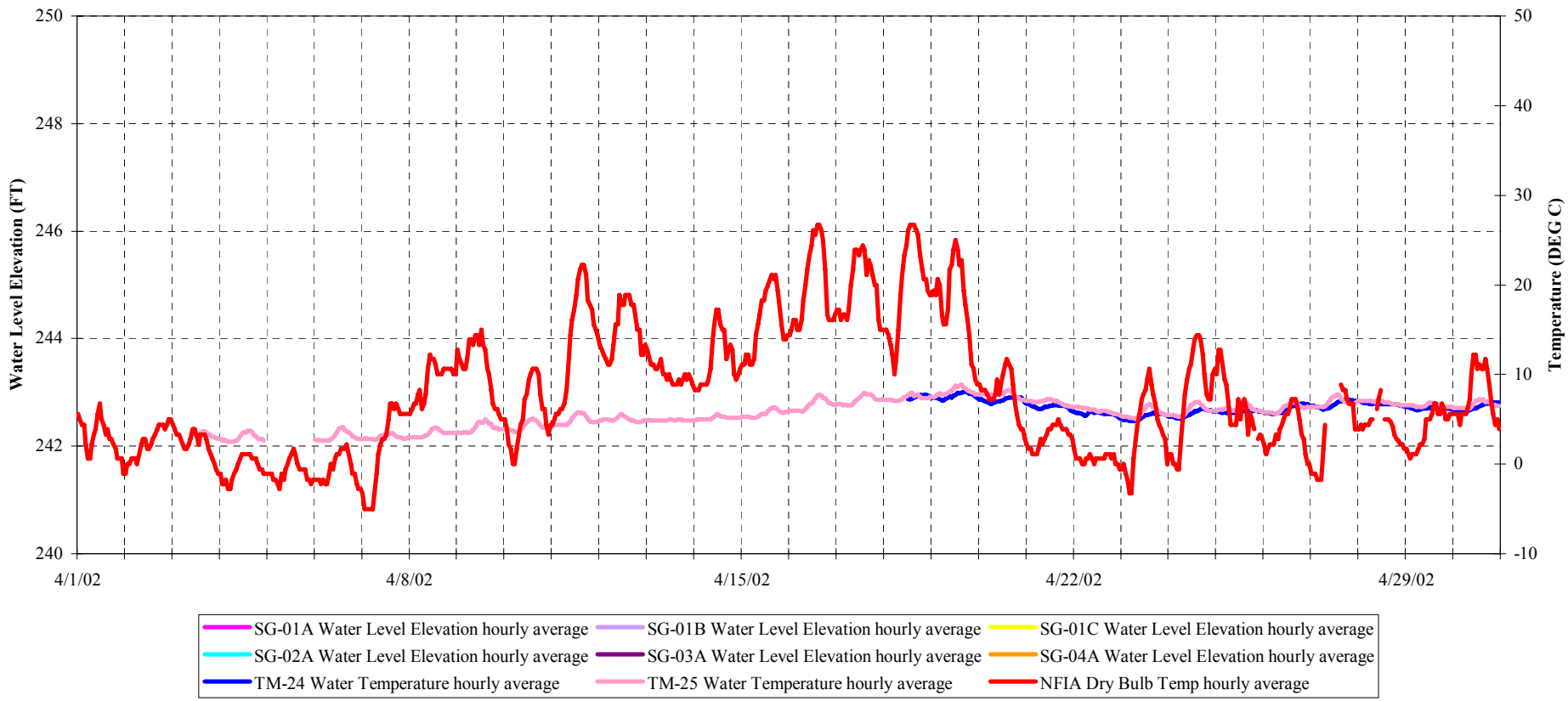

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FIGURE B-277: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2002

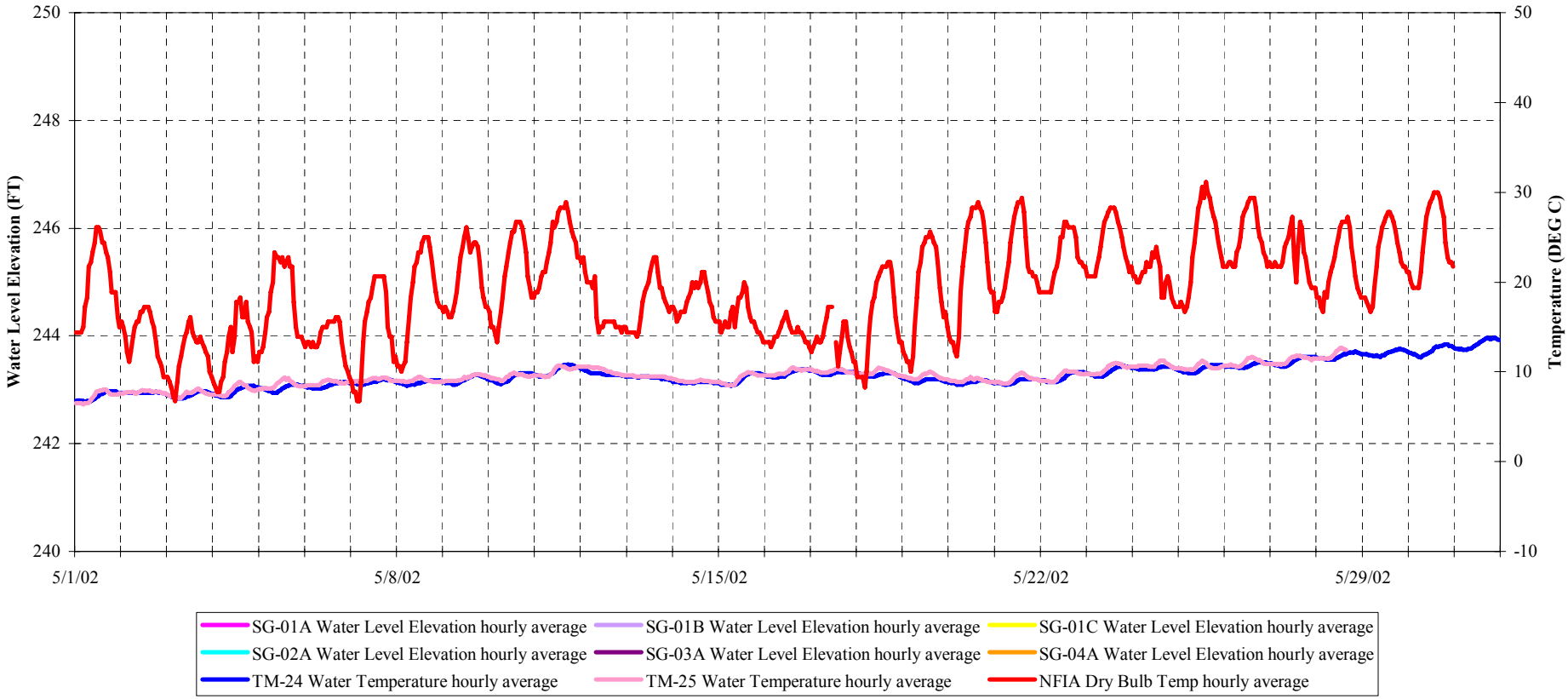

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FIGURE B-278: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2002

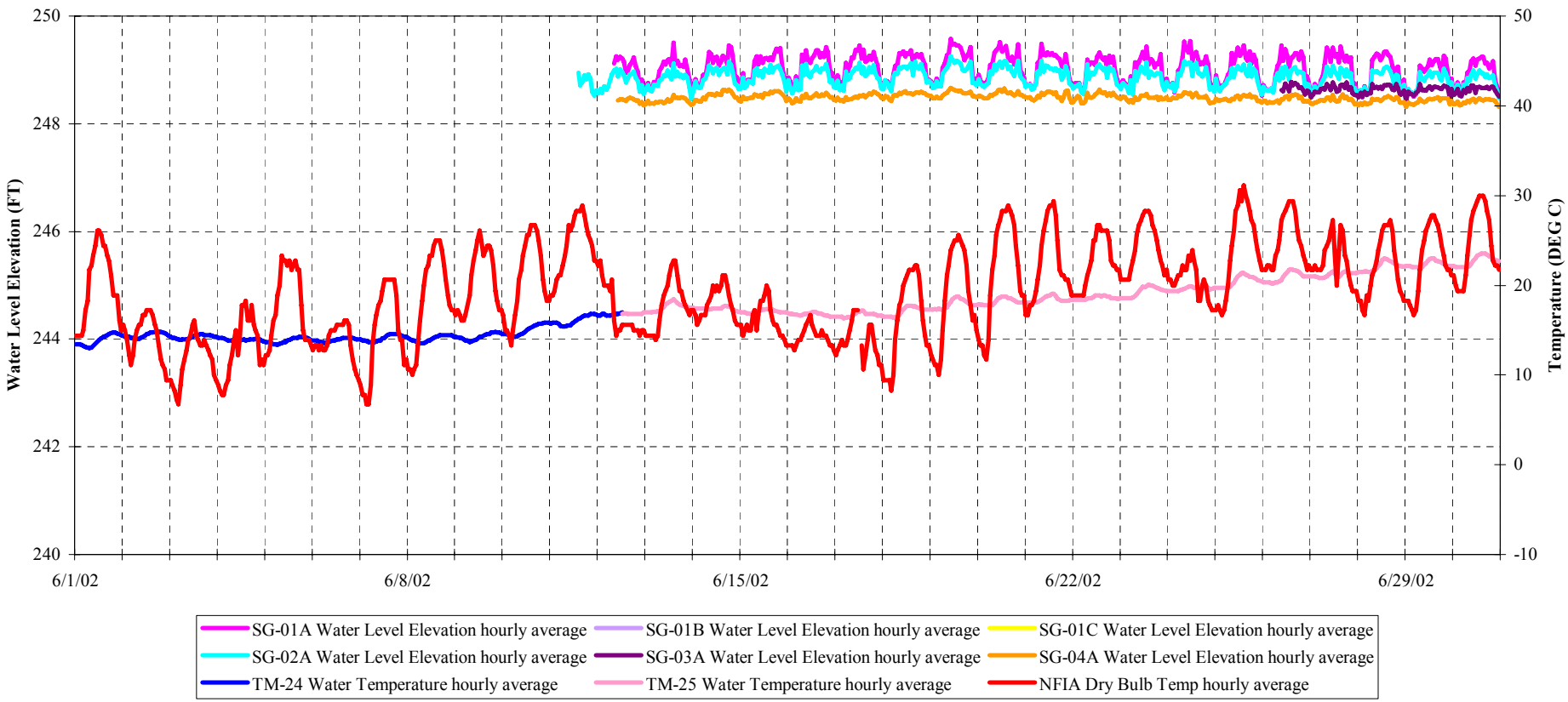

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FIGURE B-279: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2002

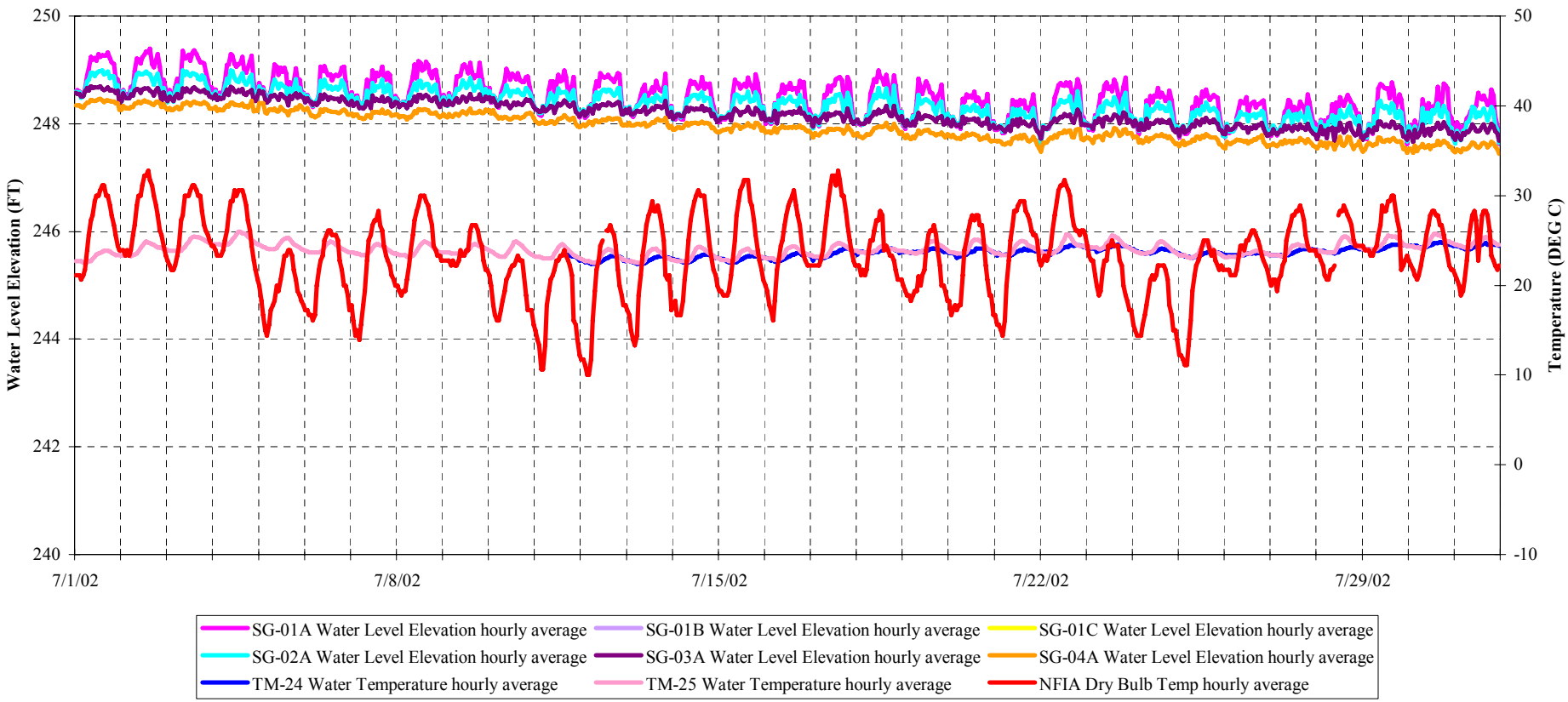

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FIGURE B-280: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2002

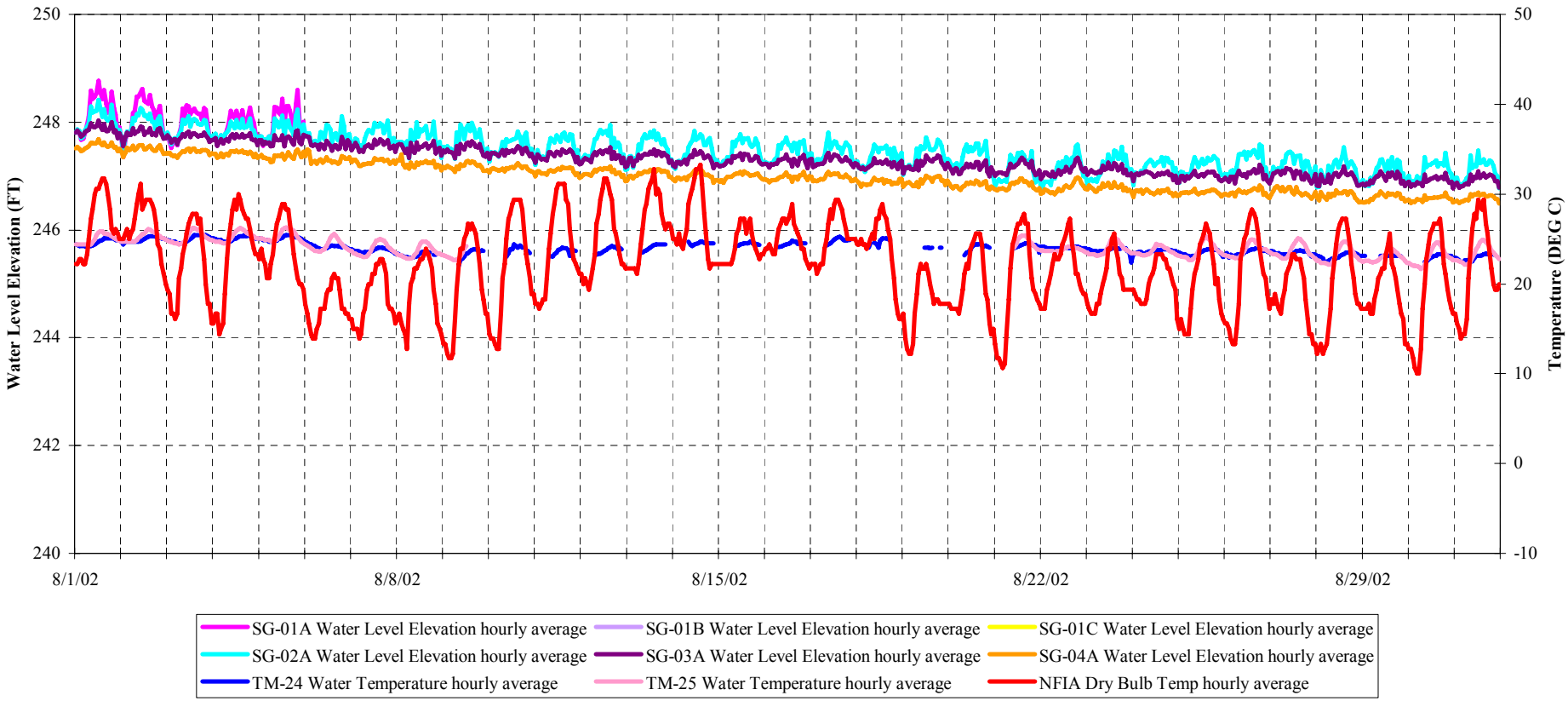

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FIGURE B-281: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2002

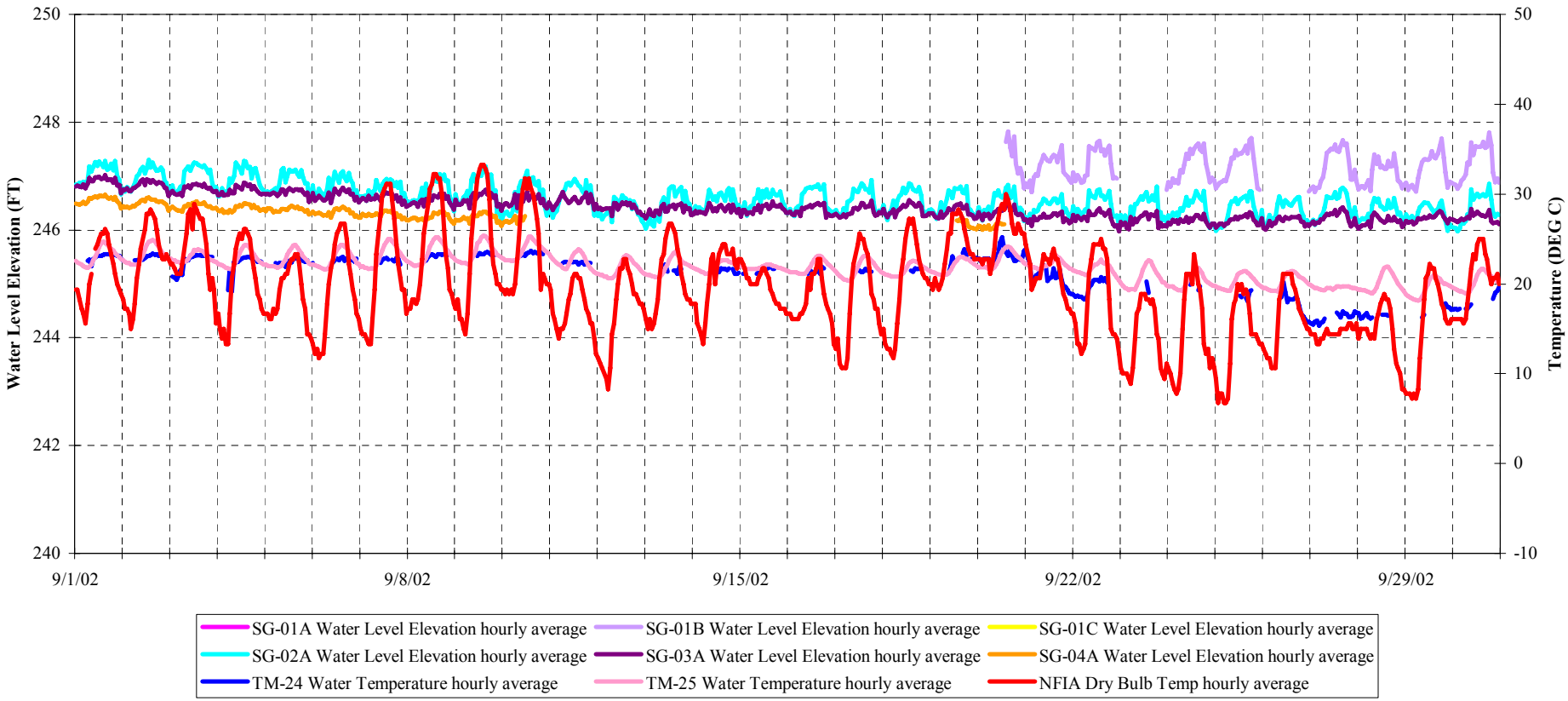

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FIGURE B-282: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2002

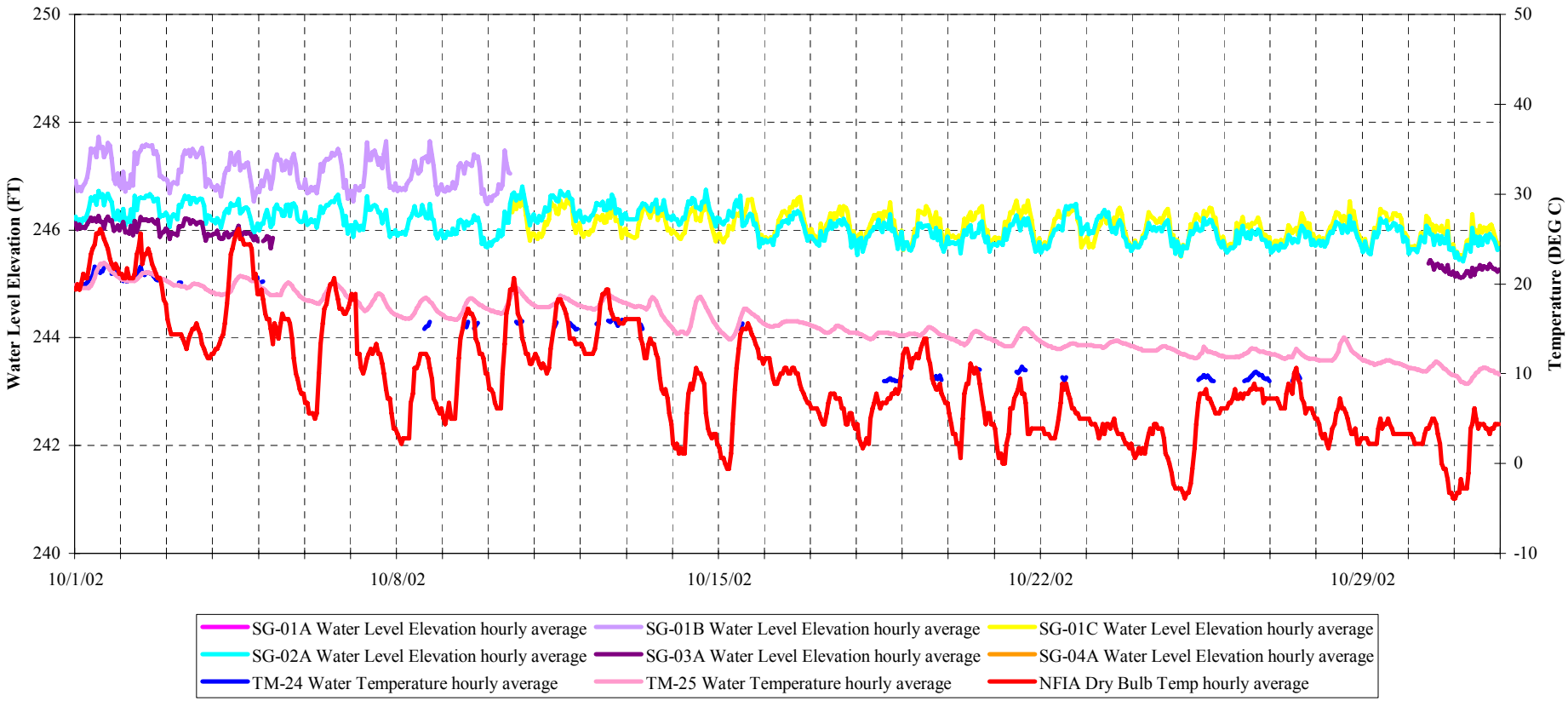

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FIGURE B-283: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2002

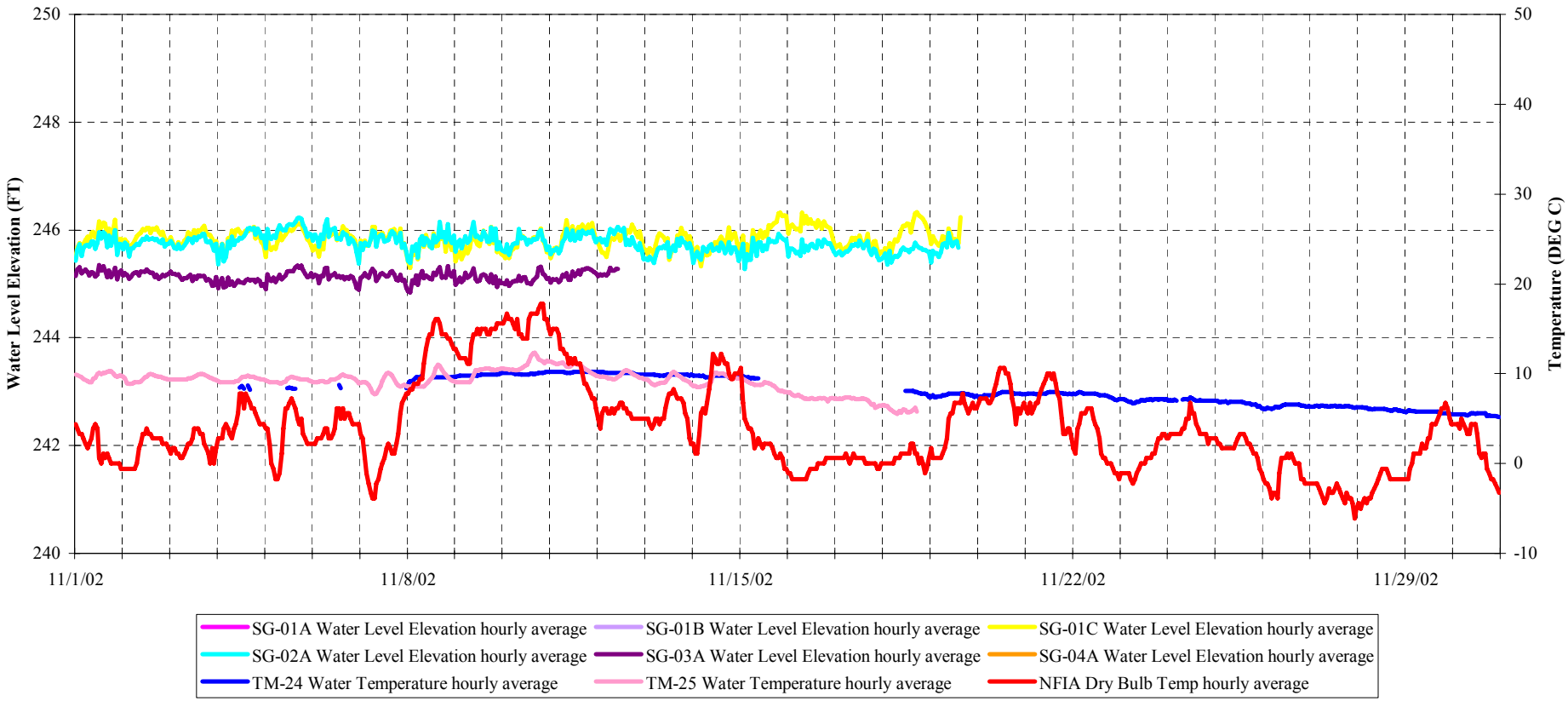

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FIGURE B-284: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

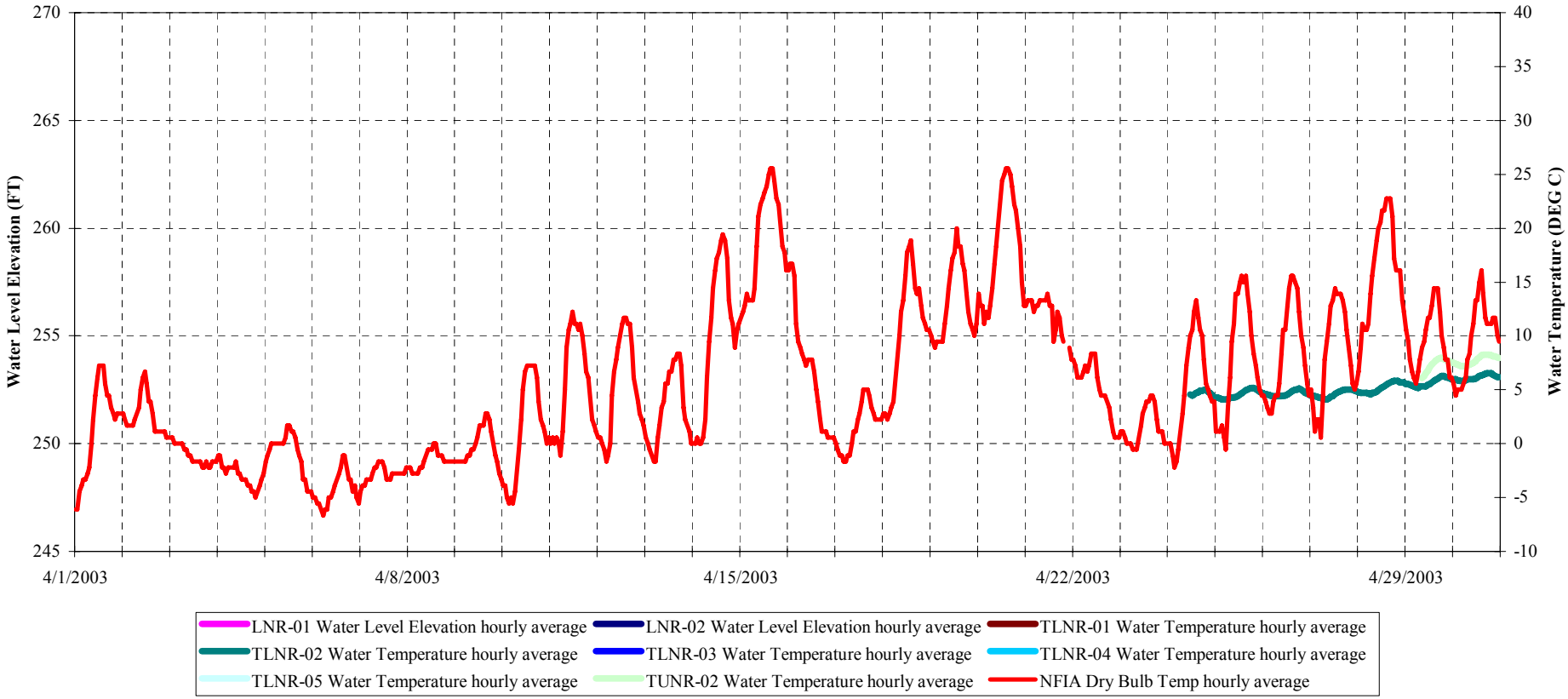

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FIGURE B-285: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

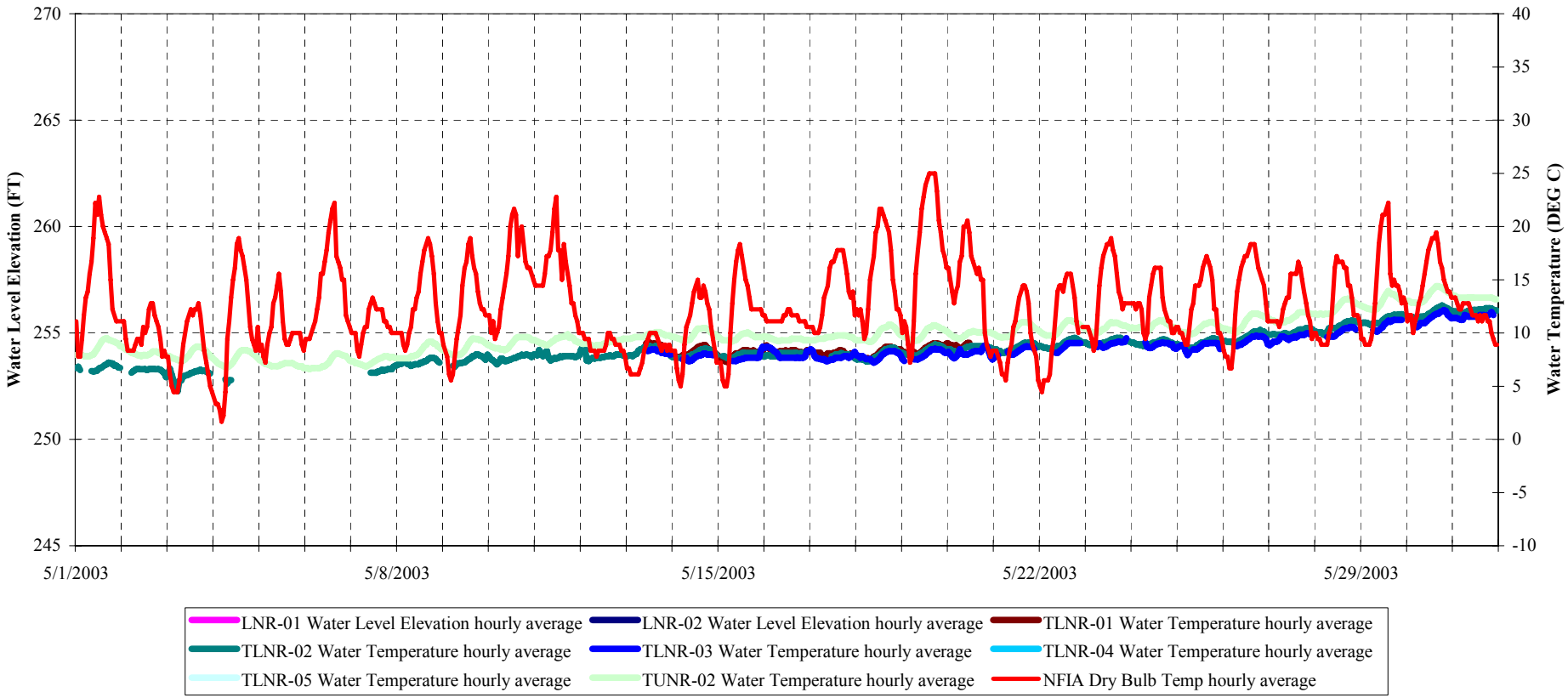

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FIGURE B-286: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

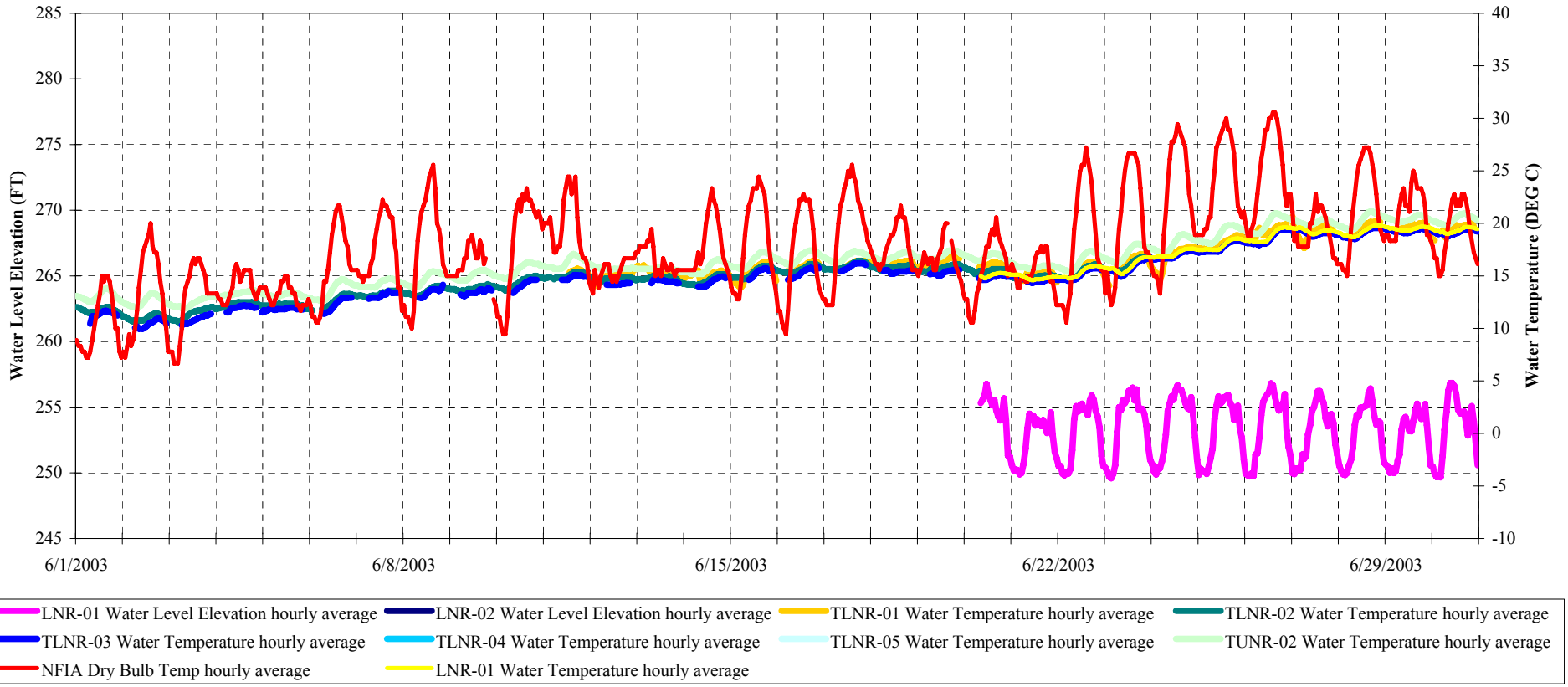

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FIGURE B-287: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

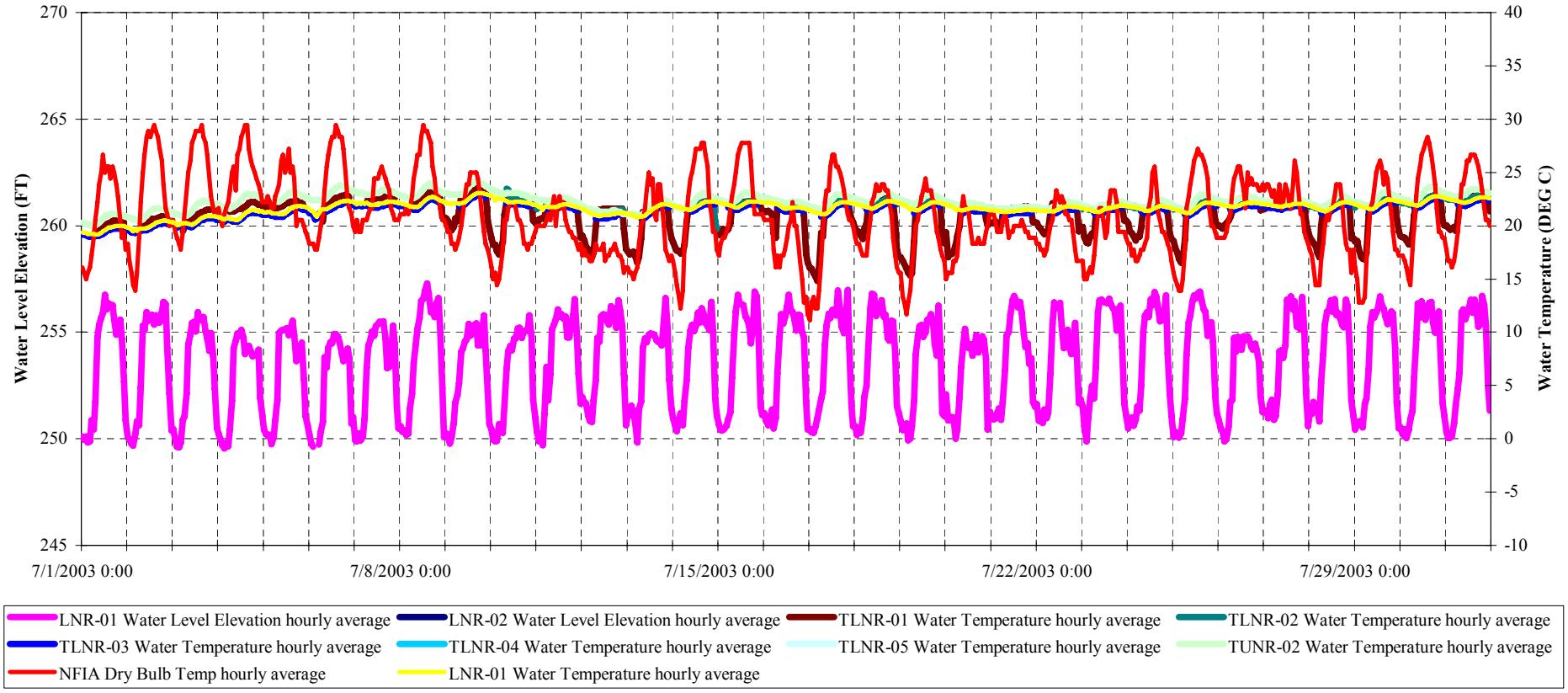

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FIGURE B-288: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

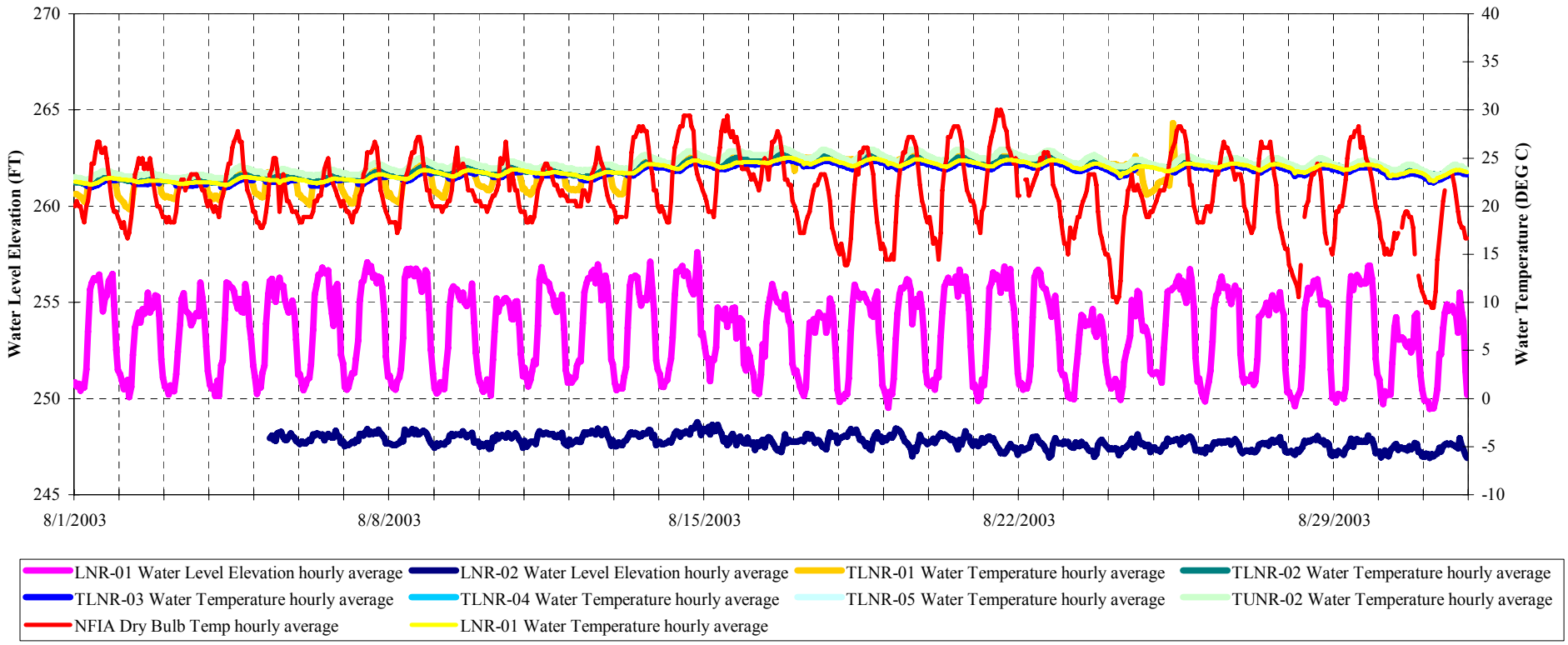

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FIGURE B-289: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

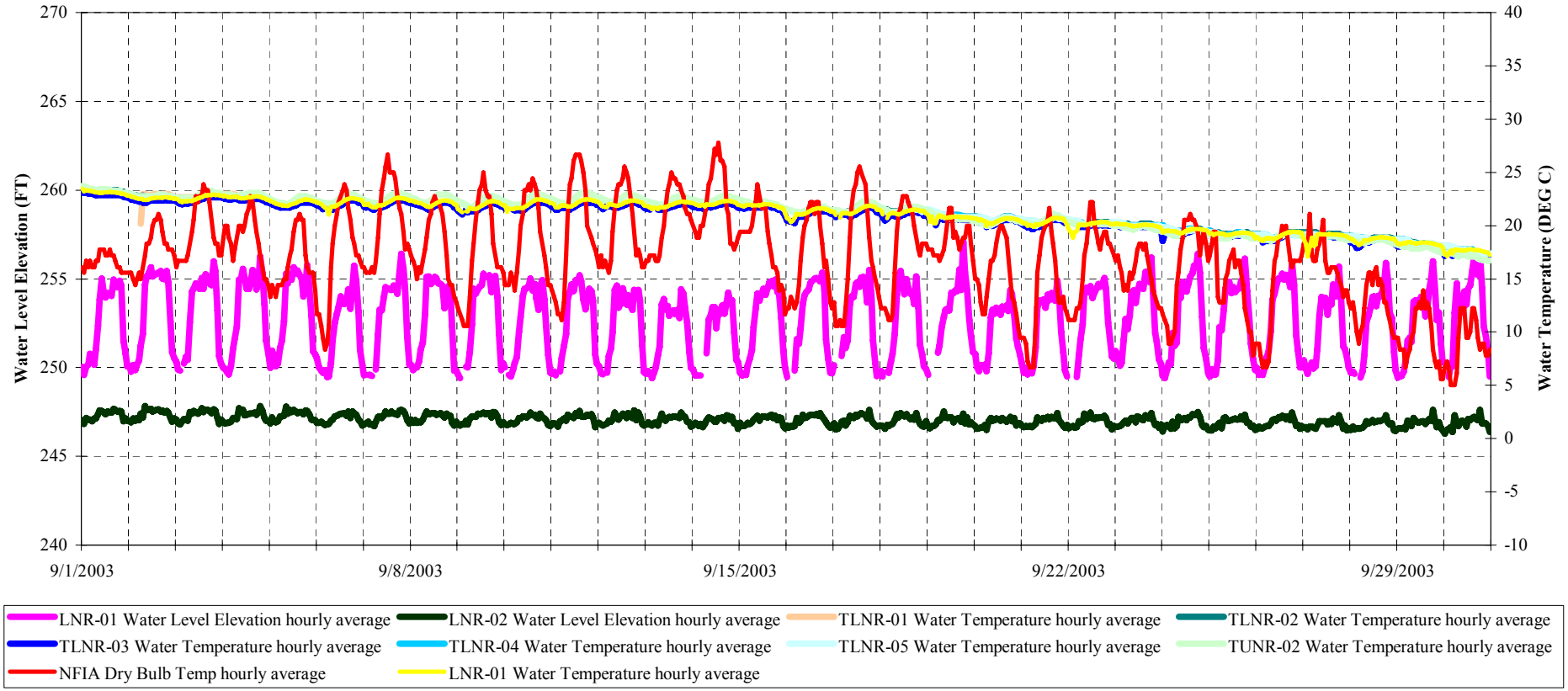

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FIGURE B-290: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

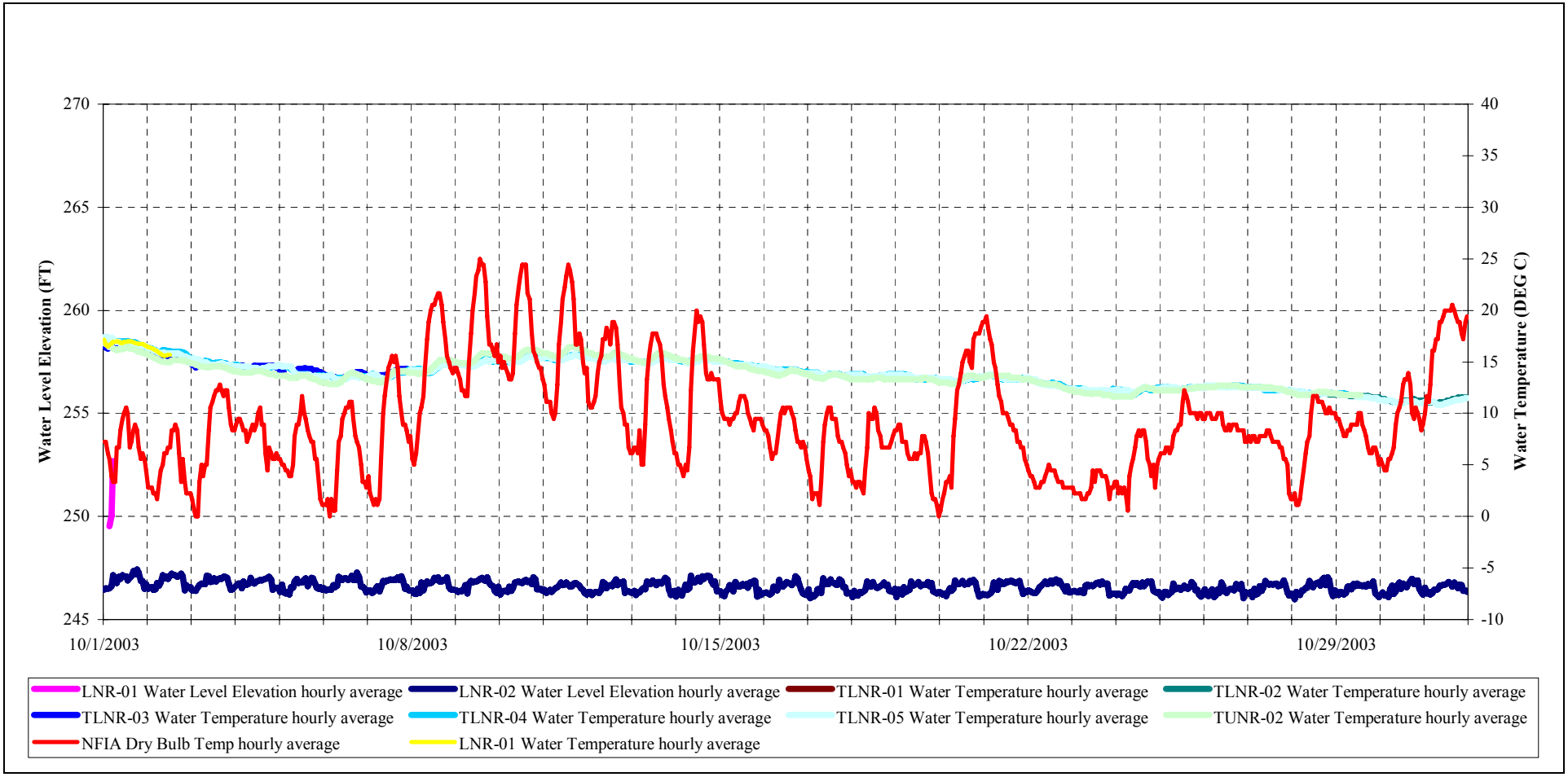

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FIGURE B-291: LOWER NIAGARA - MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

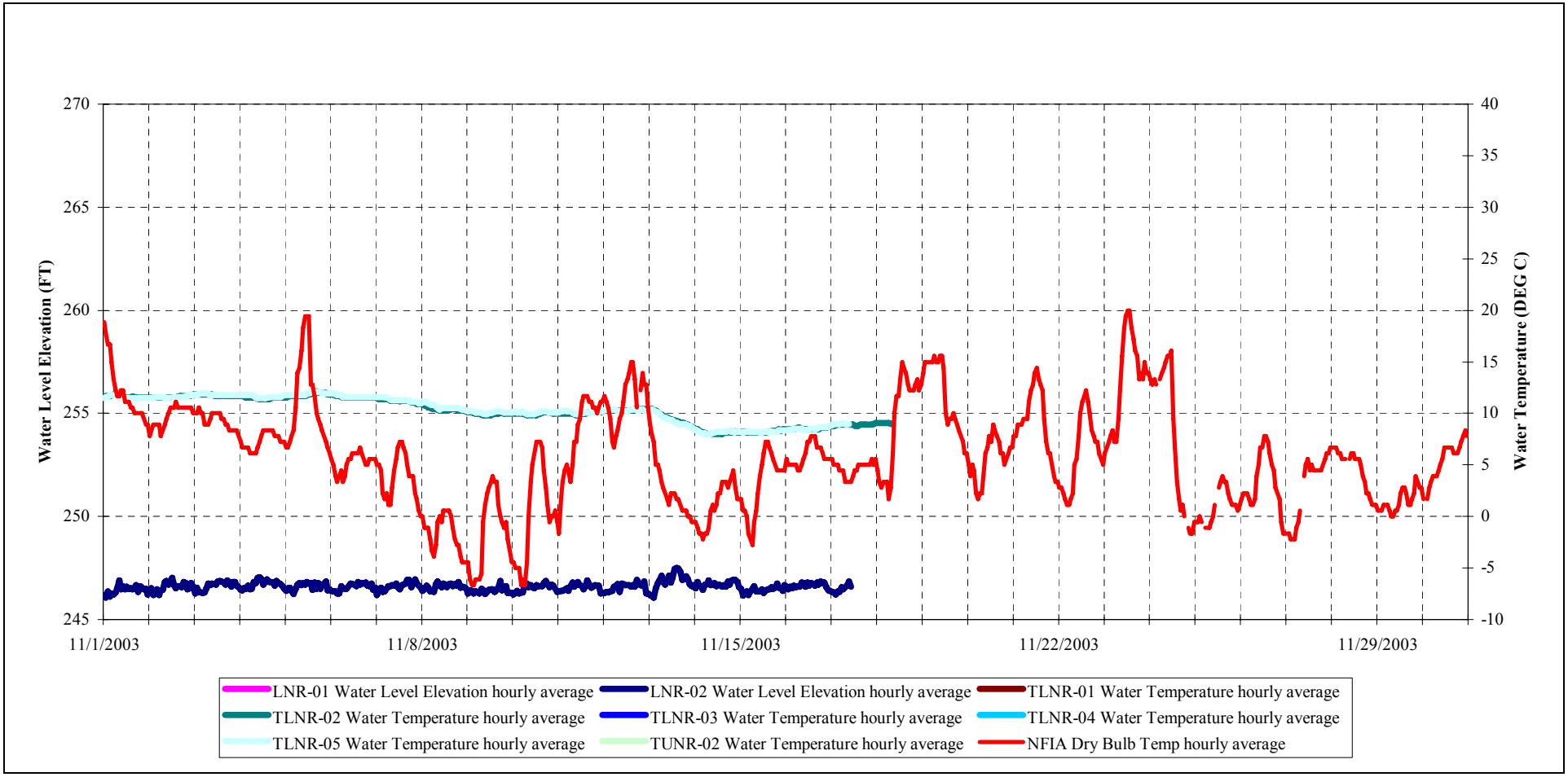

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FIGURE B-292: LEWISTON RESERVOIR

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MARCH 2003

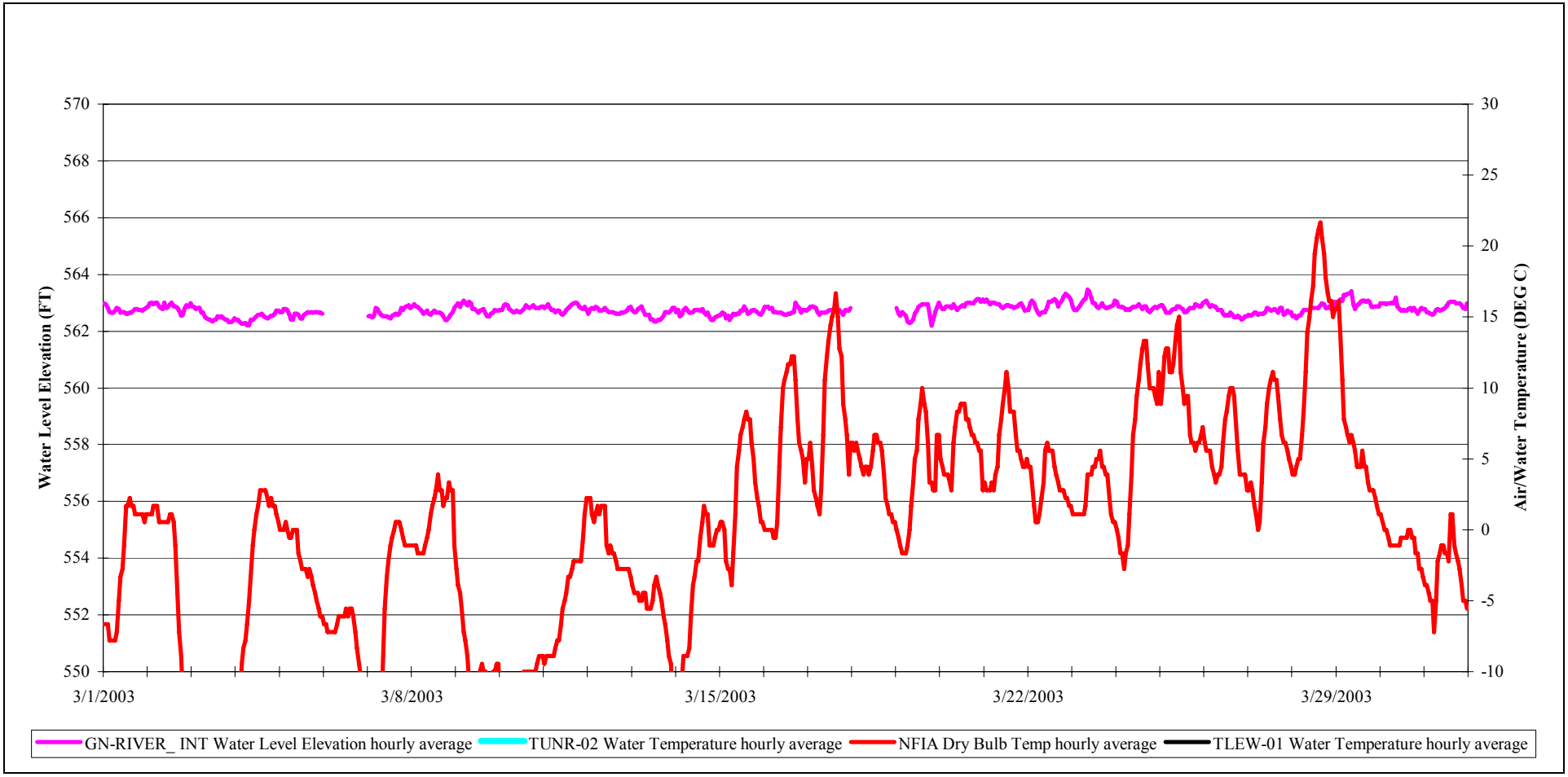

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FIGURE B-293: LEWISTON RESERVOIR

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

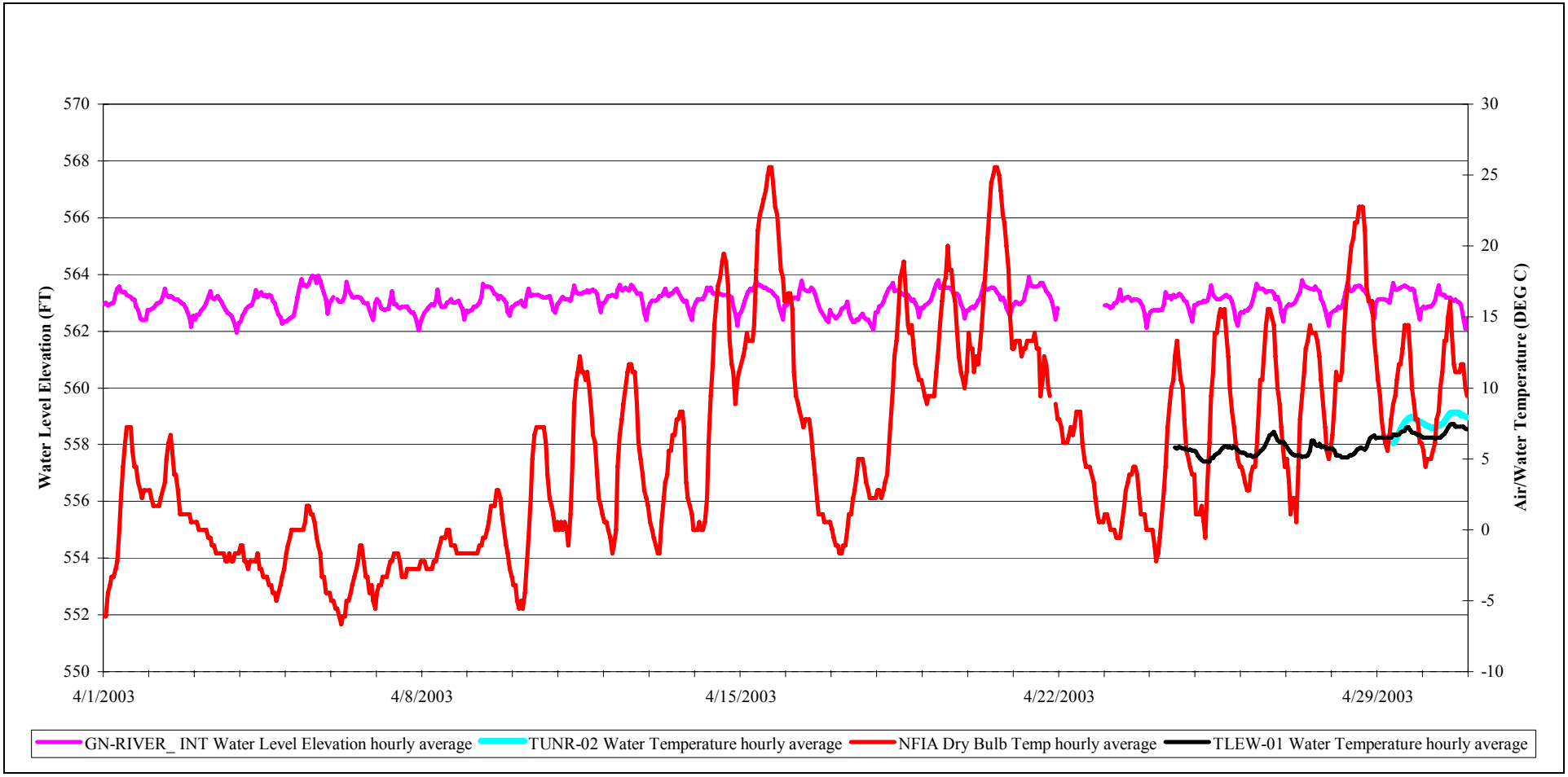

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FIGURE B-294: LEWISTON RESERVOIR

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

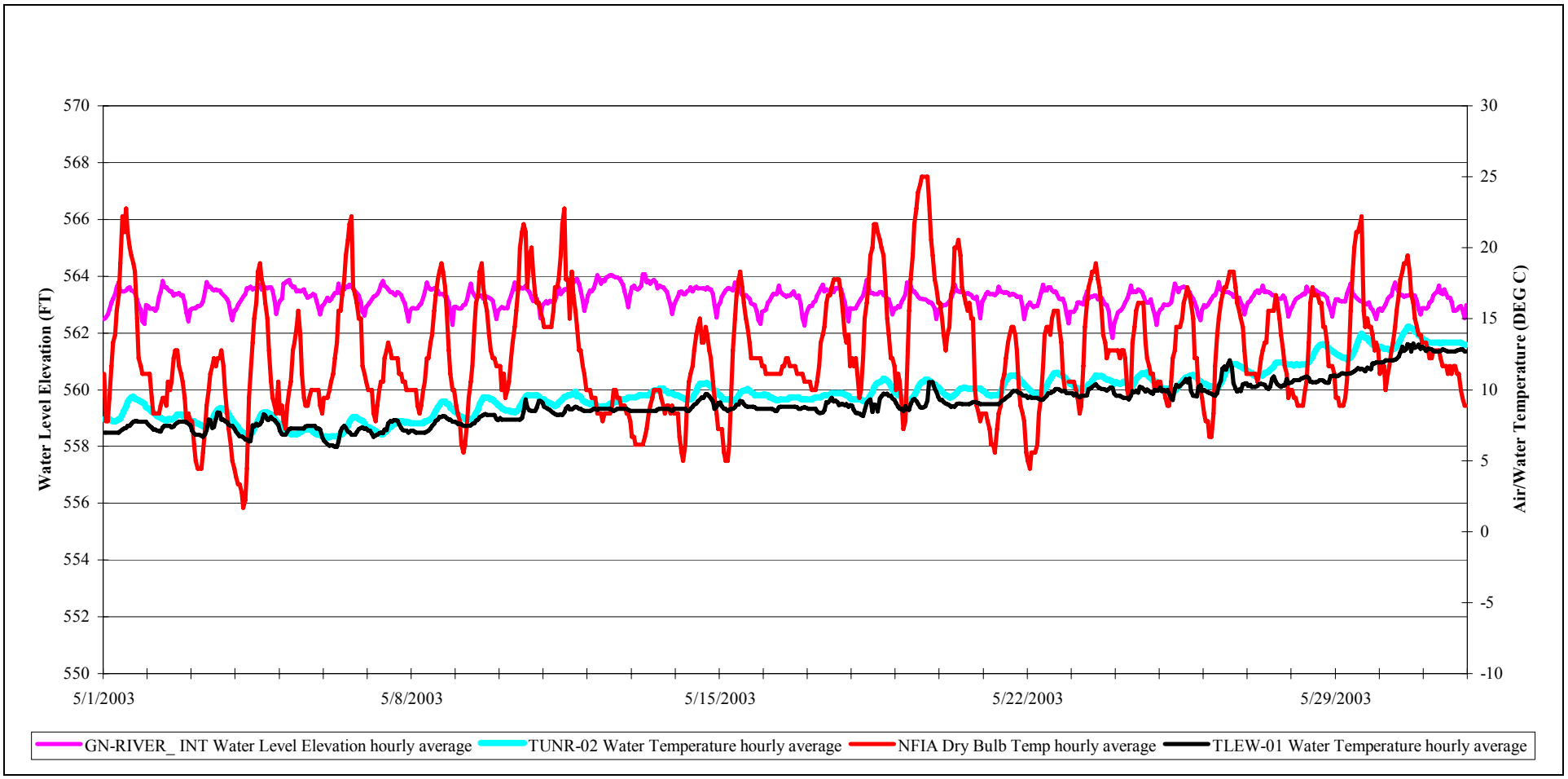

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FIGURE B-295: LEWISTON RESERVOIR

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

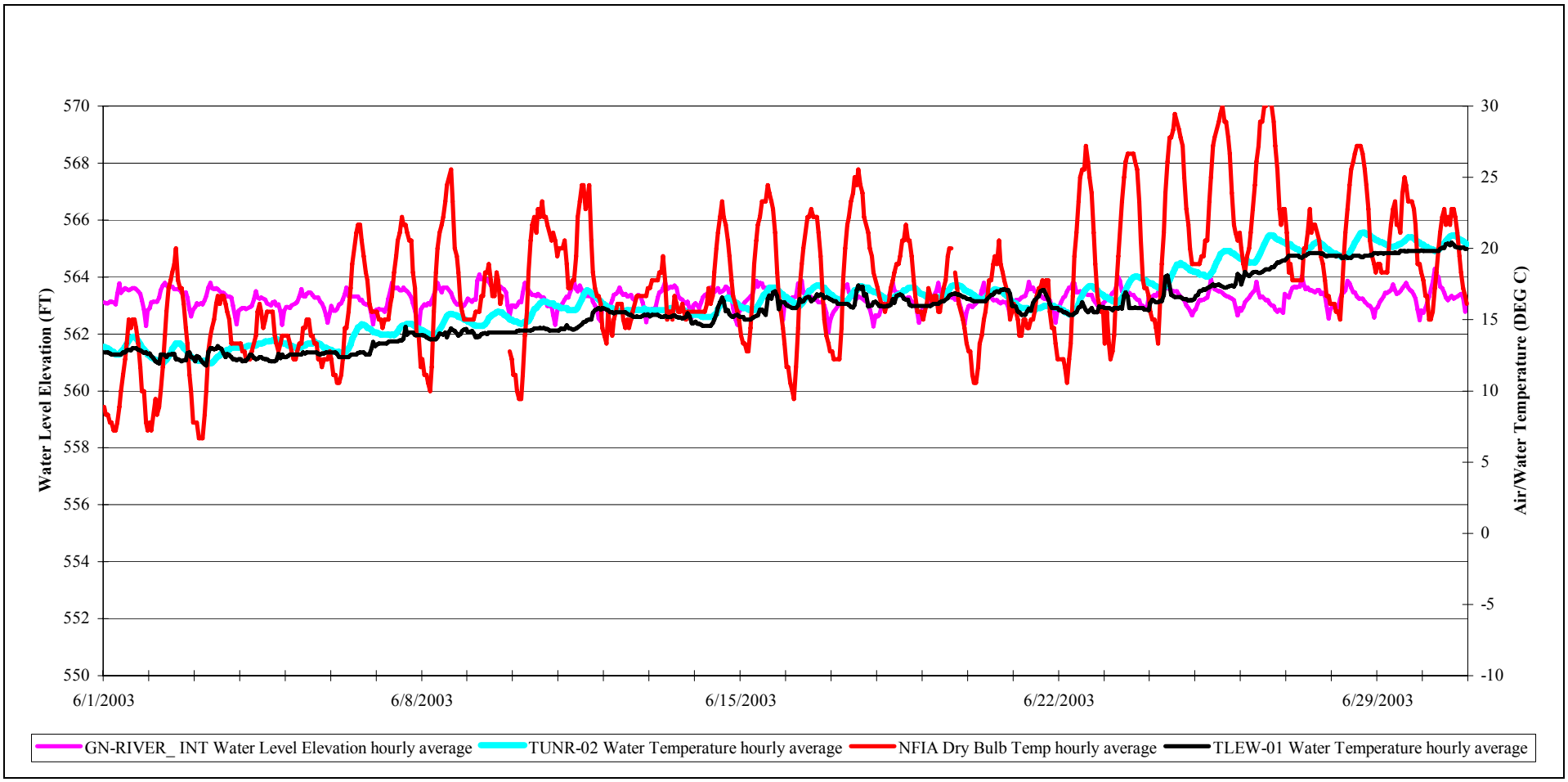

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FIGURE B-296: LEWISTON RESERVOIR

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

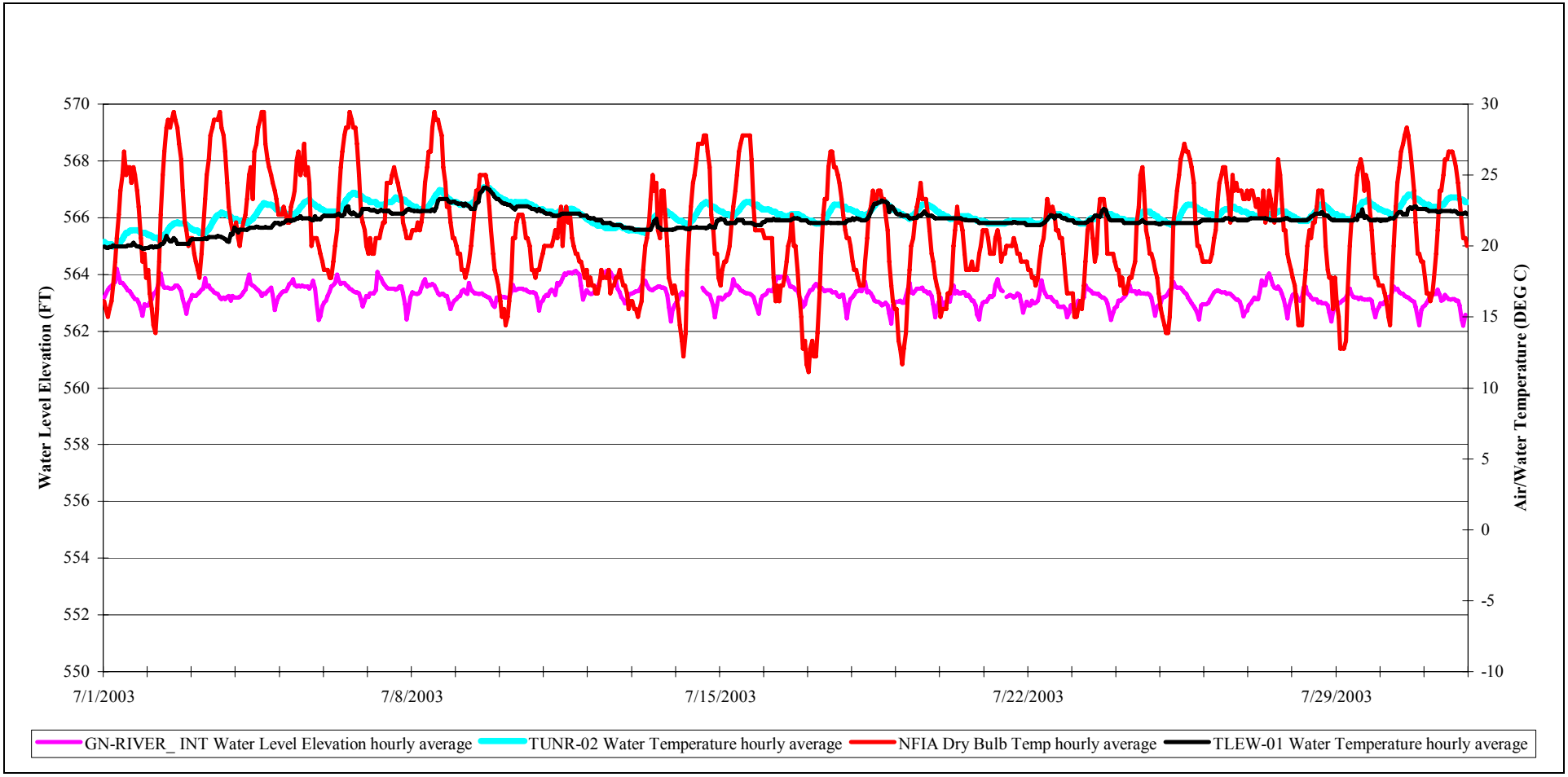

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FIGURE B-297: LEWISTON RESERVOIR

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

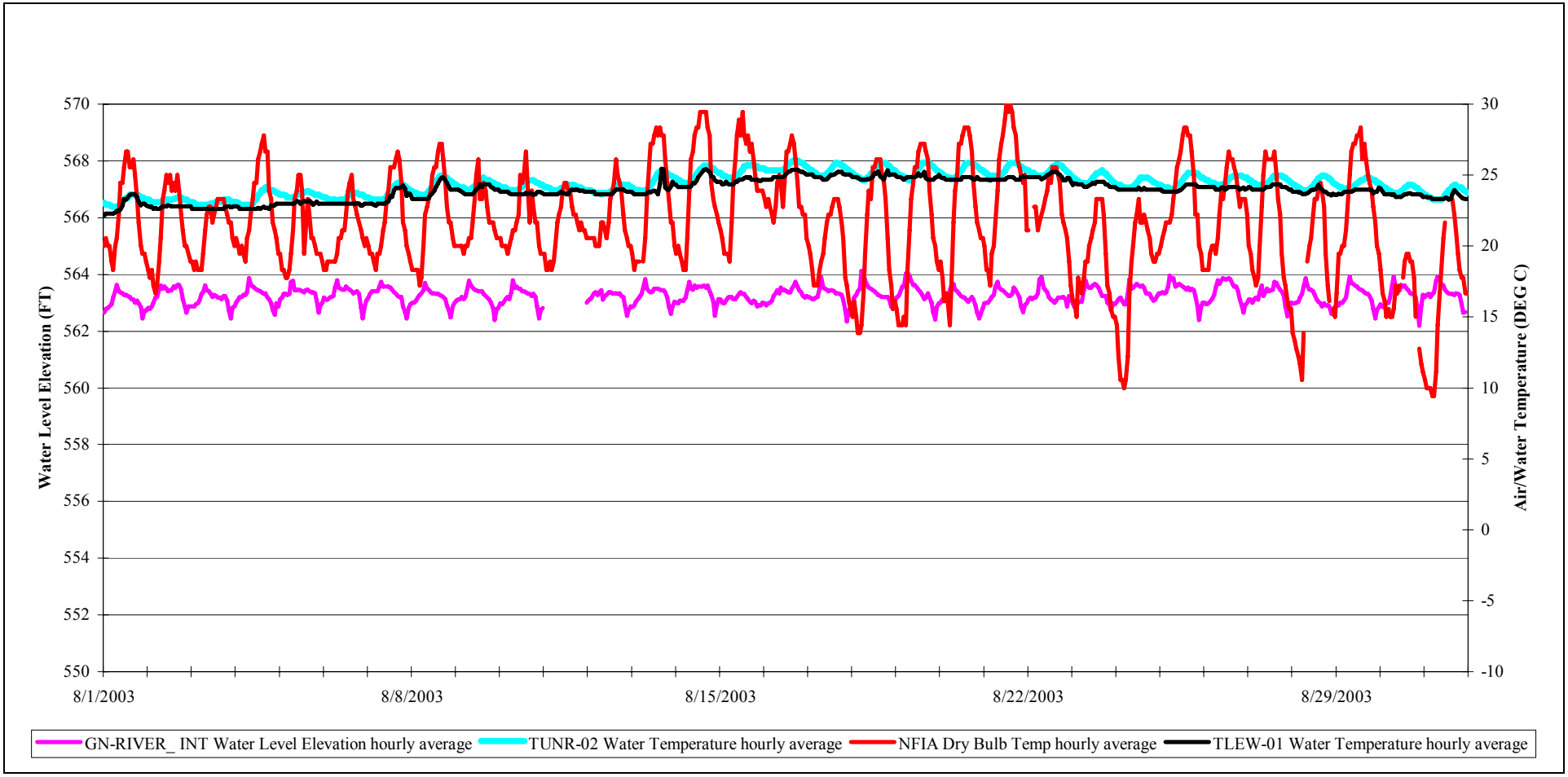

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FIGURE B-298: LEWISTON RESERVOIR

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR SEPTEMBER 2003

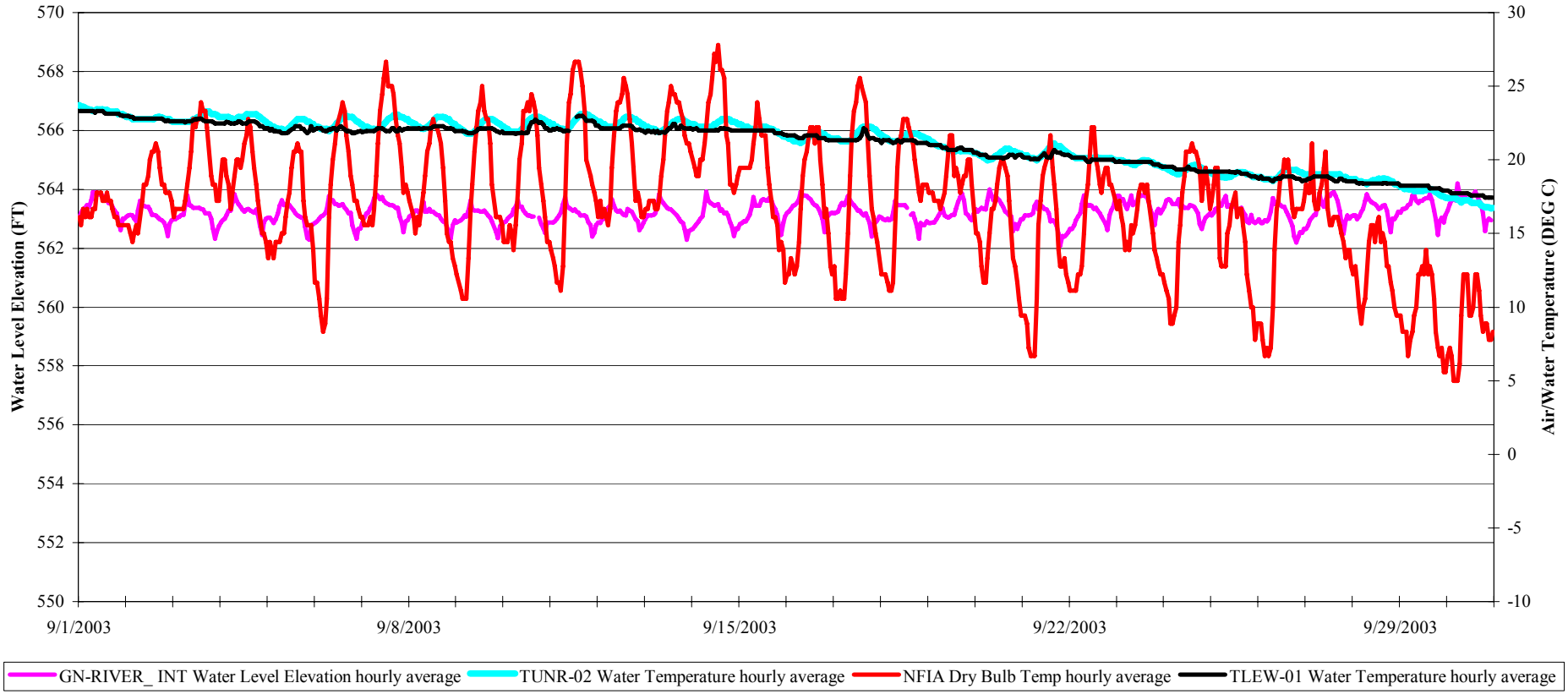

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FIGURE B-299: LEWISTON RESERVOIR

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR OCTOBER 2003

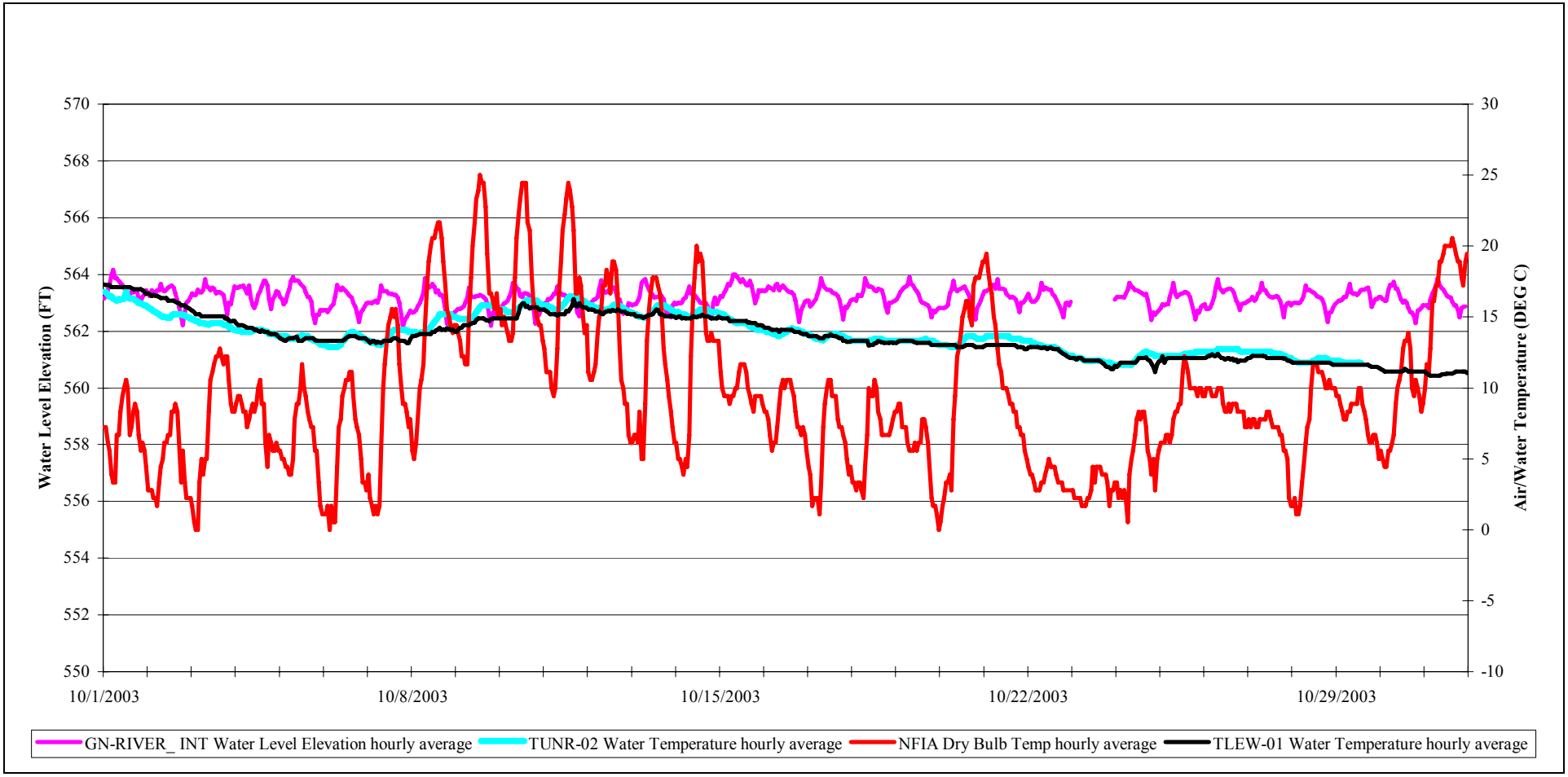

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FIGURE B-300: LEWISTON RESERVOIR

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

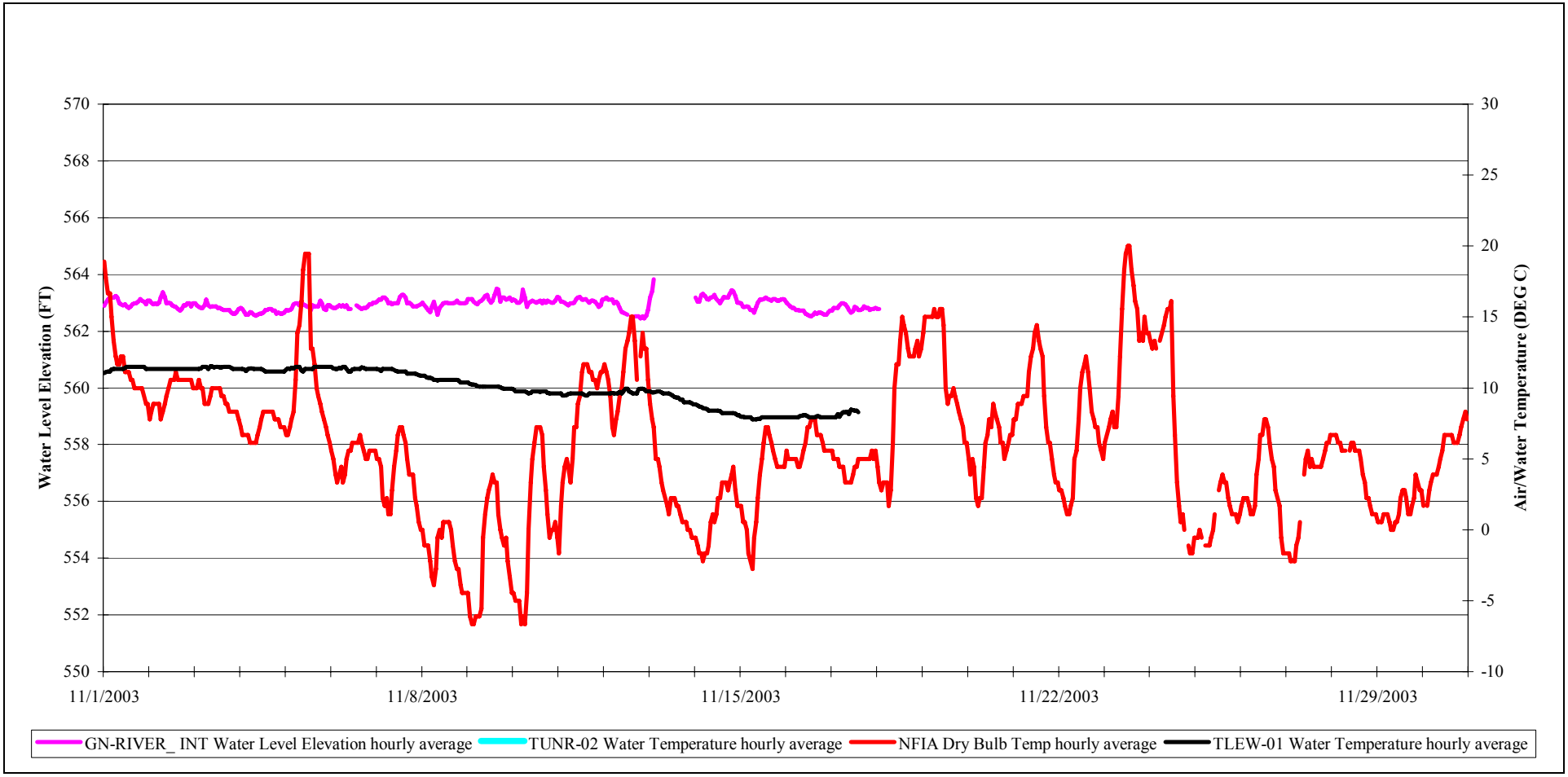

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FIGURE B-301: LOWER NIAGARA – LOWER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR APRIL 2003

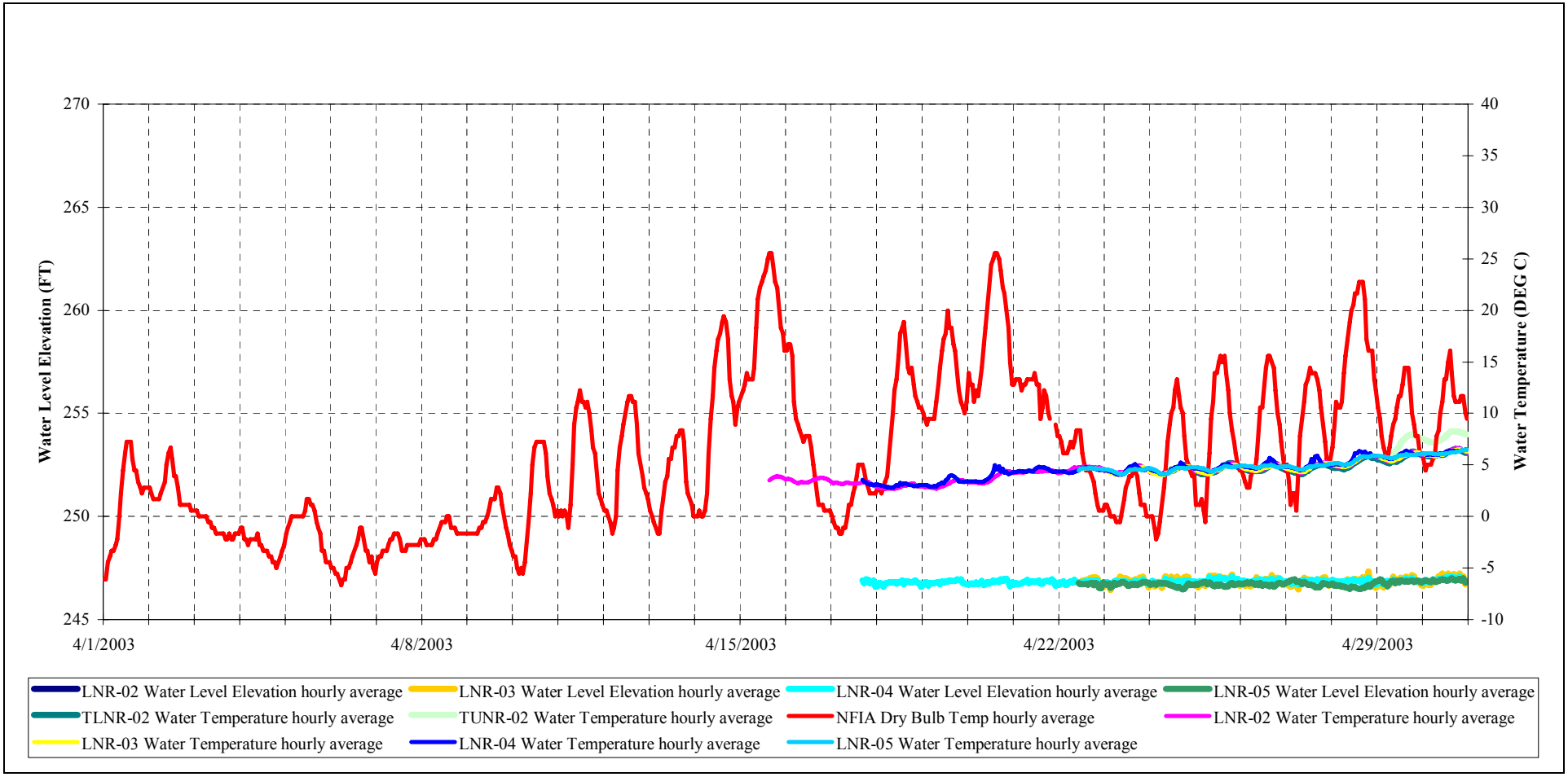

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FIGURE B-302: LOWER NIAGARA – LOWER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR MAY 2003

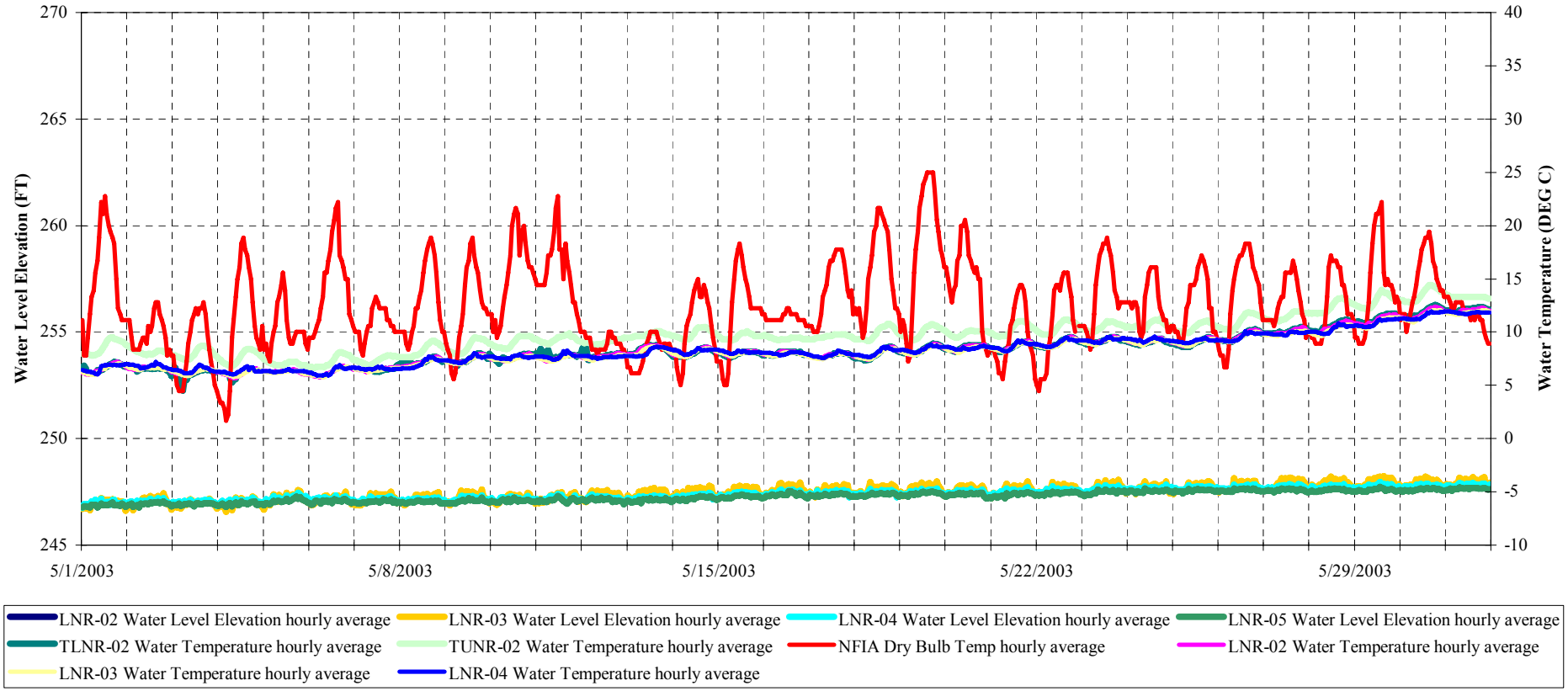

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FIGURE B-303: LOWER NIAGARA – LOWER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JUNE 2003

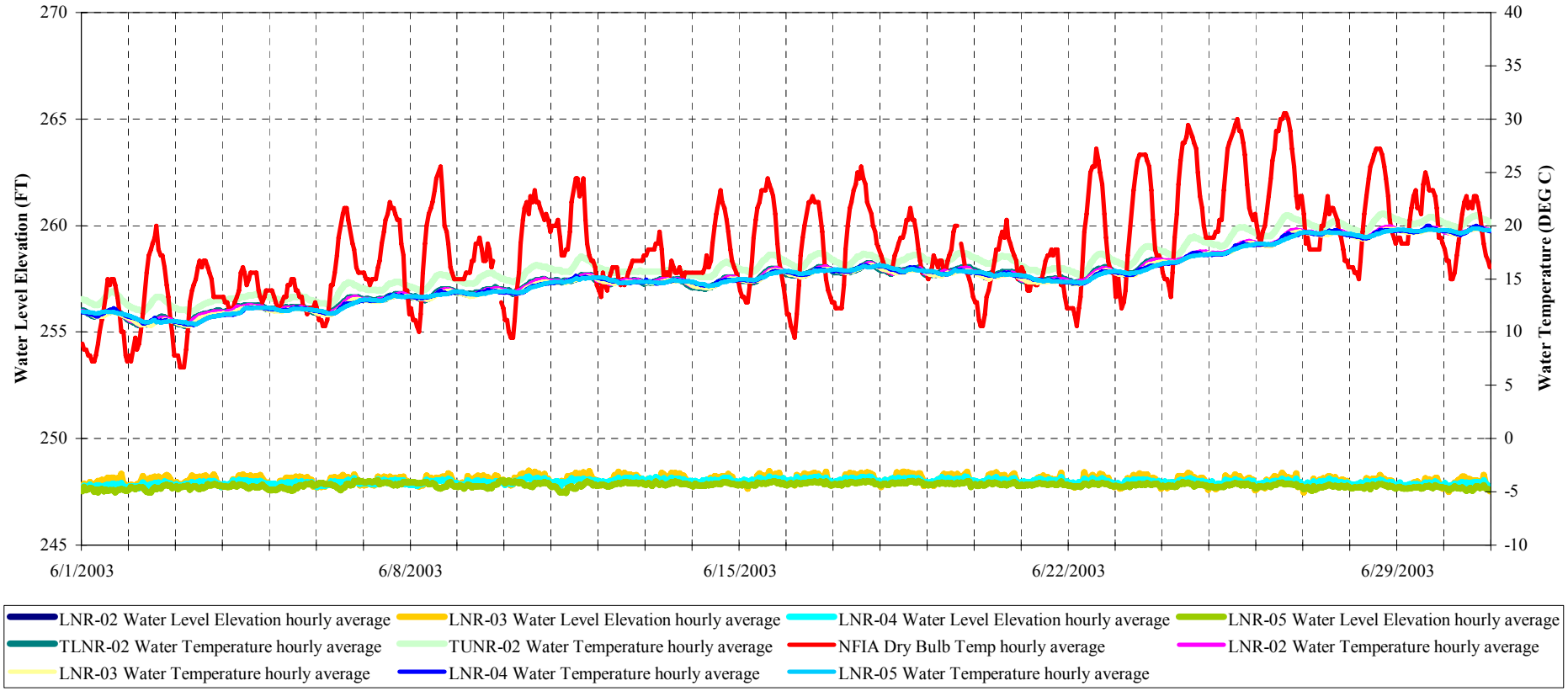

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FIGURE B-304: LOWER NIAGARA – LOWER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR JULY 2003

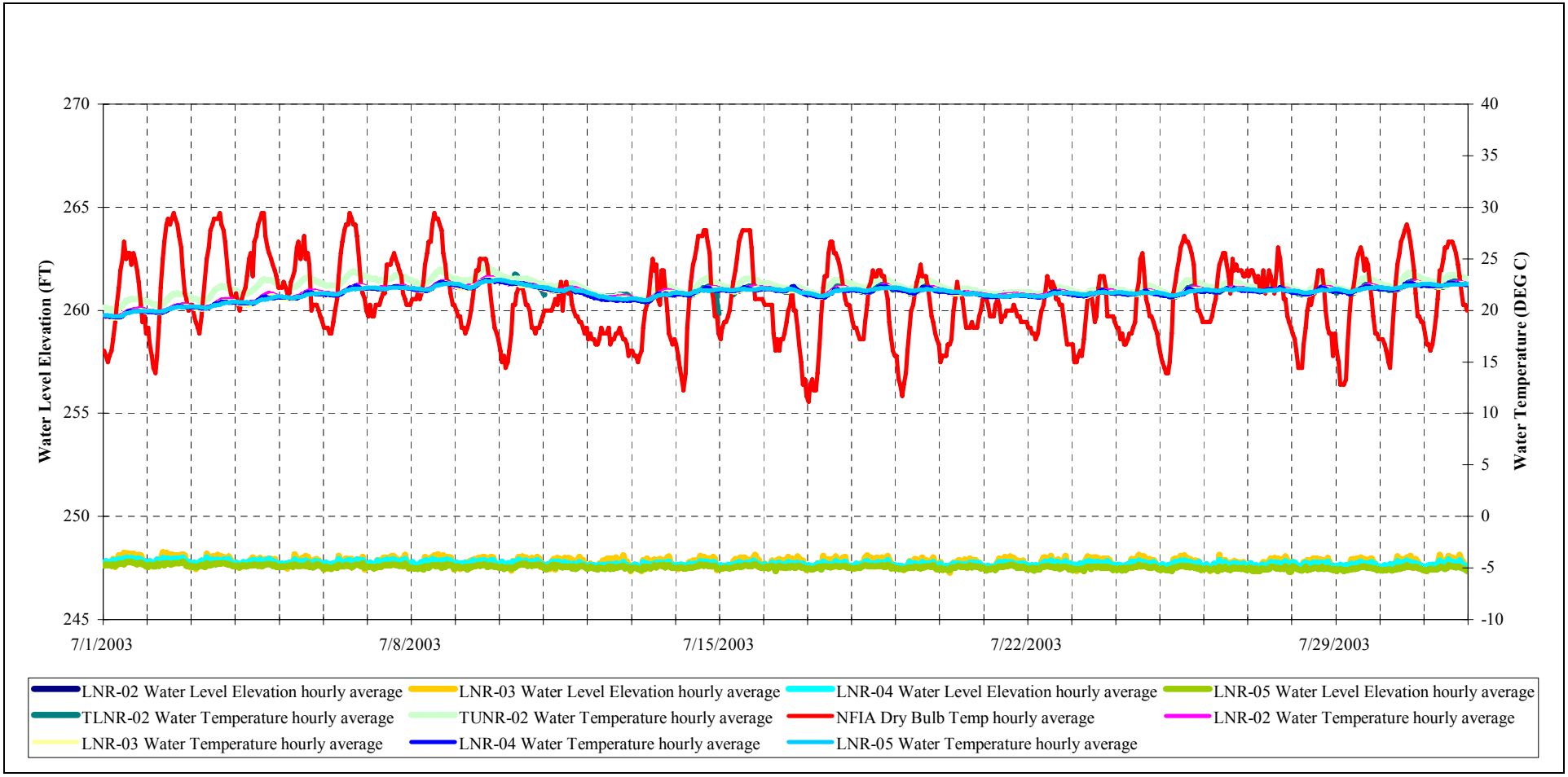

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FIGURE B-305: LOWER NIAGARA – LOWER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR AUGUST 2003

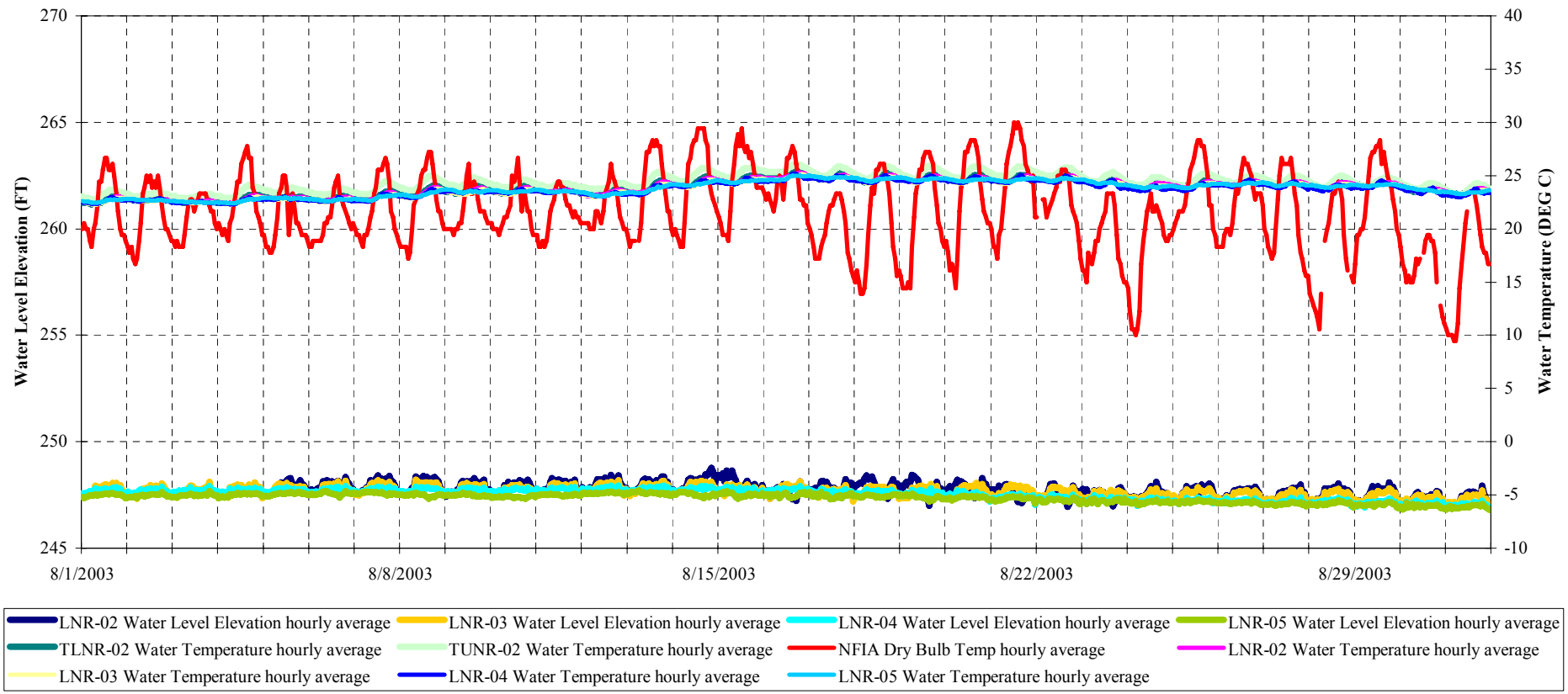

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FIGURE B-306: LOWER NIAGARA – LOWER MAIN CHANNEL

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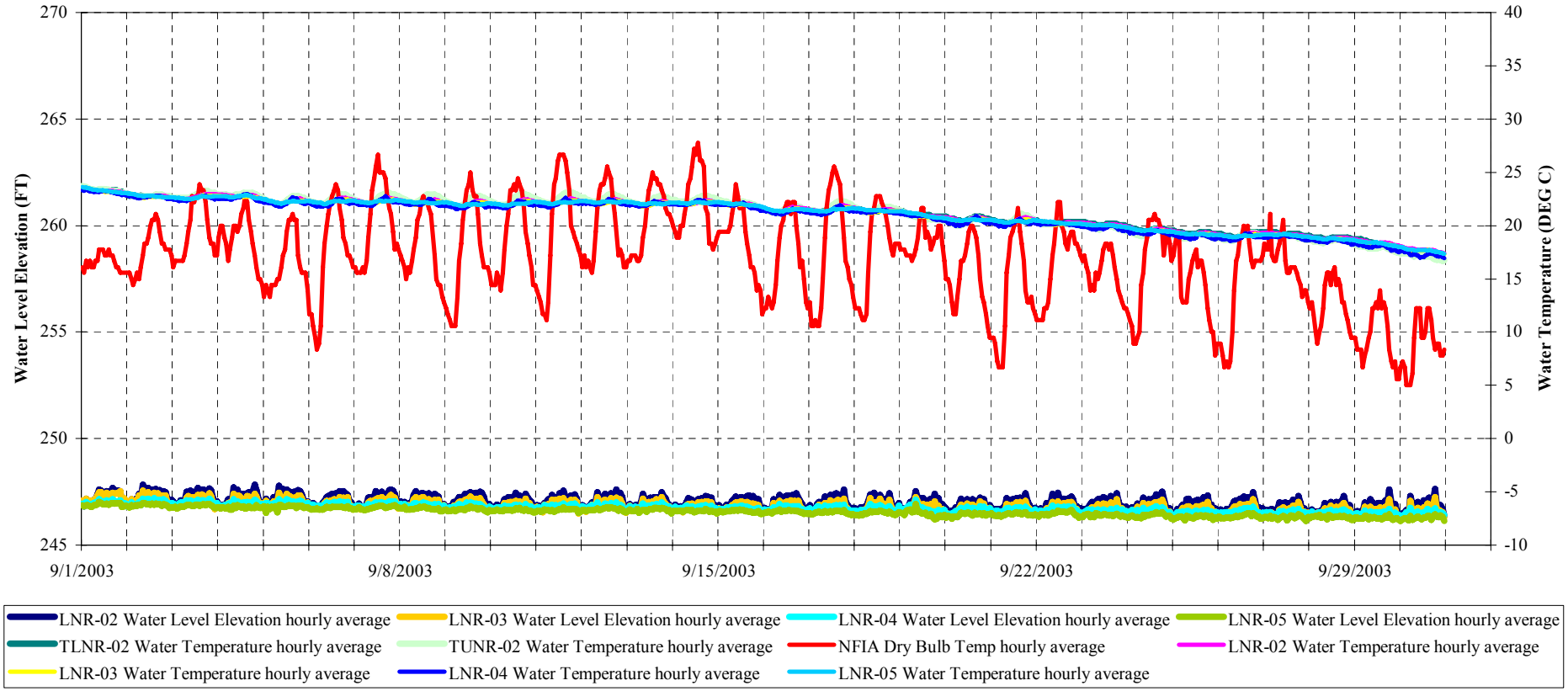

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FIGURE B-307: LOWER NIAGARA – LOWER MAIN CHANNEL

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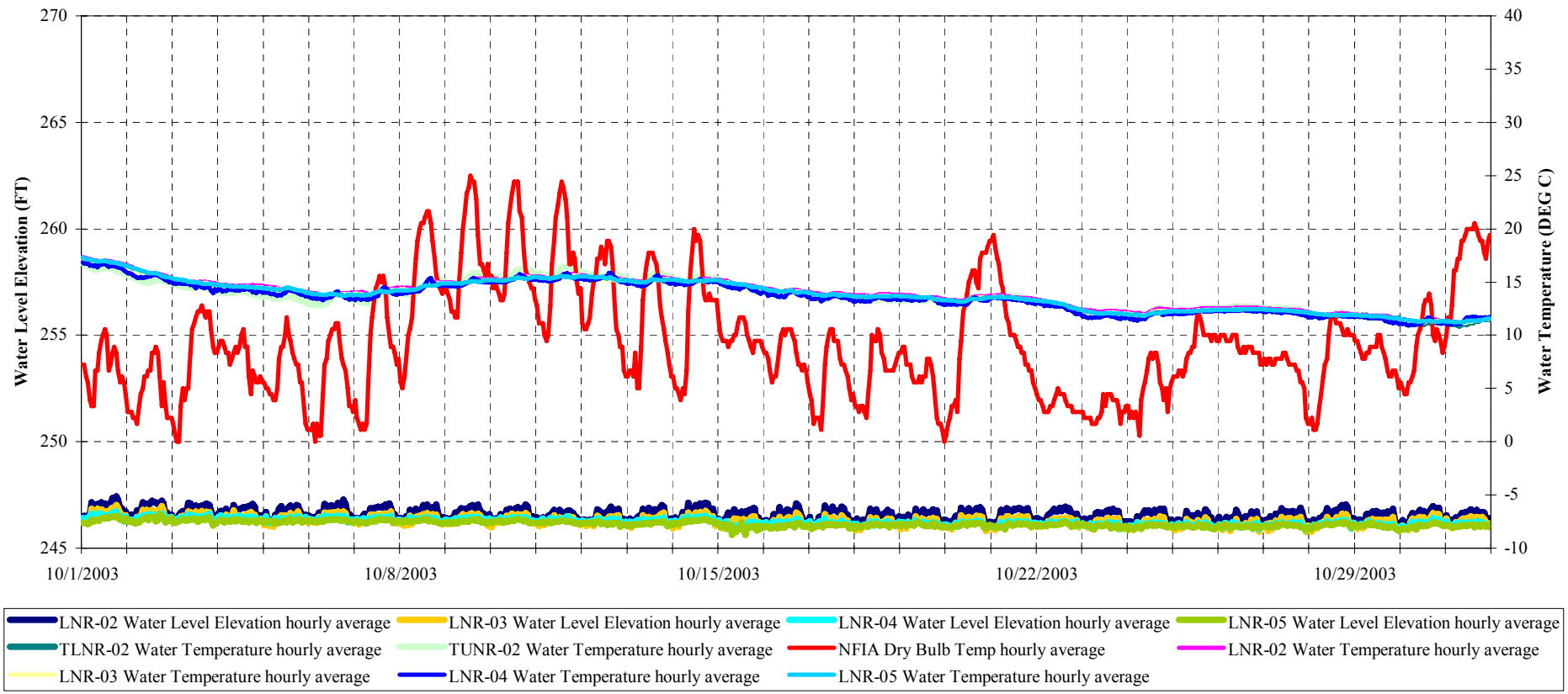

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FIGURE B-308: LOWER NIAGARA – LOWER MAIN CHANNEL

AVERAGE HOURLY WATER LEVEL AND TEMPERATURE DATA FOR NOVEMBER 2003

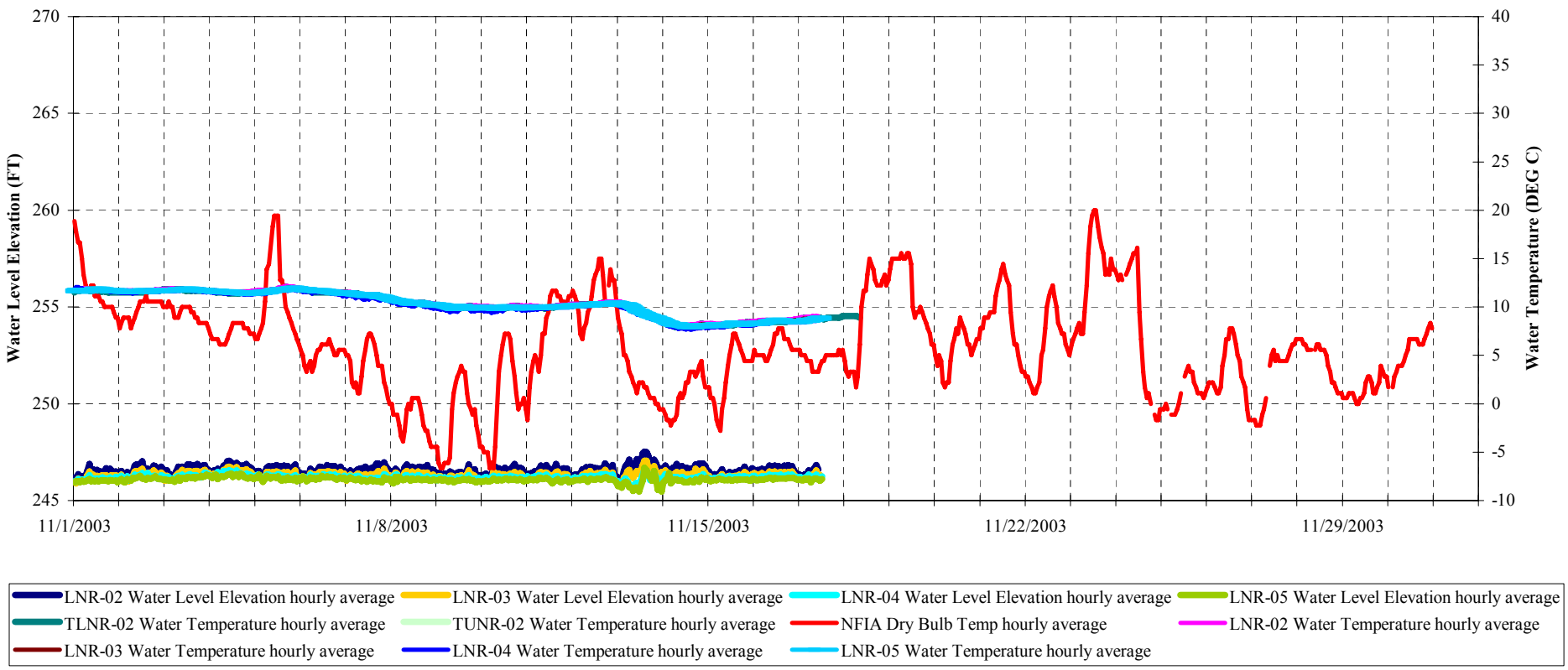

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FIGURE C-1: ANALYSIS ZONE 1 – BURNT SHIP CREEK (TBSC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES 2003

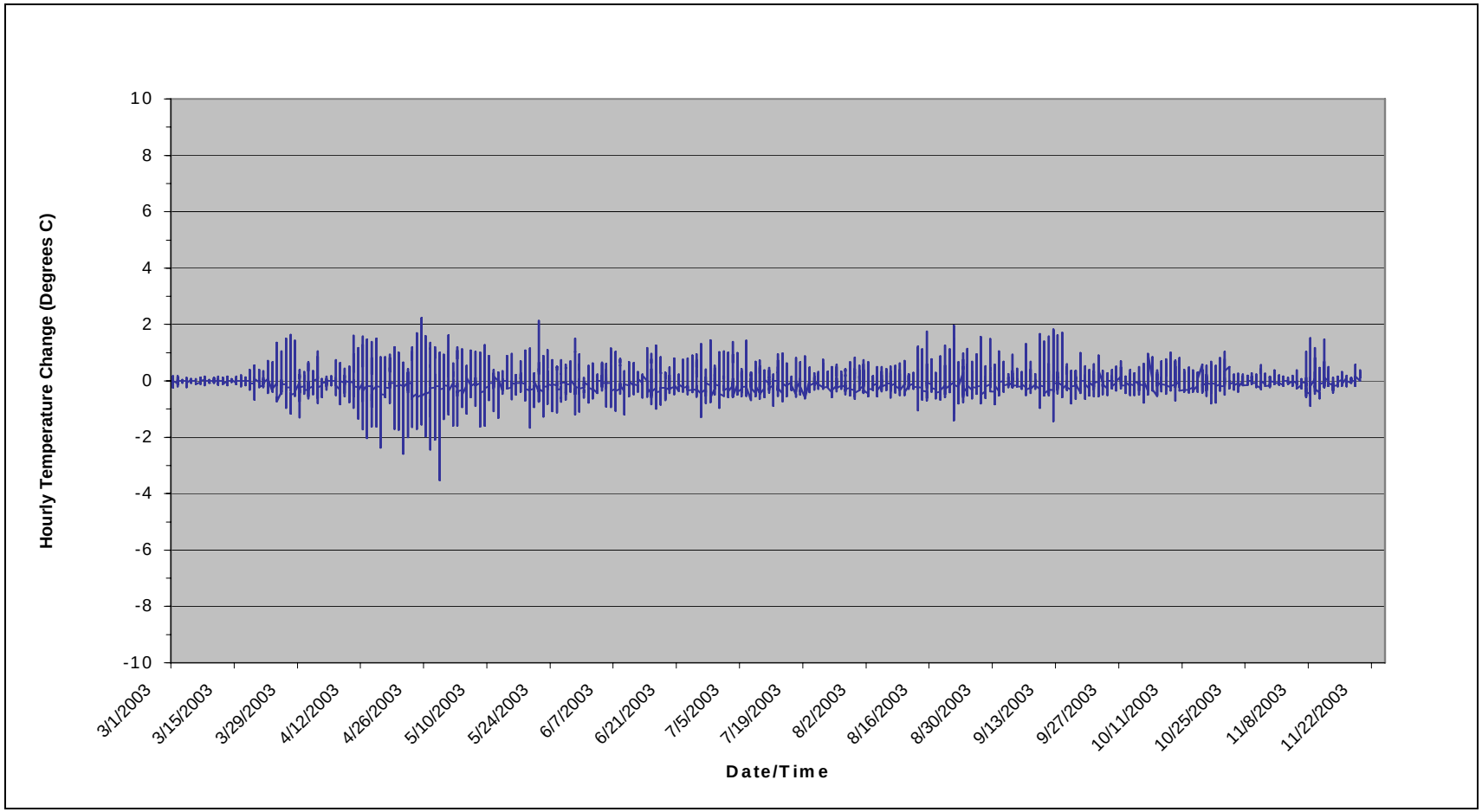

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FIGURE C-2A: ANALYSIS ZONE 1 – BURNT SHIP CREEK (TBSC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES 2003

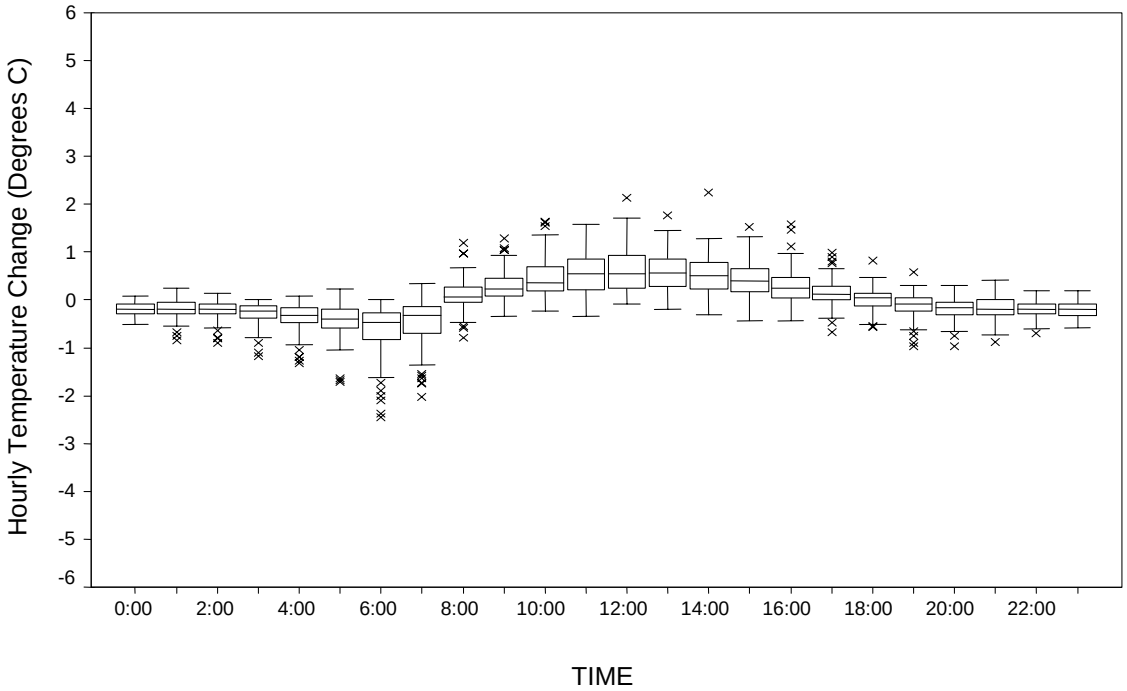

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FIGURE C-2B: ANALYSIS ZONE 1 – BURNT SHIP CREEK (TBSC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2003

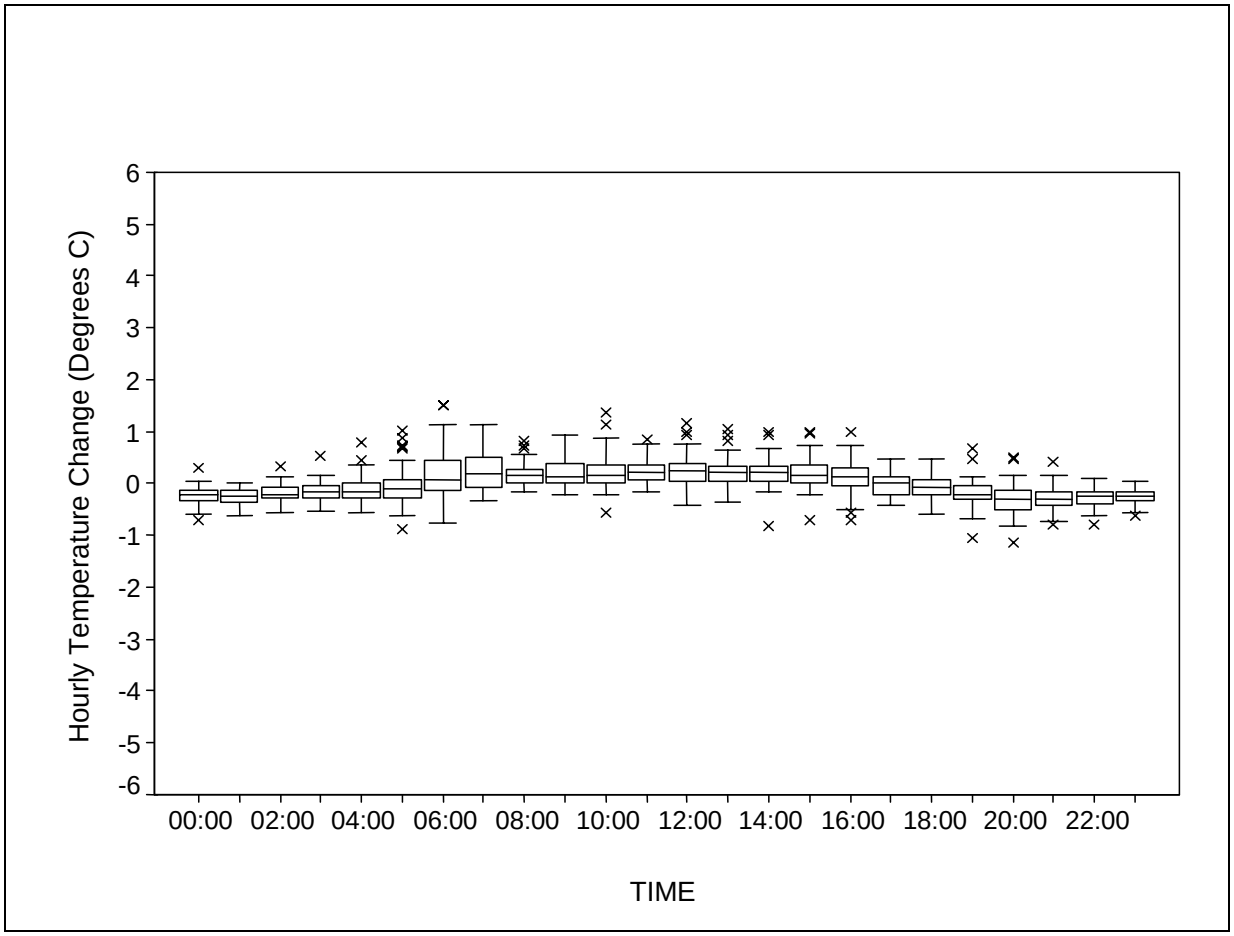

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FIGURE C-2C: ANALYSIS ZONE 1 – BURNT SHIP CREEK (TBSC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2003

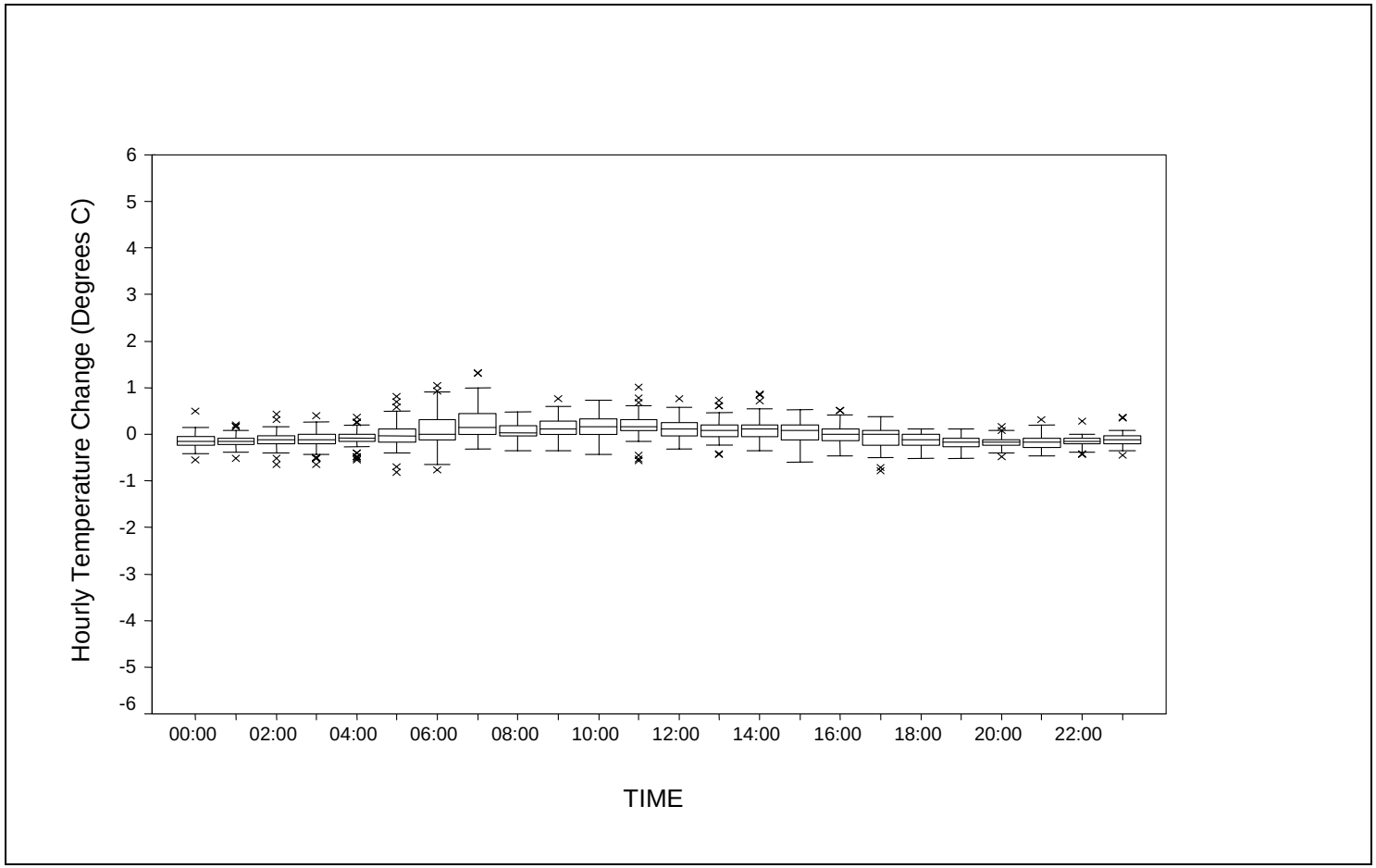

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FIGURE C-3A: ANALYSIS ZONE 1 – BURNT SHIP CREEK (BSC-01)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2003

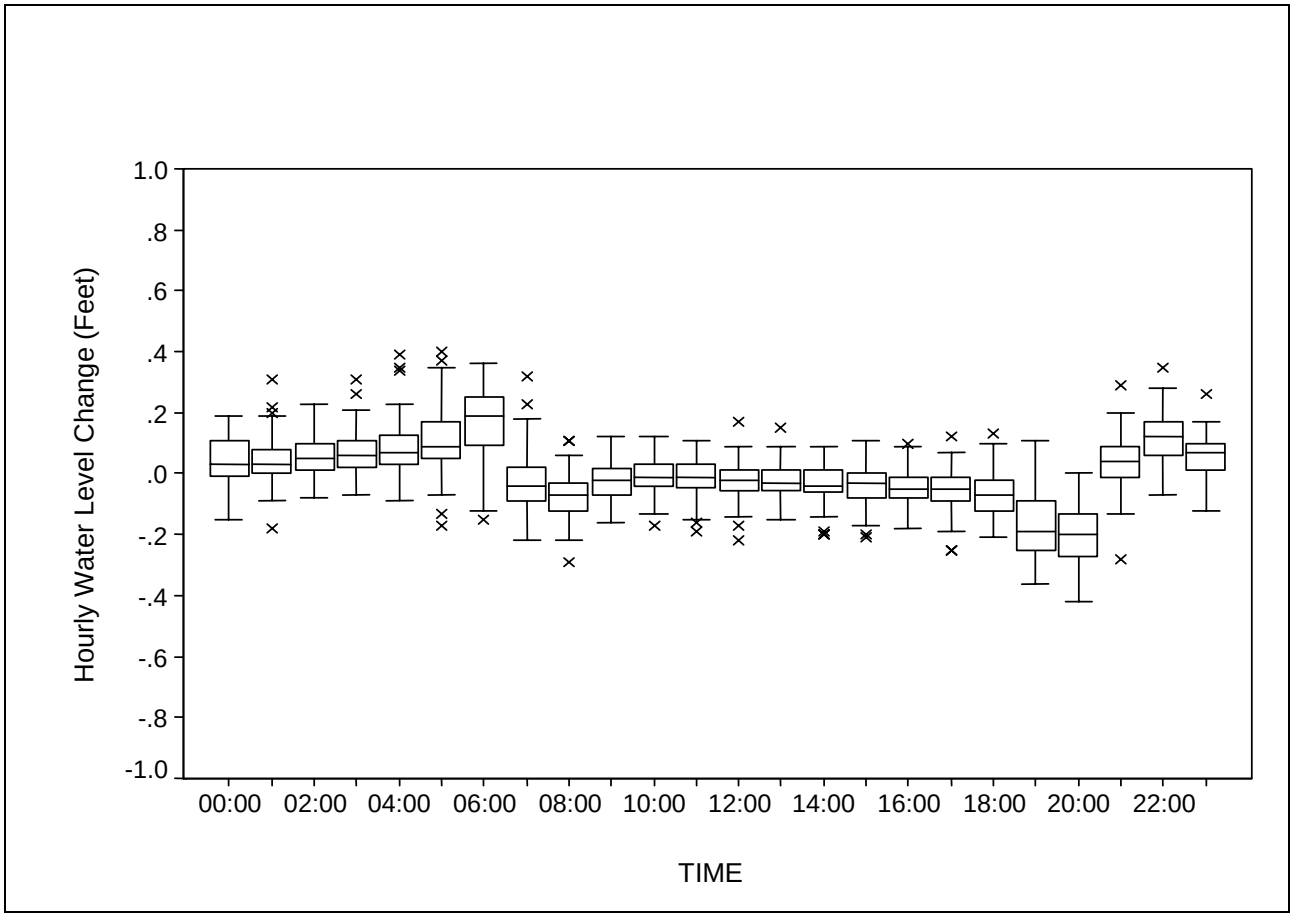

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FIGURE C-3B: ANALYSIS ZONE 1 – BURNT SHIP CREEK (BSC-01)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2003

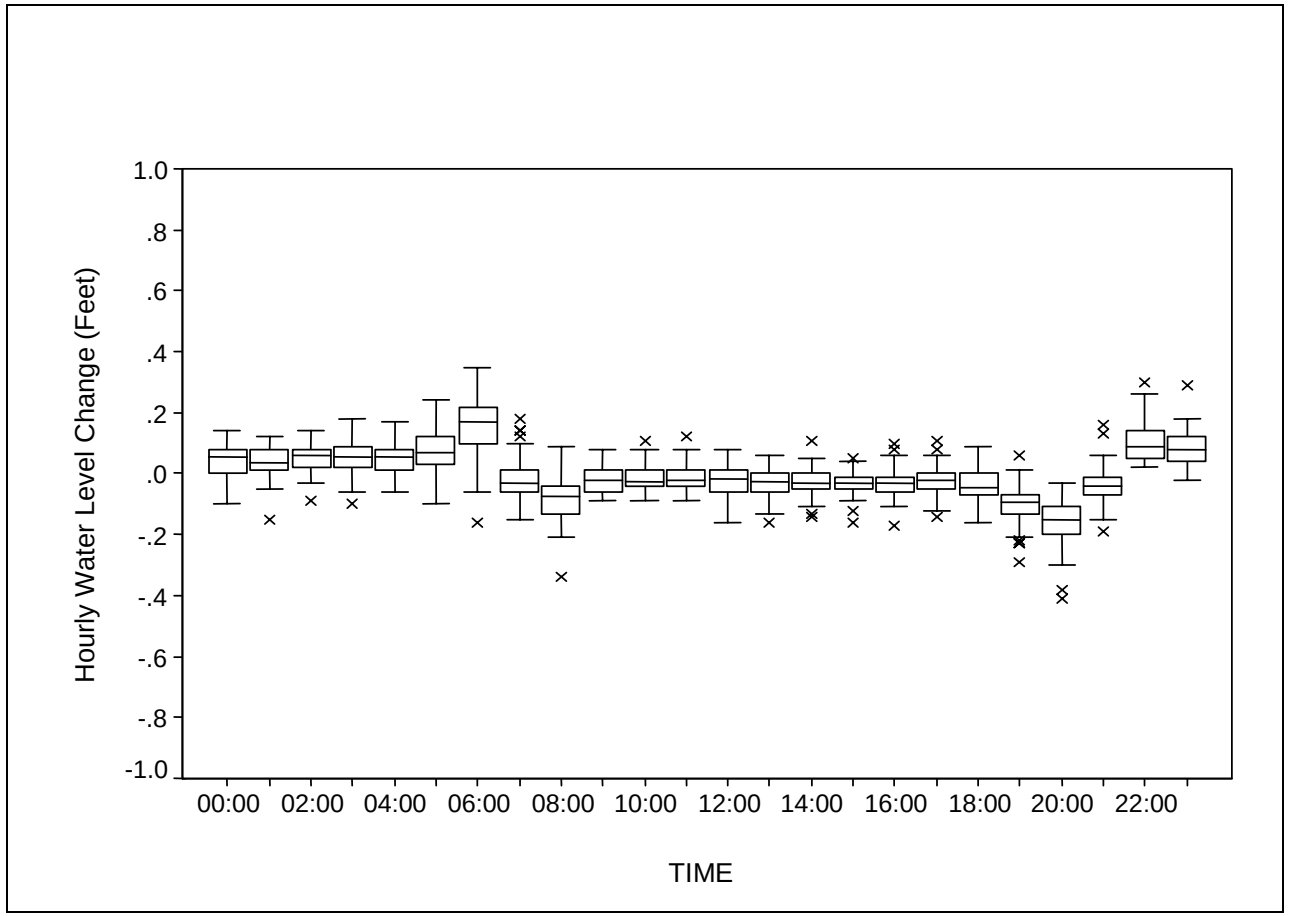

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FIGURE C-3C: ANALYSIS ZONE 1 – BURNT SHIP CREEK (BSC-01)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2003

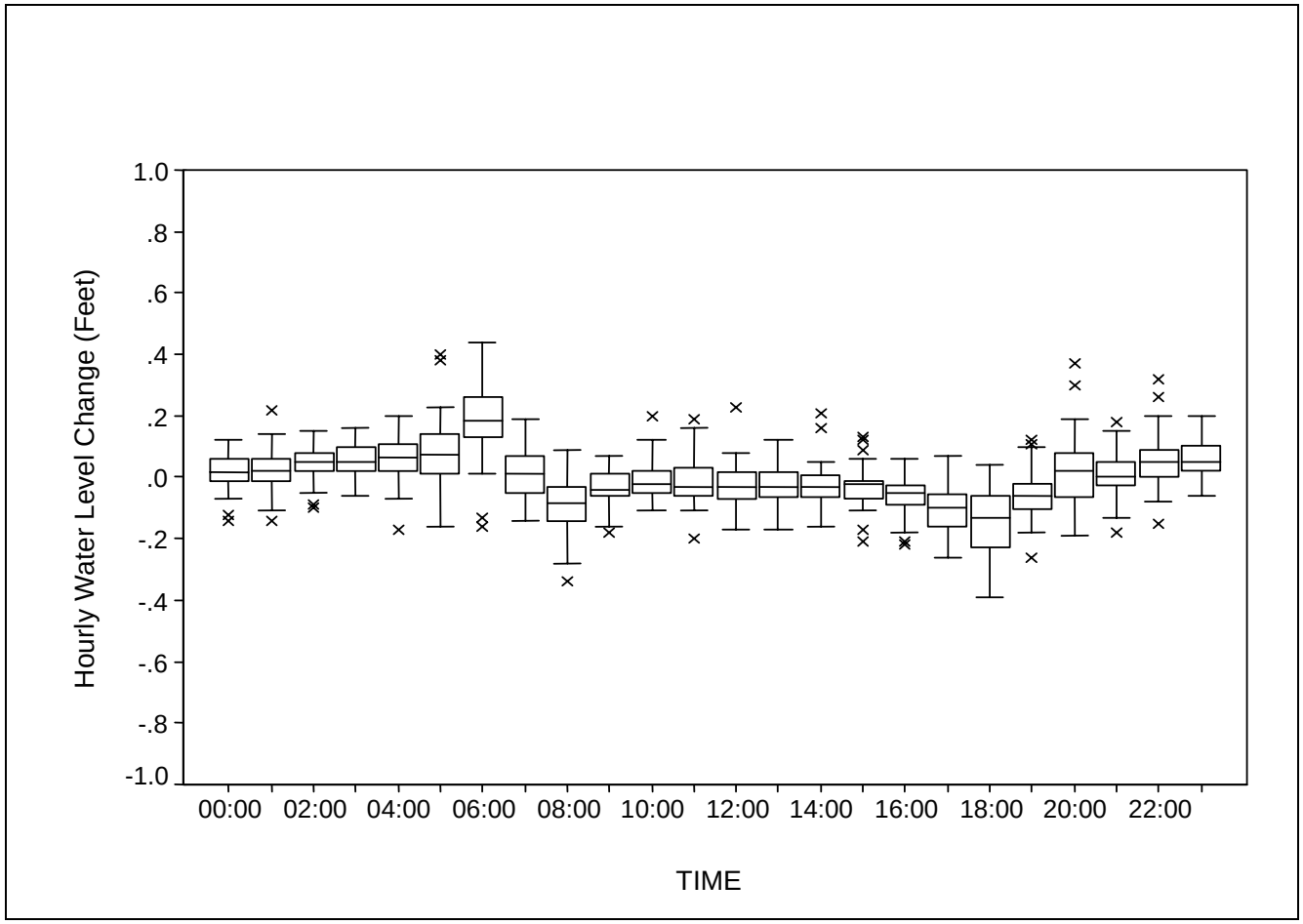

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FIGURE C-4: ANALYSIS ZONE 1 – BURNT SHIP CREEK (TBSC-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

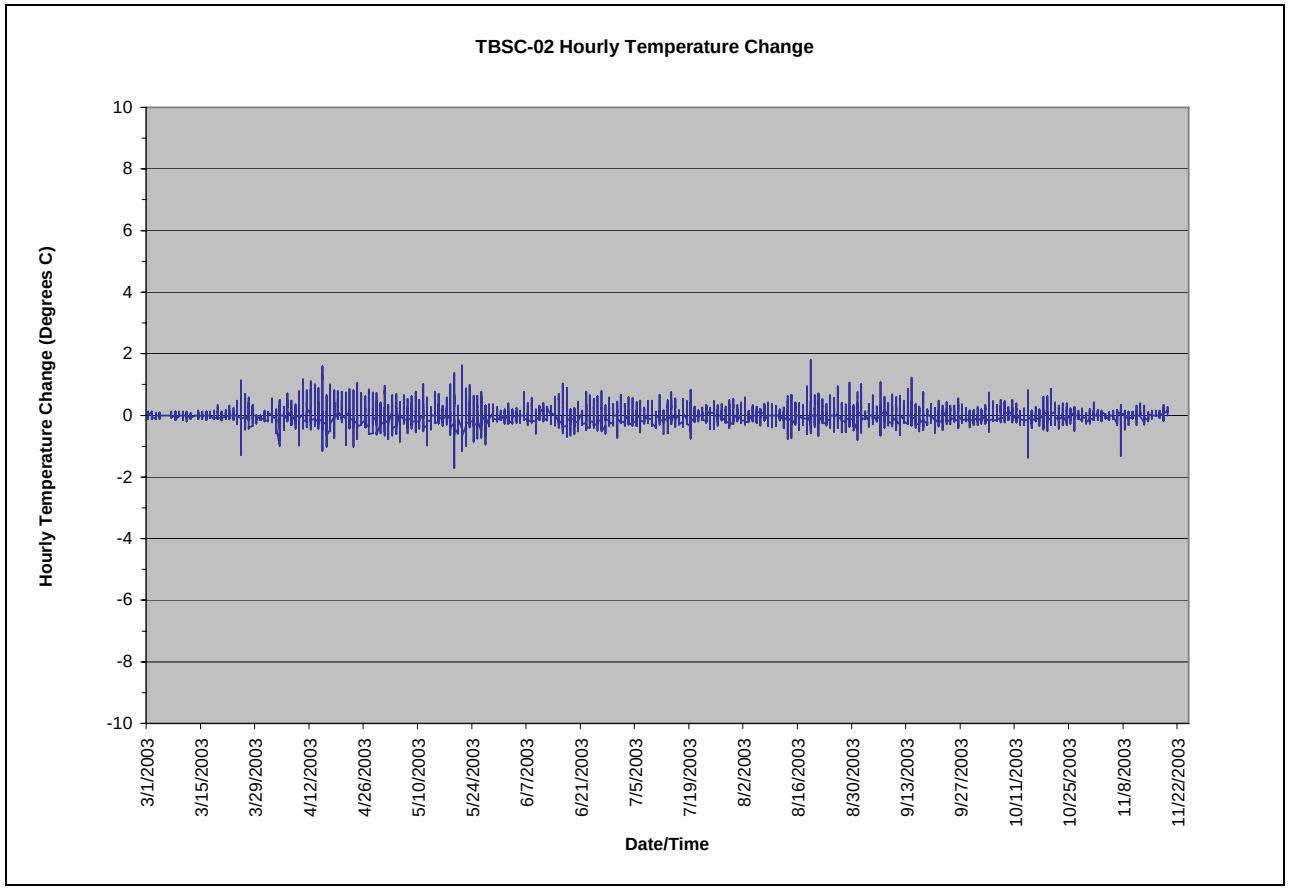

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FIGURE C-5A: ANALYSIS ZONE 1 – BURNT SHIP CREEK (TBSC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2003

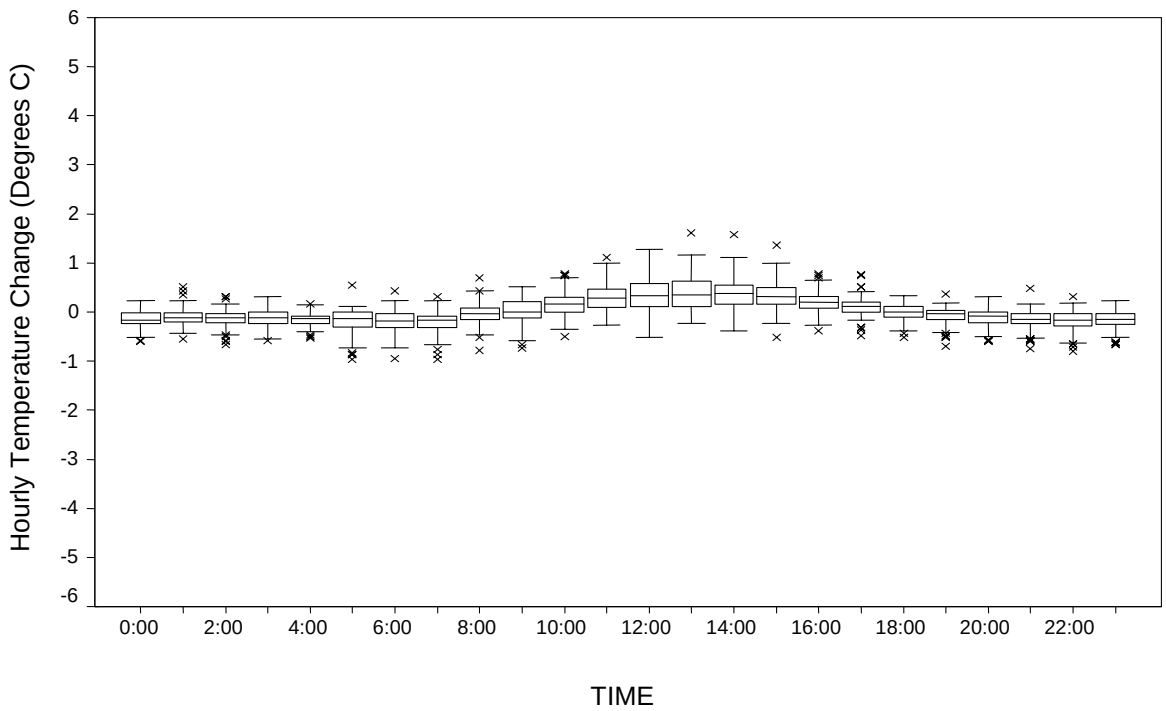

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FIGURE C-5B: ANALYSIS ZONE 1 – BURNT SHIP CREEK (TBSC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2003

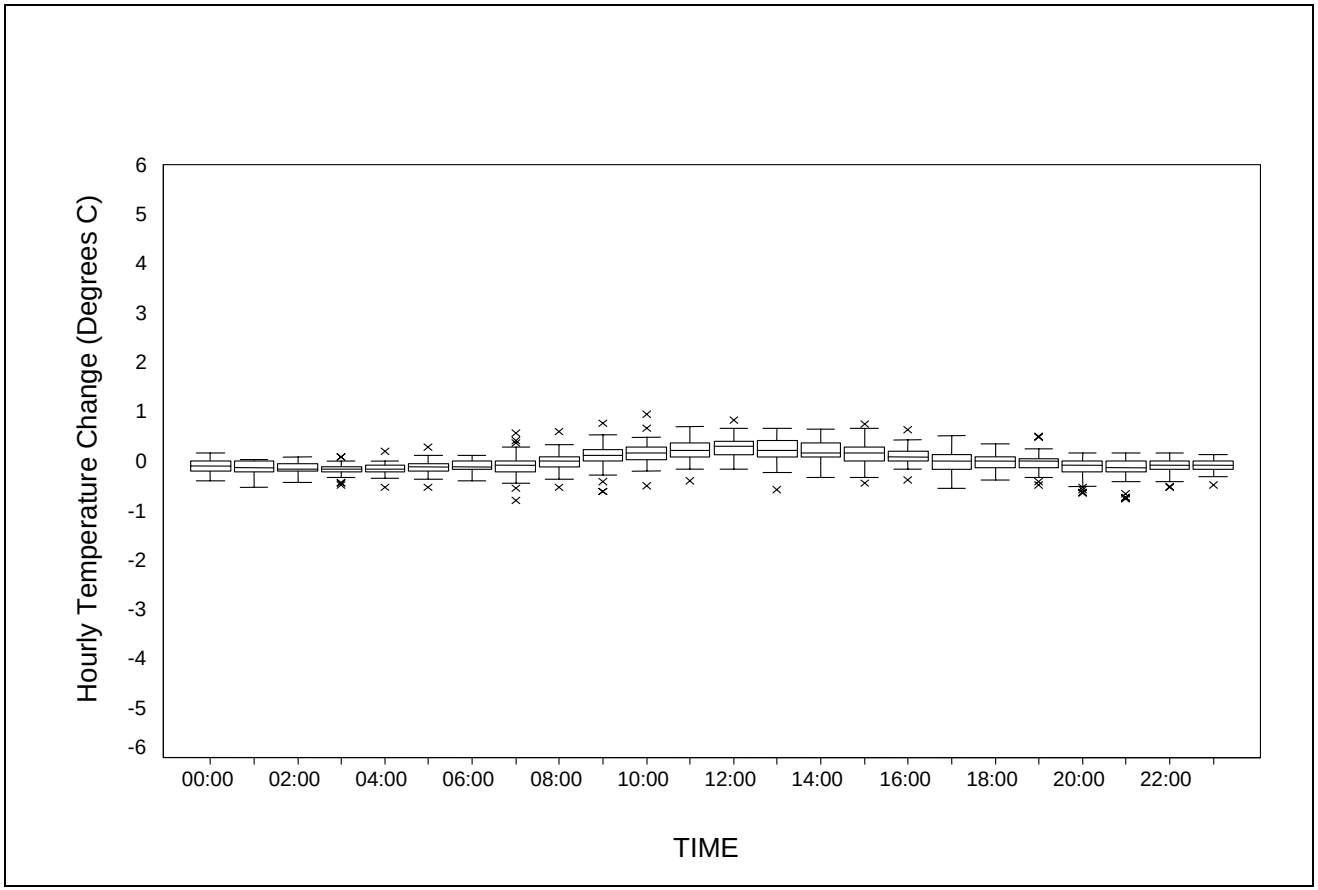

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FIGURE C-5C: ANALYSIS ZONE 1 – BURNT SHIP CREEK (TBSC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2003

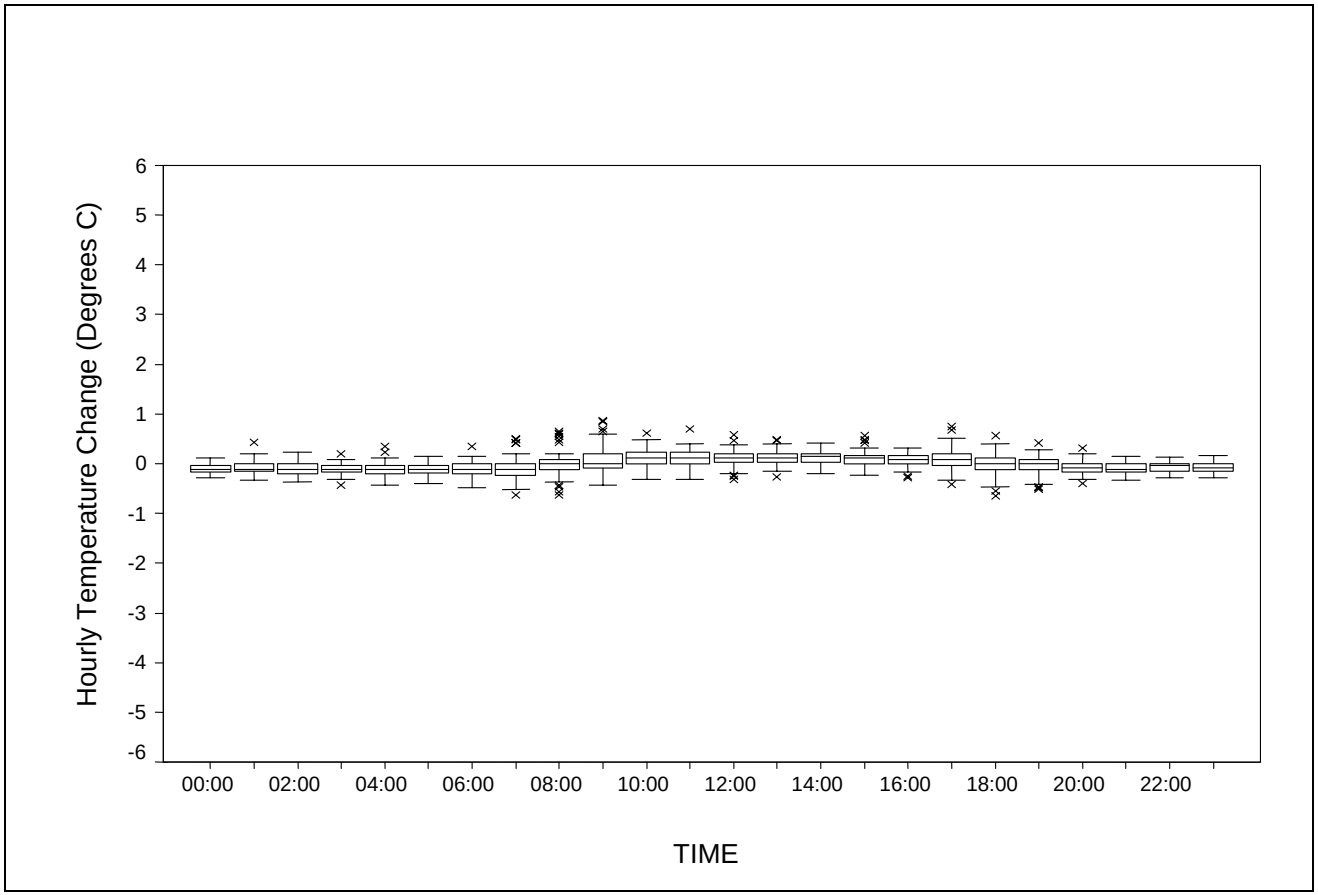

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FIGURE C-6A: ANALYSIS ZONE 1 – BURNT SHIP CREEK (BSC-02)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2003

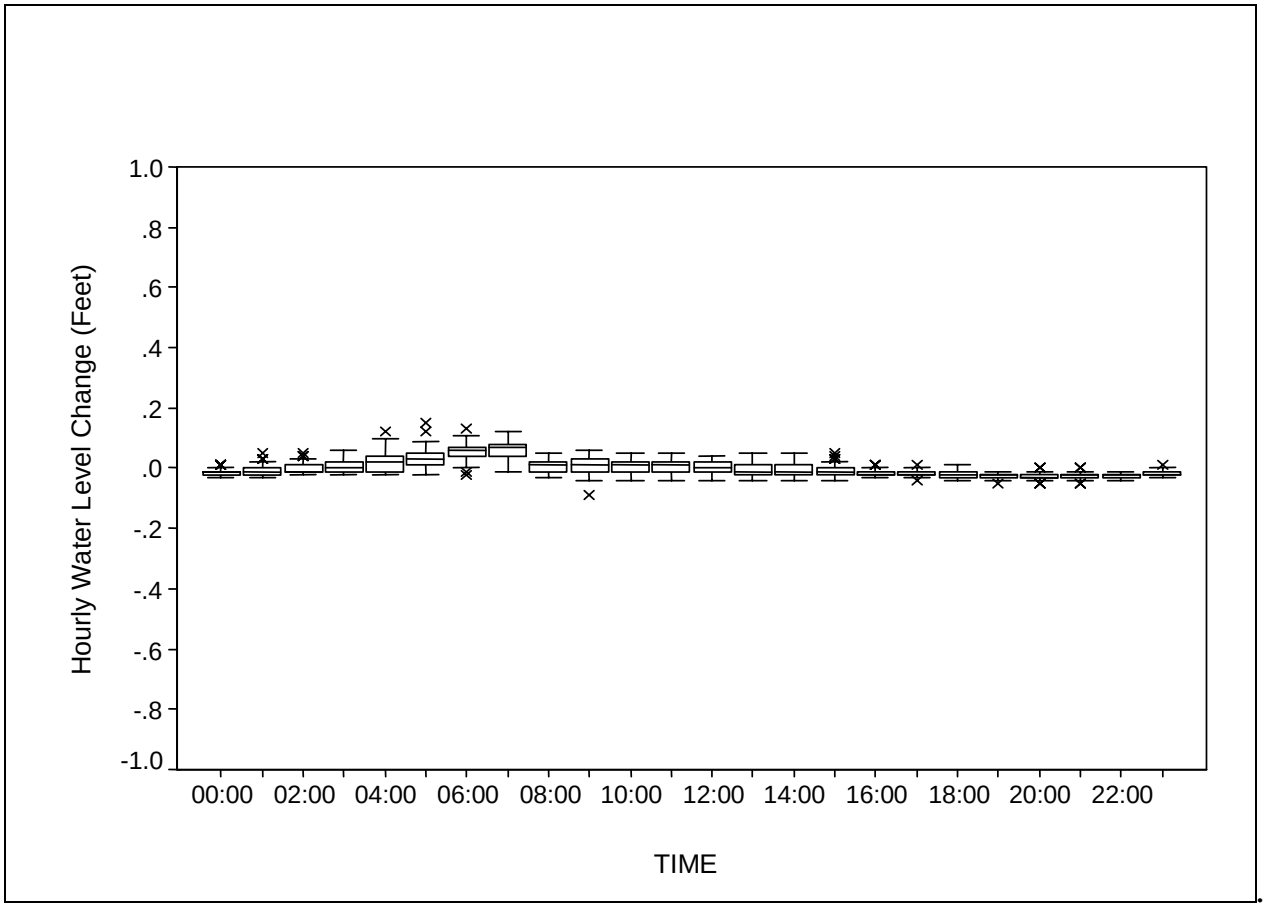

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FIGURE C-6B: ANALYSIS ZONE 1 – BURNT SHIP CREEK (BSC-02)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2003

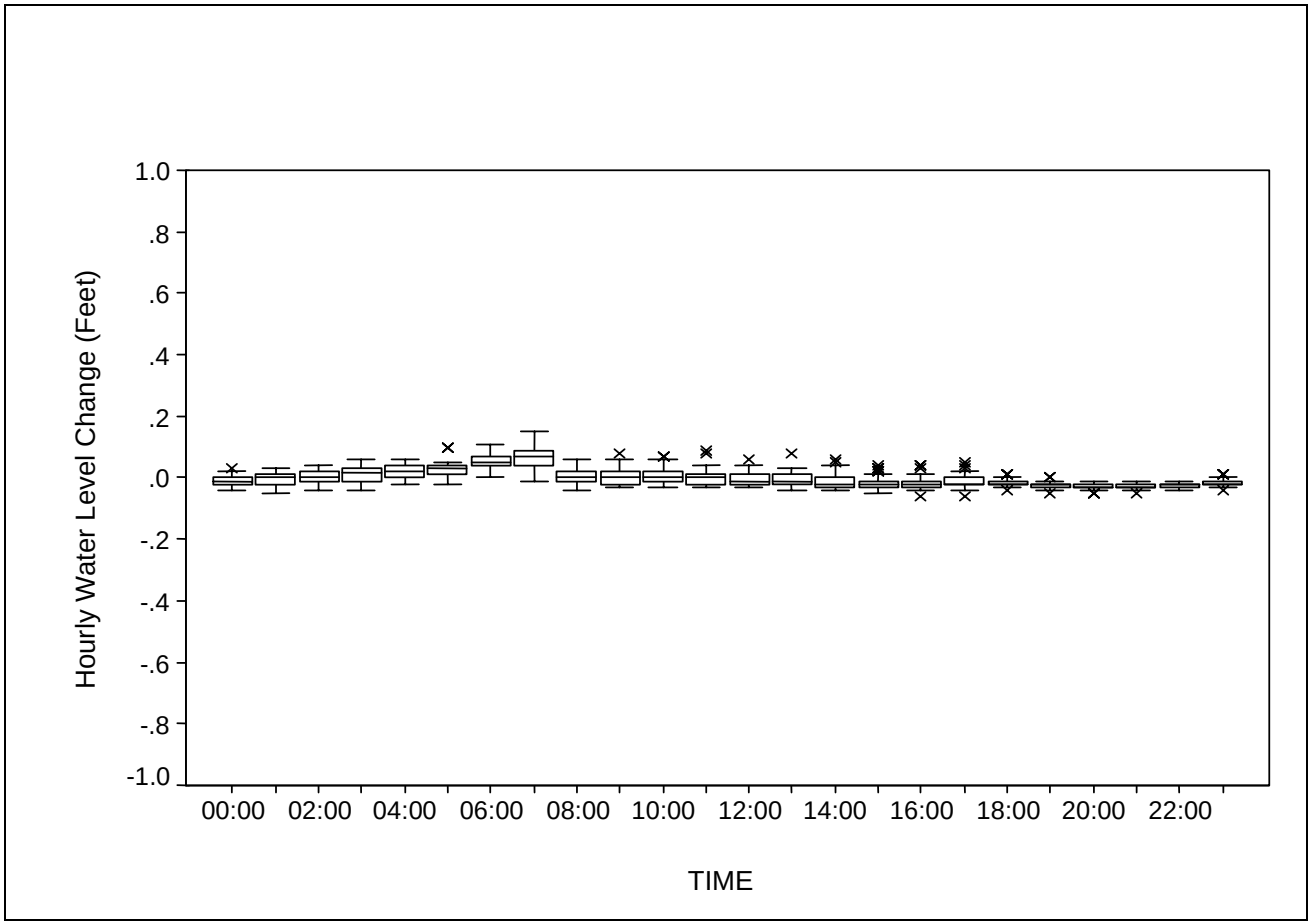

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FIGURE C-6C: ANALYSIS ZONE 1 – BURNT SHIP CREEK (BSC-02)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2003

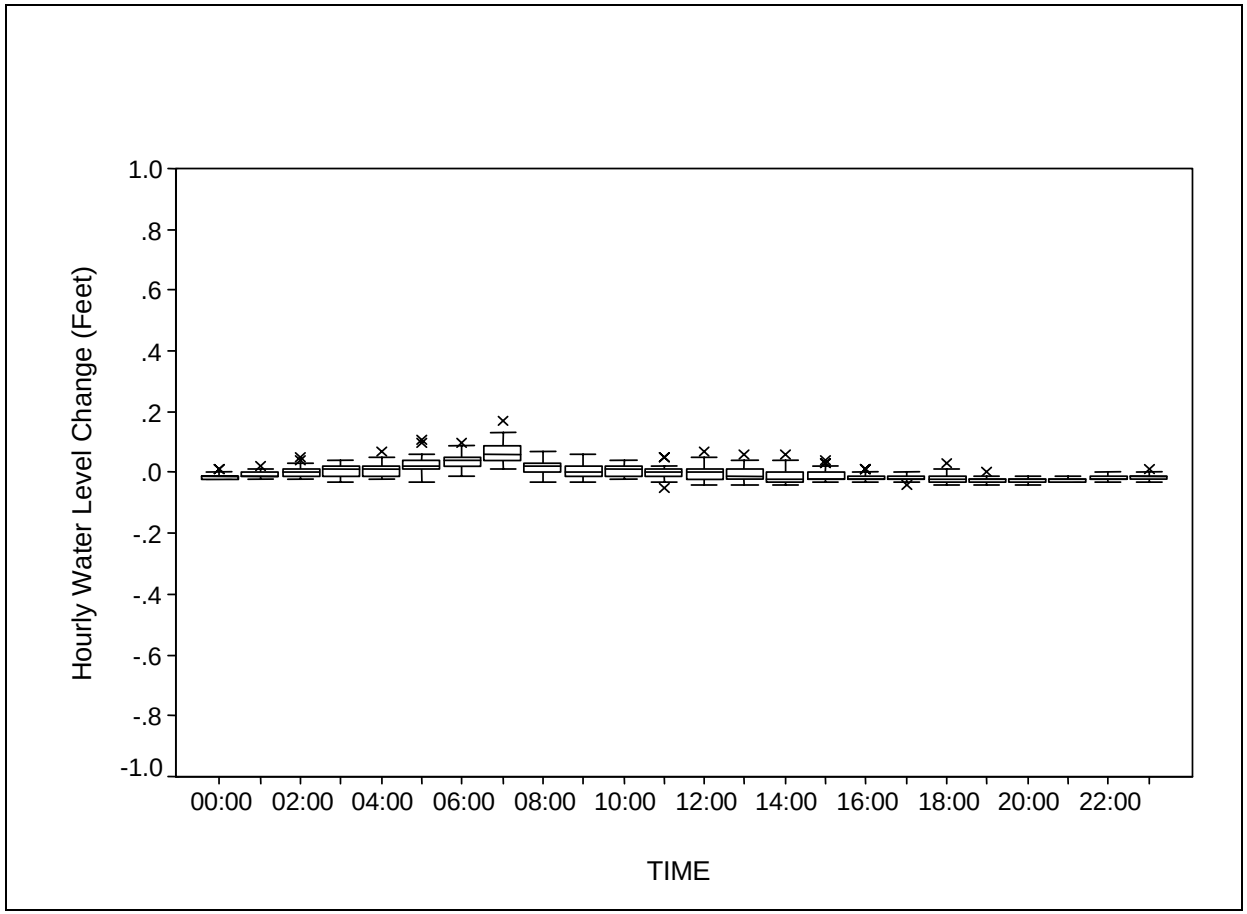

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FIGURE C-7: ANALYSIS ZONE 1 – BURNT SHIP CREEK (TSBC-03)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

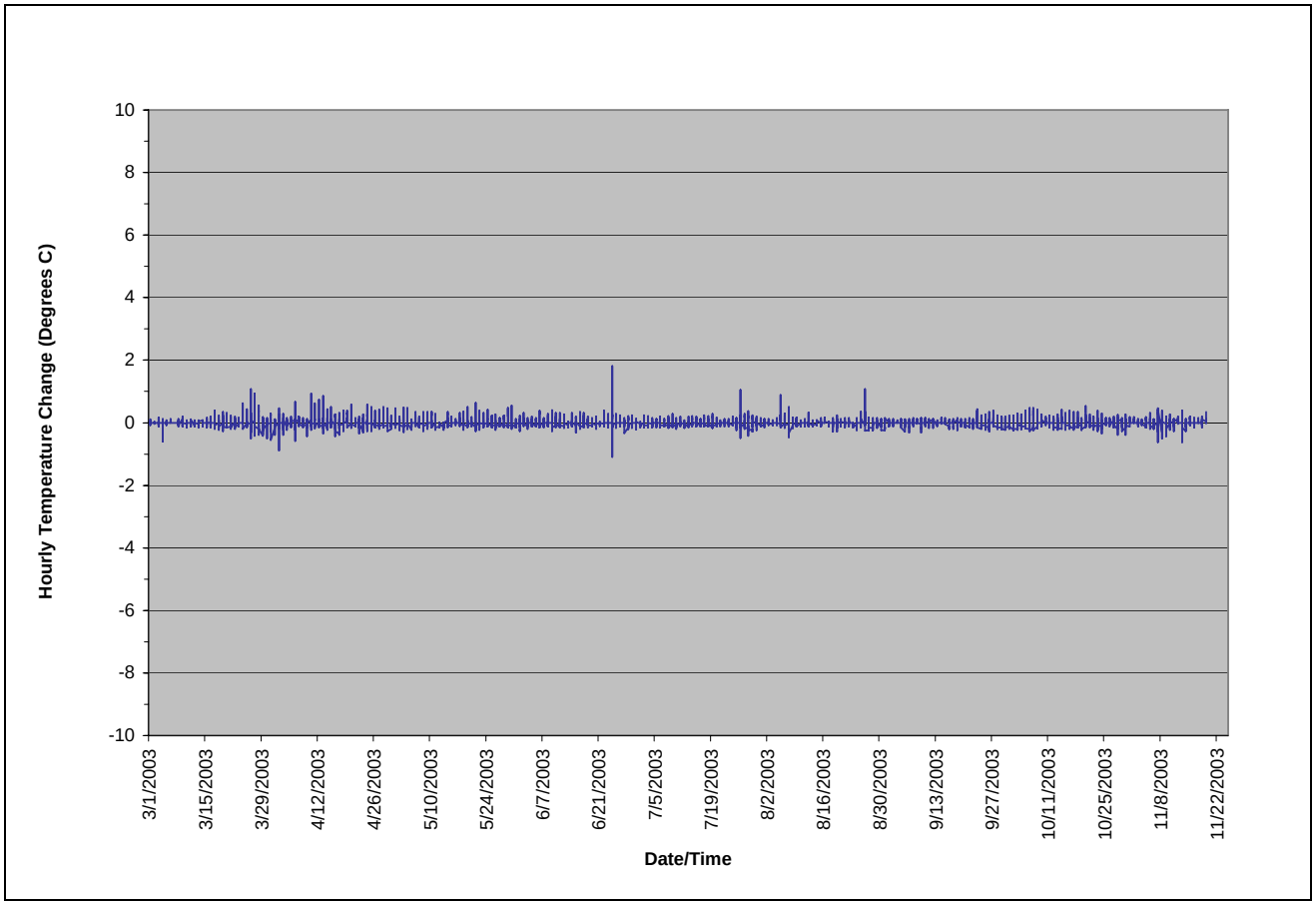

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FIGURE C-8: ANALYSIS ZONE 1 – BUCKHORN MARSH (TM-12)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

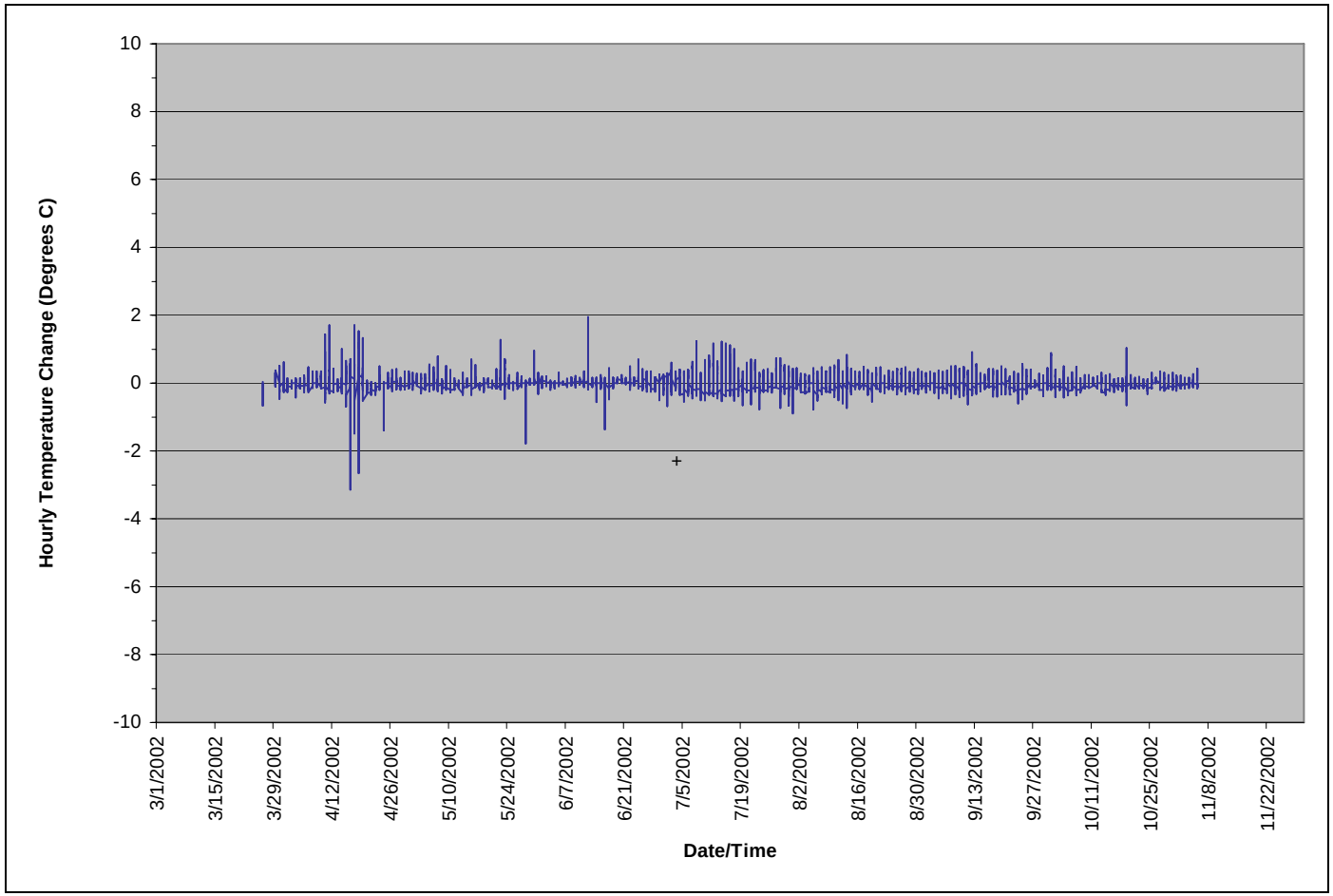

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FIGURE C-9: ANALYSIS ZONE 1 - BUCKHORN MARSH (TBHM-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

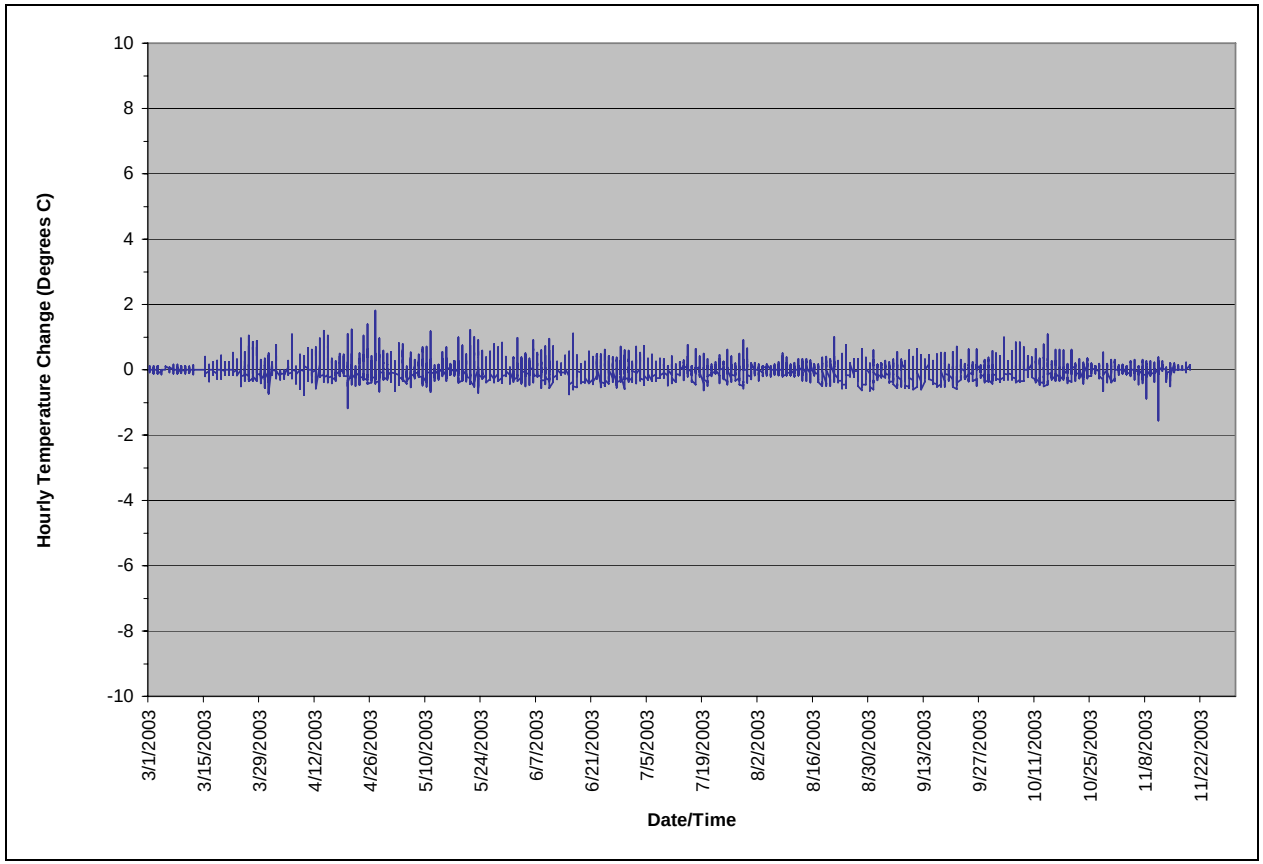

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FIGURE C-10: ANALYSIS ZONE 1 – BUCKHORN MARSH (TBHM-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

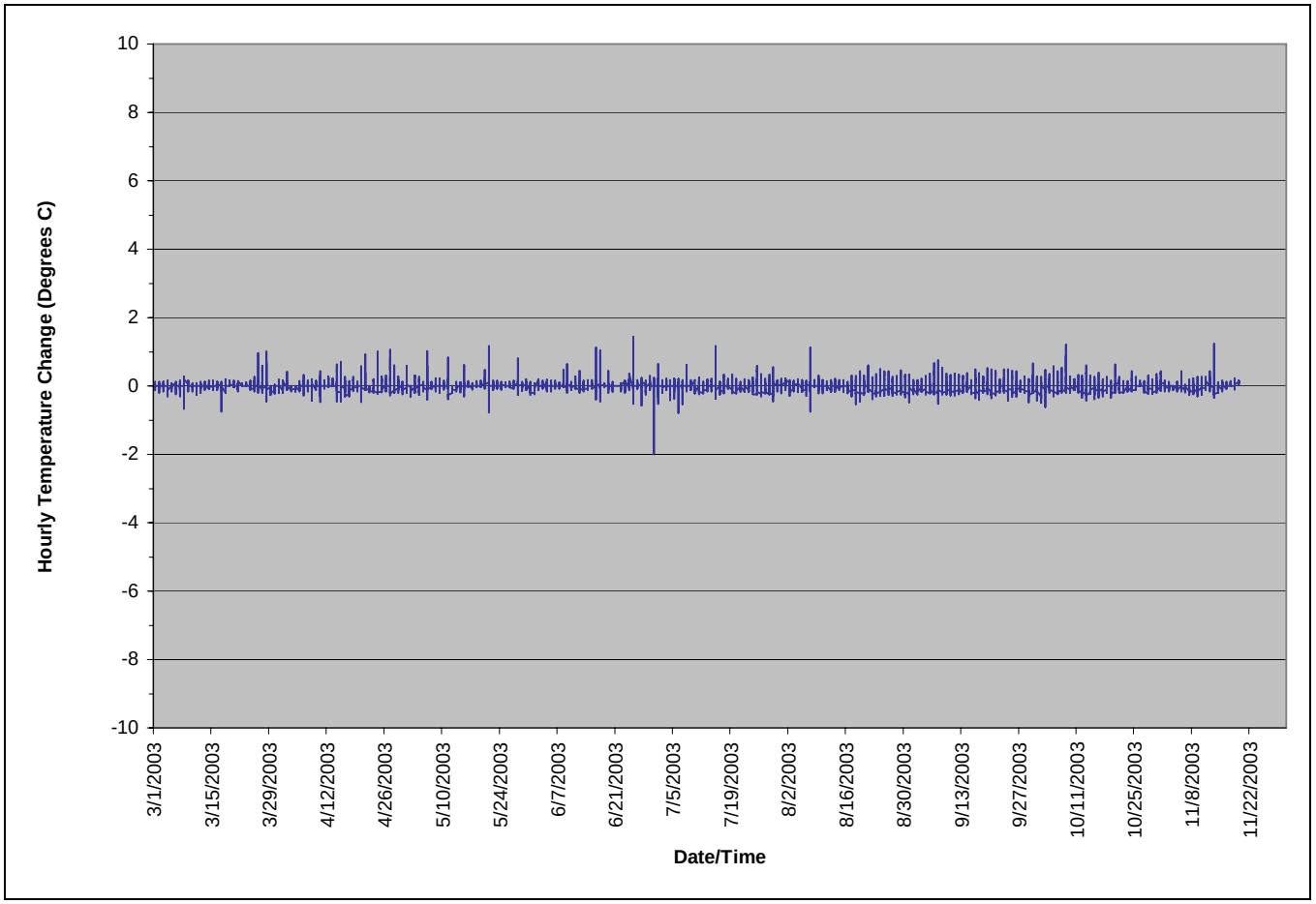

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FIGURE C-11: ANALYSIS ZONE 1 – WOODS CREEK (TWC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

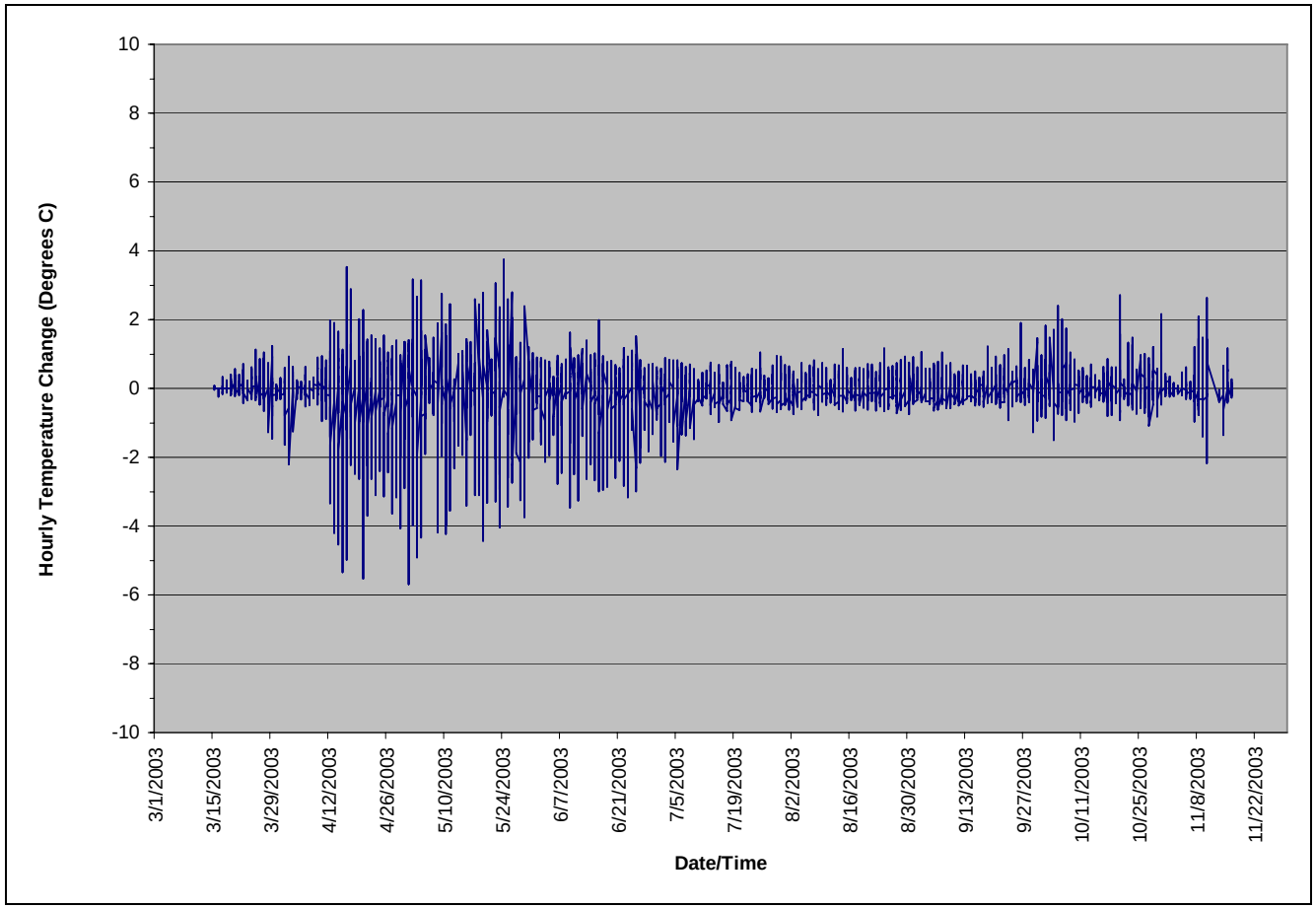

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FIGURE C-12A: ANALYSIS ZONE 1 – WOODS CREEK (TWC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2003

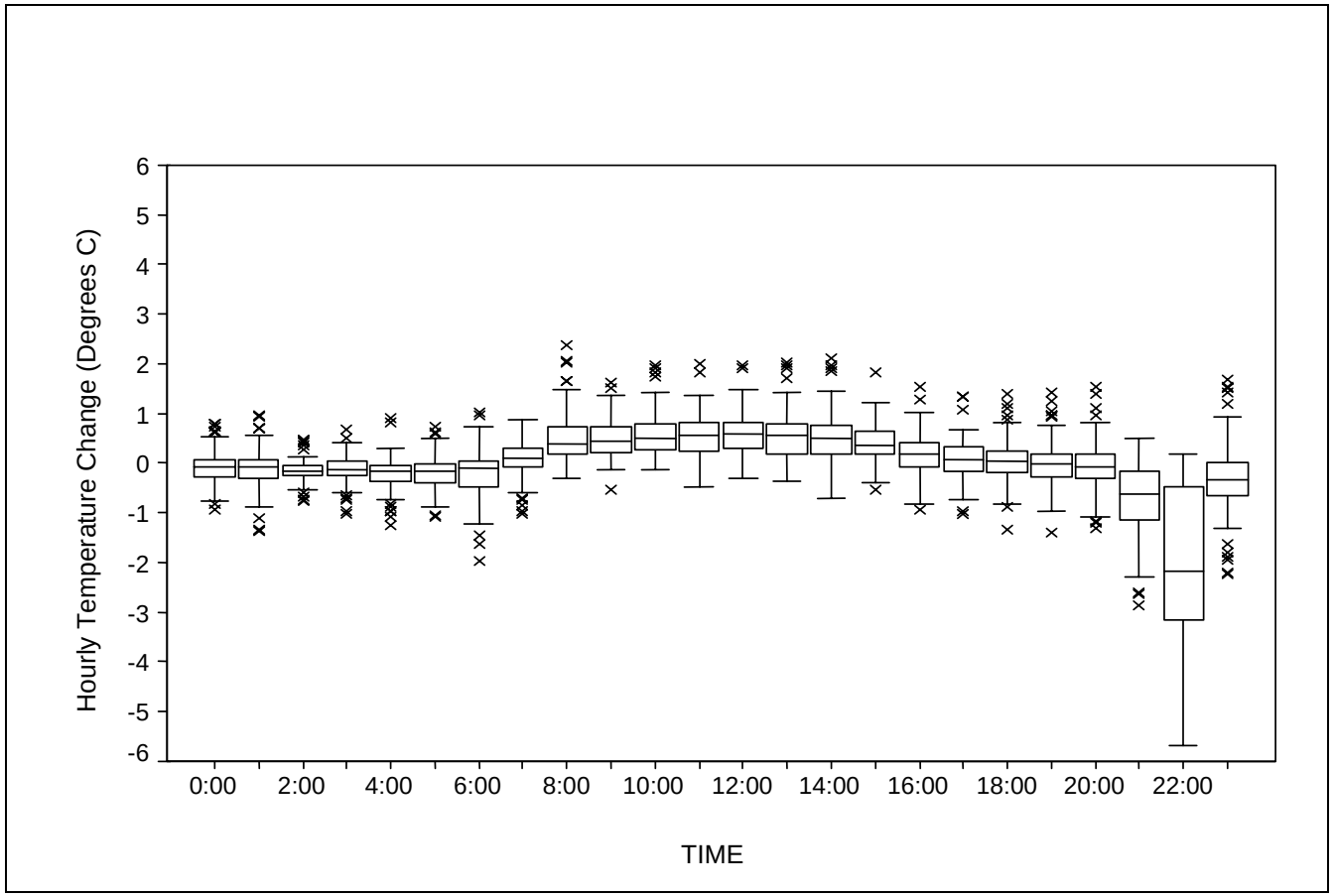

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FIGURE C-12B: ANALYSIS ZONE 1 – WOODS CREEK (TWC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2003

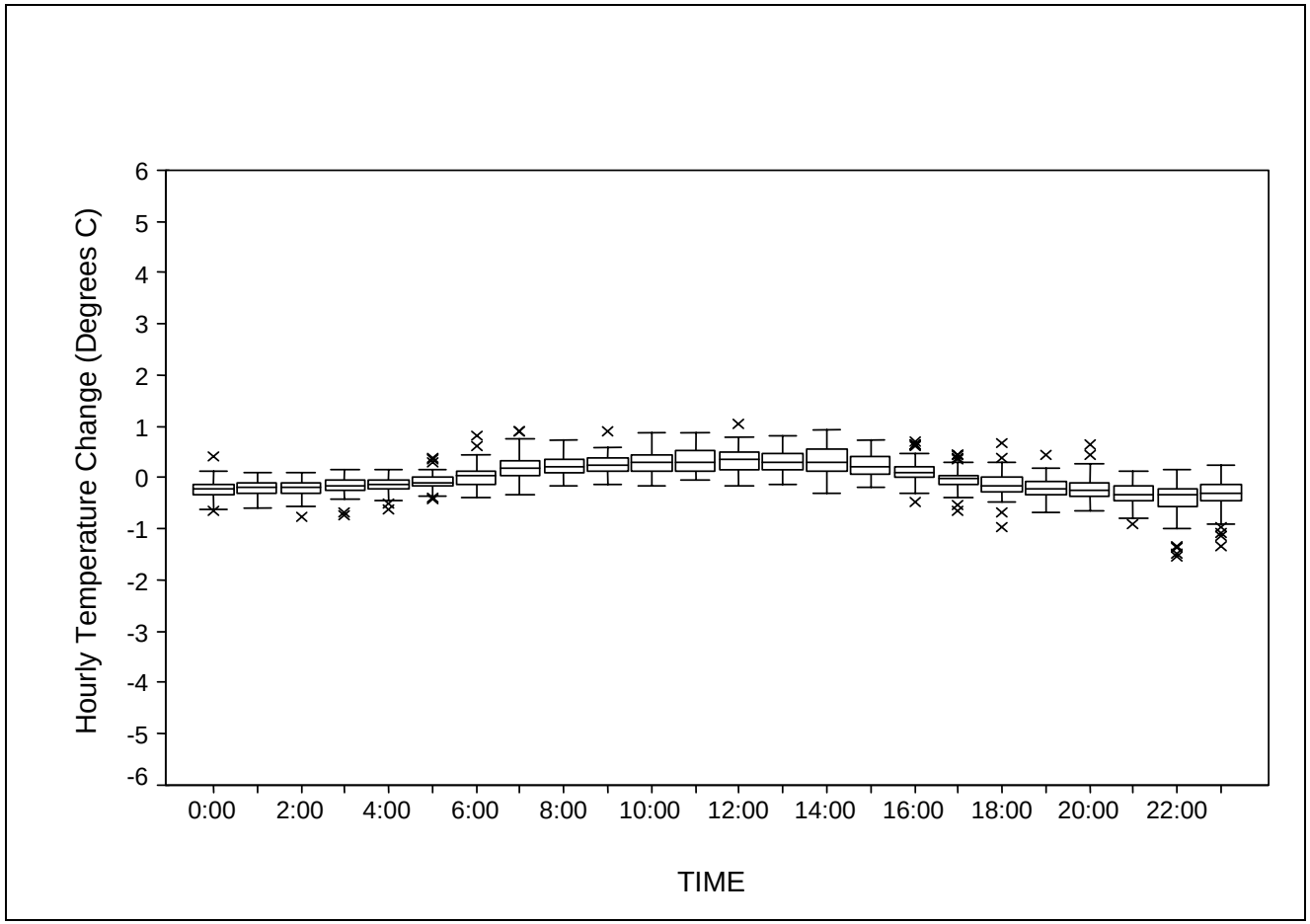

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FIGURE C-12C: ANALYSIS ZONE 1 – WOODS CREEK (TWC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2003

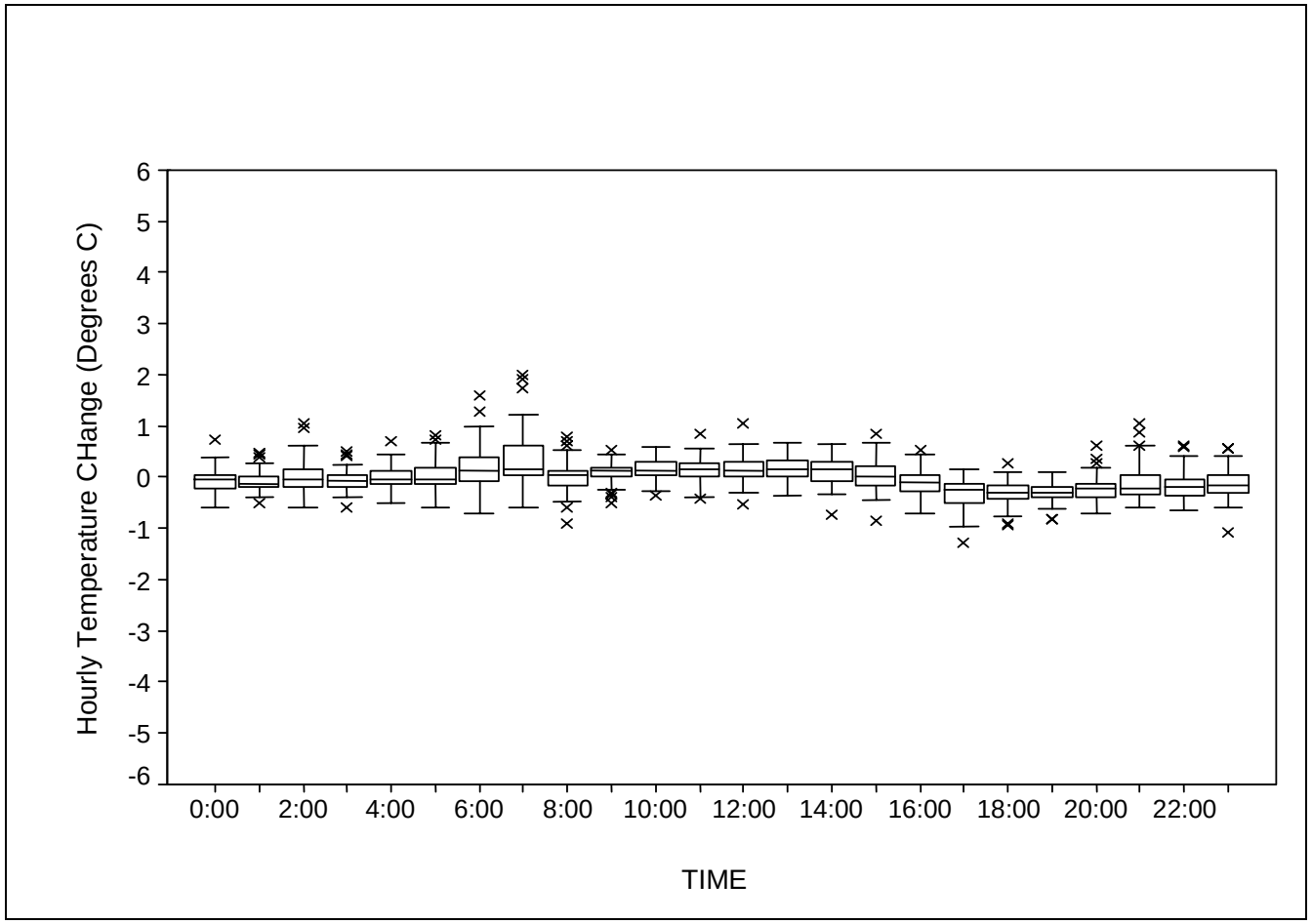

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FIGURE C-13A: ANALYSIS ZONE 1 – WOODS CREEK (WC-01)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2003

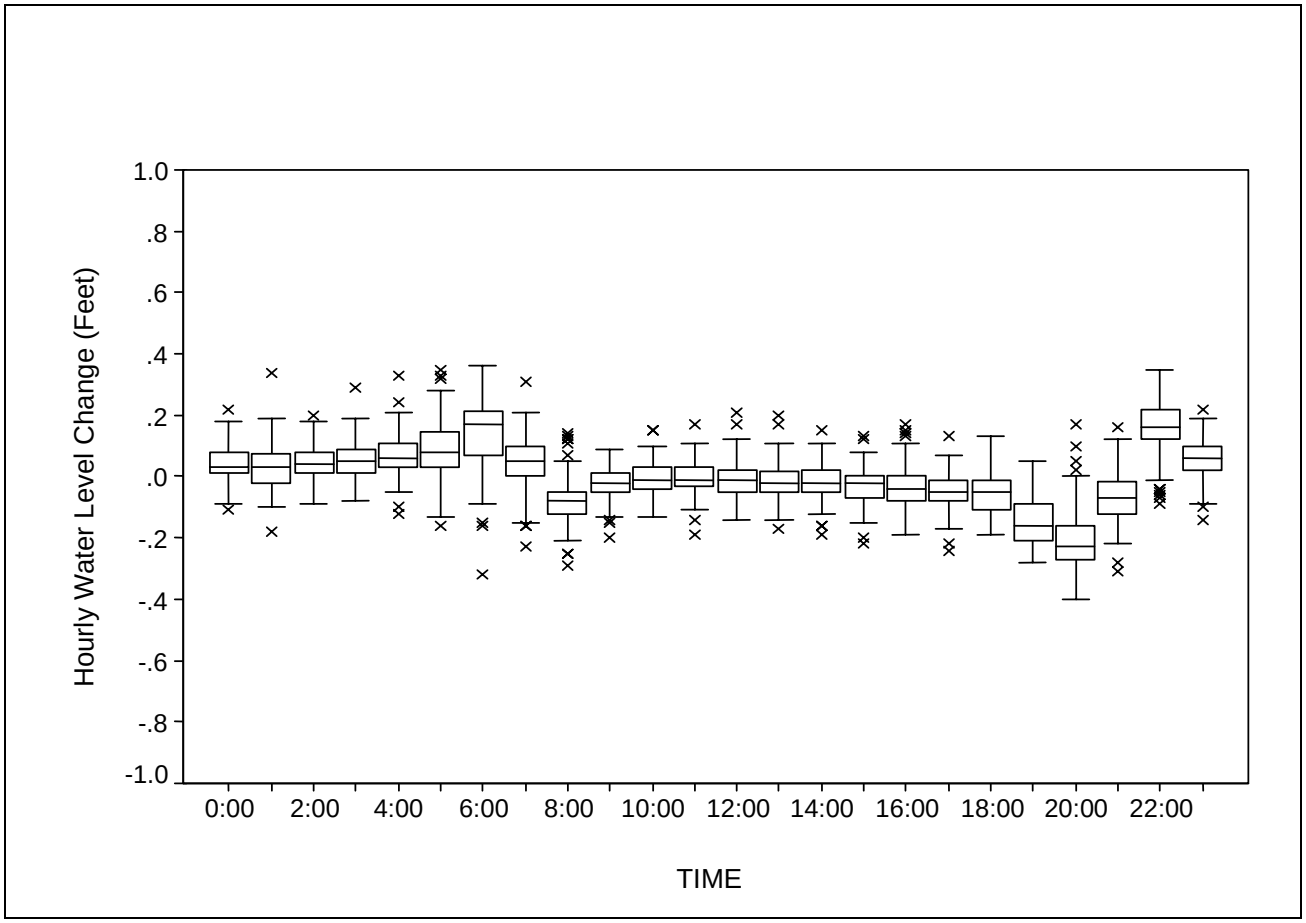

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FIGURE C-13B: ANALYSIS ZONE 1 – WOODS CREEK (WC-01)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2003

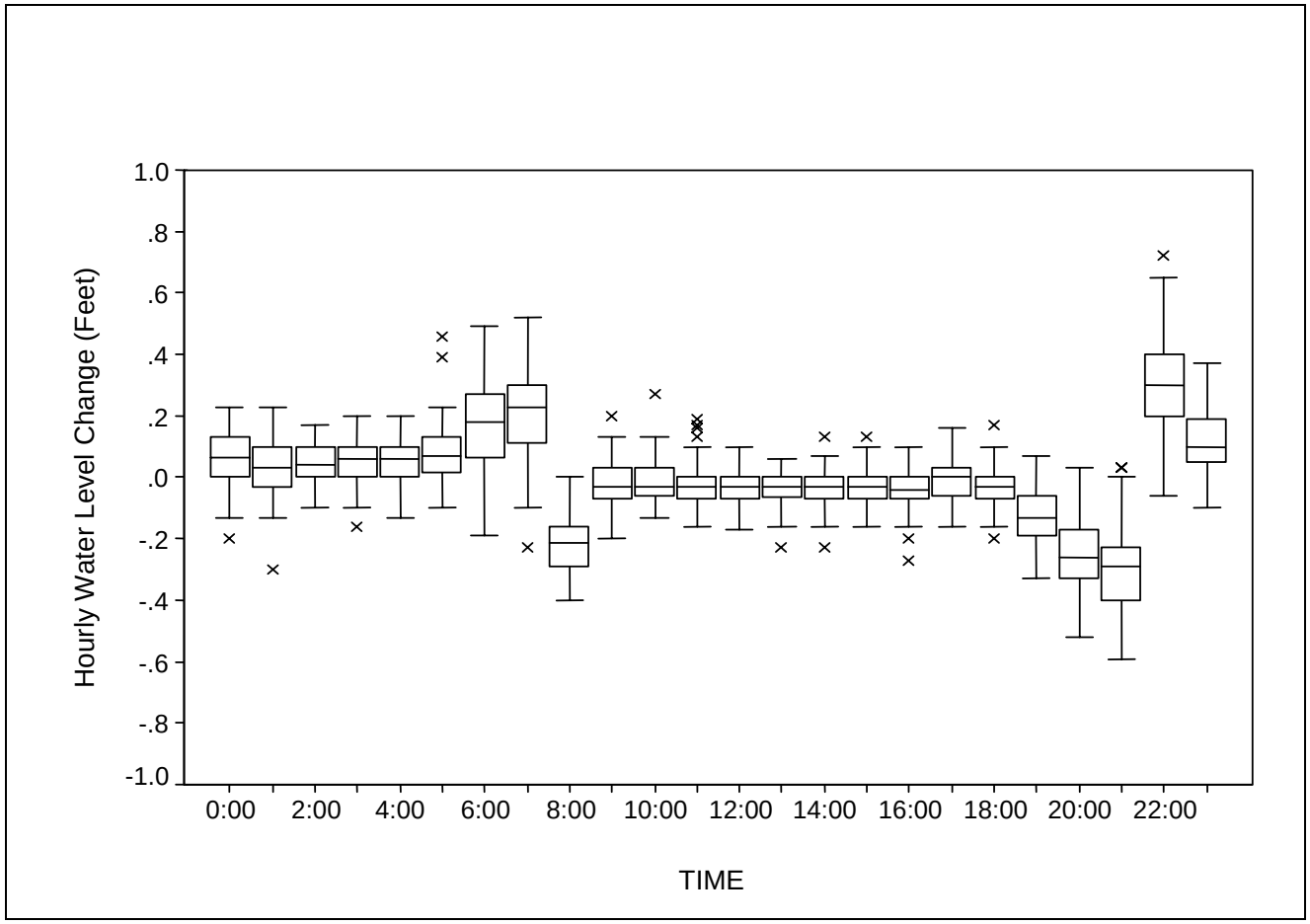

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FIGURE C-13C: ANALYSIS ZONE 1 – WOODS CREEK (WC-01)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2003

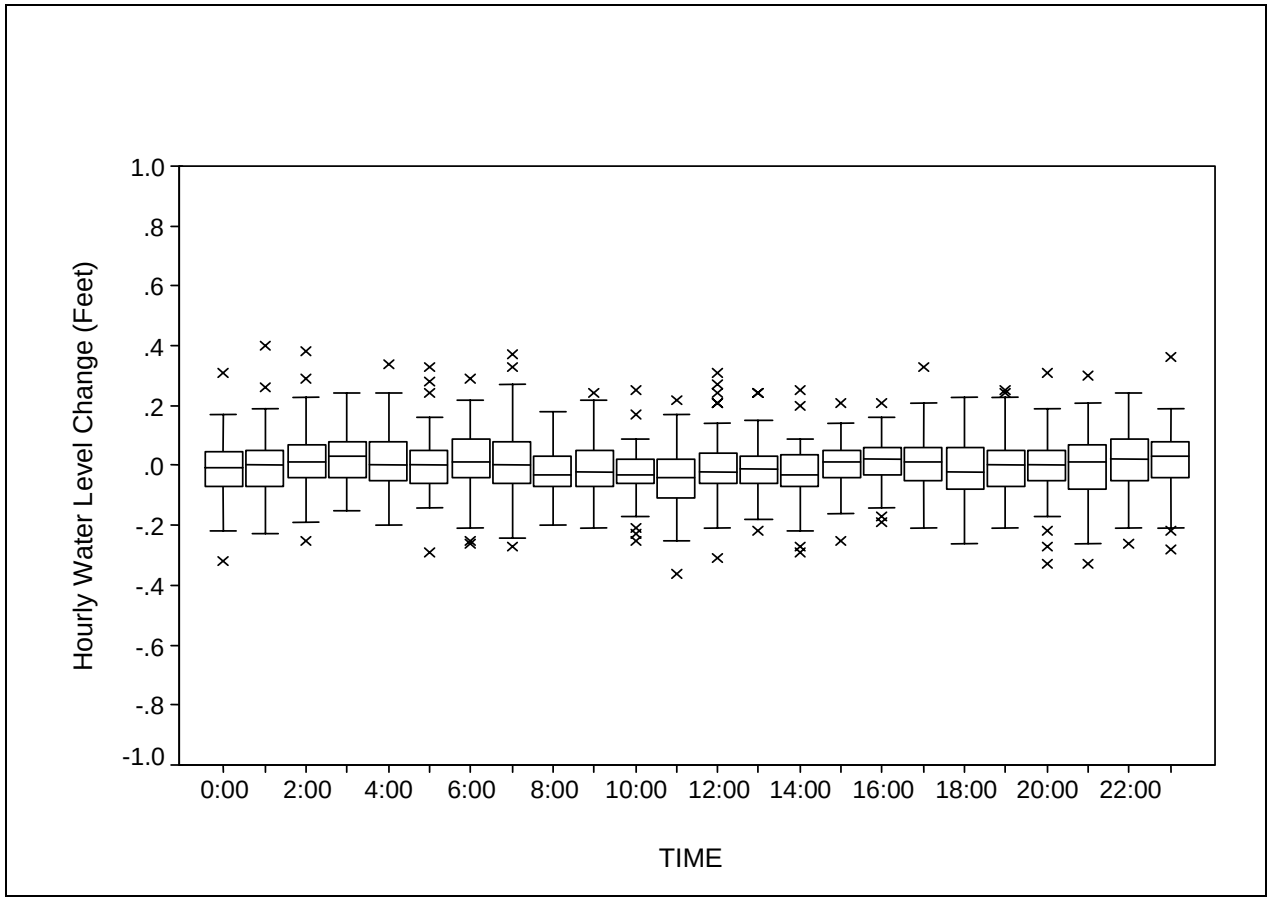

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FIGURE C-14: ANALYSIS ZONE 1 – WOODS CREEK (TM-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

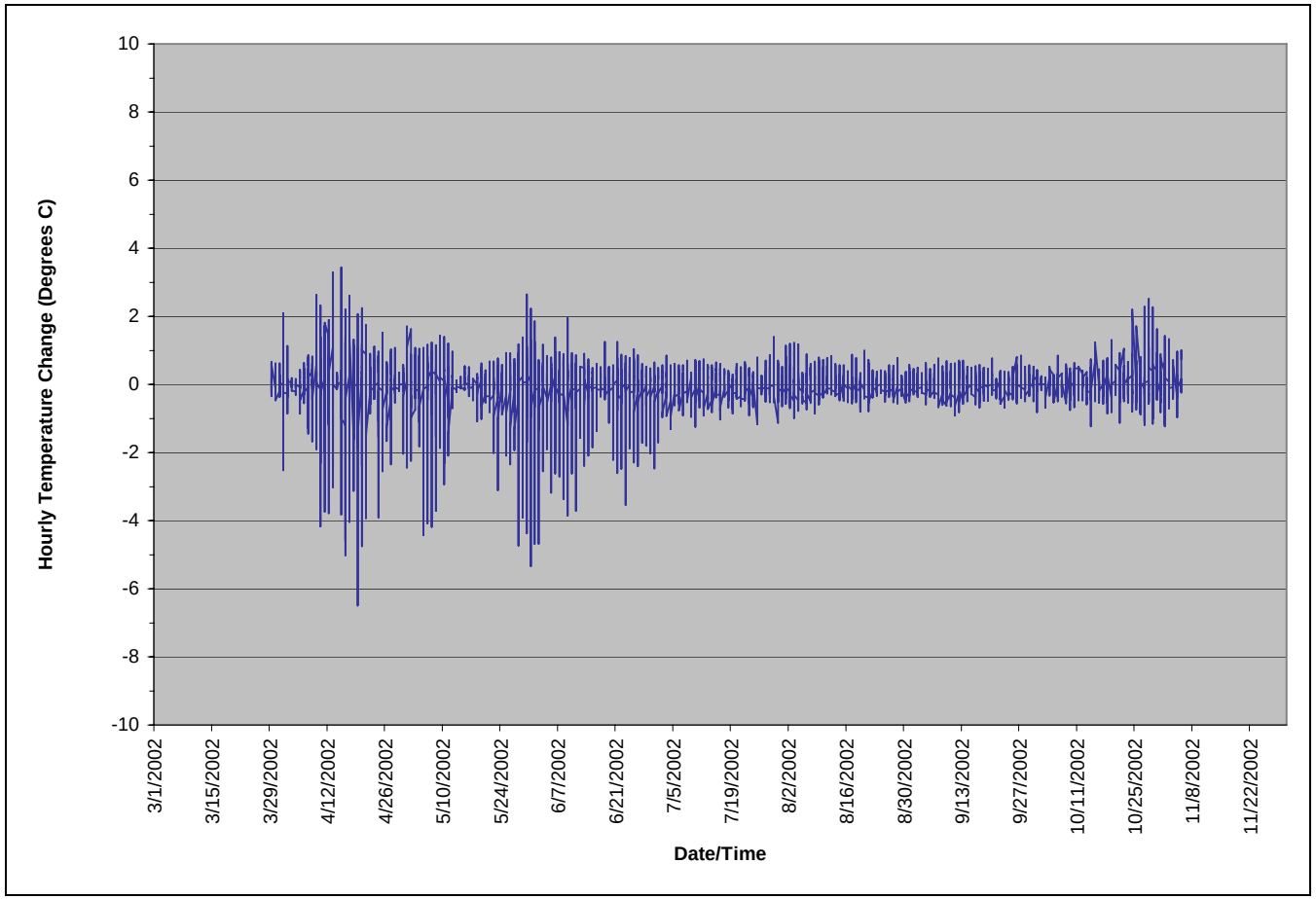

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FIGURE C-15A: ANALYSIS ZONE 1 – WOODS CREEK (TM-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2002

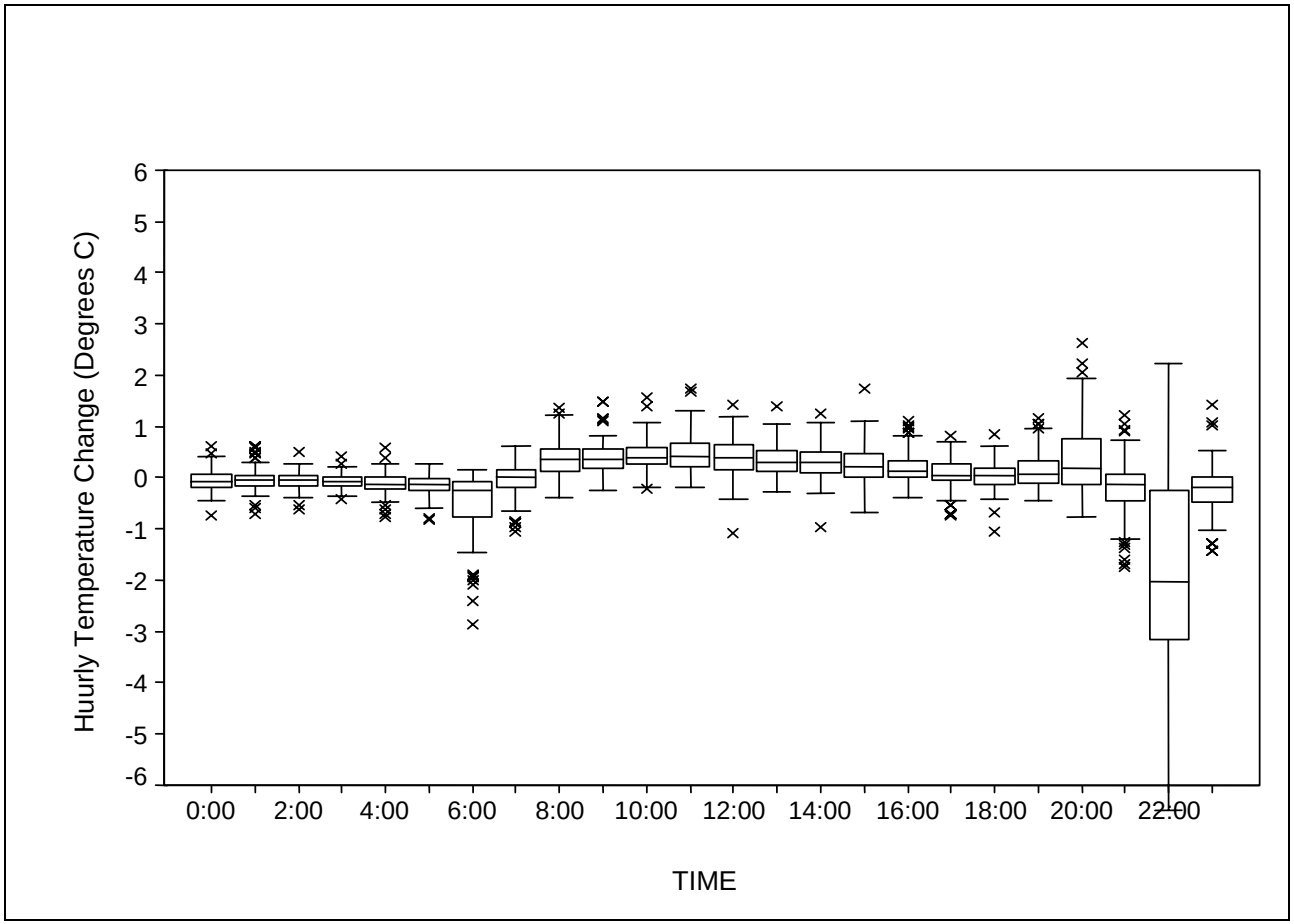

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FIGURE C-15B: ANALYSIS ZONE 1 – WOODS CREEK (TM-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2002

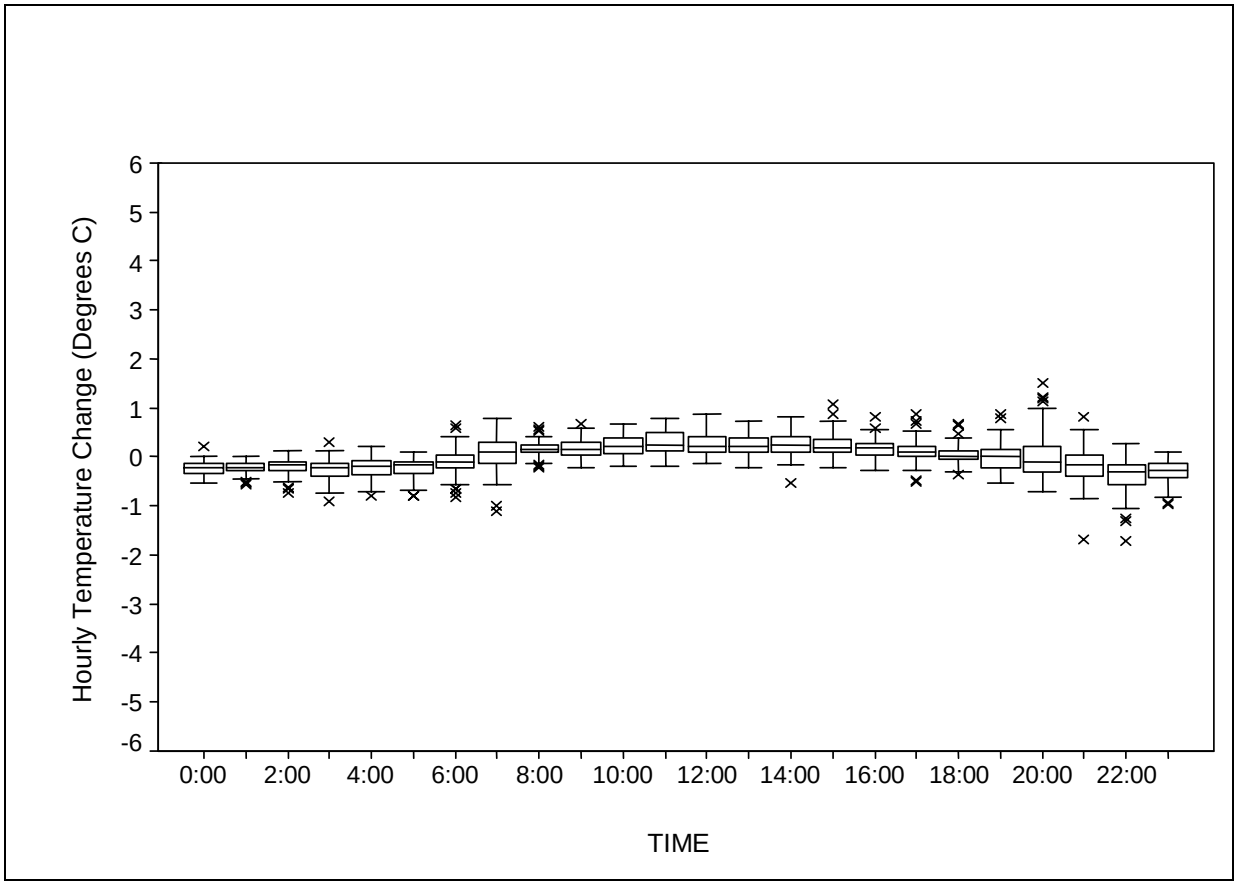

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FIGURE C-15C: ANALYSIS ZONE 1 – WOODS CREEK (TM-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2002

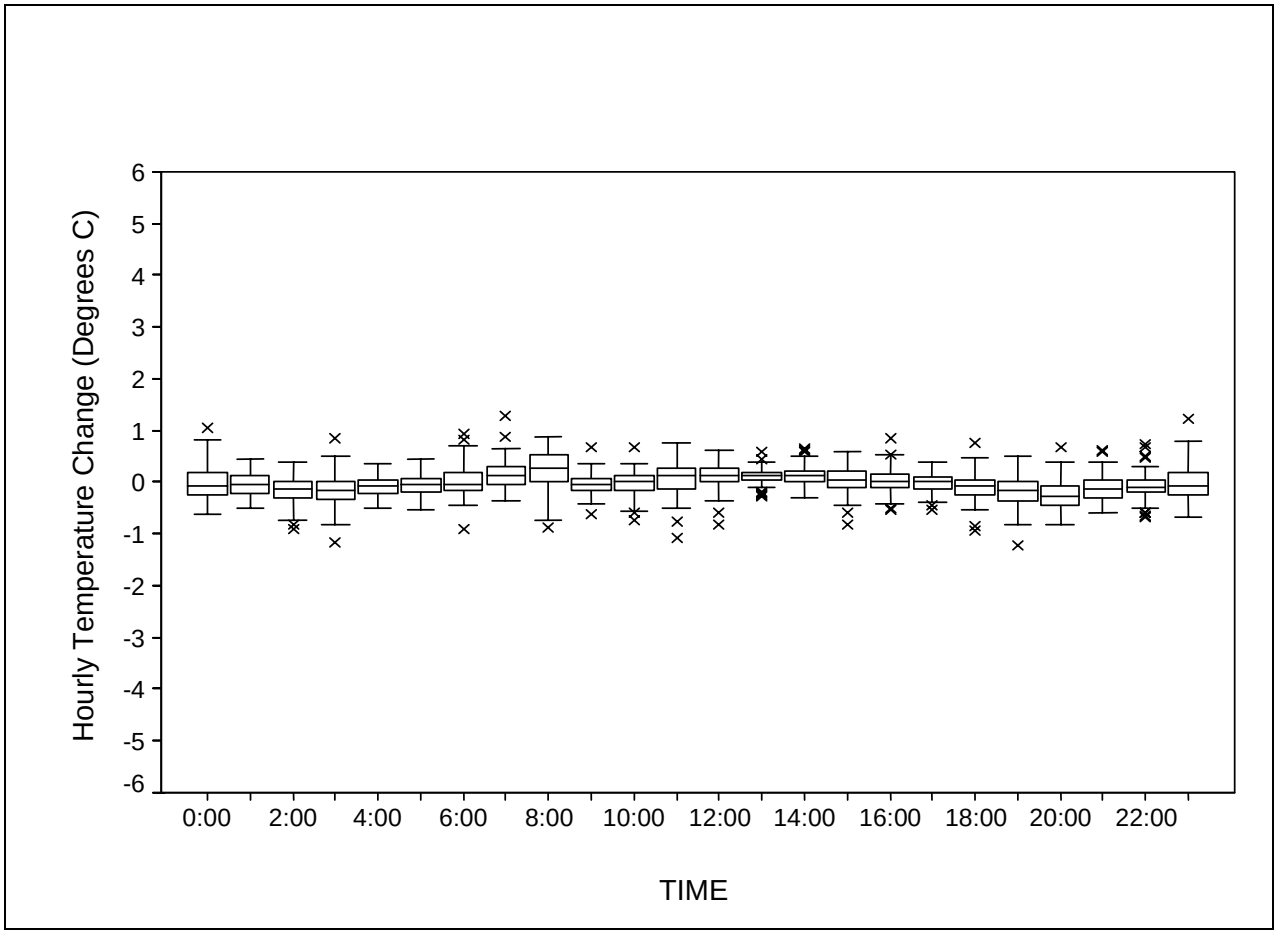

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FIGURE C-16A: ANALYSIS ZONE 1 – WOODS CREEK (SD-04)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2002

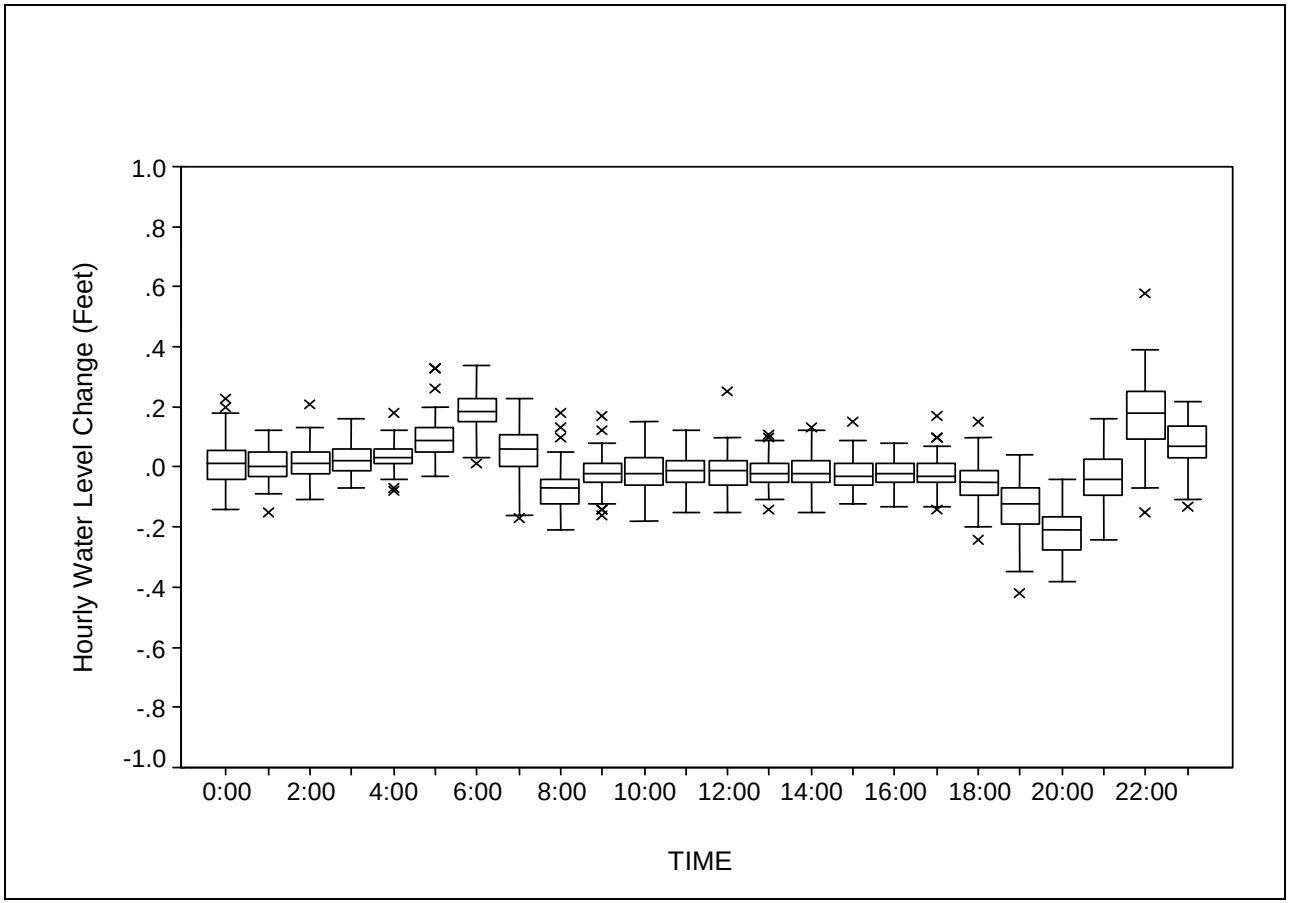

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FIGURE C-16B: ANALYSIS ZONE 1 – WOODS CREEK (SD-04)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2002

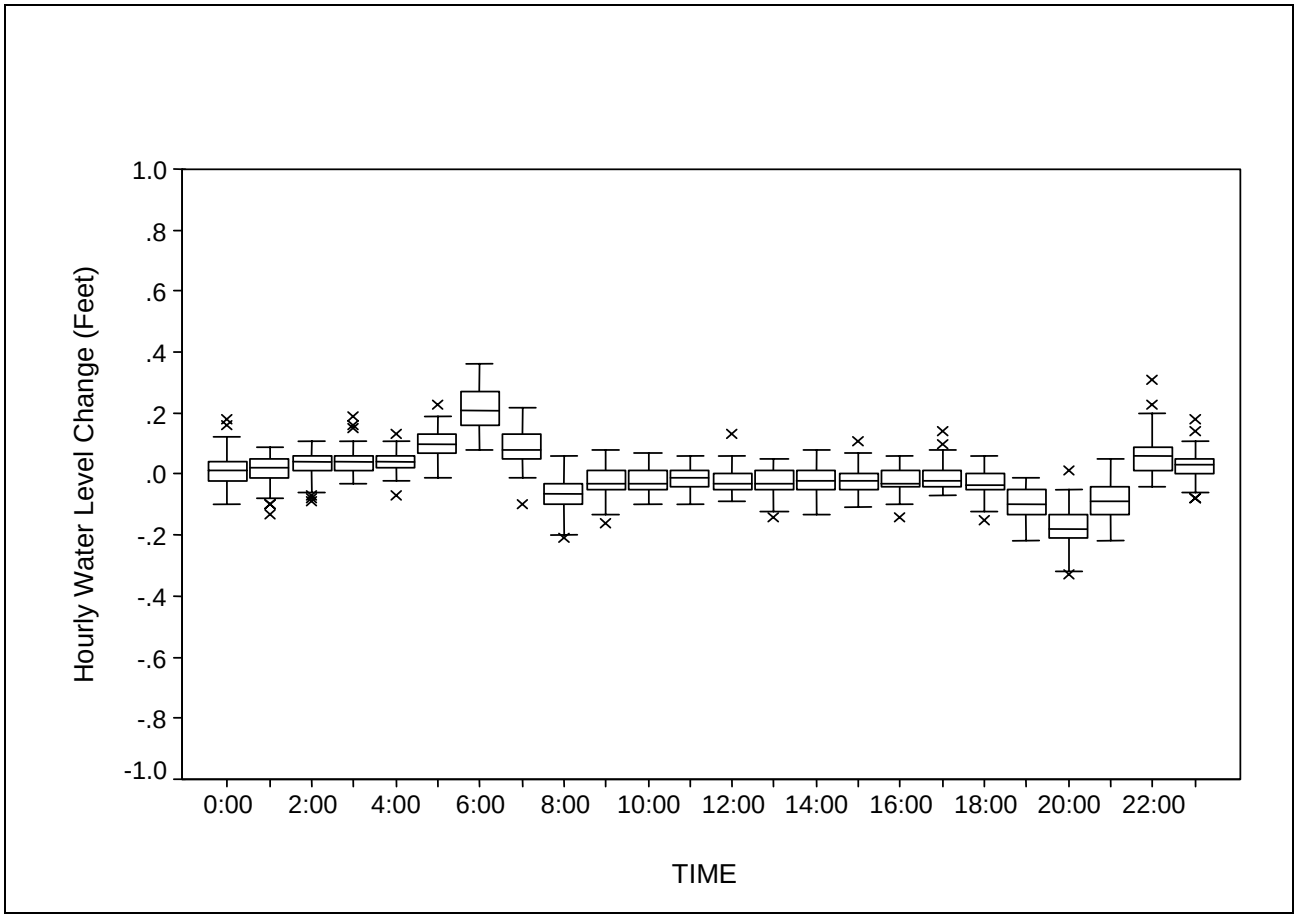

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FIGURE C-16C: ANALYSIS ZONE 1 – WOODS CREEK (SD-04)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2002

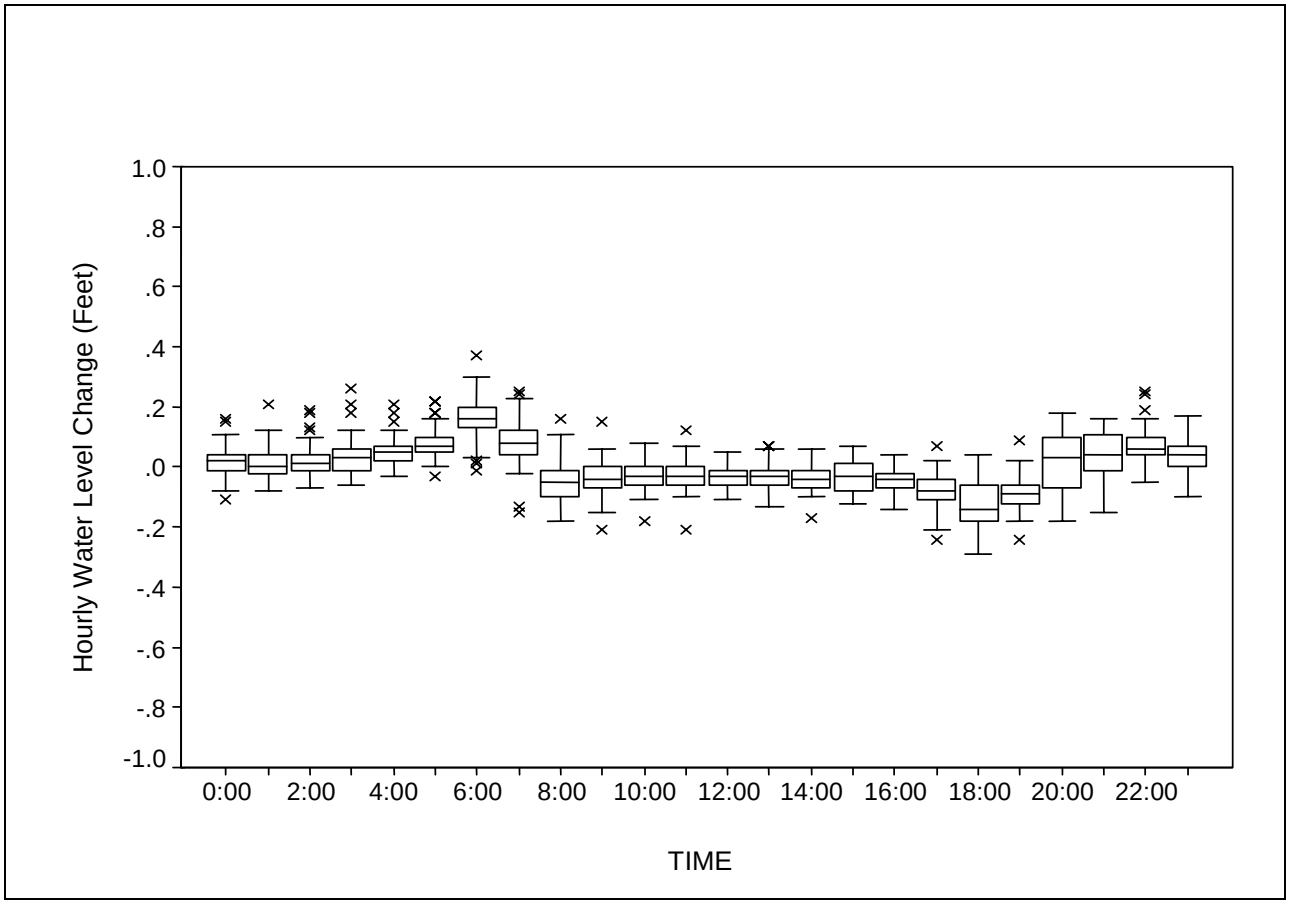

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FIGURE C-17: ANALYSIS ZONE 1 – WOODS CREEK (TM-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

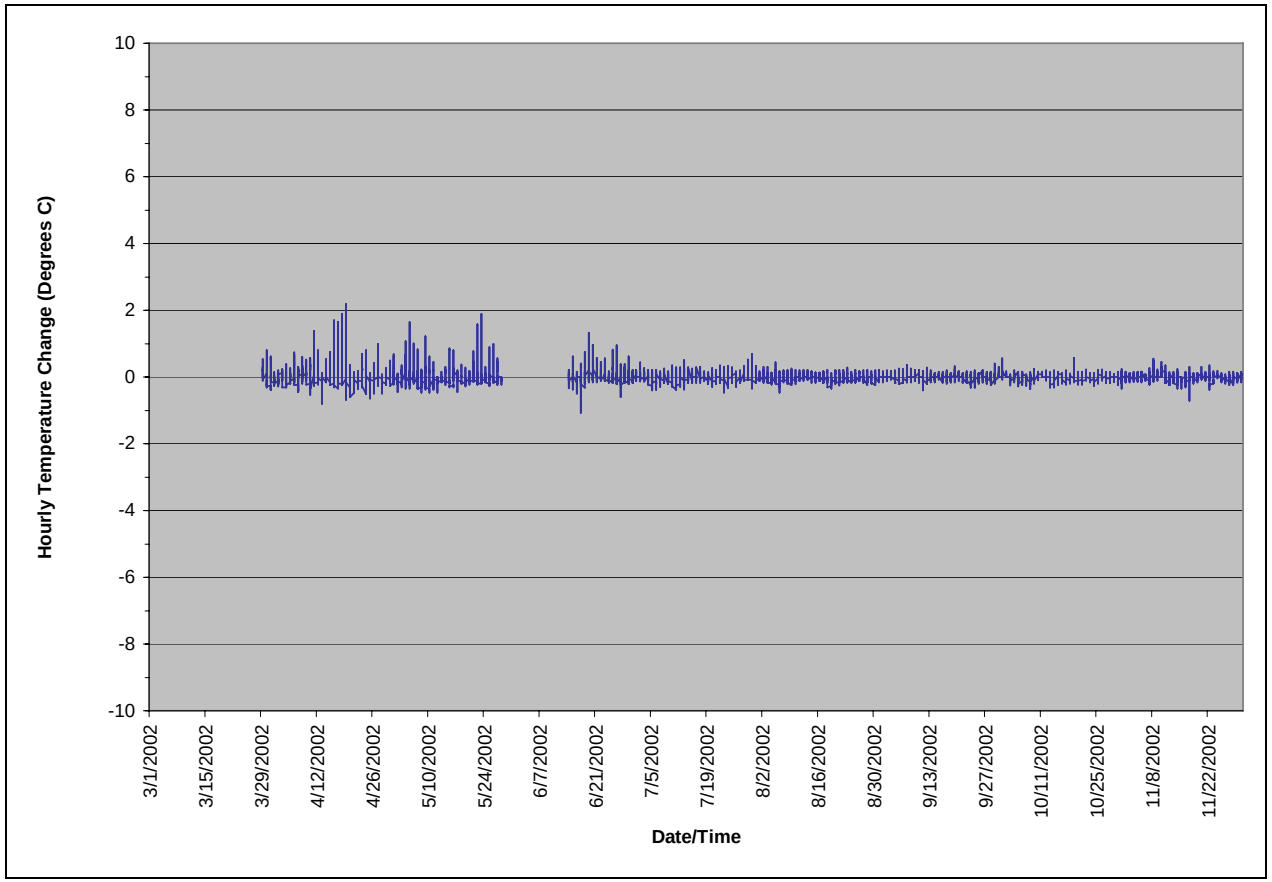

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FIGURE C-18A: ANALYSIS ZONE 1 – WOODS CREEK (TM-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

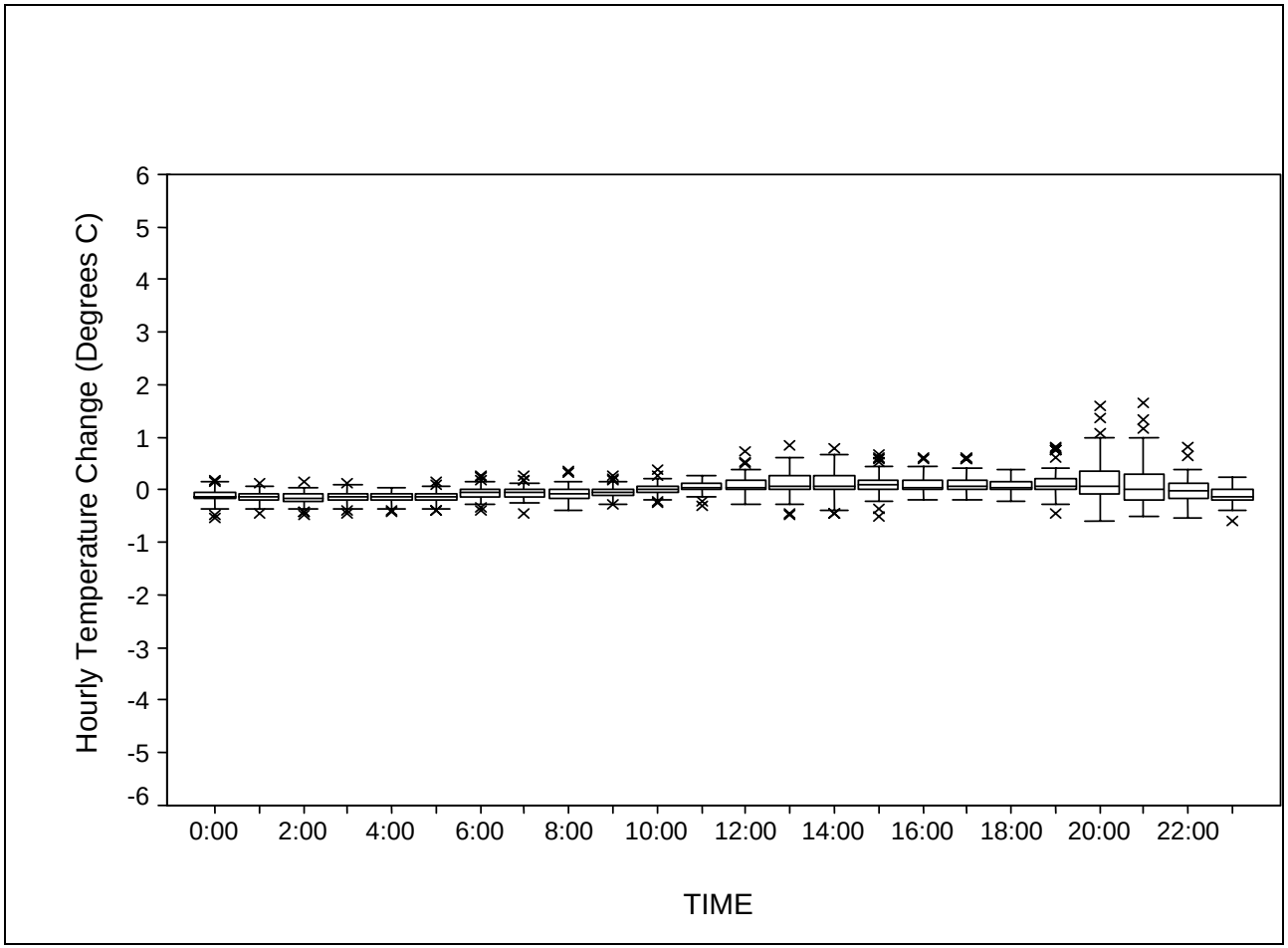

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FIGURE C-18B: ANALYSIS ZONE 1 – WOODS CREEK (TM-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

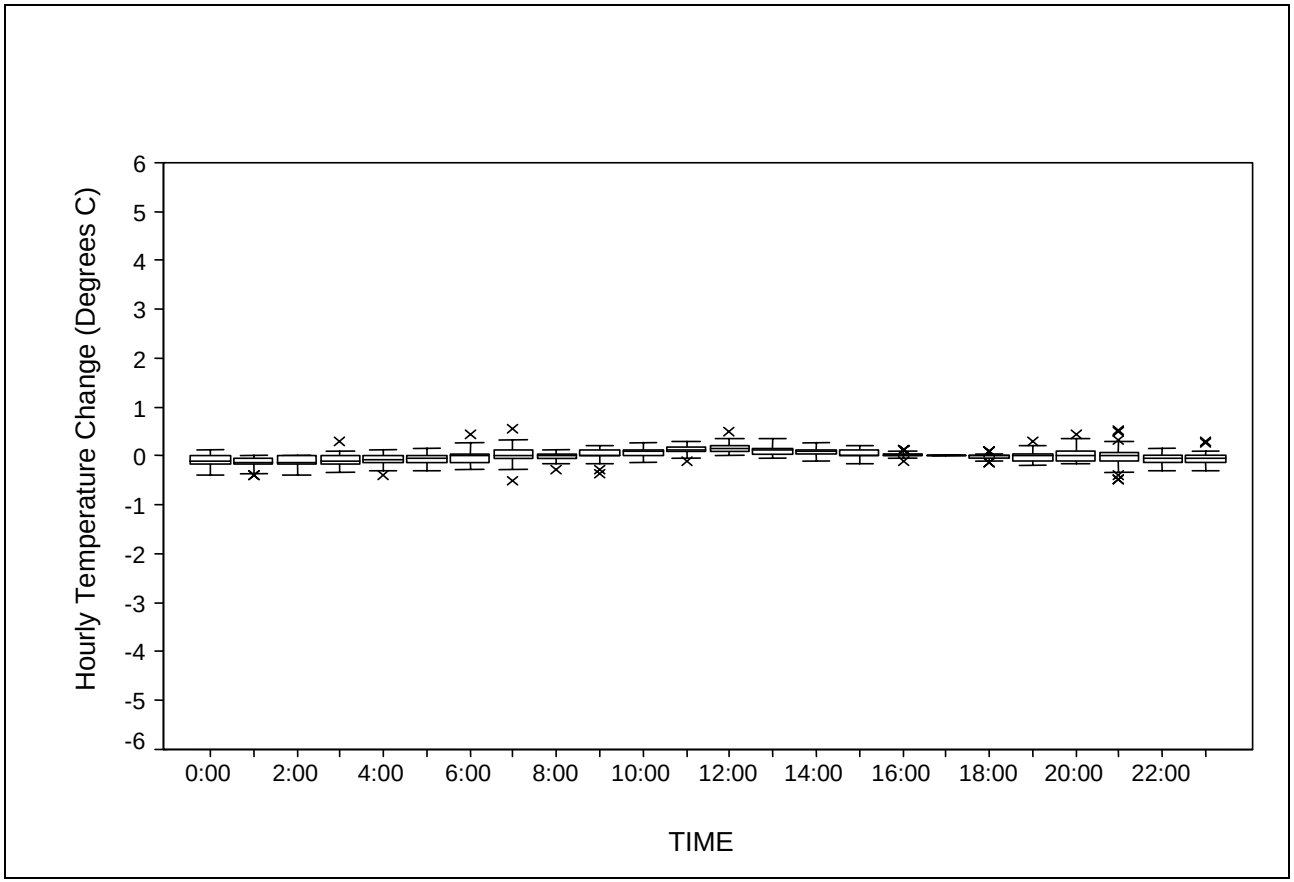

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FIGURE C-18C: ANALYSIS ZONE 1 – WOODS CREEK (TM-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

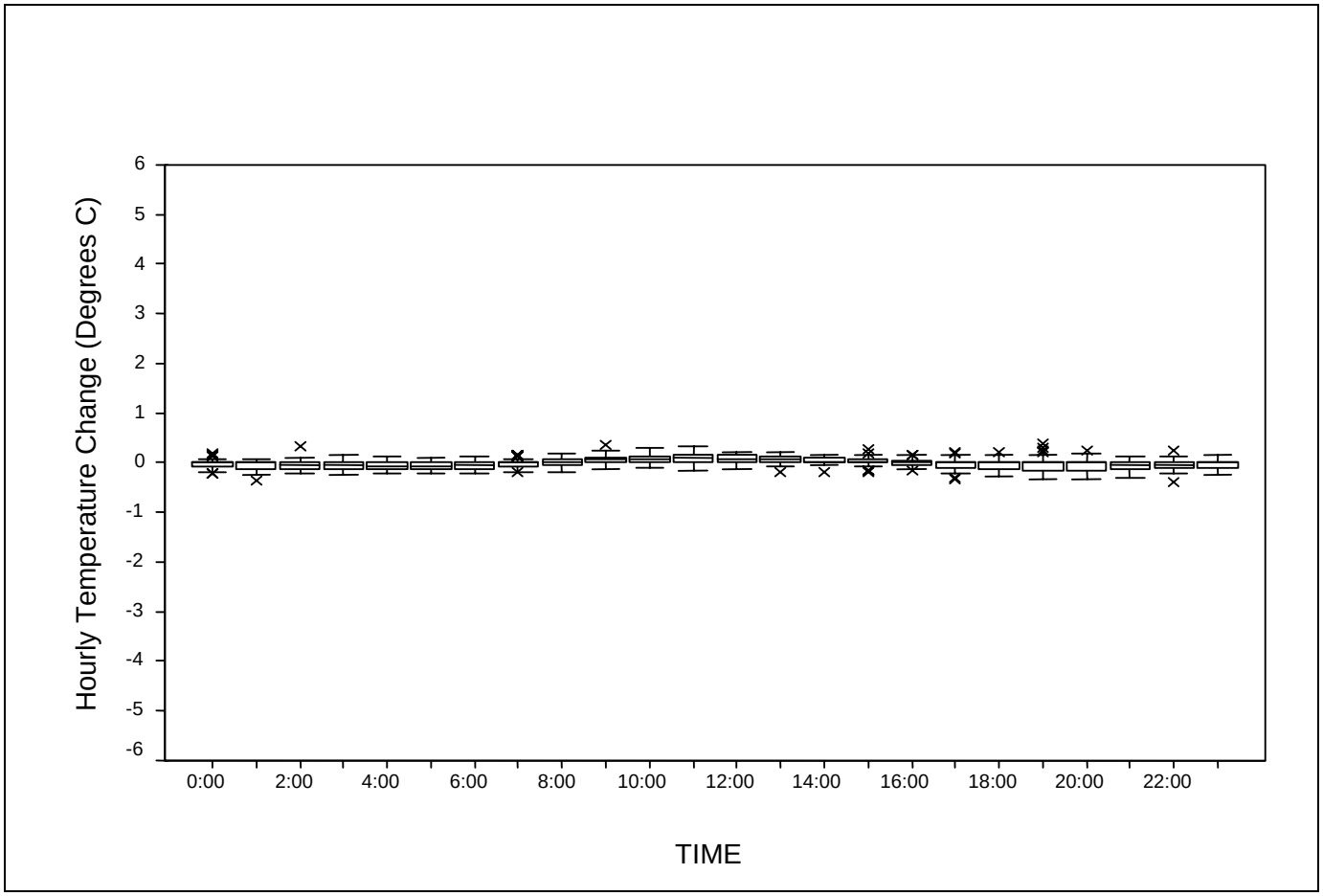

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FIGURE C-19: ANALYSIS ZONE 1 – WOODS CREEK (TM-04)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

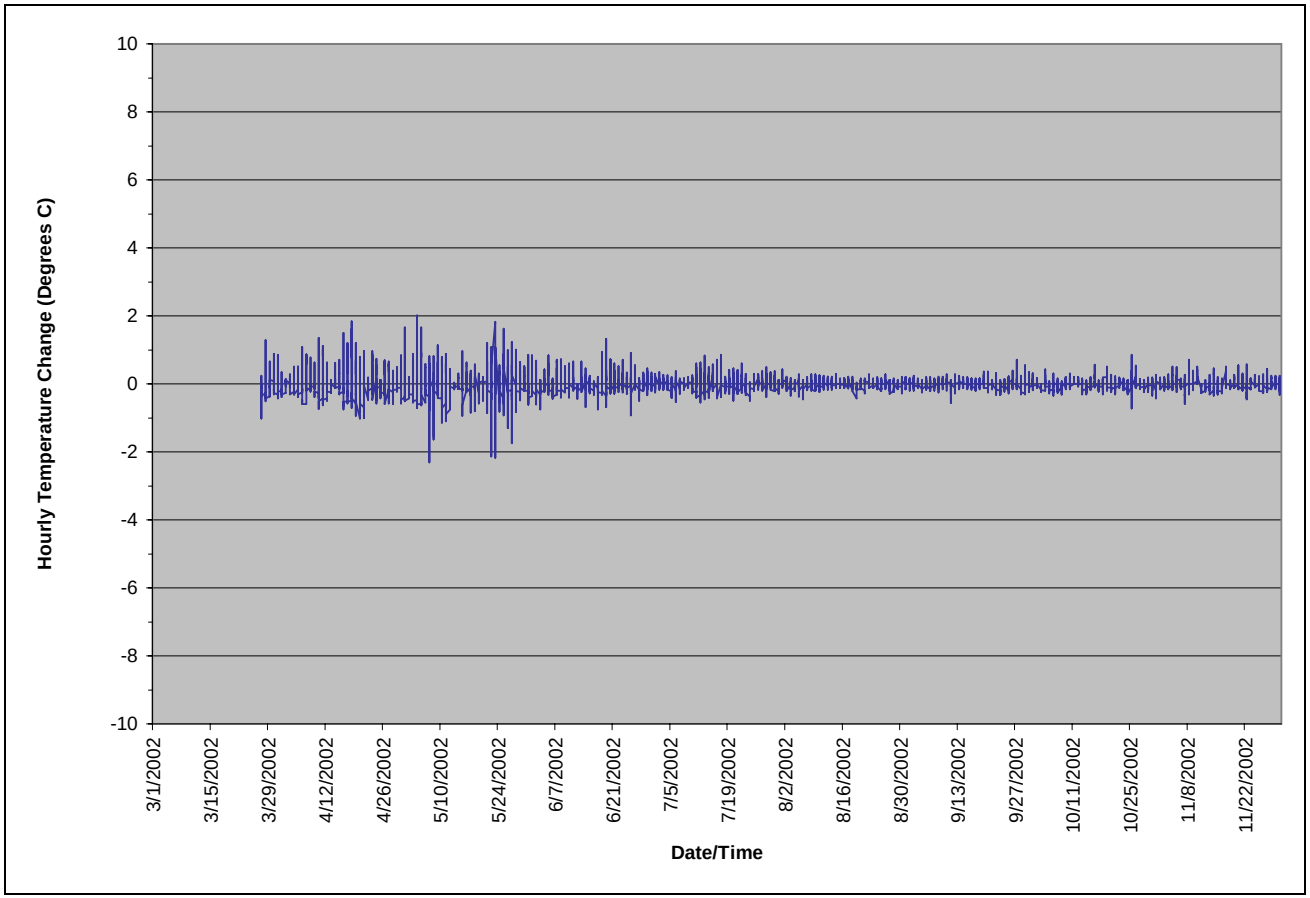

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FIGURE C-20A: ANALYSIS ZONE 1 – WOODS CREEK (TM-04)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

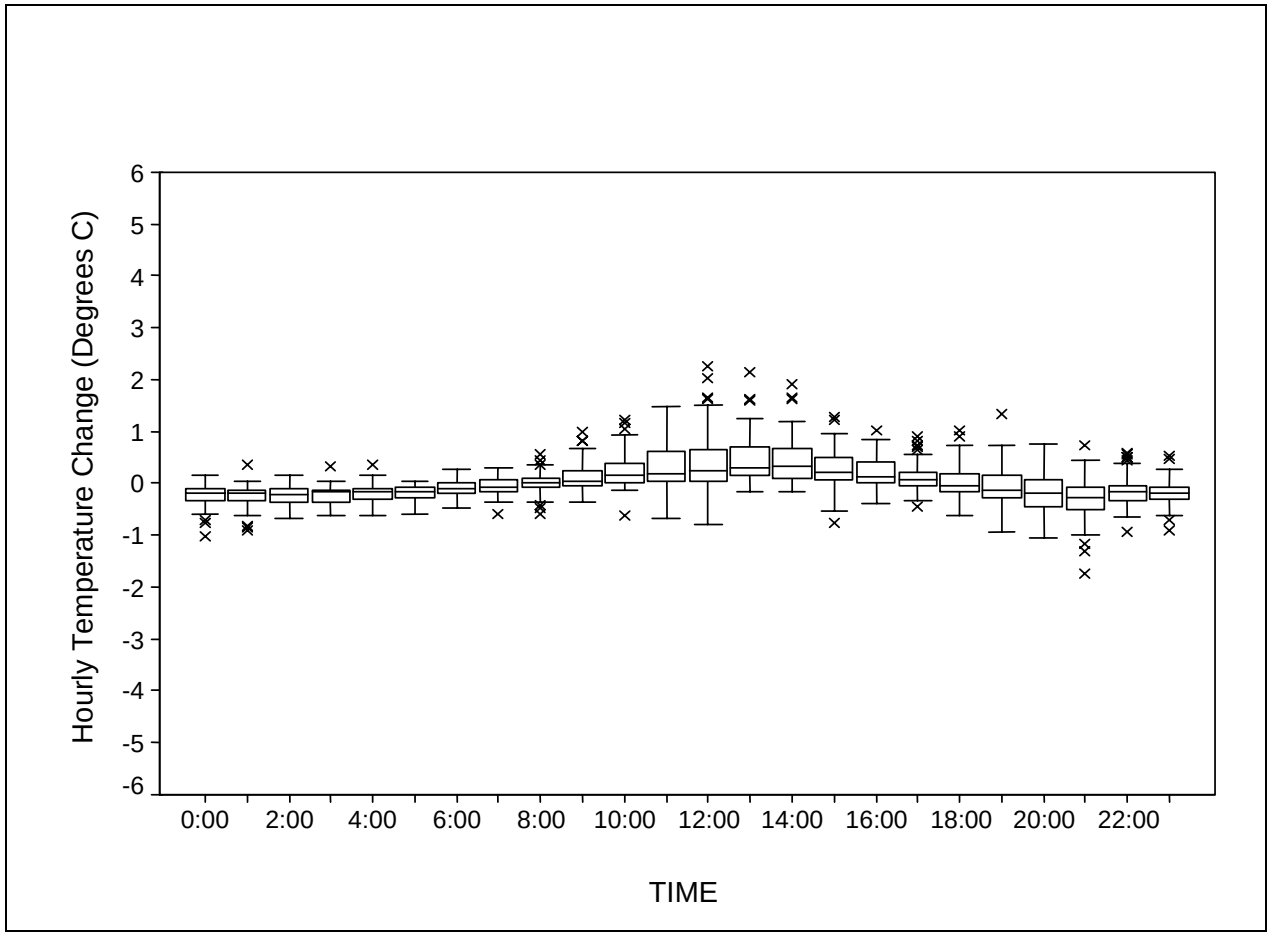

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FIGURE C-20B: ANALYSIS ZONE 1 – WOODS CREEK (TM-04)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

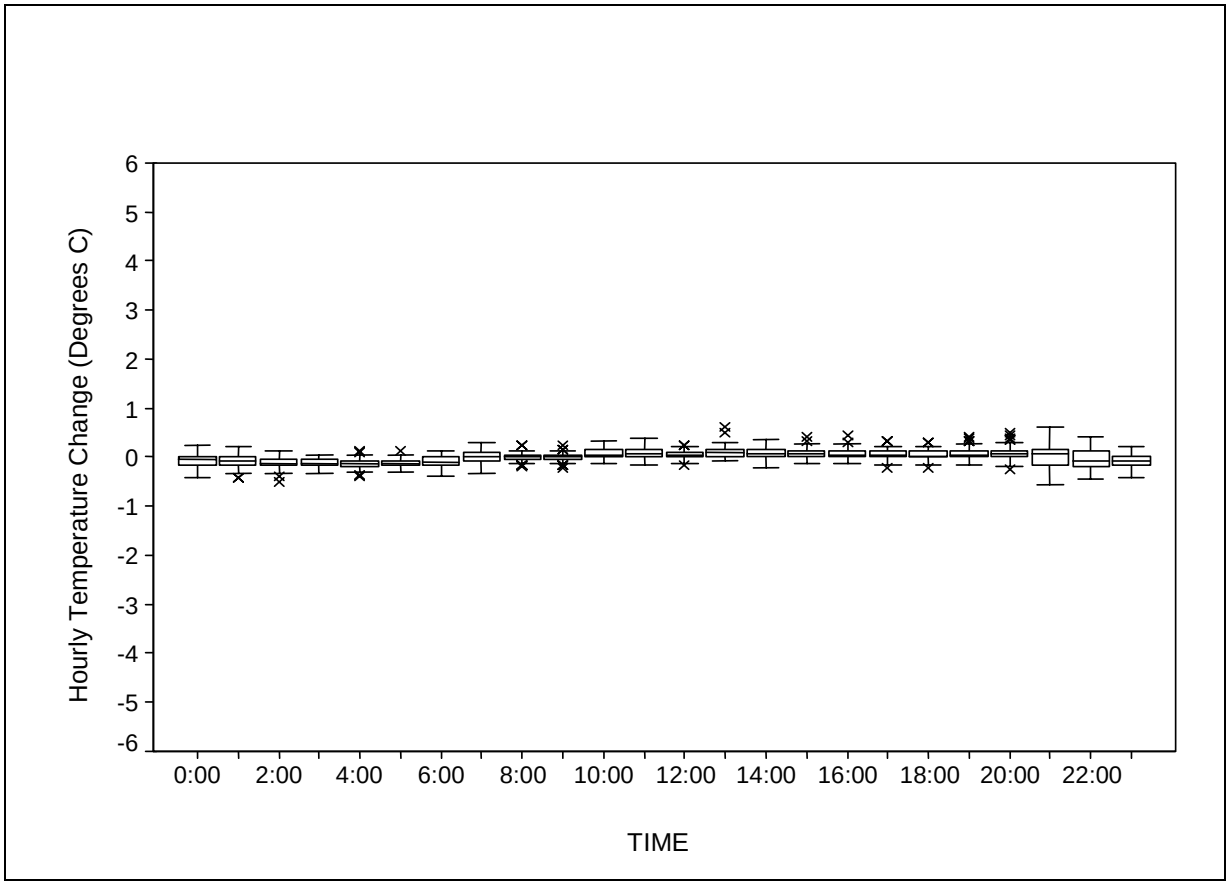

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FIGURE C-20C: ANALYSIS ZONE 1 – WOODS CREEK (TM-04)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

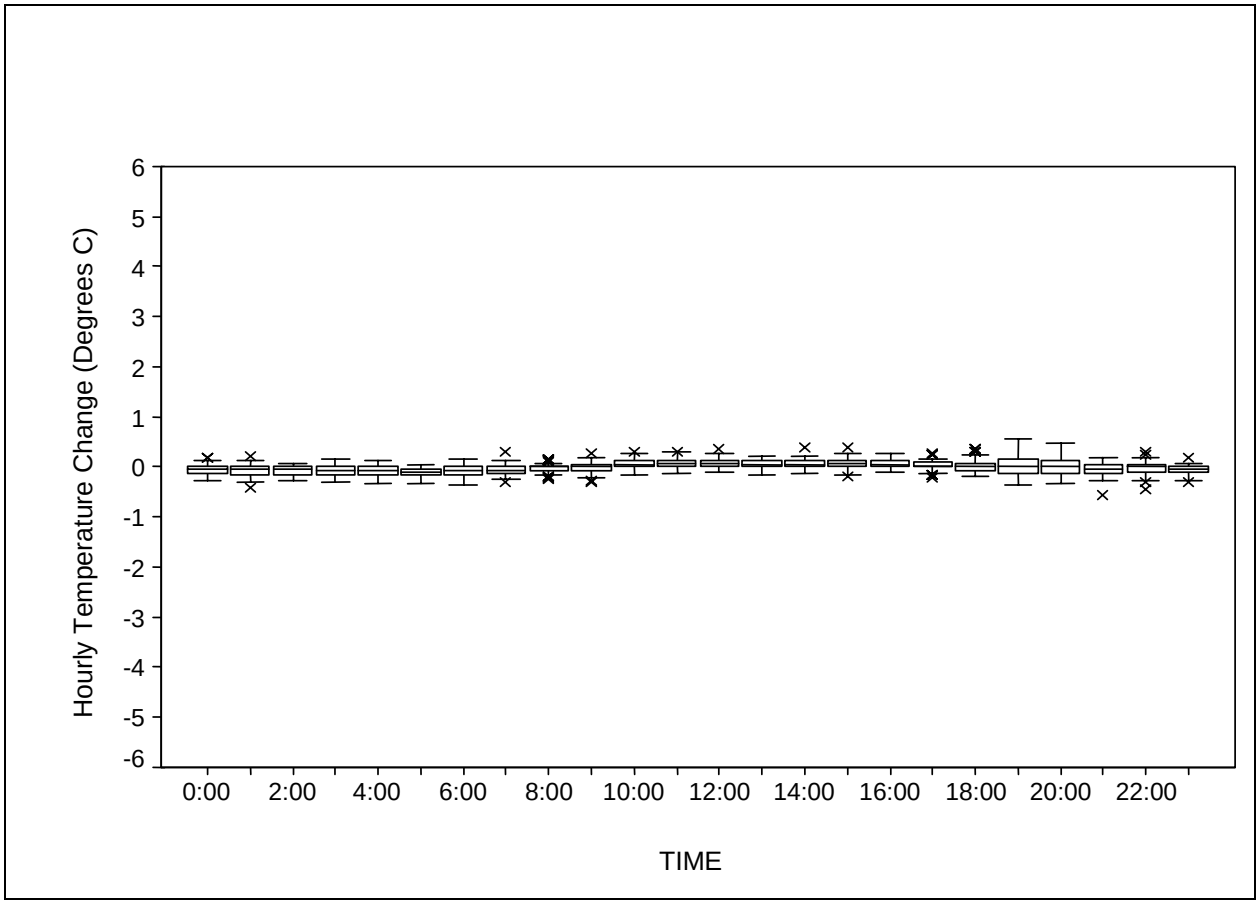

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FIGURE C-21: ANALYSIS ZONE 1 – WOODS CREEK (TWC-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

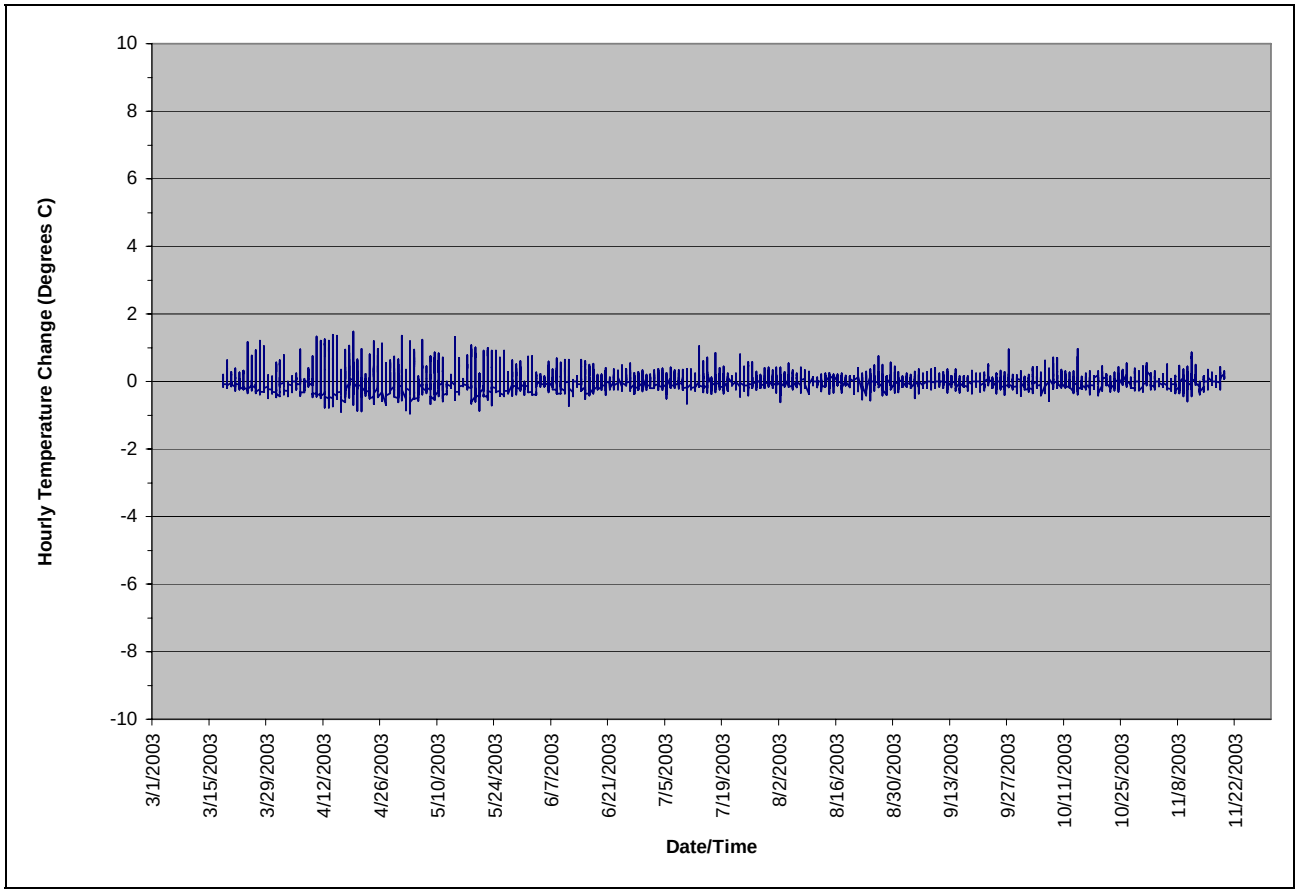

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FIGURE C-22A: ANALYSIS ZONE 1 – WOODS CREEK (TWC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

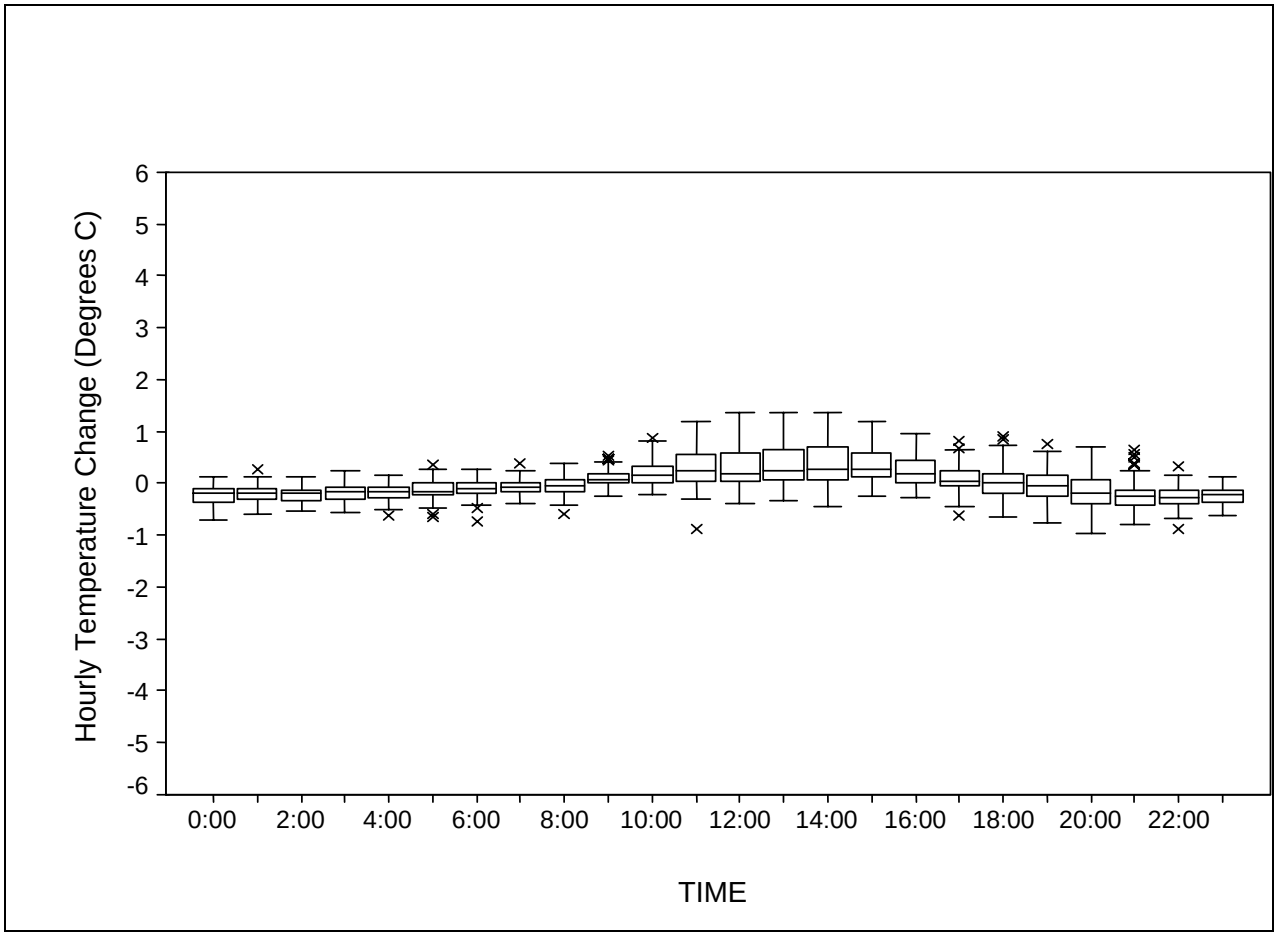

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FIGURE C-22B: ANALYSIS ZONE 1 – WOODS CREEK (TWC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

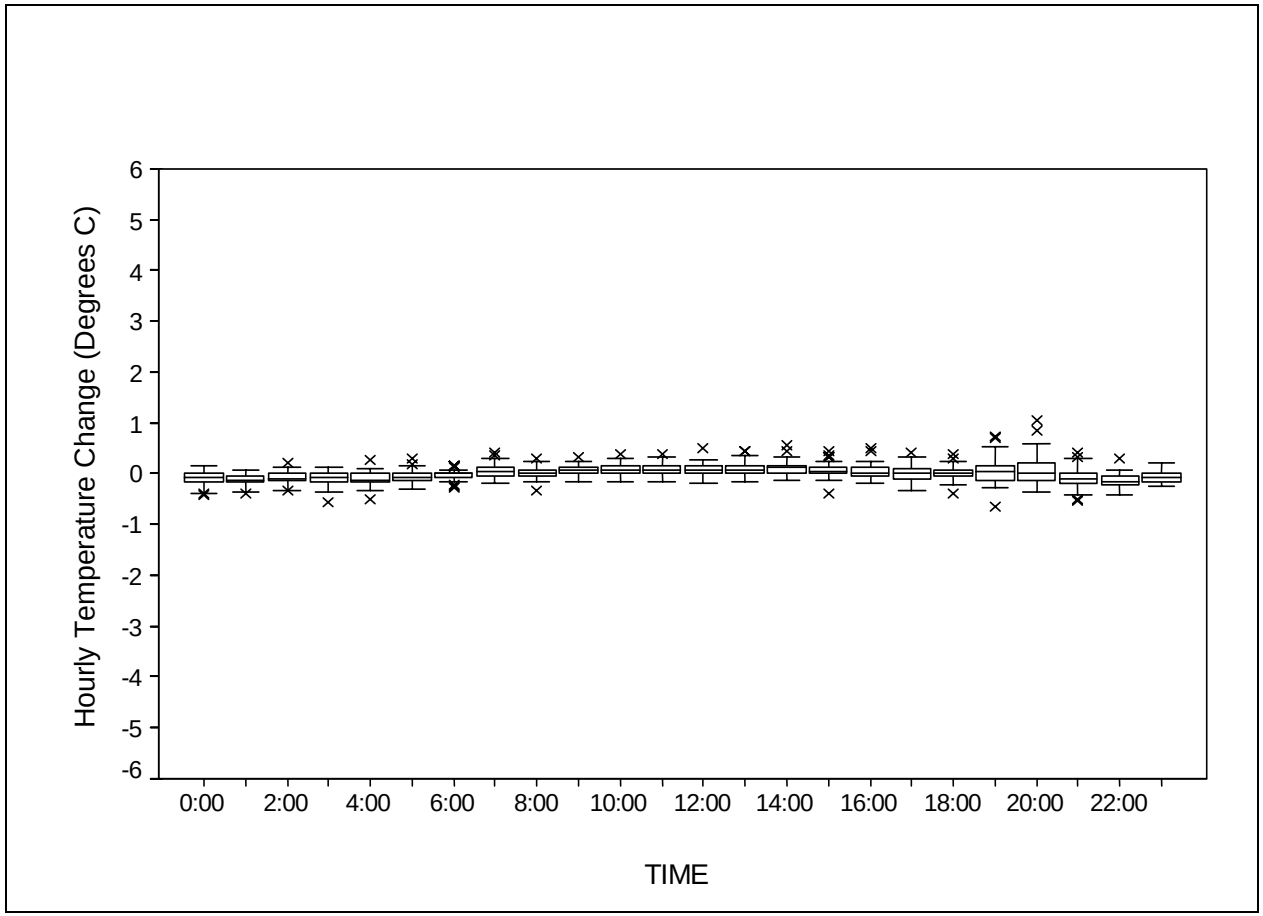

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FIGURE C-22C: ANALYSIS ZONE 1 – WOODS CREEK (TWC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

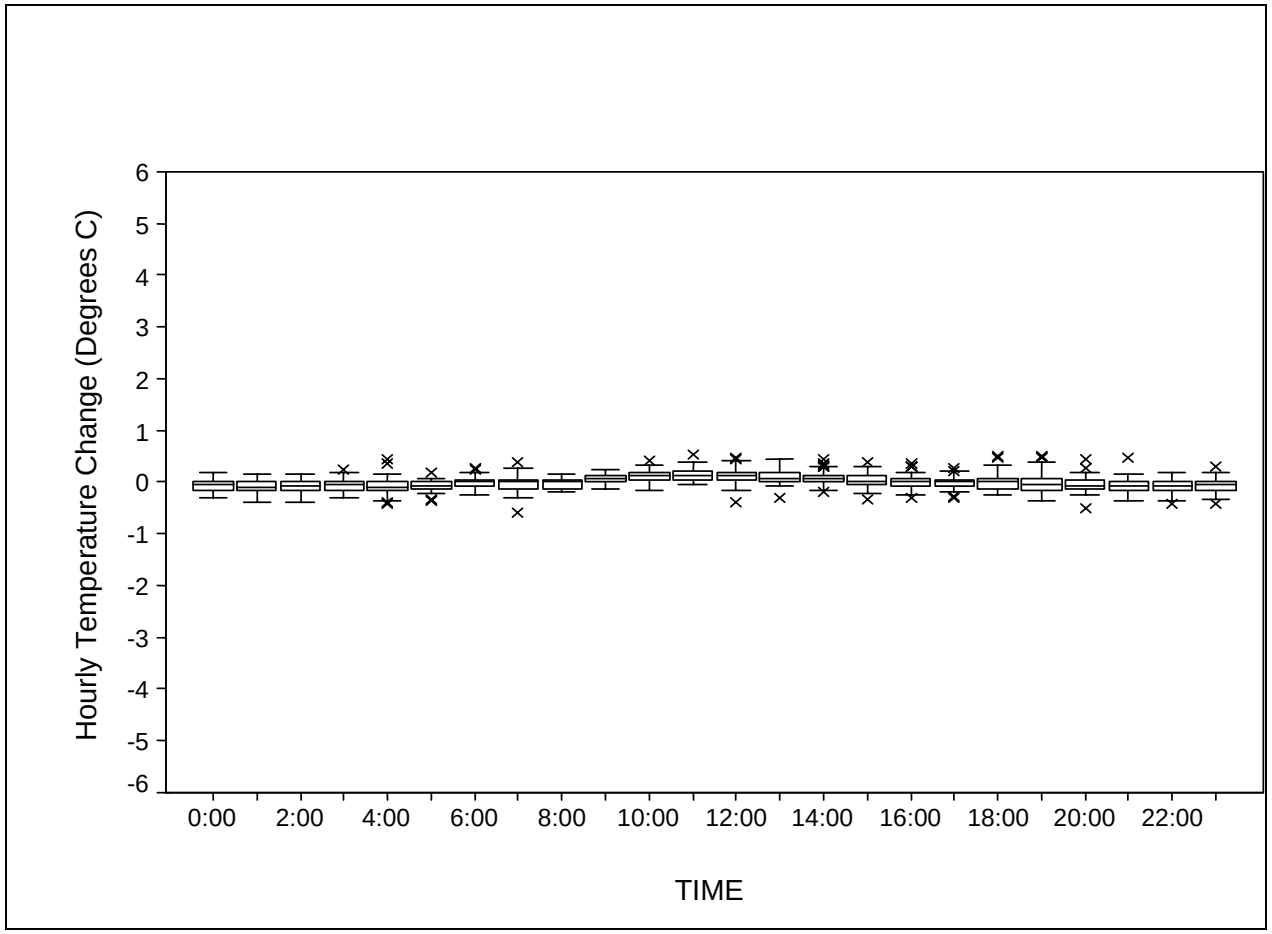

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FIGURE C-23: ANALYSIS ZONE 1 – GUN CREEK (TM-03)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

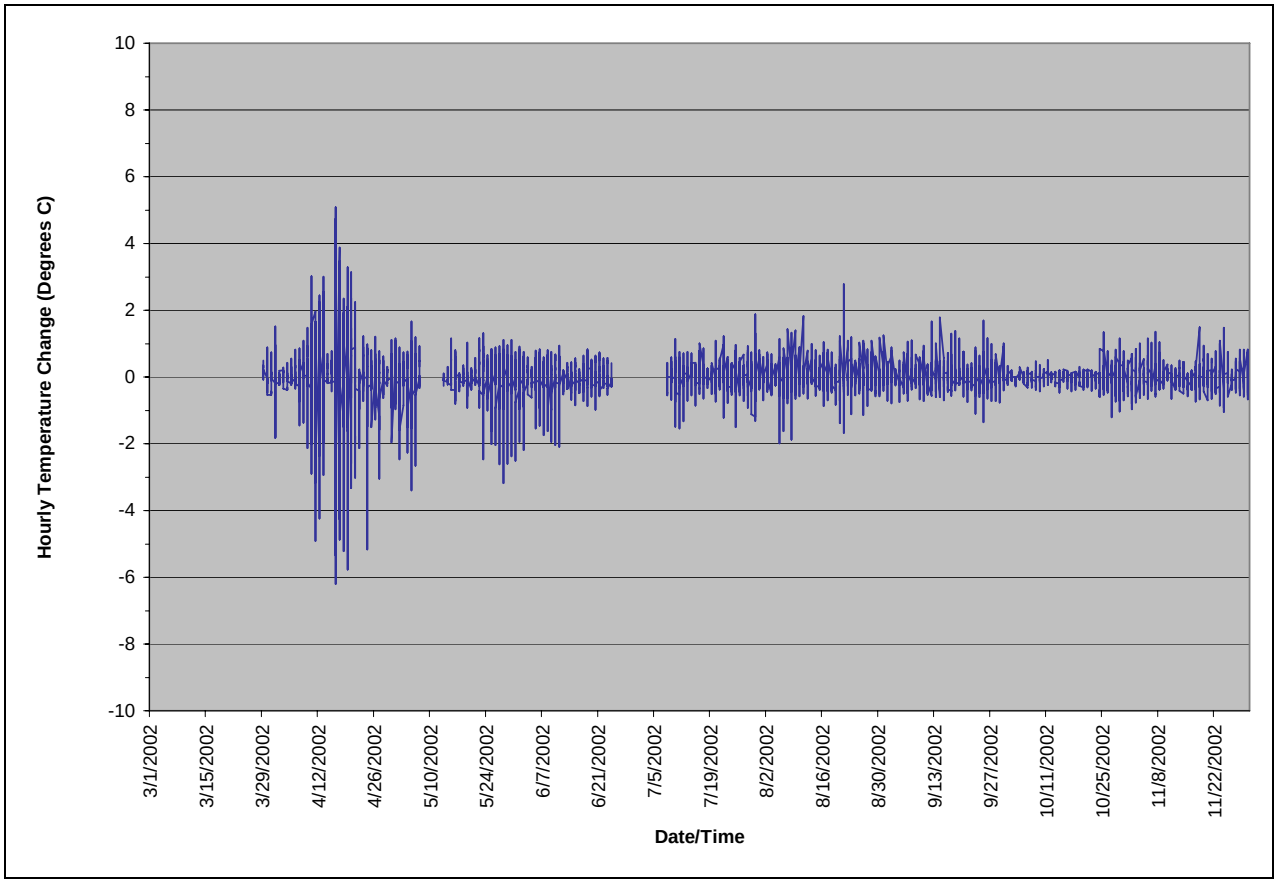

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FIGURE C-24A: ANALYSIS ZONE 1 – GUN CREEK (TM-03)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

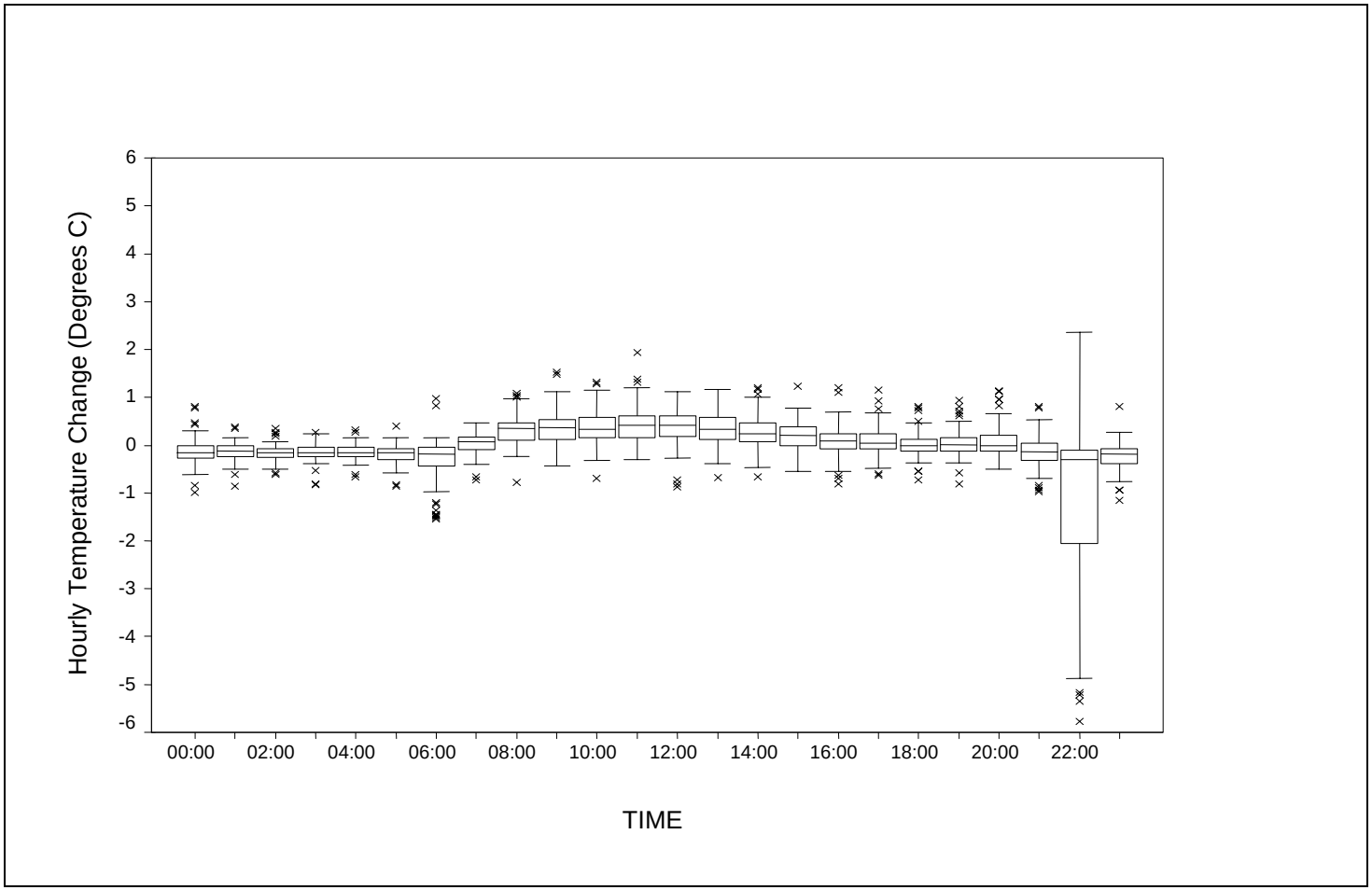

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FIGURE C-24B: ANALYSIS ZONE 1 – GUN CREEK (TM-03)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

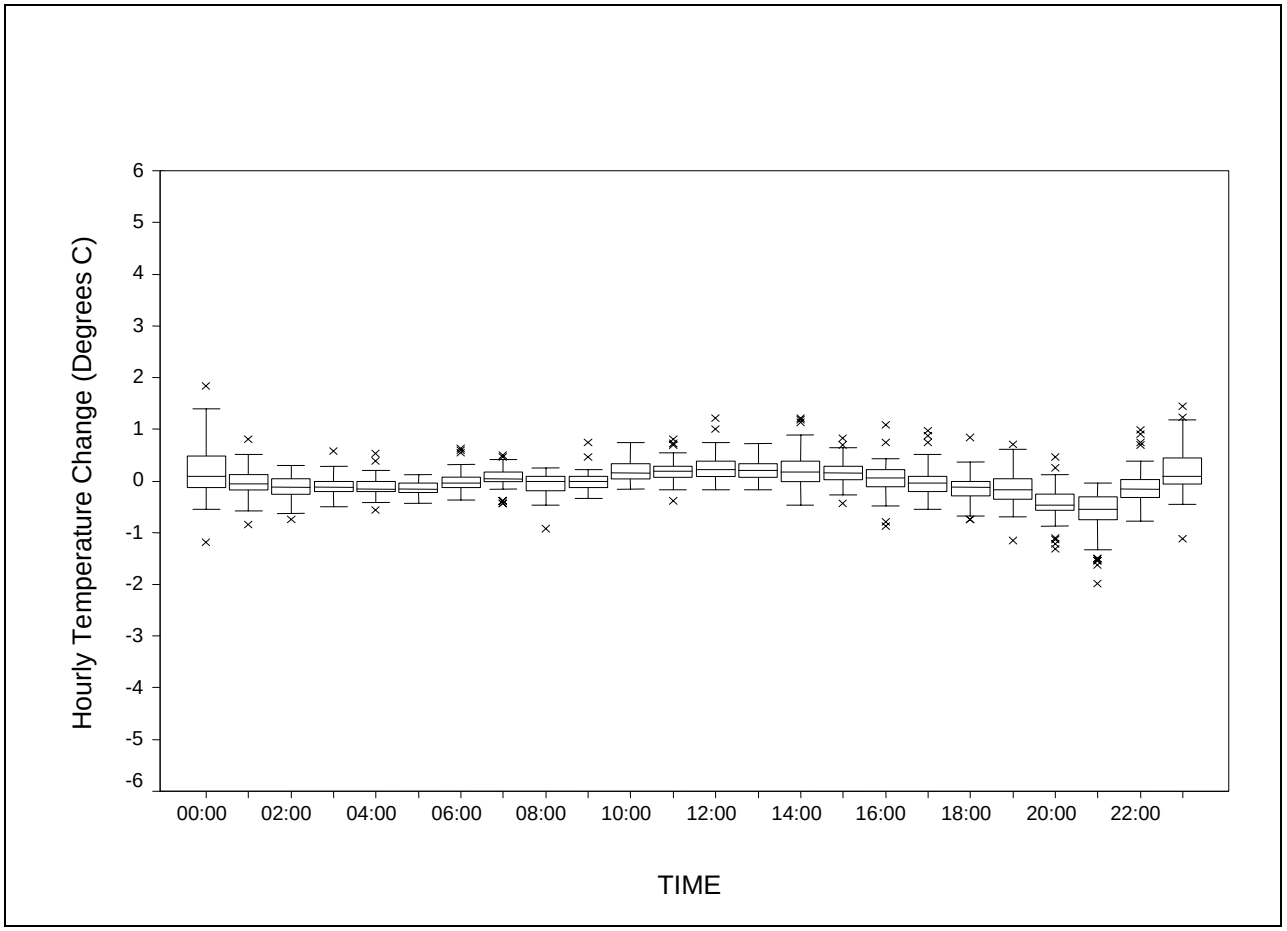

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FIGURE C-24C: ANALYSIS ZONE 1 – GUN CREEK (TM-03)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

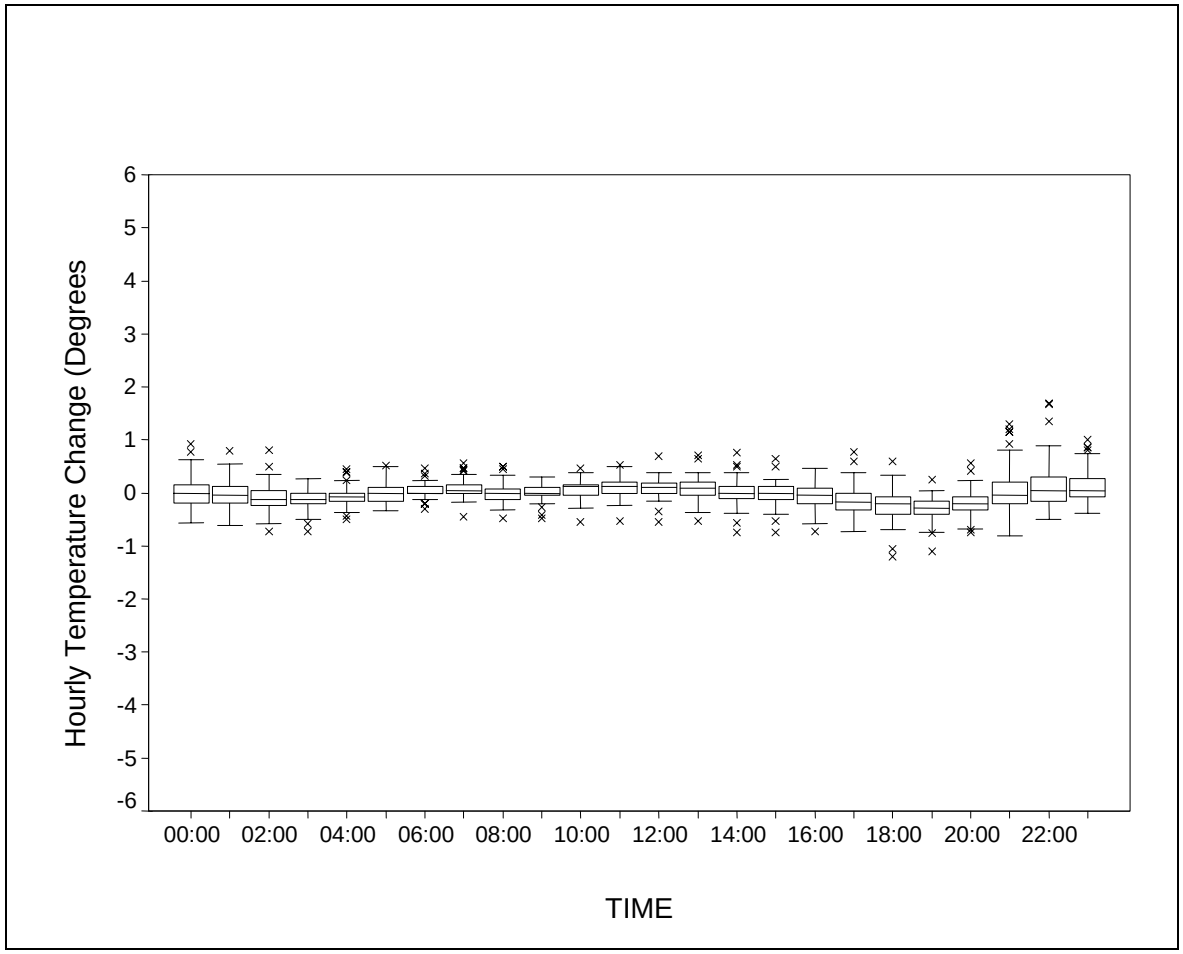

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FIGURE C-25: ANALYSIS ZONE 1 – GUN CREEK (GC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

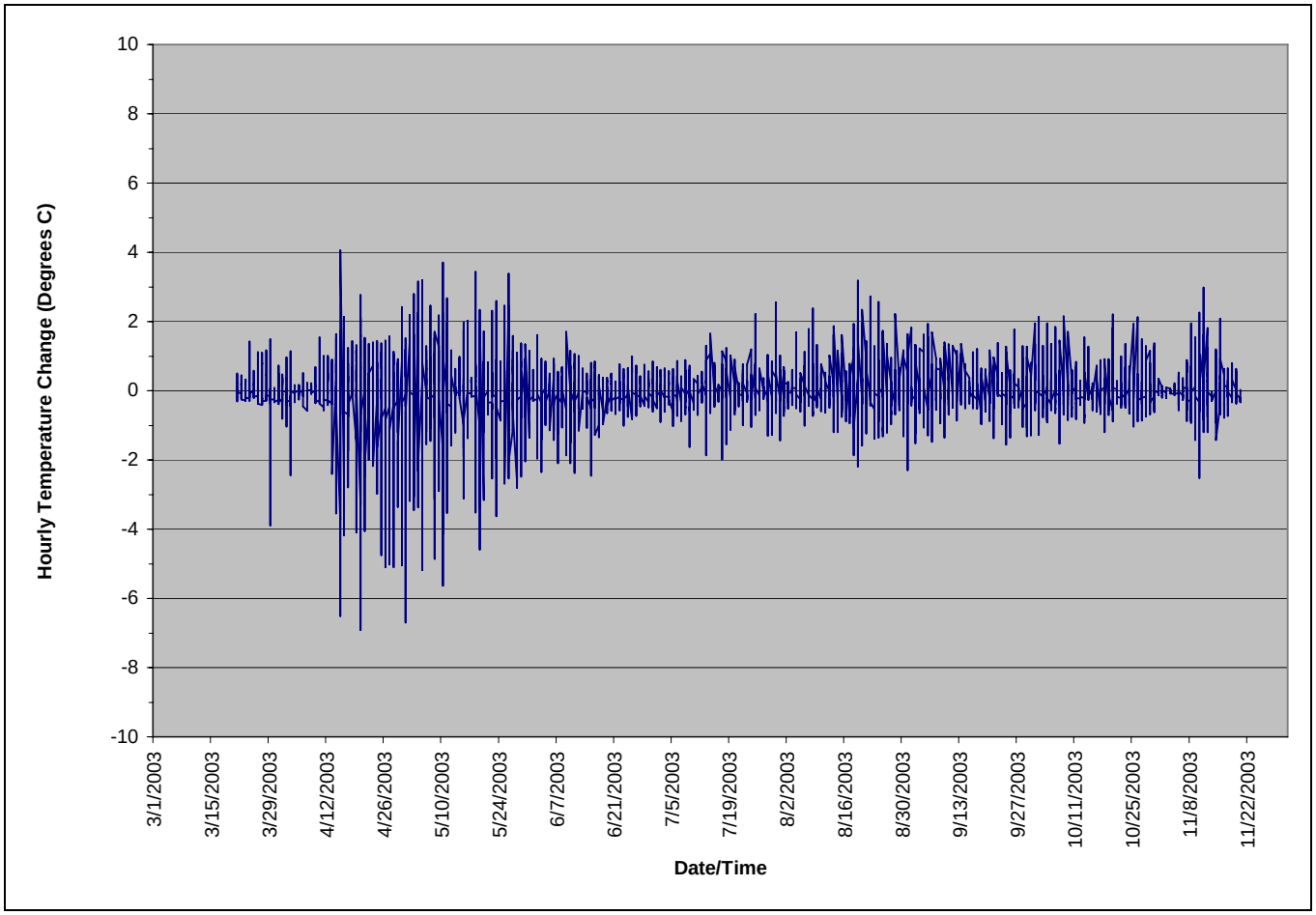

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FIGURE C-26A: ANALYSIS ZONE 1 – GUN CREEK (TGC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

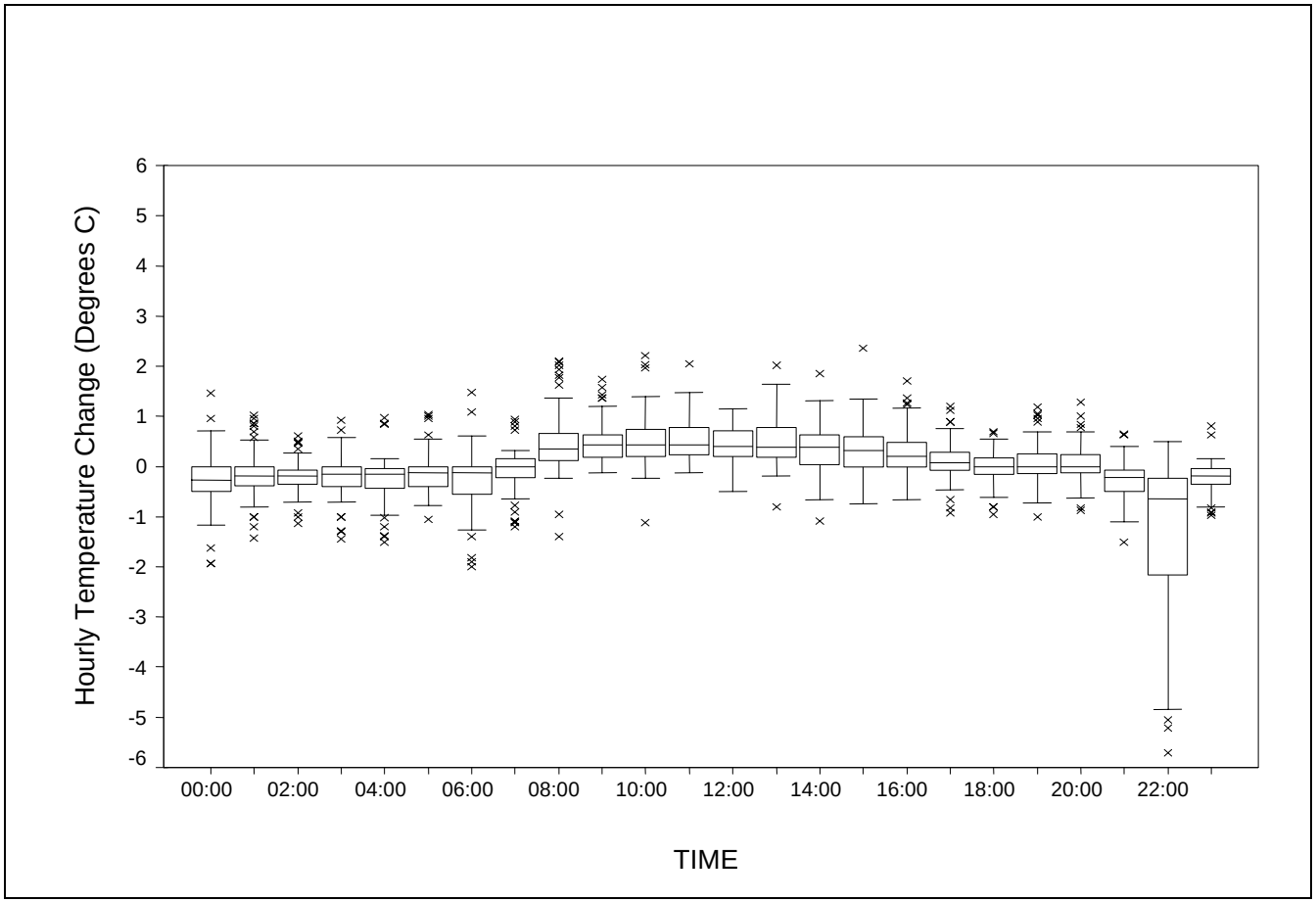

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FIGURE C-26B: ANALYSIS ZONE 1 – GUN CREEK (TGC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

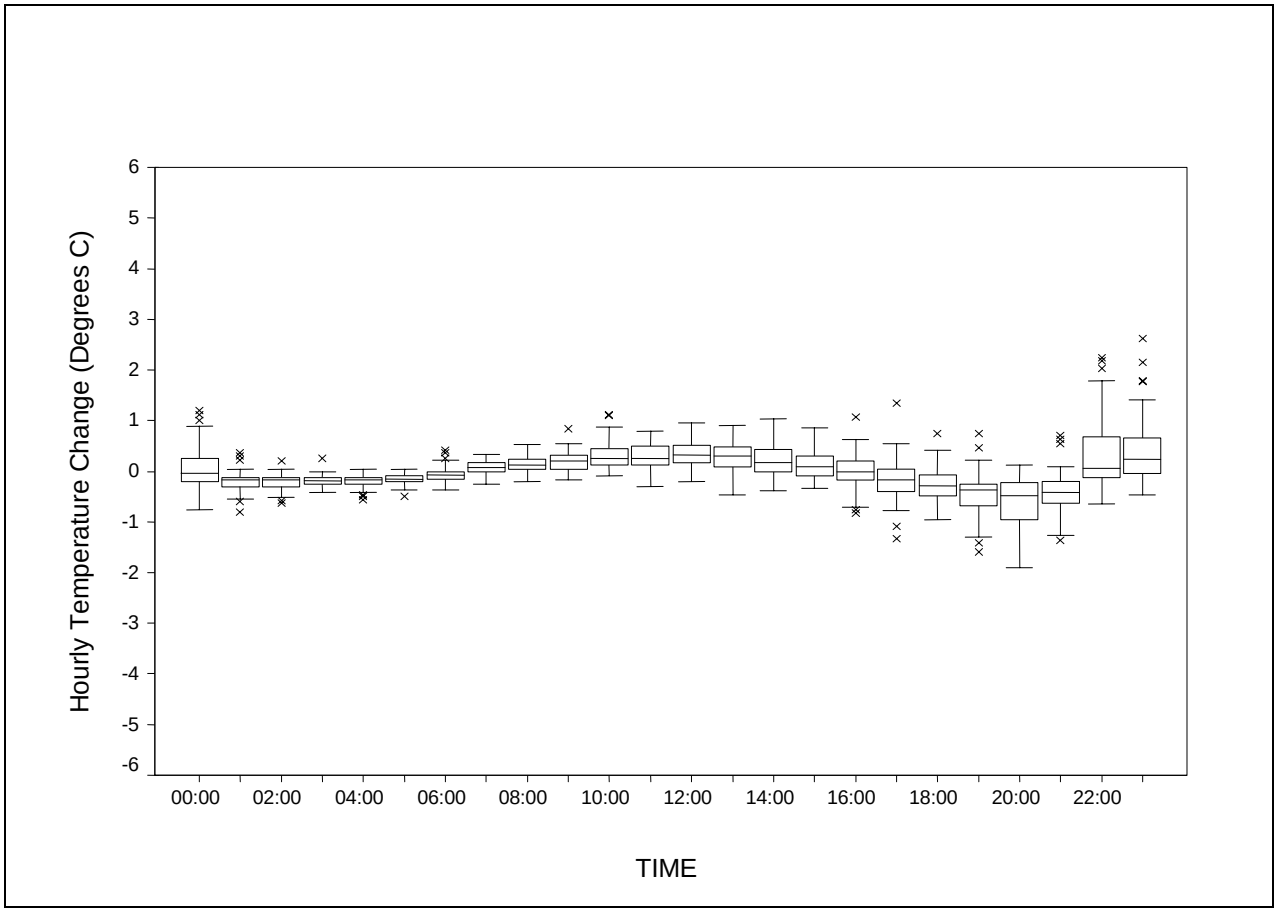

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FIGURE C-26C: ANALYSIS ZONE 1 – GUN CREEK (TGC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

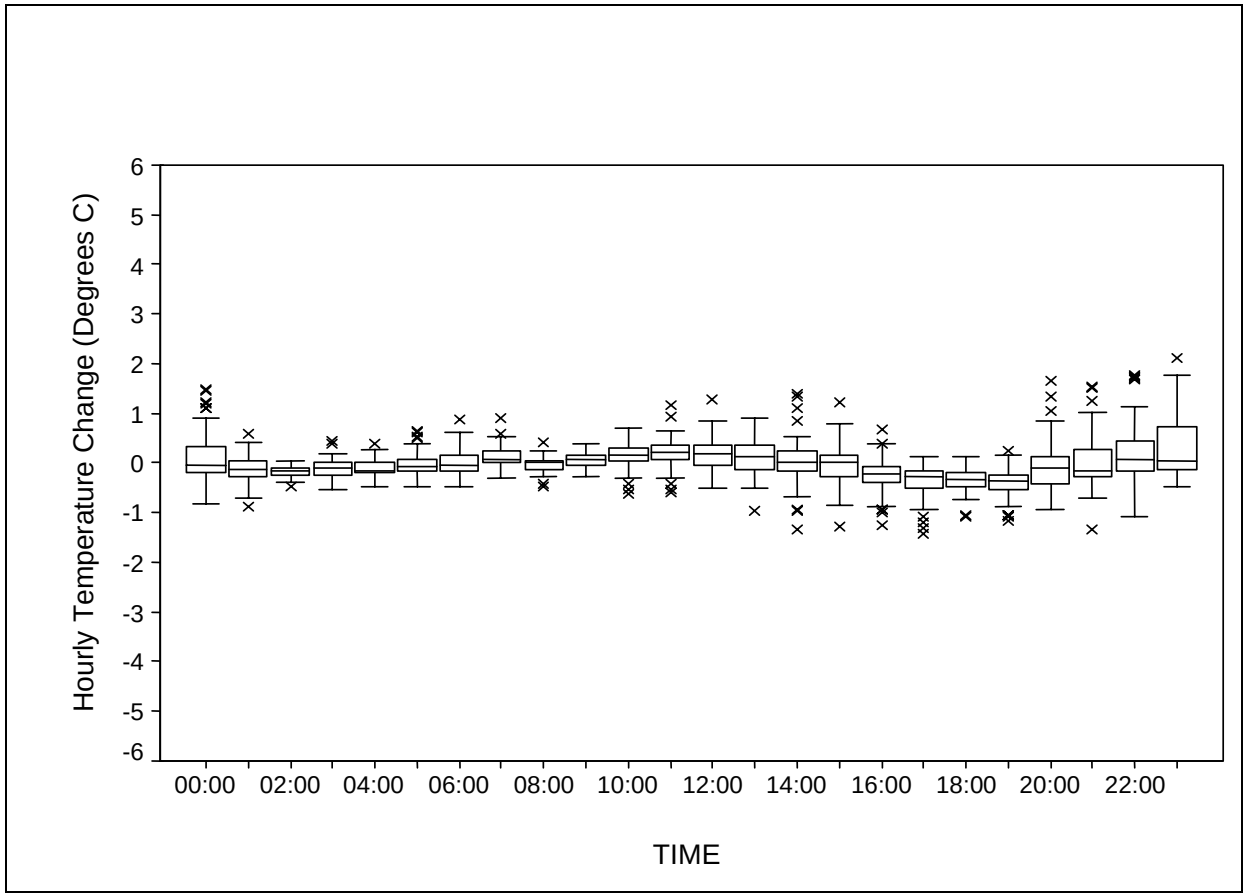

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FIGURE C-27A: ANALYSIS ZONE 1 – GUN CREEK (GC-01)

FREQUENCY DISTRIBUTION OF D_{WT} VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

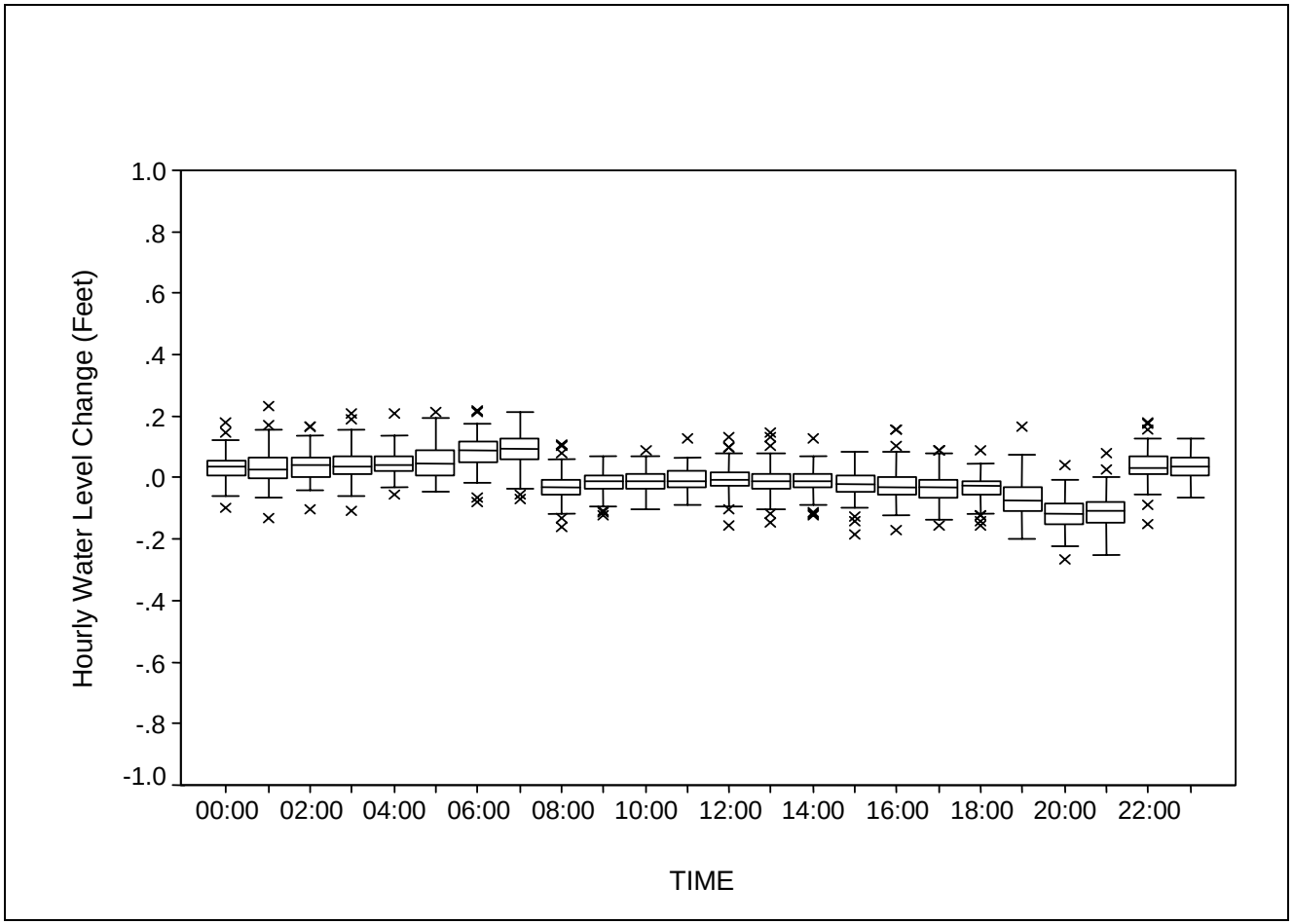

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FIGURE C-27B: ANALYSIS ZONE 1 – GUN CREEK (GC-01)

FREQUENCY DISTRIBUTION OF D_{WT} VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

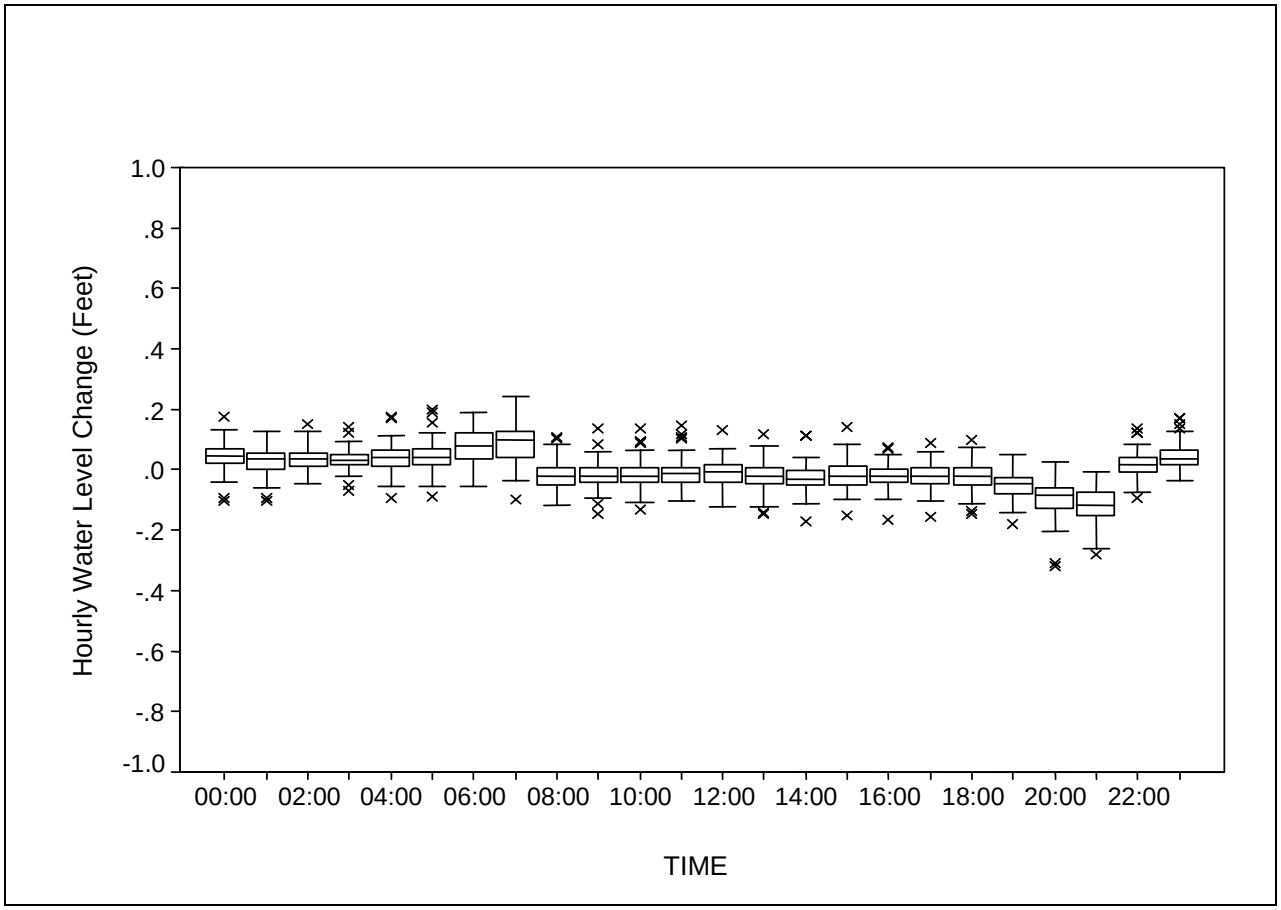

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FIGURE C-27C: ANALYSIS ZONE 1 – GUN CREEK (GC-01)

FREQUENCY DISTRIBUTION OF D_{WT} VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

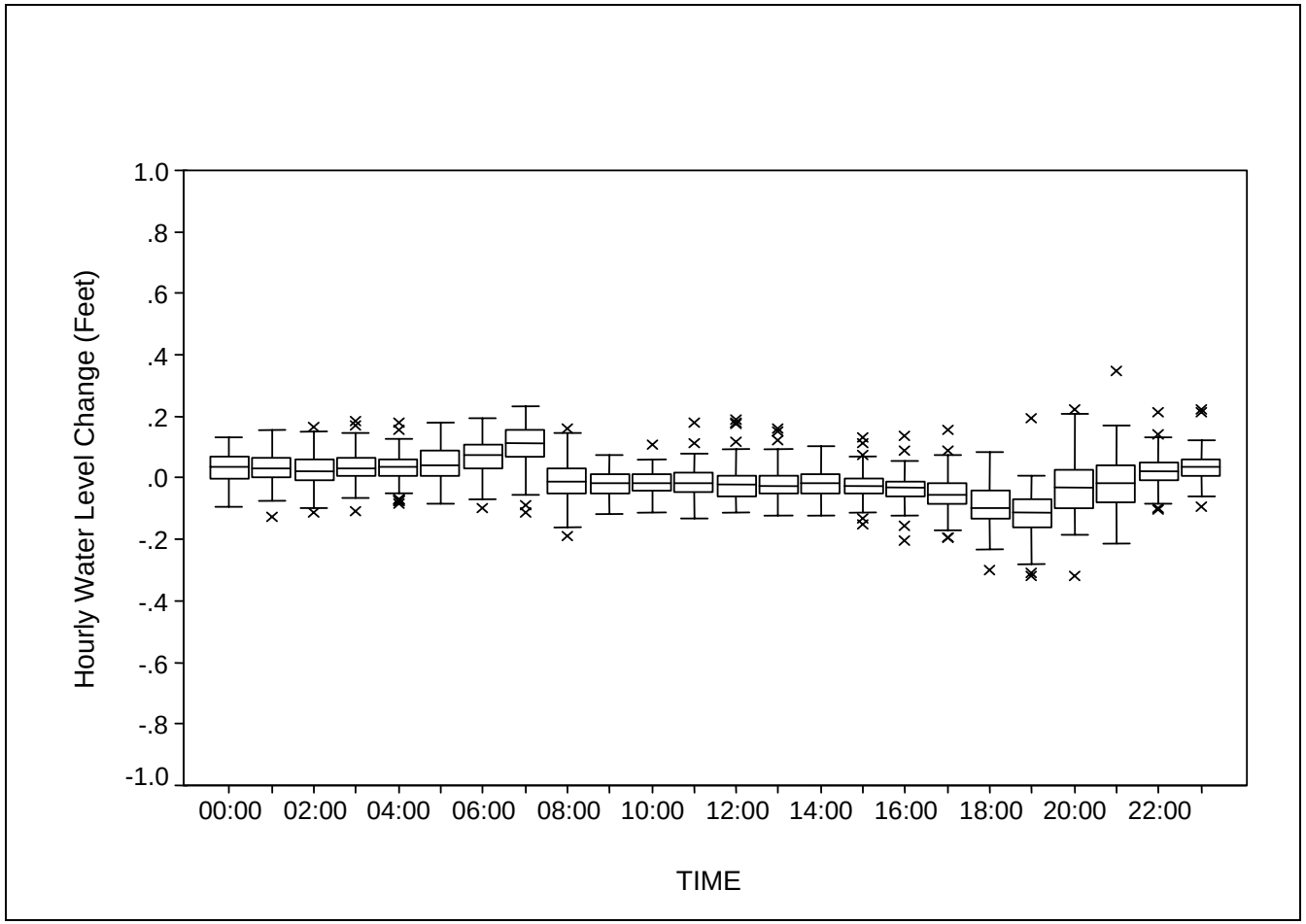

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FIGURE C-28: ANALYSIS ZONE 1 GUN CREEK (TM-05)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

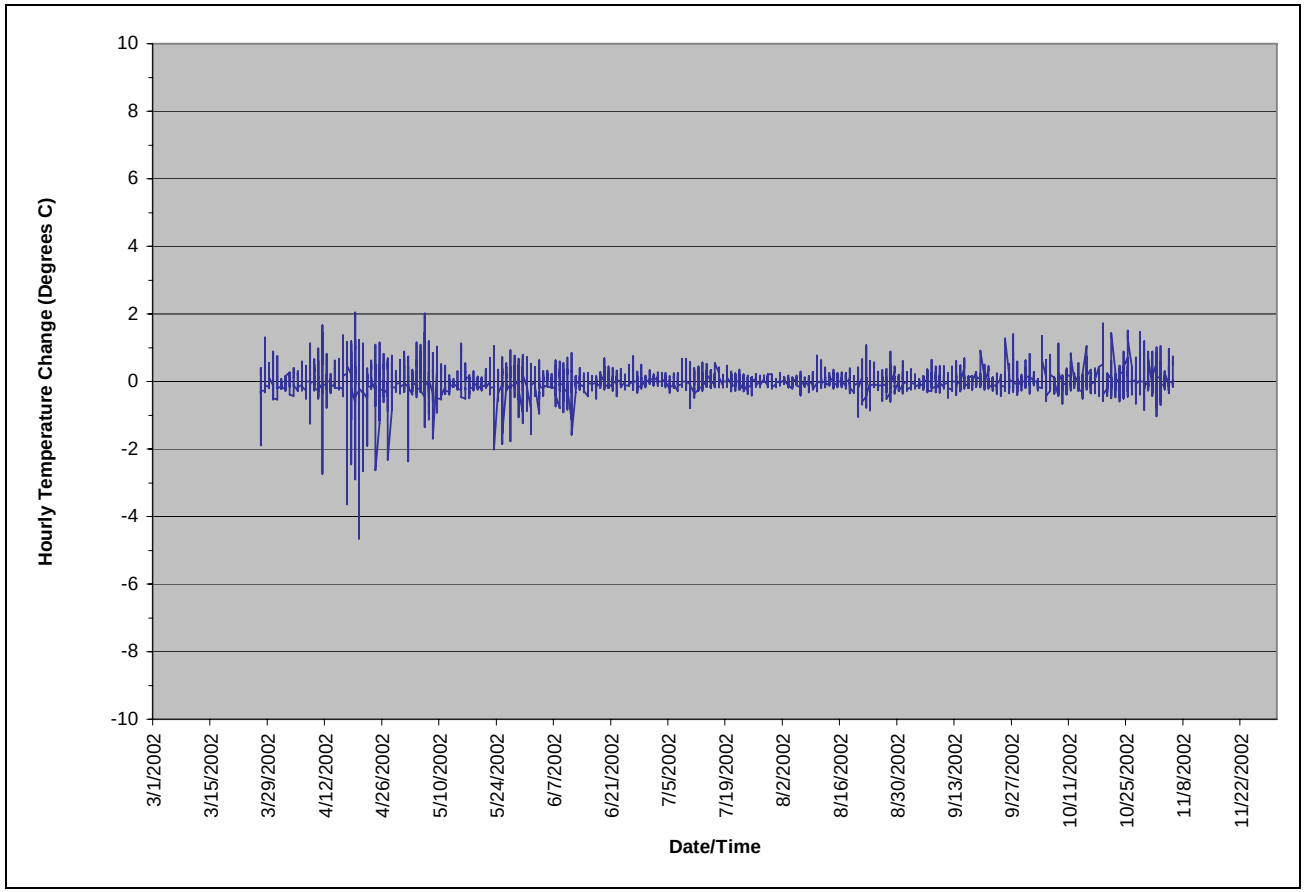

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FIGURE C-29A: ANALYSIS ZONE 1 – GUN CREEK (TM-05)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

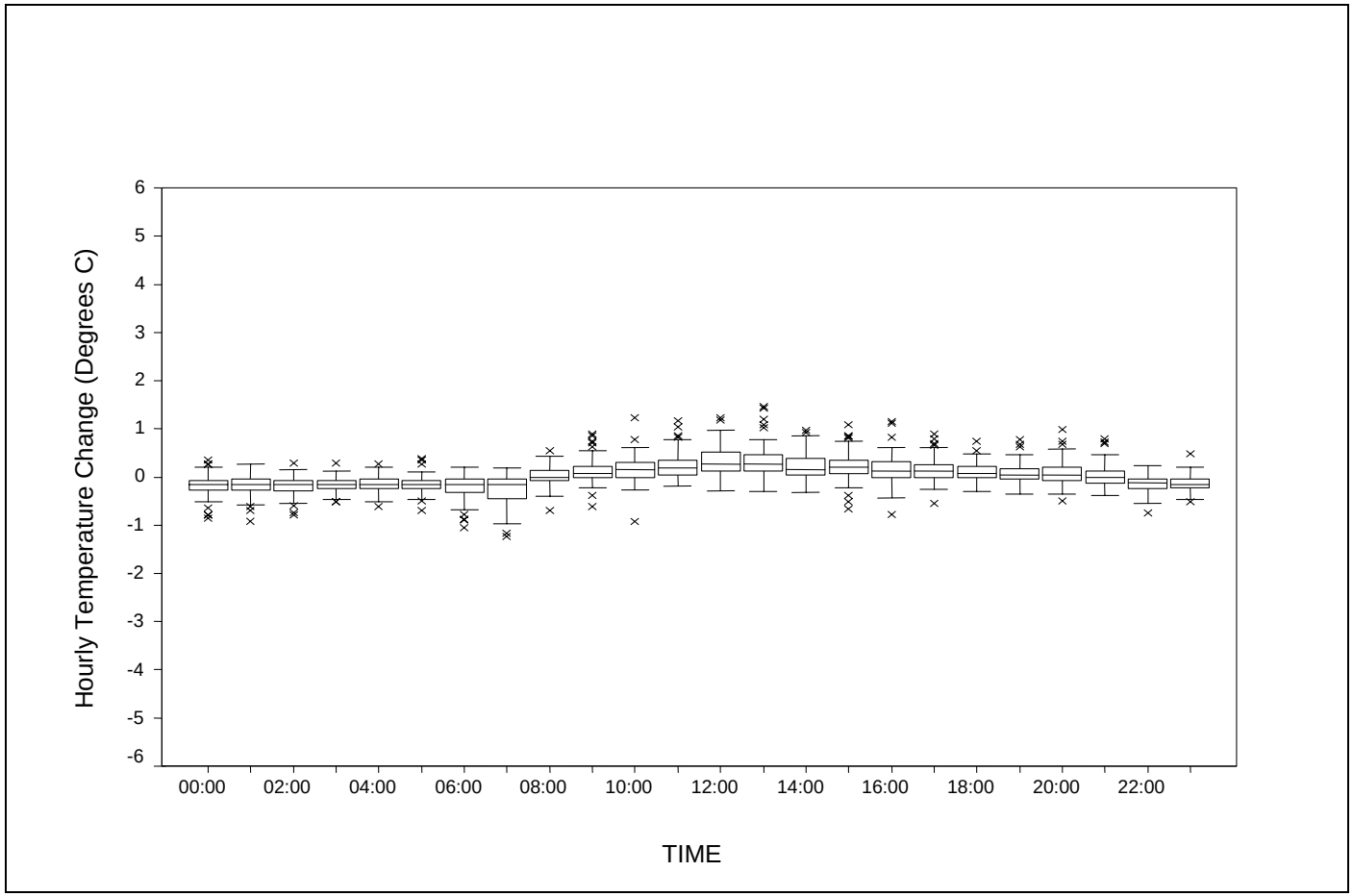

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FIGURE C-29B: ANALYSIS ZONE 1 – GUN CREEK (TM-05)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

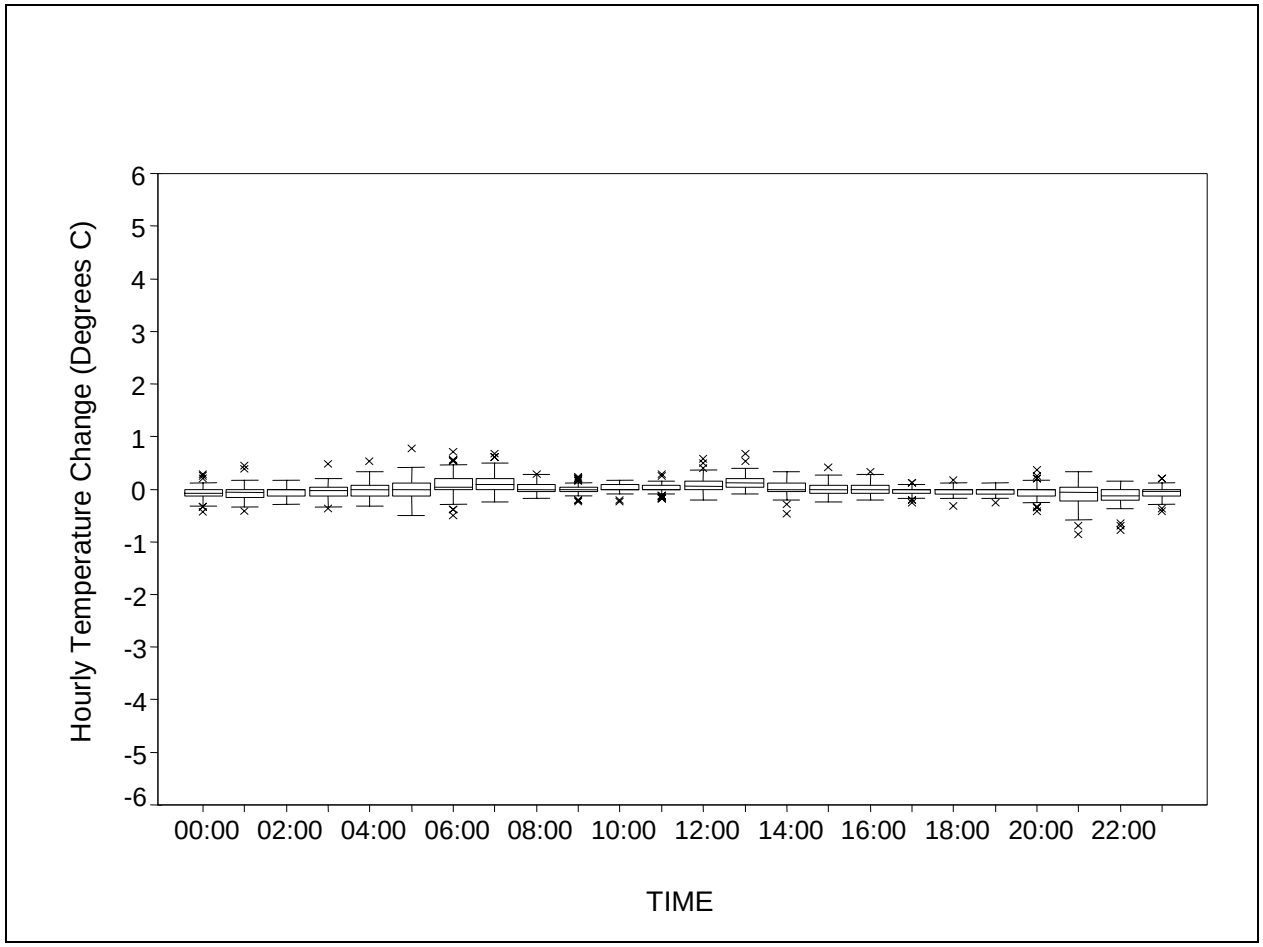

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FIGURE C-29C: ANALYSIS ZONE 1 – GUN CREEK (TM-05)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

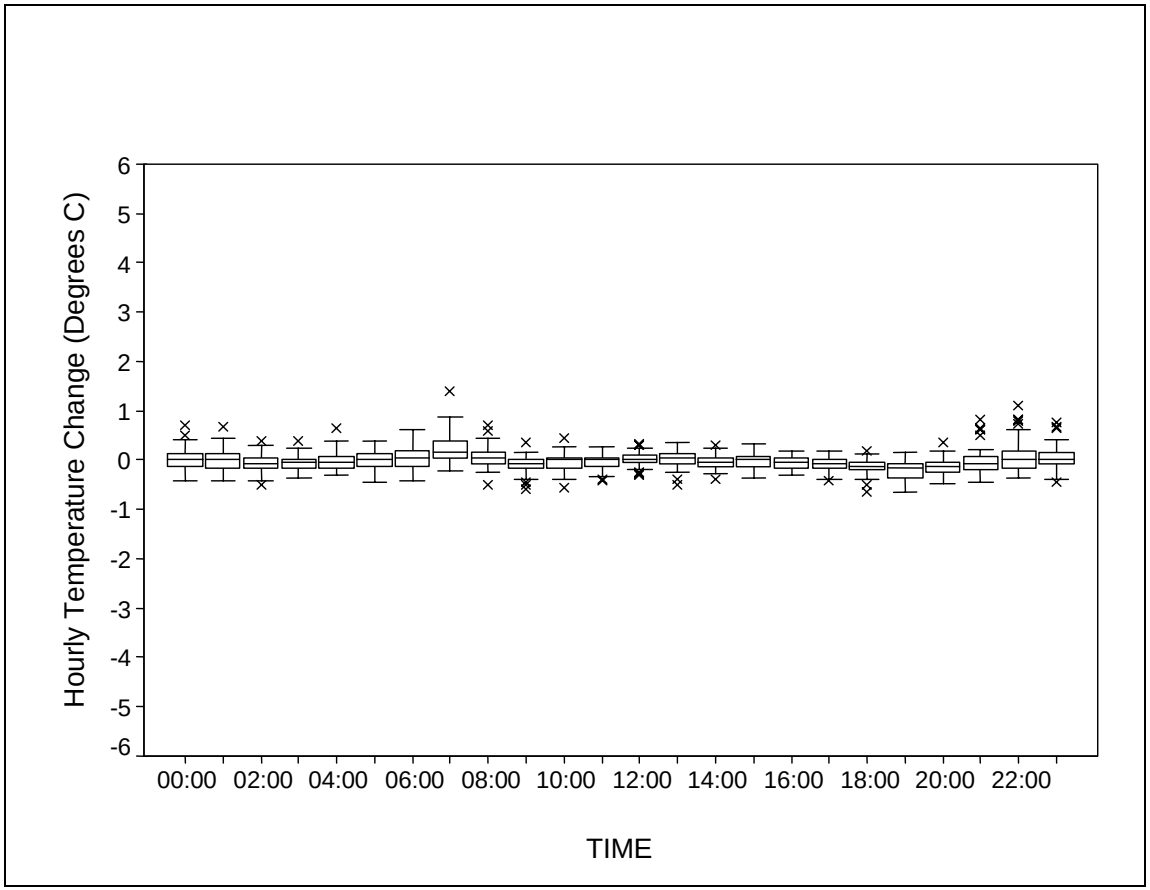

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FIGURE C-30: ANALYSIS ZONE 1 – GUN CREEK (GC-02A)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

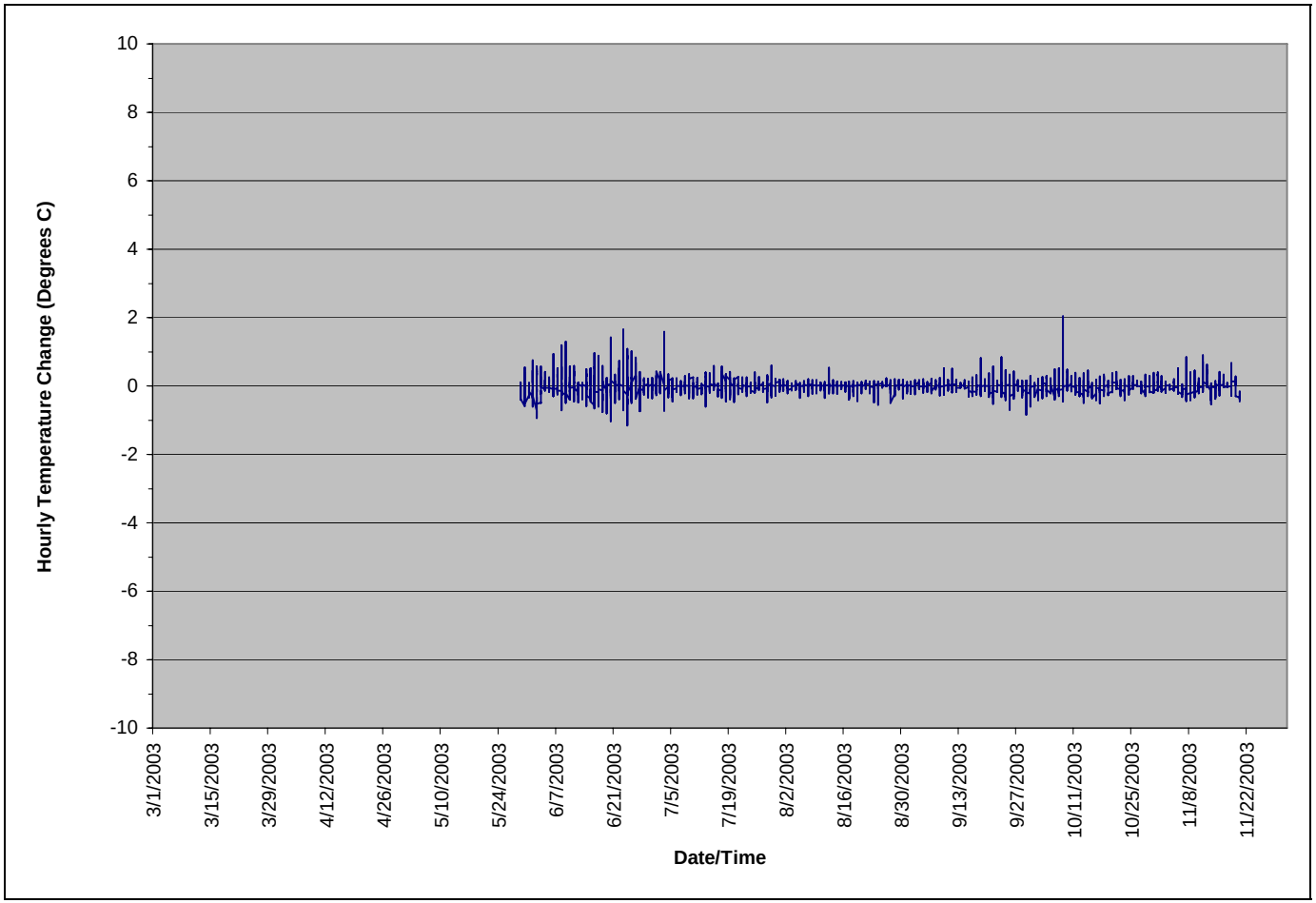

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FIGURE C-31A: ANALYSIS ZONE 1 – GUN CREEK (GC-02A)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2003

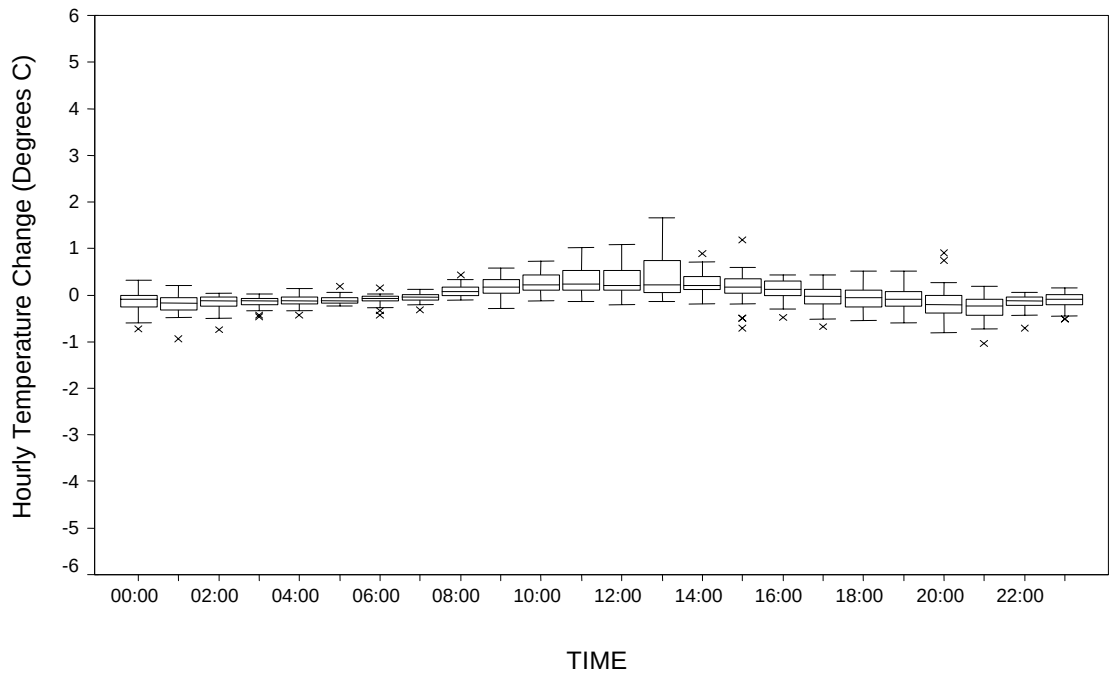

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FIGURE C-31B: ANALYSIS ZONE 1 – GUN CREEK (GC-02A)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2003

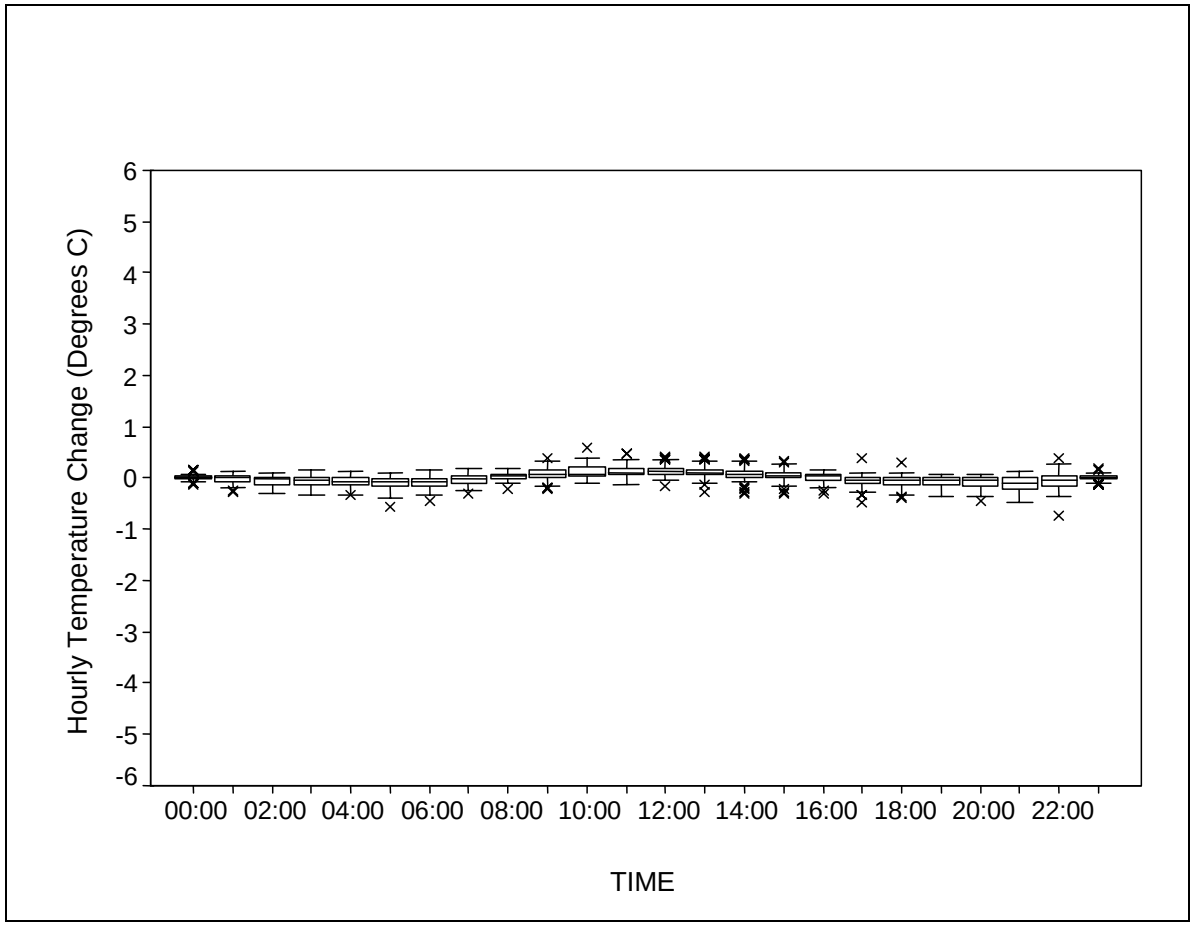

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FIGURE C-31C: ANALYSIS ZONE 1 – GUN CREEK (GC-02A)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2003

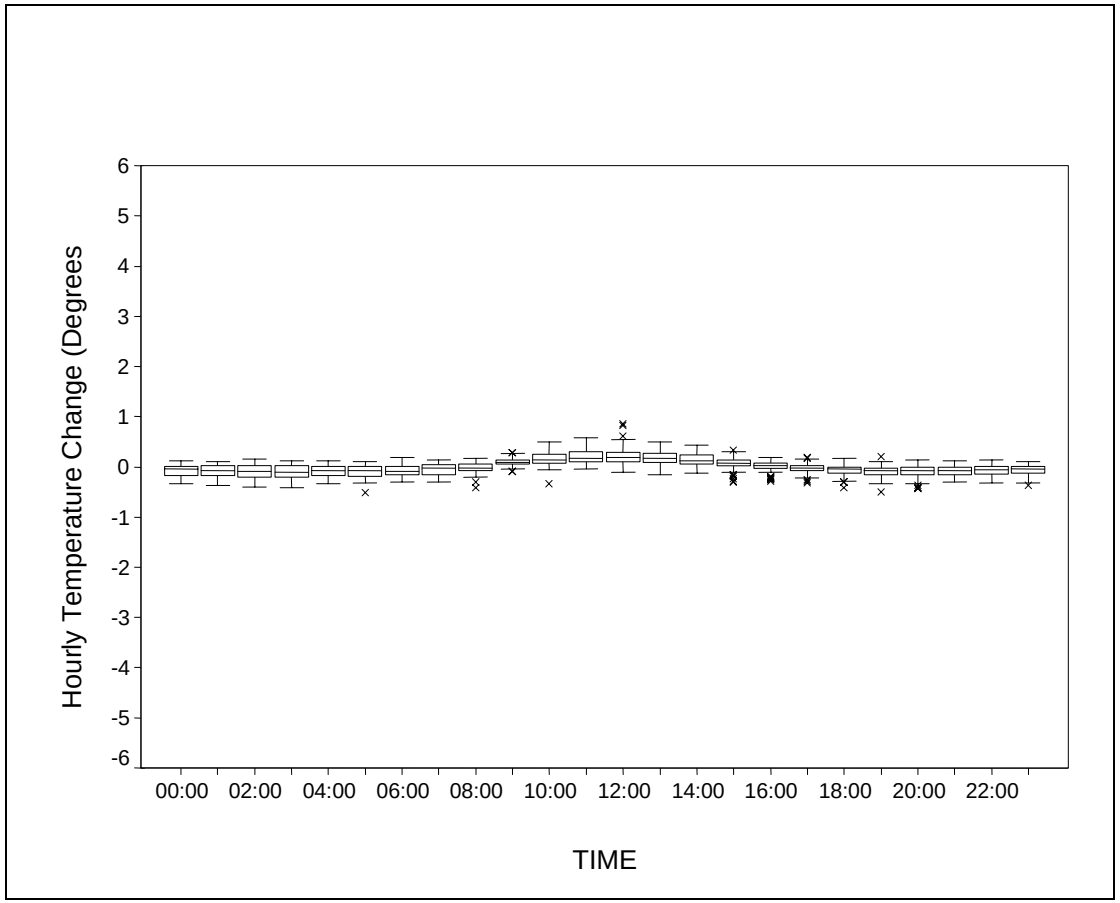

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FIGURE C-32: ANALYSIS ZONE 1 – SPICER CREEK (TM-06)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

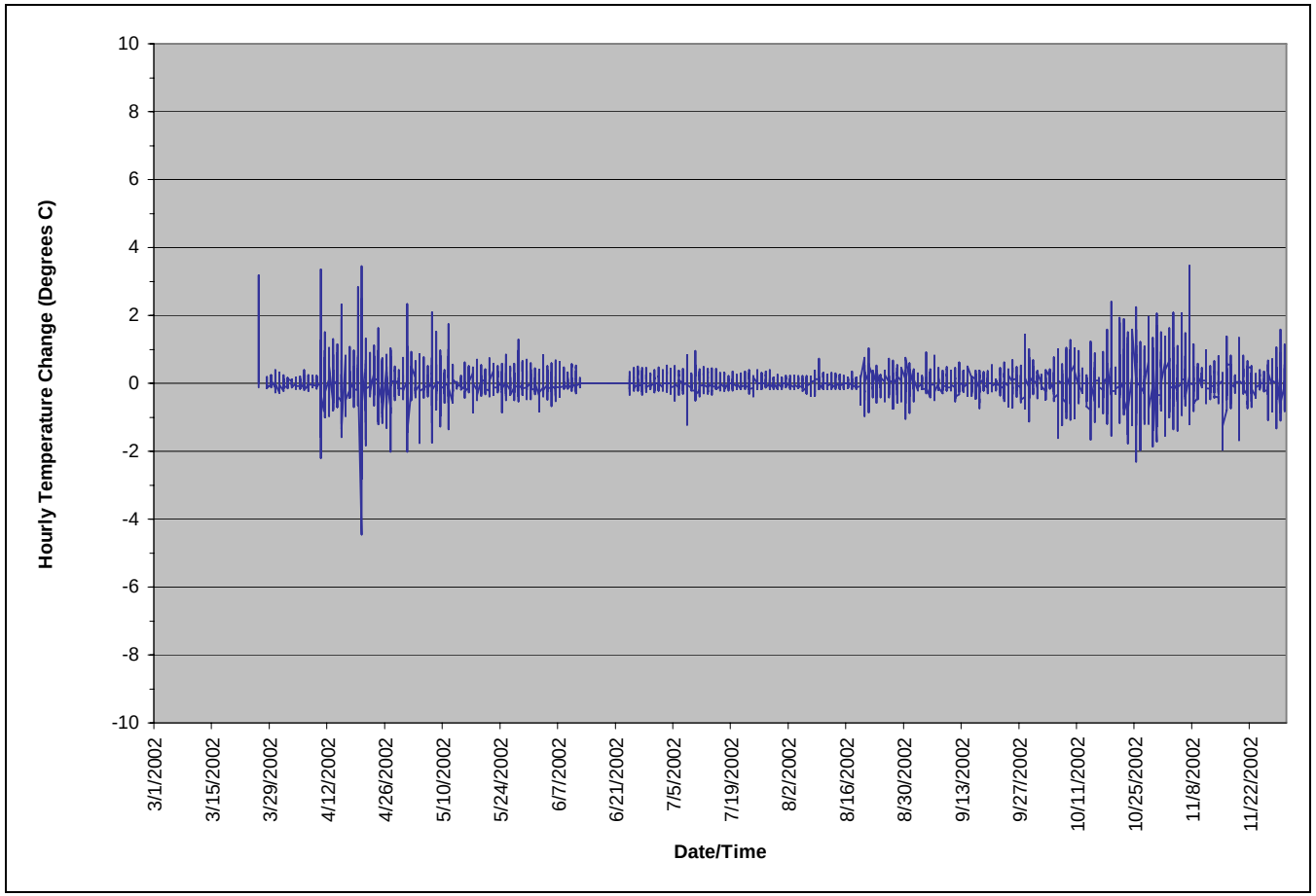

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FIGURE C-33A: ANALYSIS ZONE 1 – SPICER CREEK (TM-06)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2002

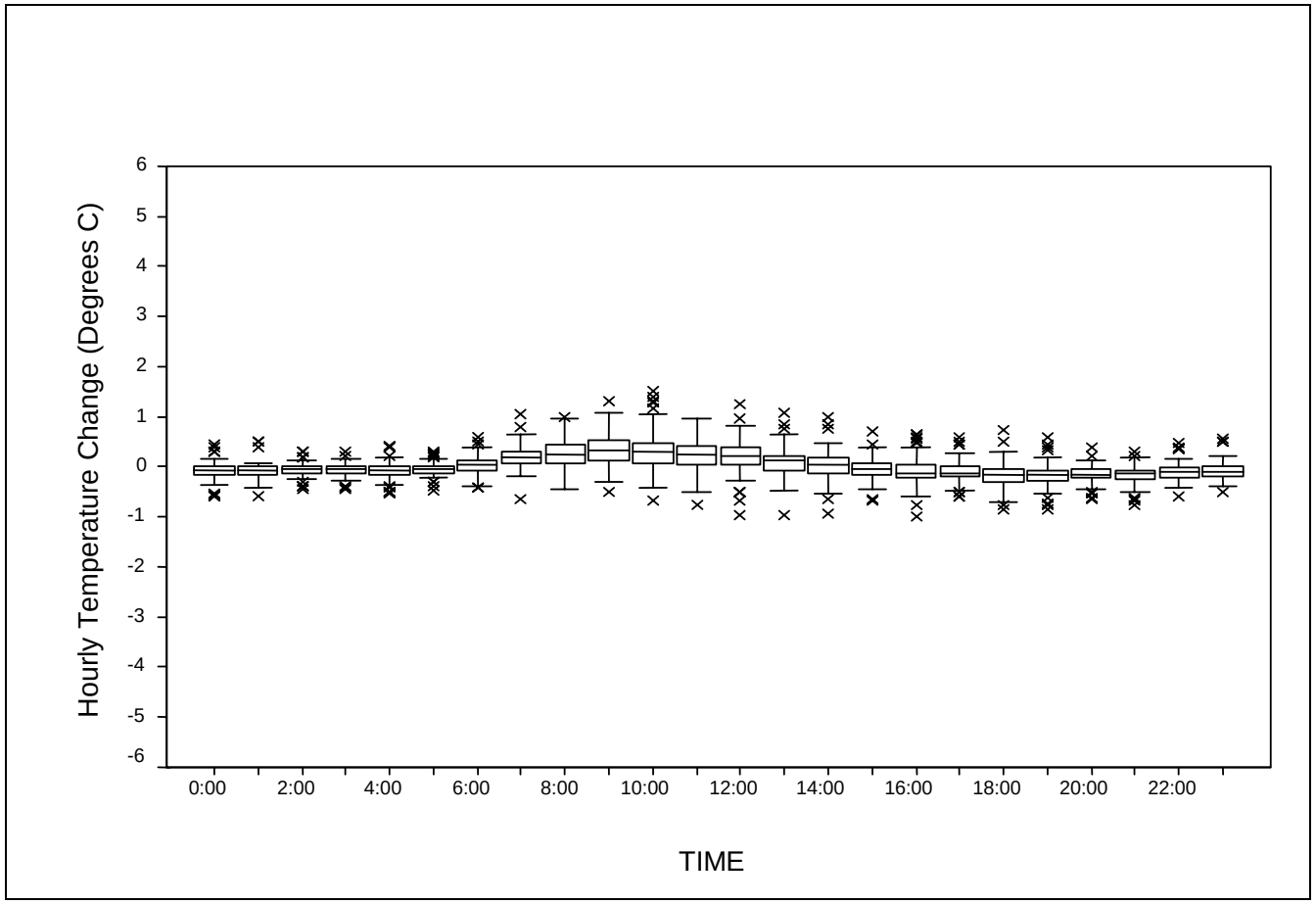

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FIGURE C-33B: ANALYSIS ZONE 1 – SPICER CREEK (TM-06)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2002

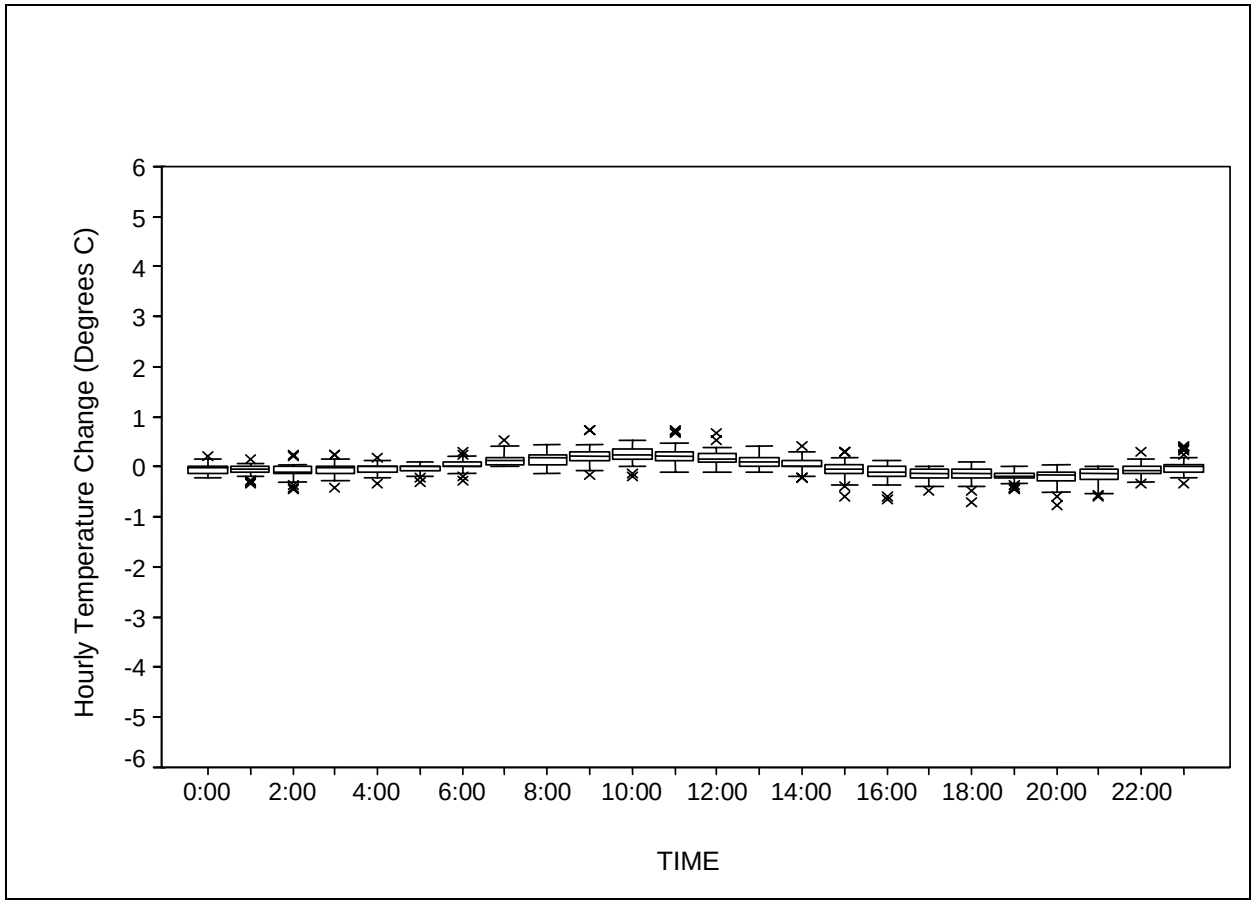

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FIGURE C-33C: ANALYSIS ZONE 1 – SPICER CREEK (TM-06)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 9/1 TO 10/31, 2002

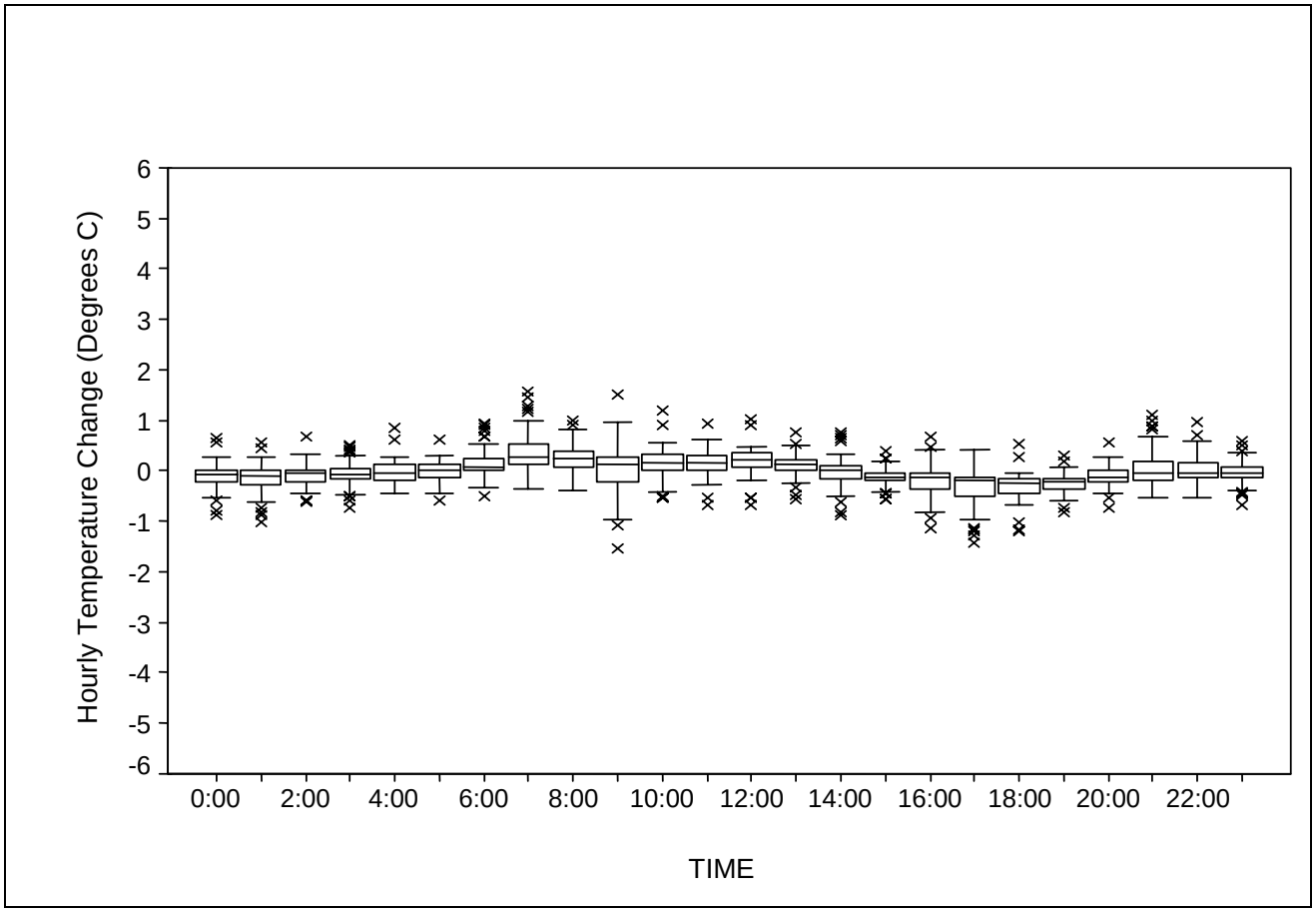

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FIGURE C-34: ANALYSIS ZONE 1 – SPICER CREEK (TM-07)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

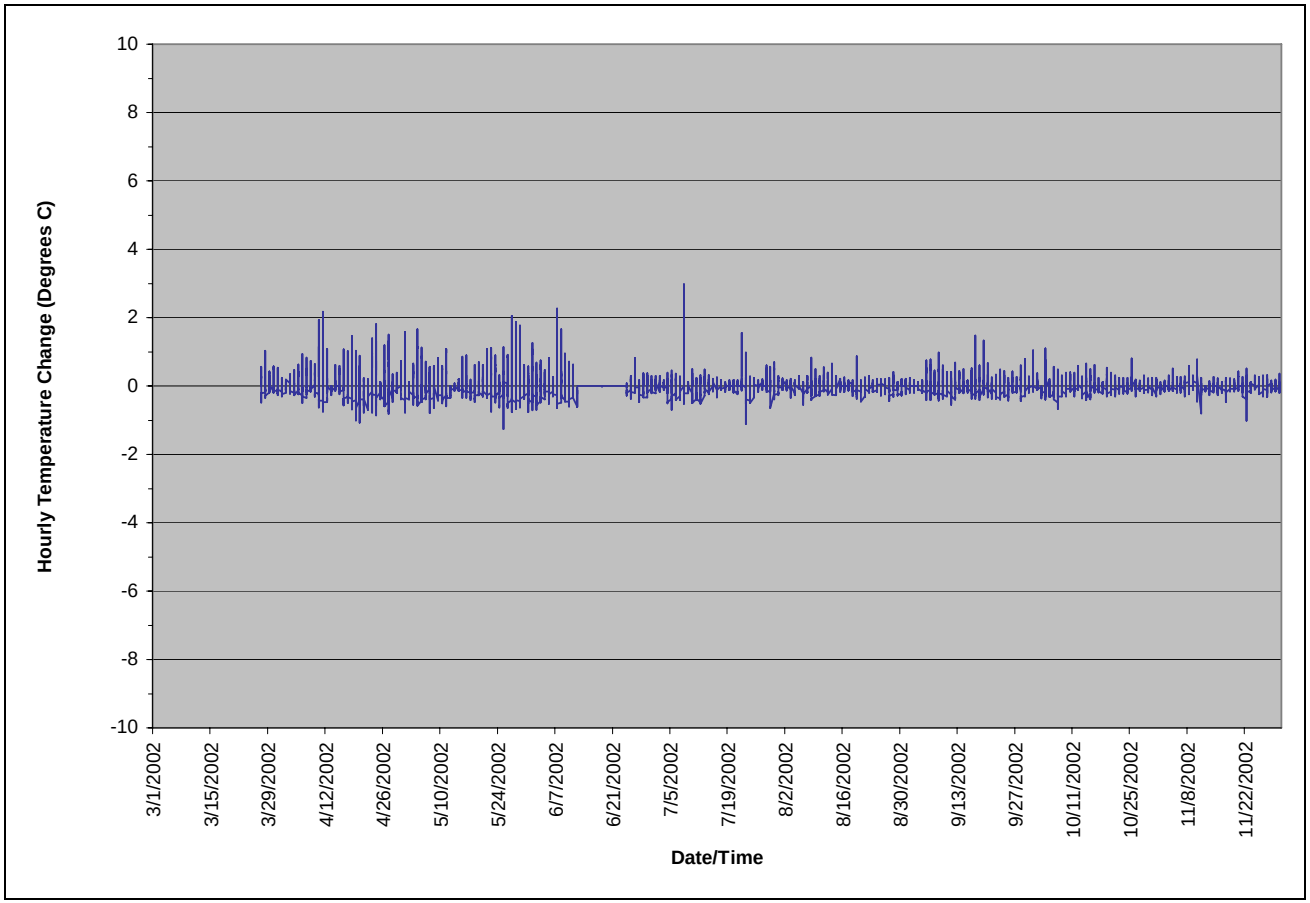

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FIGURE C-35A: ANALYSIS ZONE 1 – SPICER CREEK (TM-07)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 4/1 TO 6/30, 2002

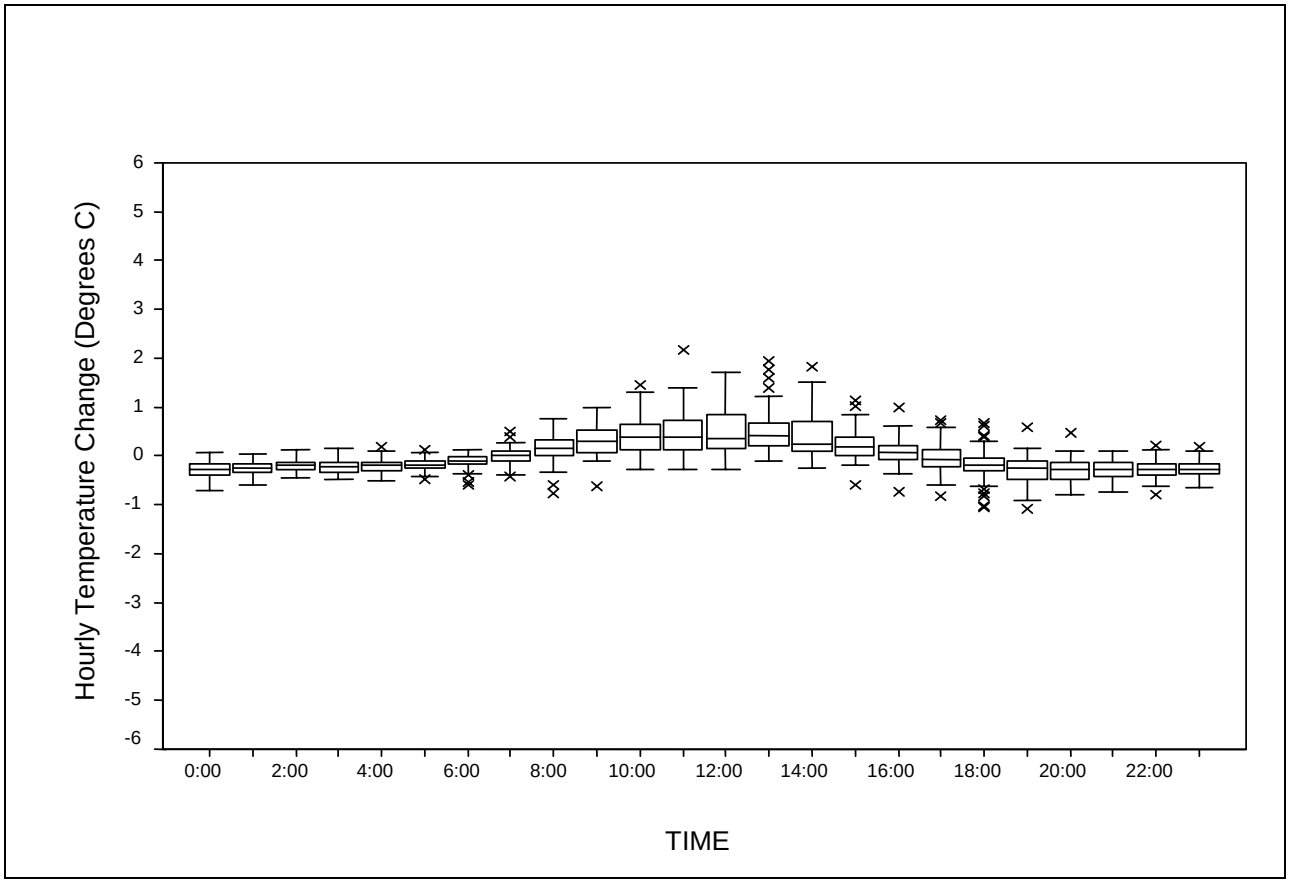

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FIGURE C-35B: ANALYSIS ZONE 1 – SPICER CREEK (TM-07)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FROM 7/1 TO 8/31, 2002

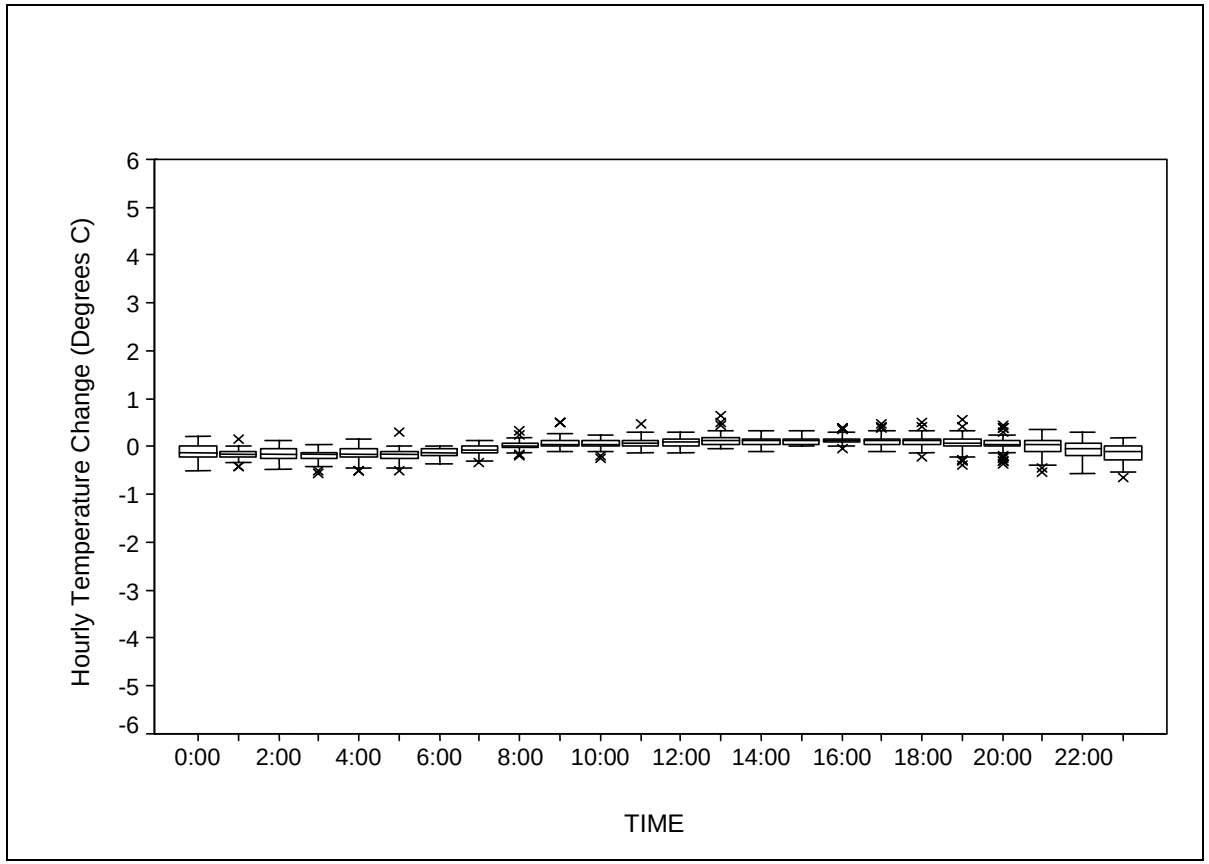

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FIGURE C-35C: ANALYSIS ZONE 1 – SPICER CREEK (TM-07)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

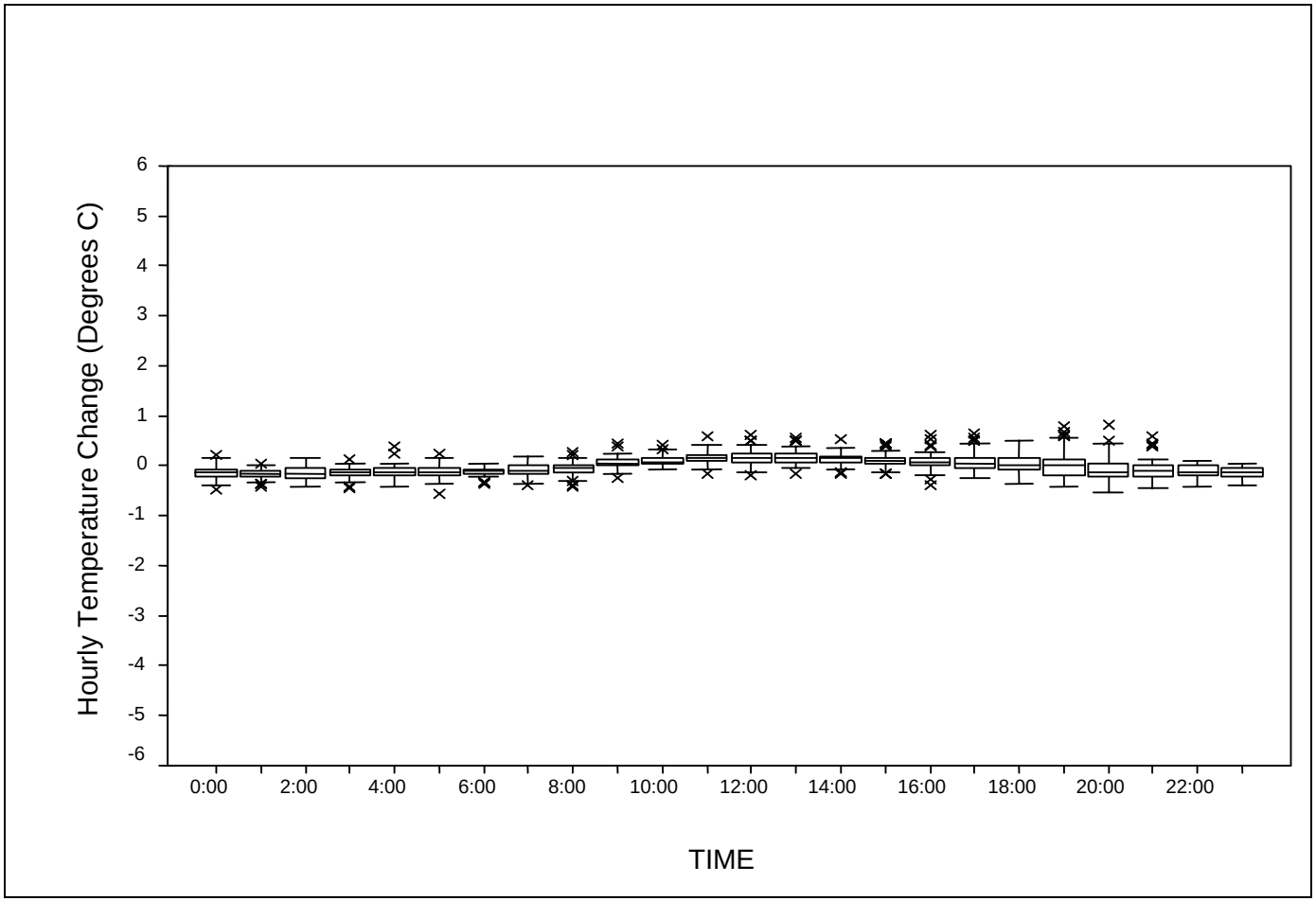

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FIGURE C-36: ANALYSIS ZONE 1 – SPICER CREEK (TM-08)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

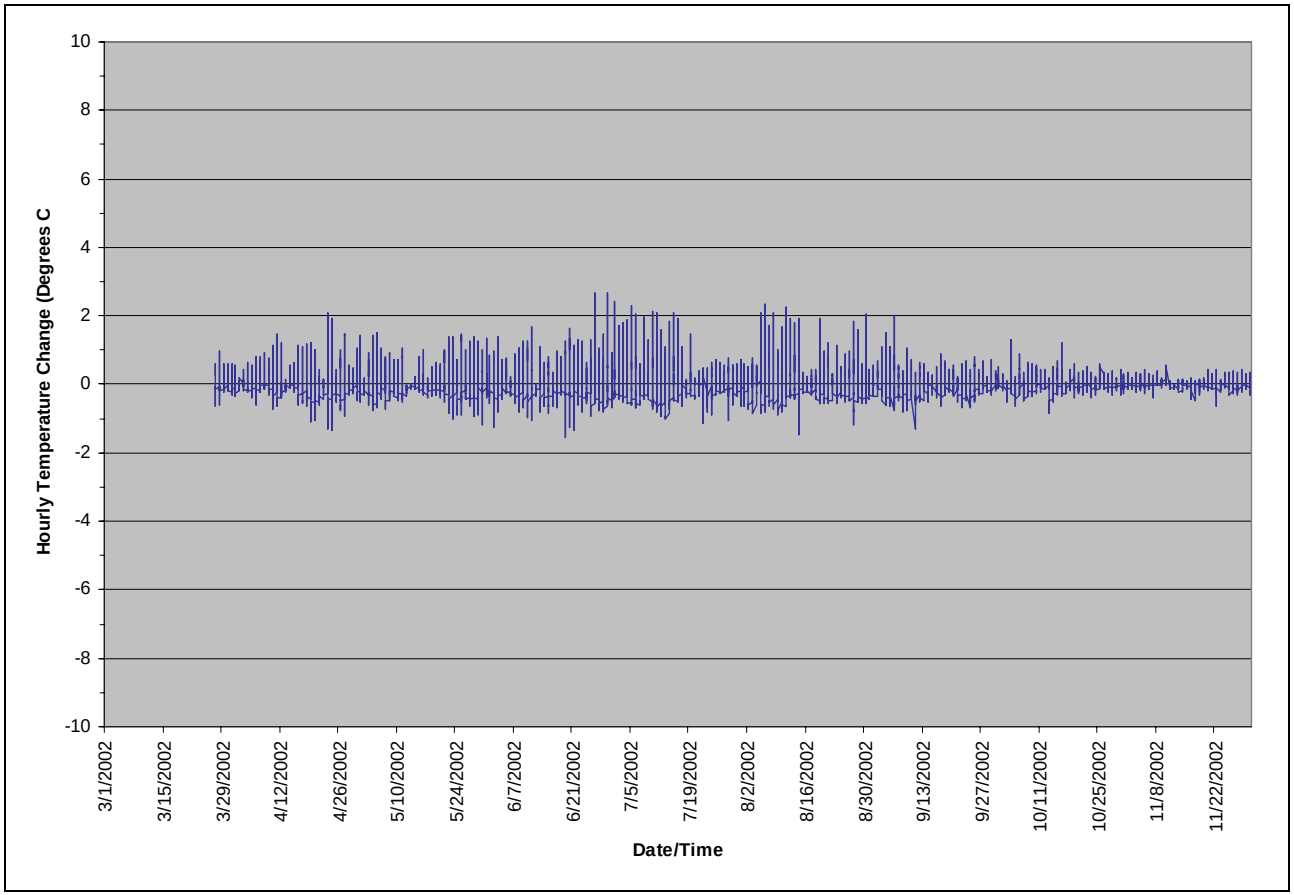

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FIGURE C-37A: ANALYSIS ZONE 1 – SPICER CREEK (TM-08)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

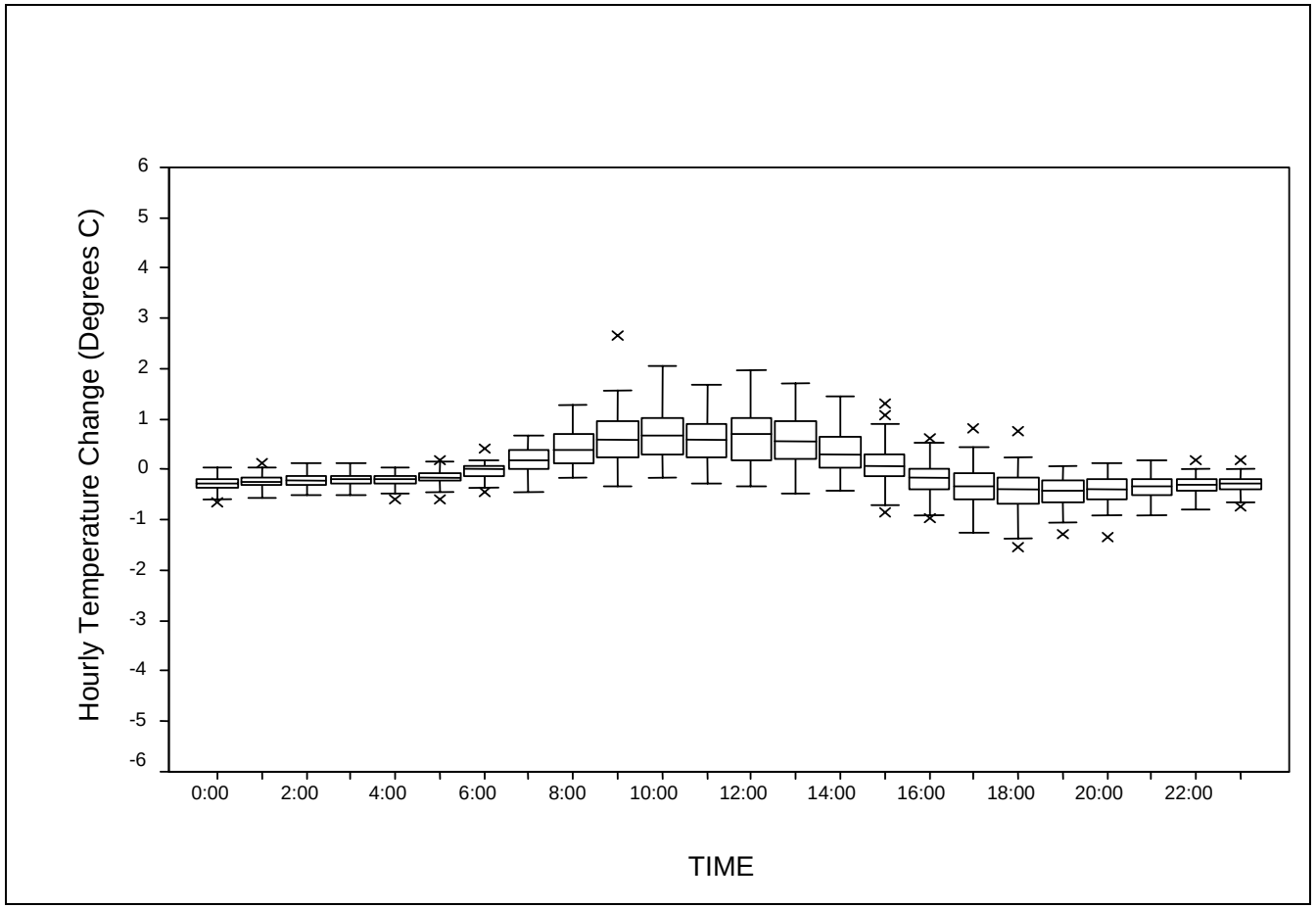

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FIGURE C-37B: ANALYSIS ZONE 1 – SPICER CREEK (TM-08)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

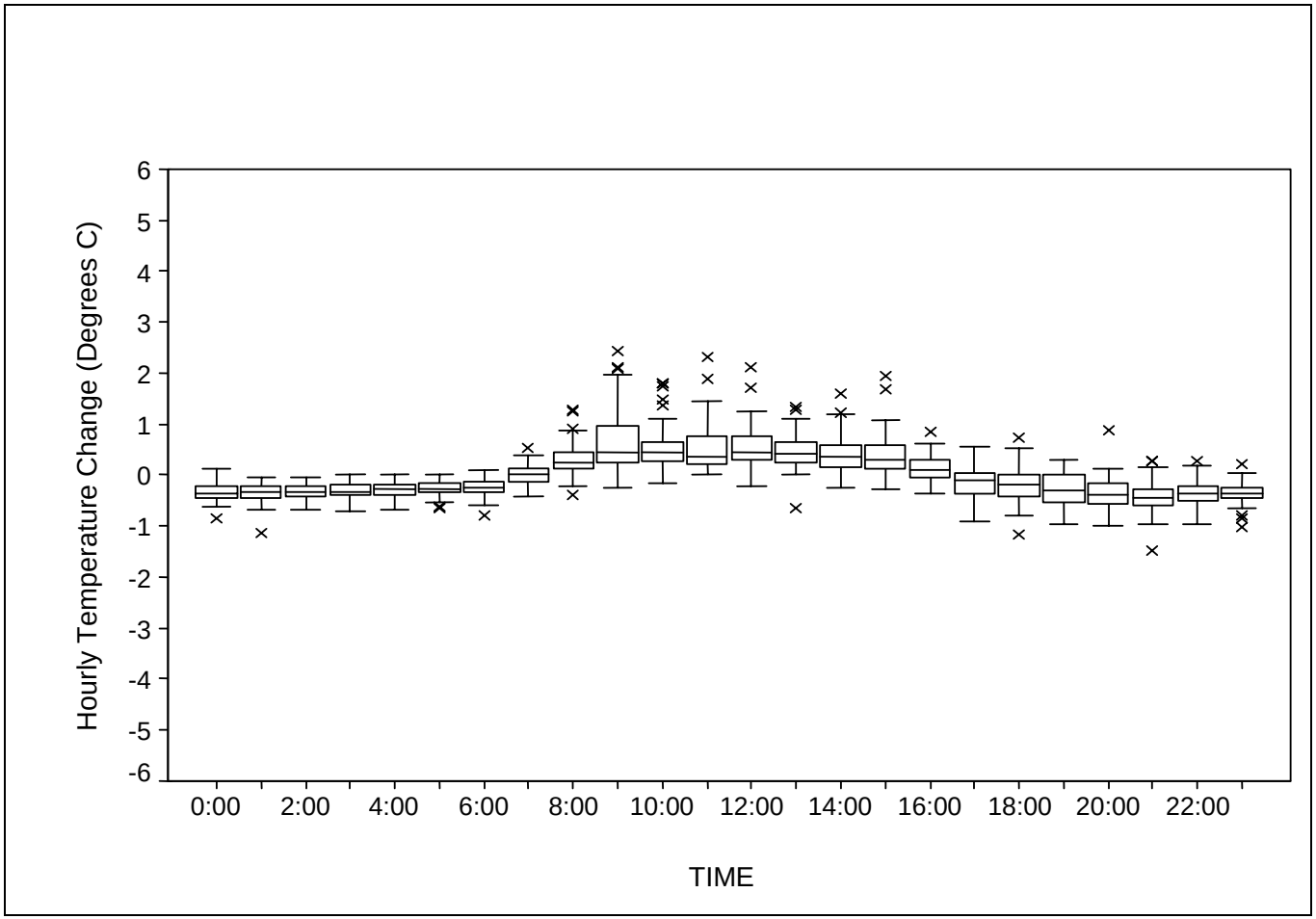

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FIGURE C-37C: ANALYSIS ZONE 1 – SPICER CREEK (TM-08)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

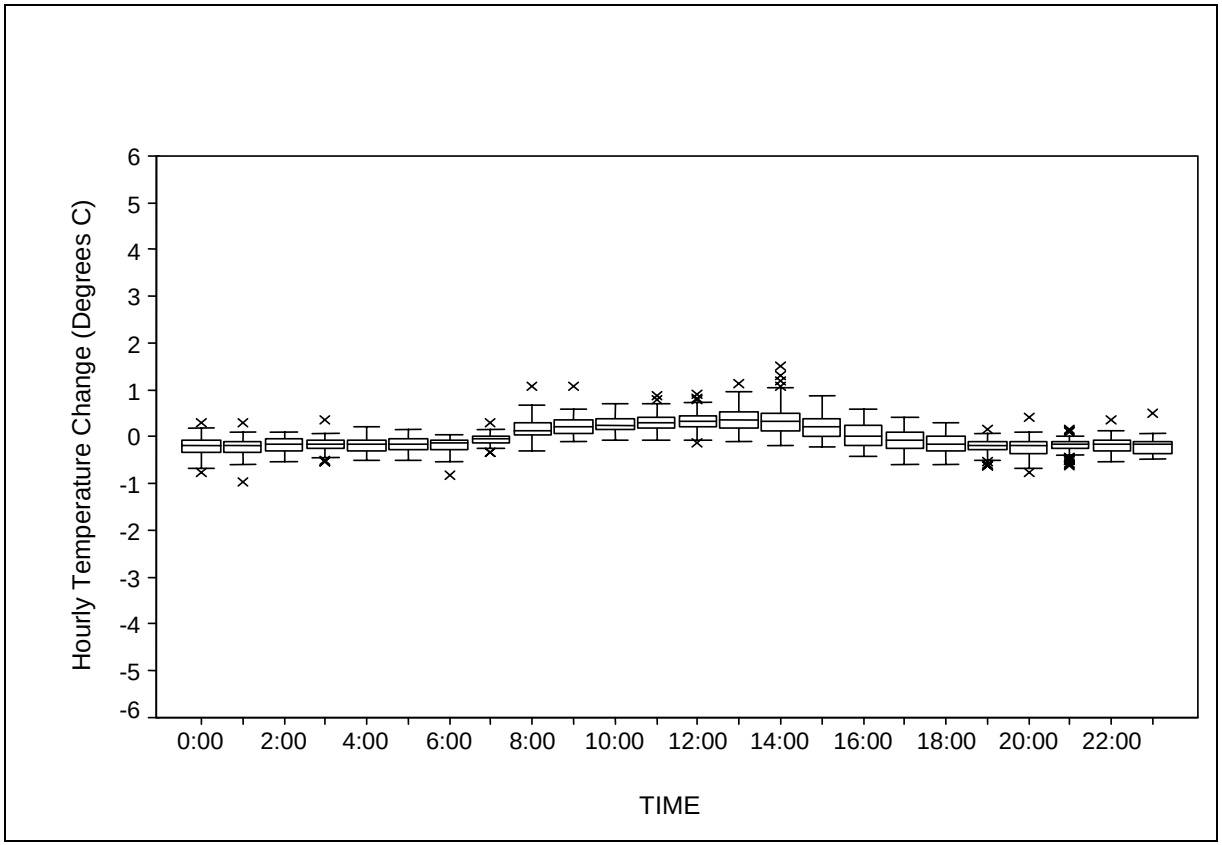

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FIGURE C-38: ANALYSIS ZONE 1 – SPICER CREEK (TSC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

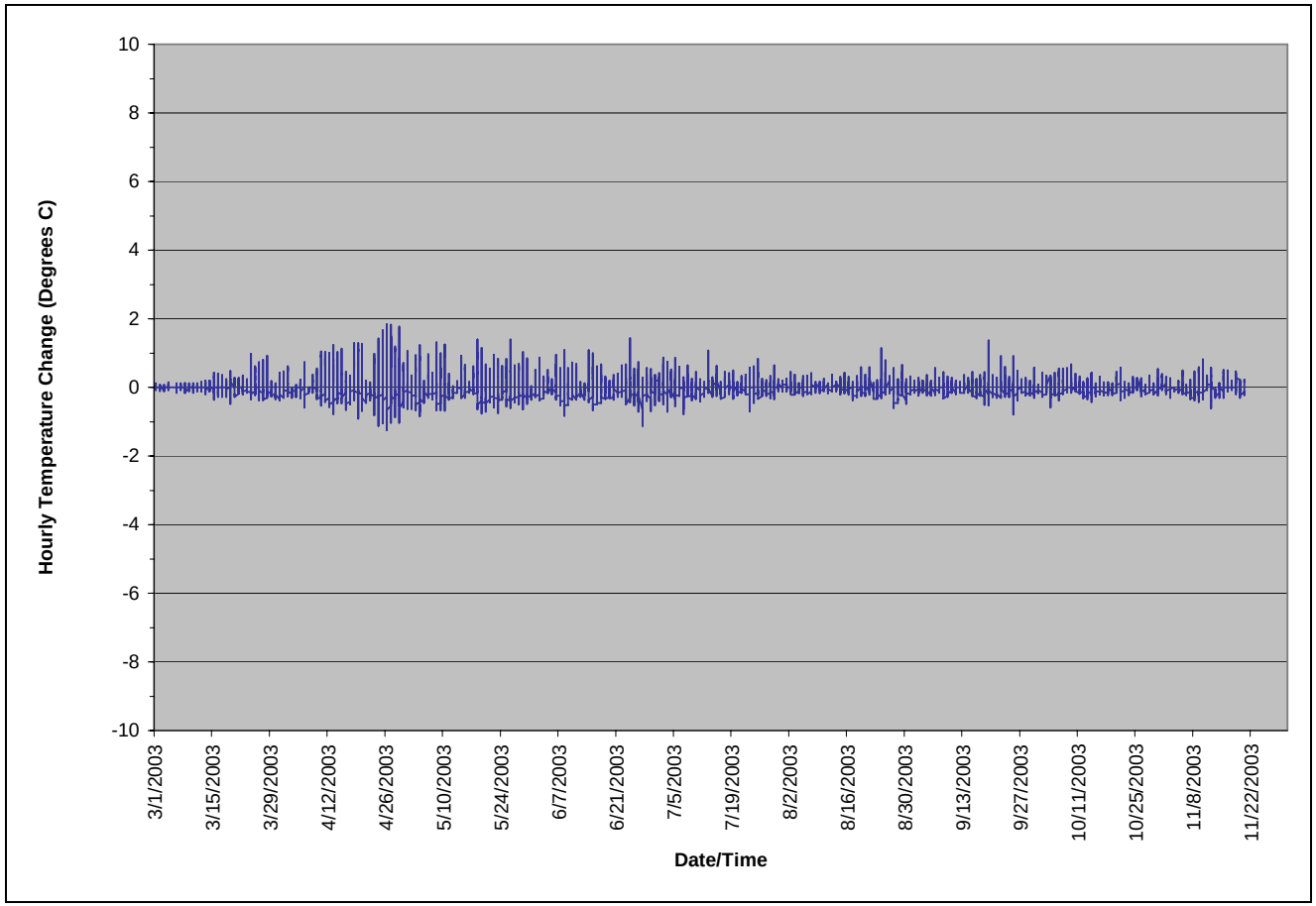

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FIGURE C-39A: ANALYSIS ZONE 1 – SPICER CREEK (TSC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

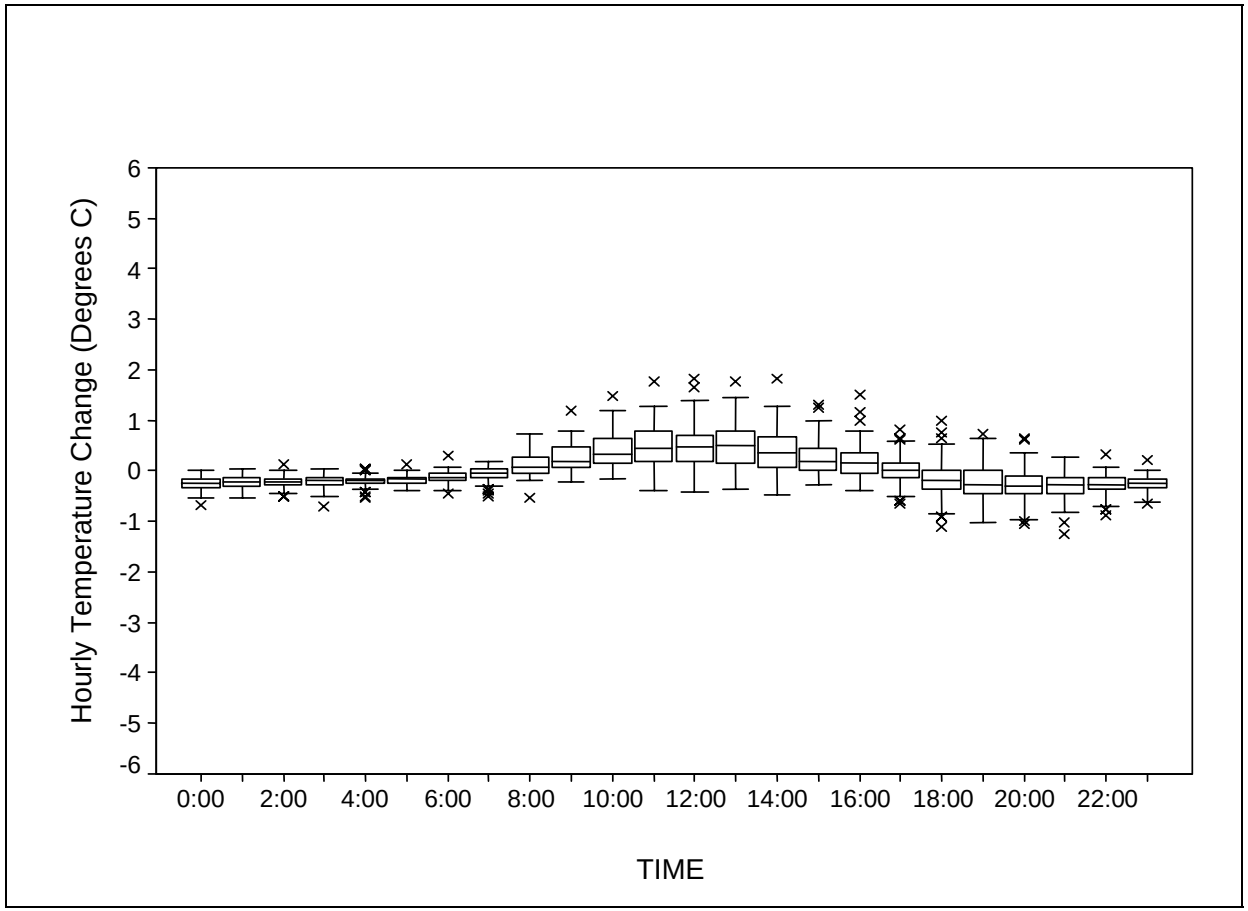

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FIGURE C-39B: ANALYSIS ZONE 1 – SPICER CREEK (TSC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

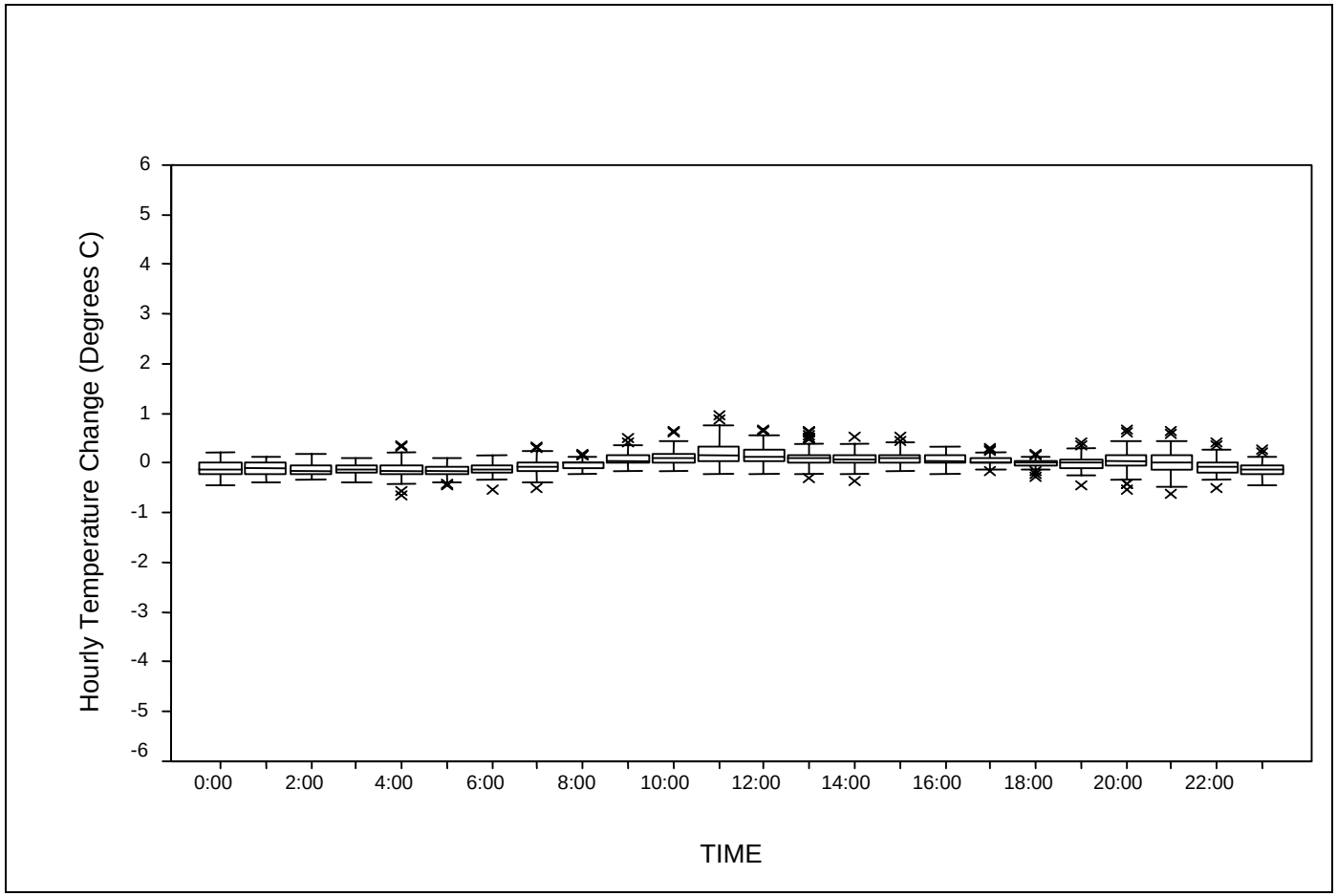

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FIGURE C-39C: ANALYSIS ZONE 1 – SPICER CREEK (TSC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

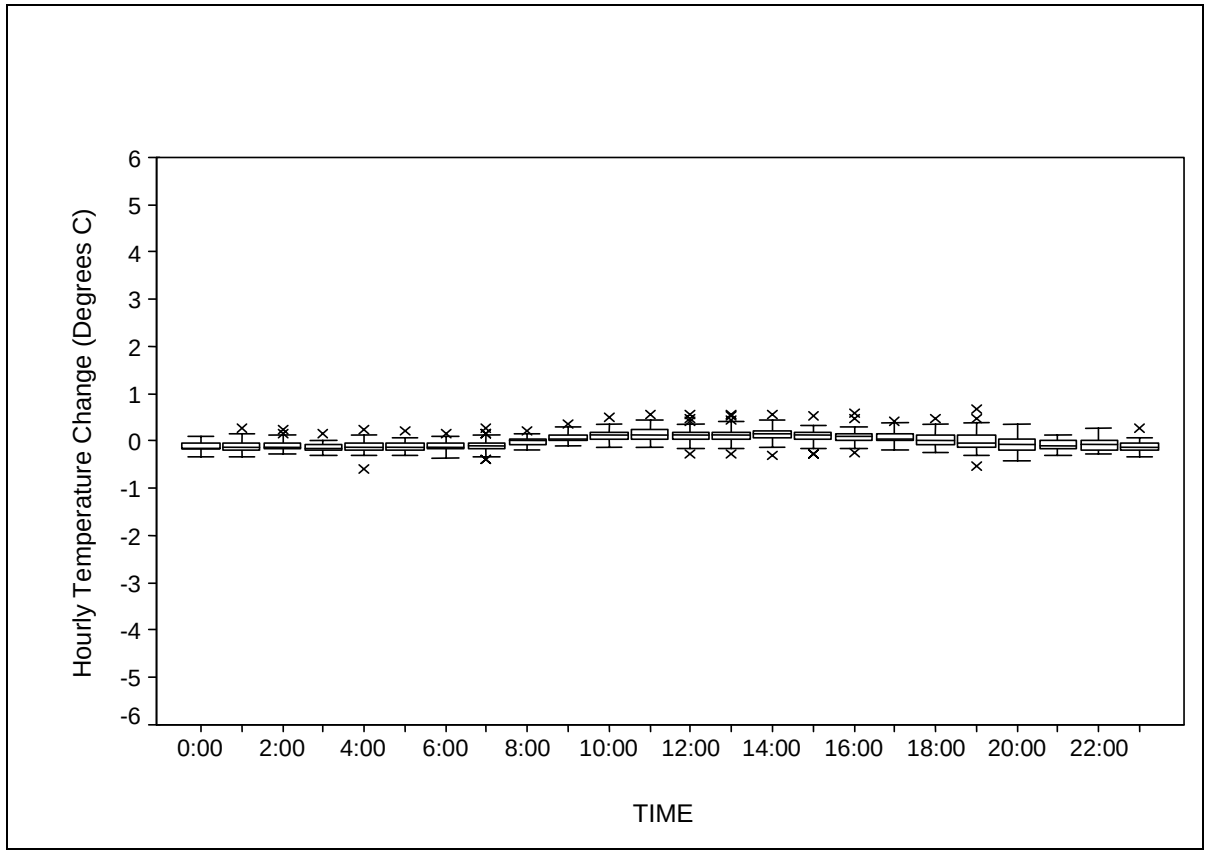

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FIGURE C-40A: ANALYSIS ZONE 1 - GN-TONAWANDA

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

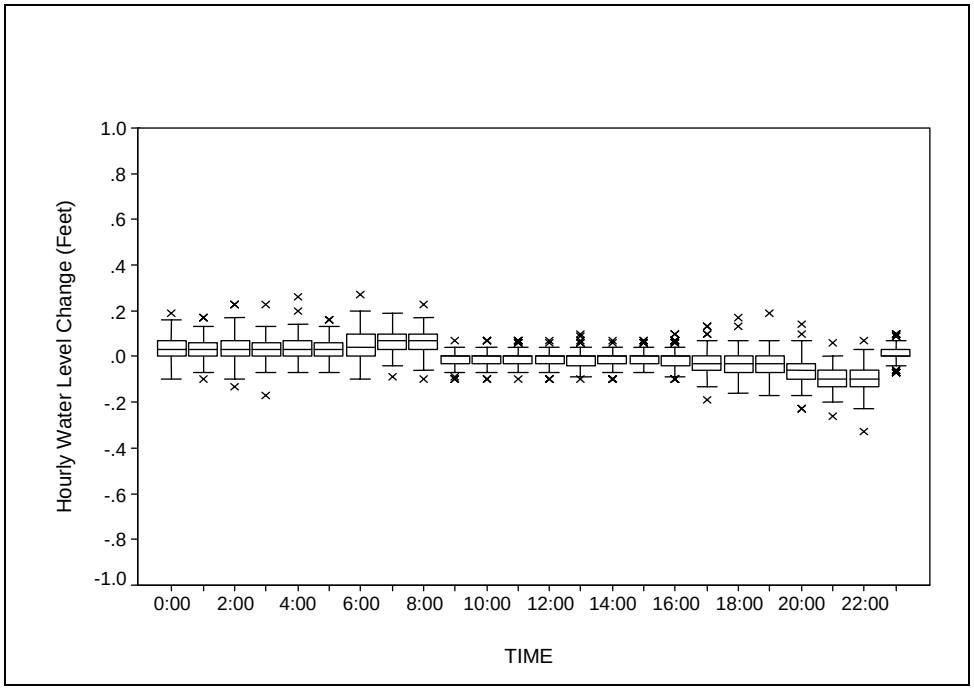

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FIGURE C-40B: ANALYSIS ZONE 1 - GN-TONAWANDA

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

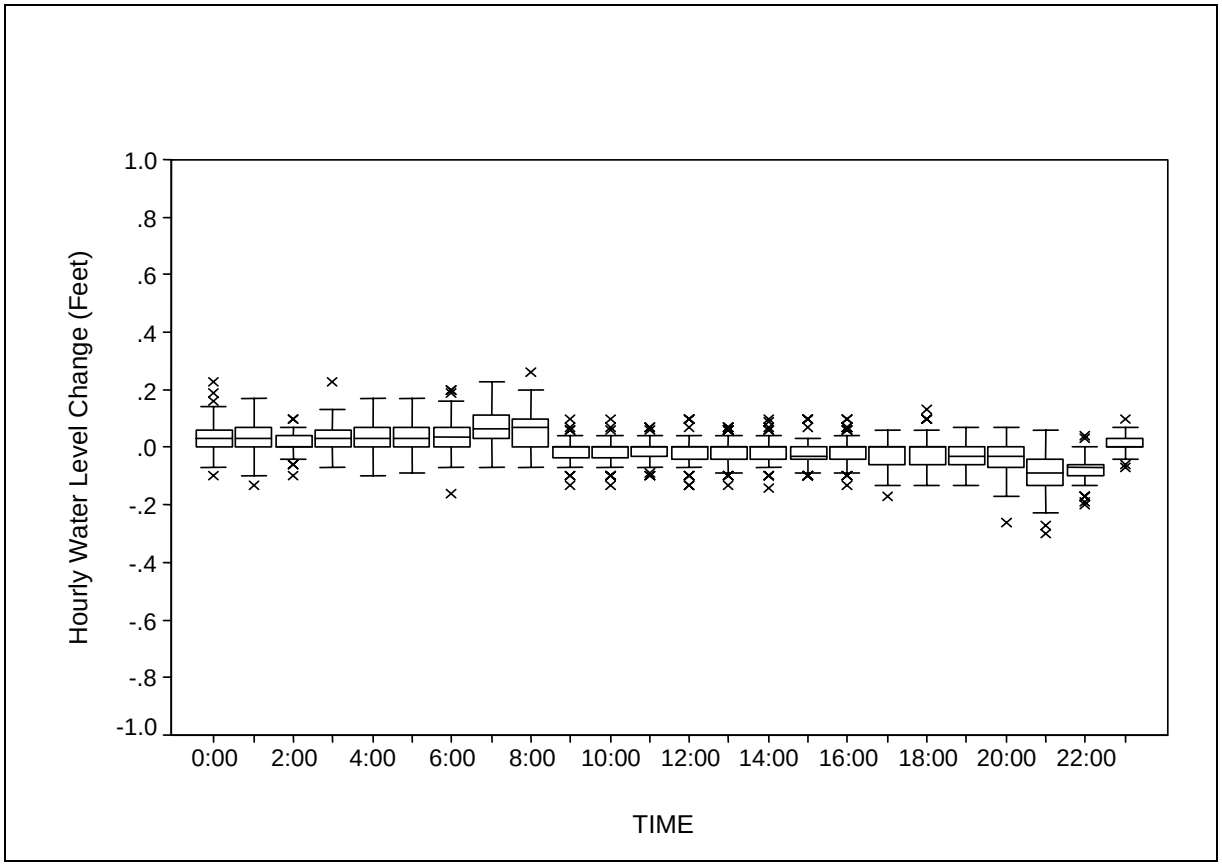

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FIGURE C-40C: ANALYSIS ZONE 1 - GN-TONAWANDA

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

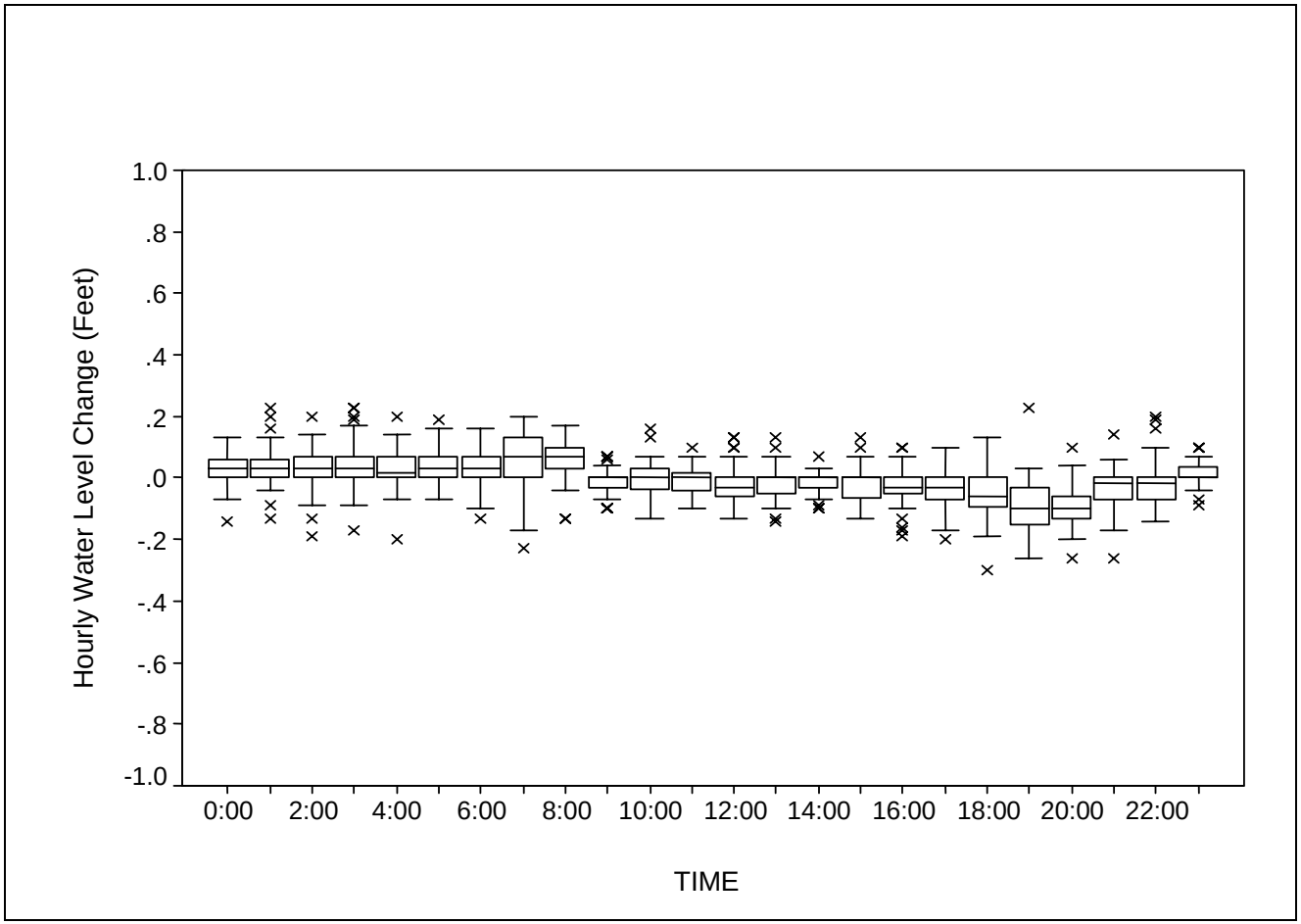

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FIGURE C-41: ANALYSIS ZONE 1 – SPICER CREEK (TSC-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

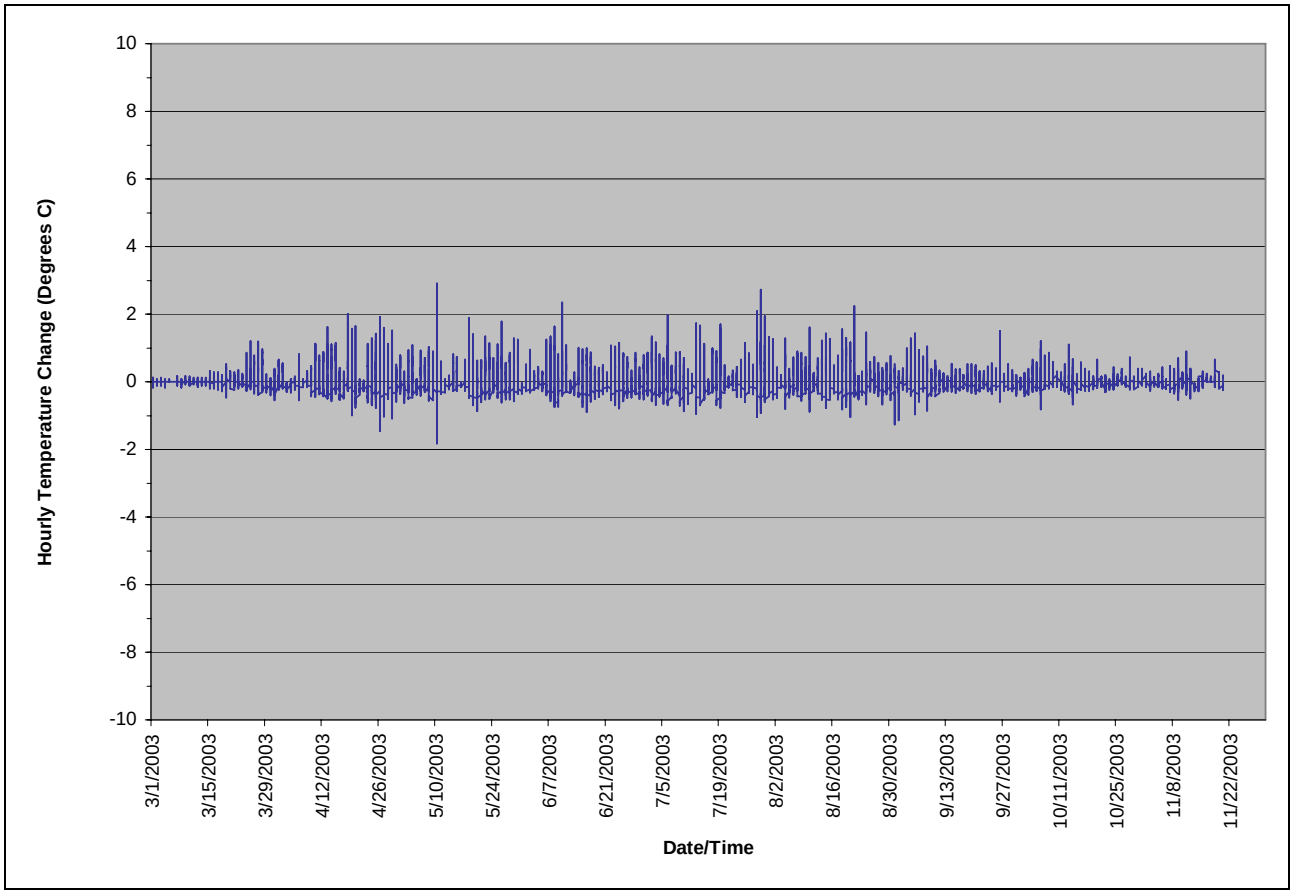

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FIGURE C-42A: ANALYSIS ZONE 1 – SPICER CREEK (TSC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

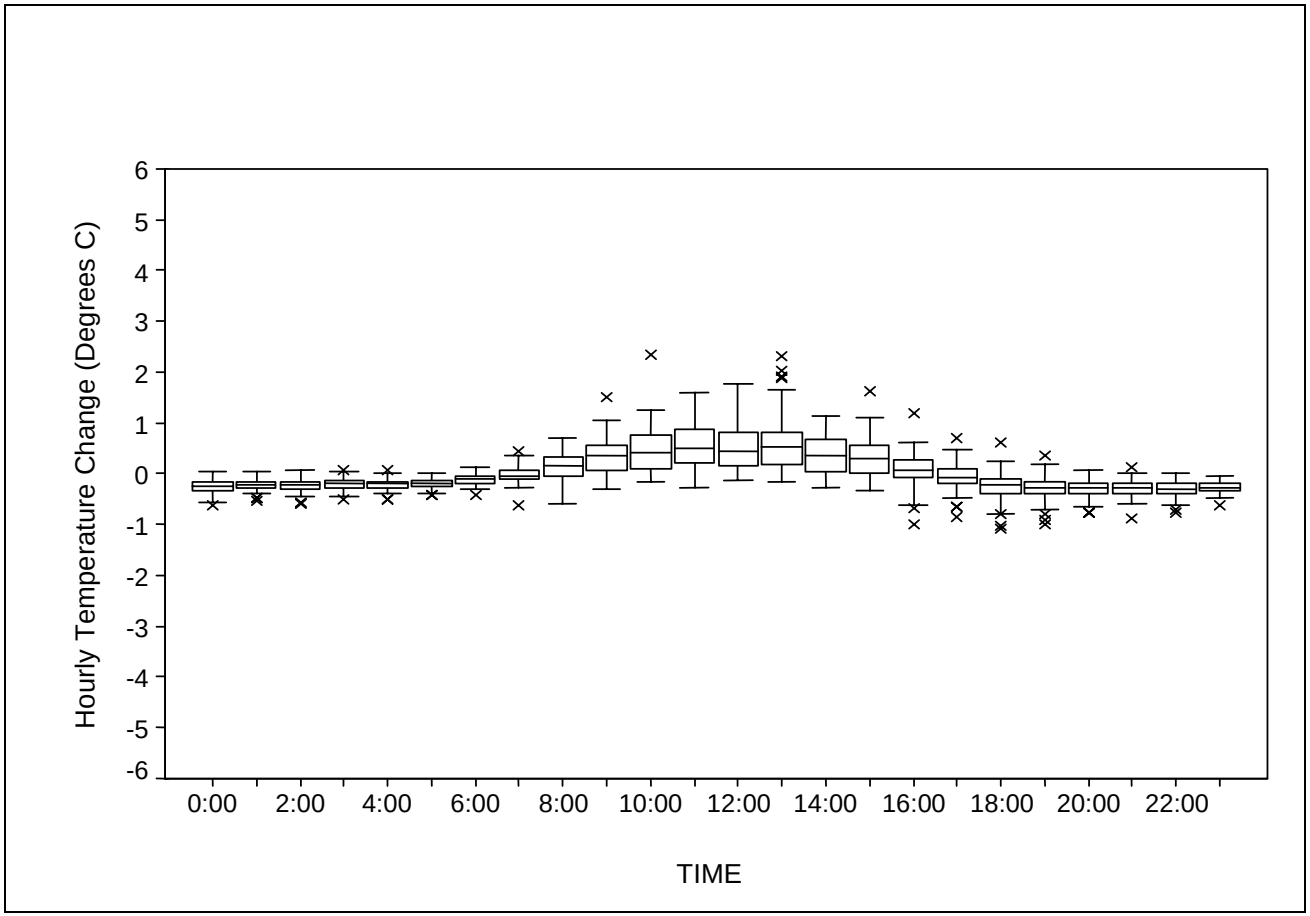

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FIGURE C-42B: ANALYSIS ZONE 1 – SPICER CREEK (TSC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

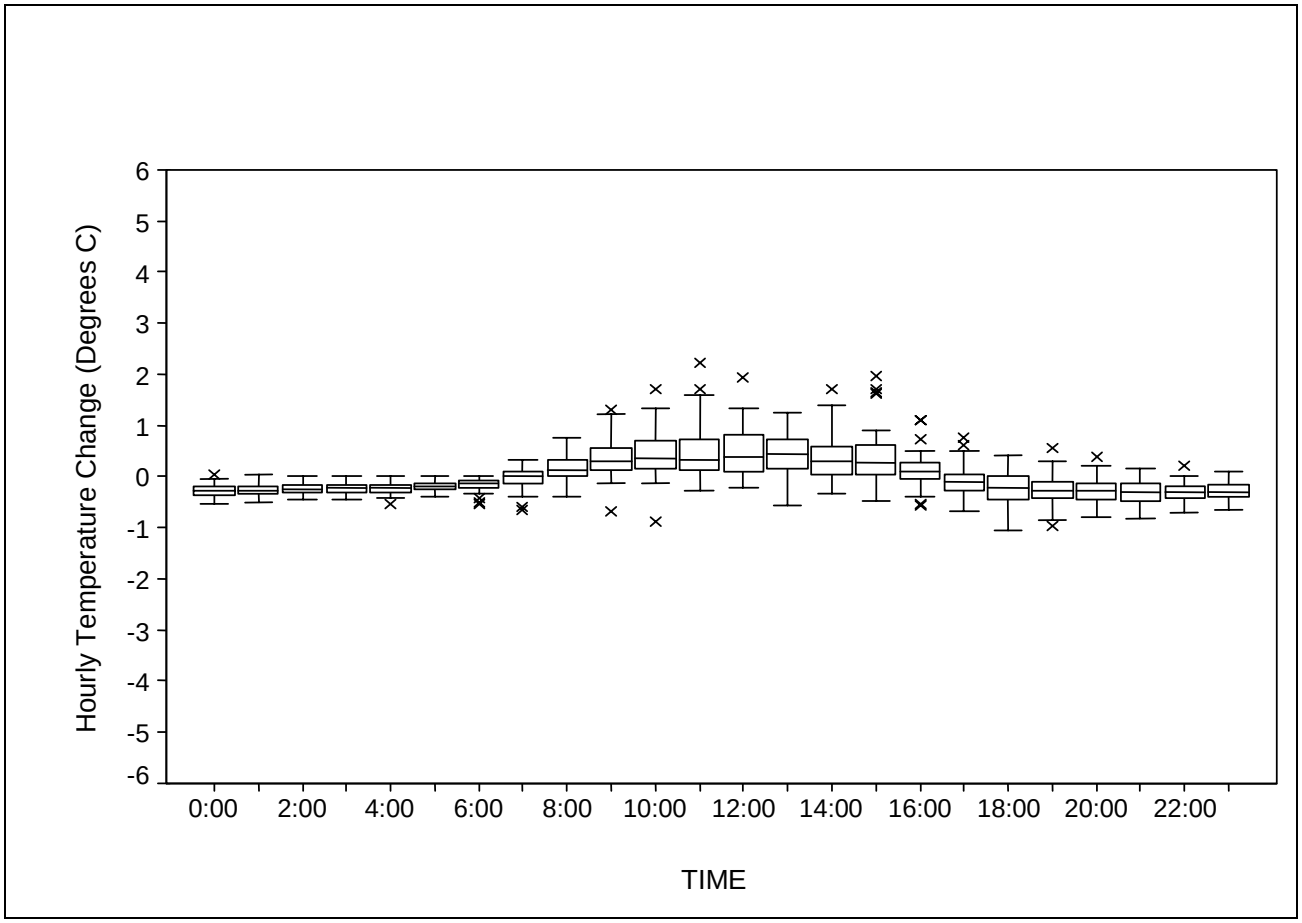

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FIGURE C-42C: ANALYSIS ZONE 1 – SPICER CREEK (TSC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

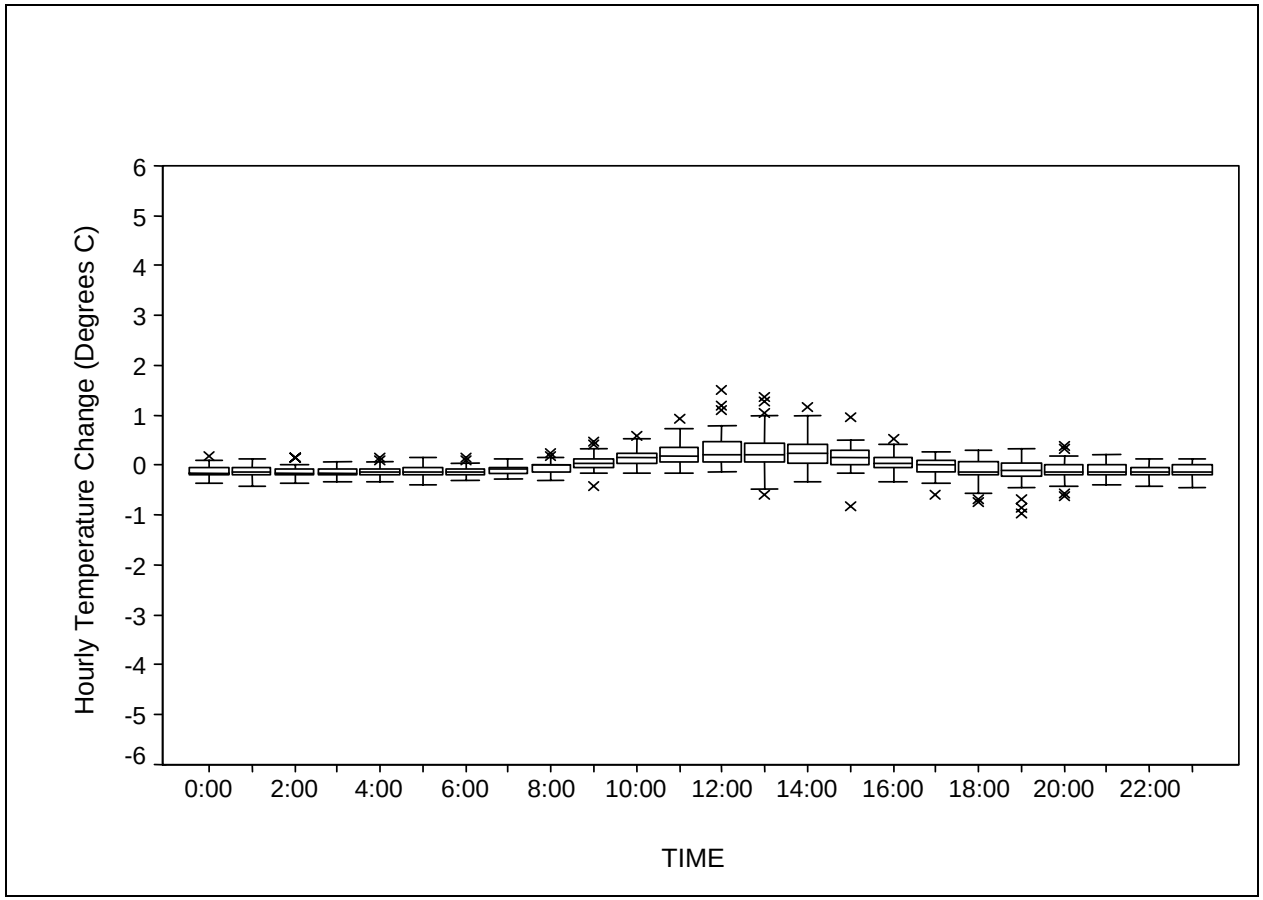

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FIGURE C-43: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (TM-19)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

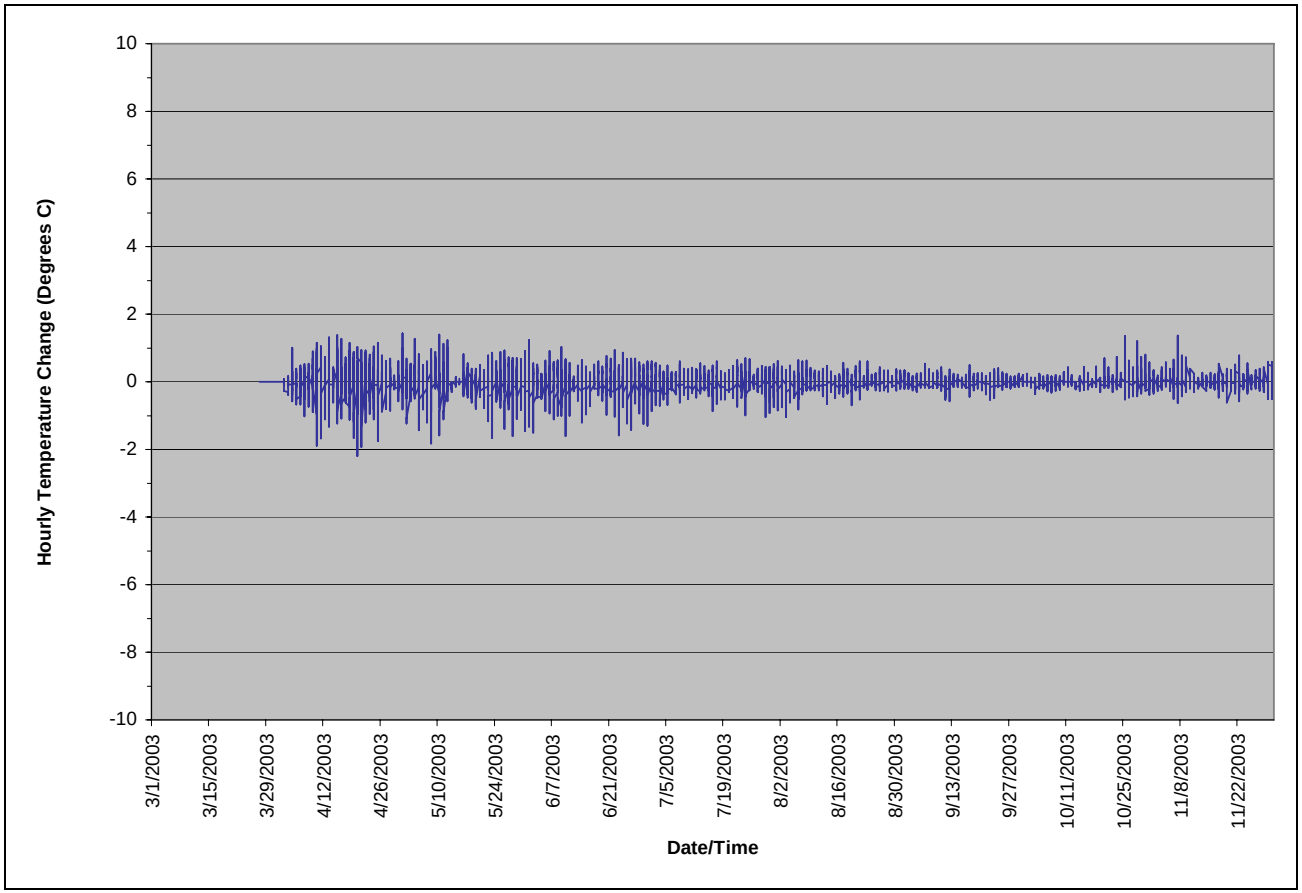

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FIGURE C-44A: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (TM-19)

FREQUENCY DISTRIBUTION OF Δ°CWT VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

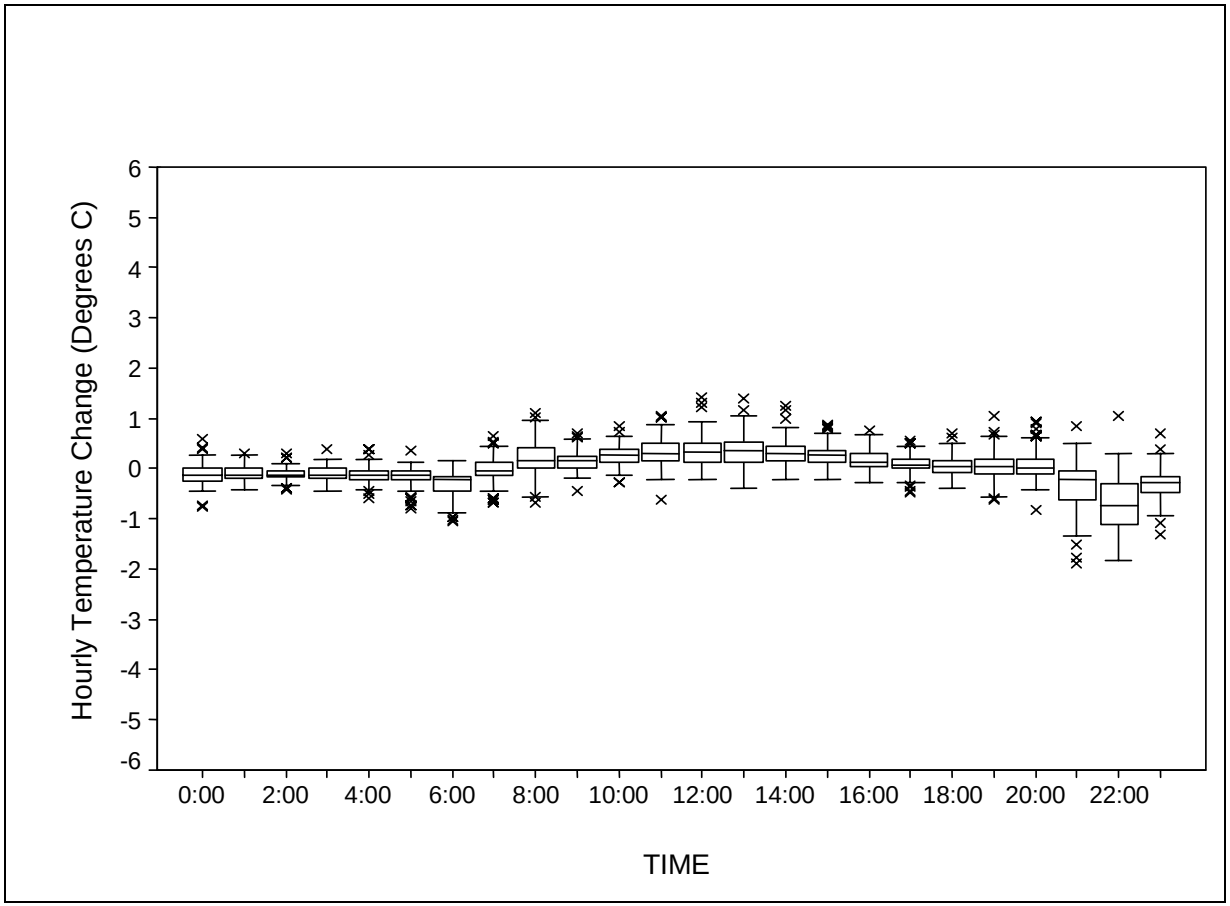

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FIGURE C-44B: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (TM-19)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

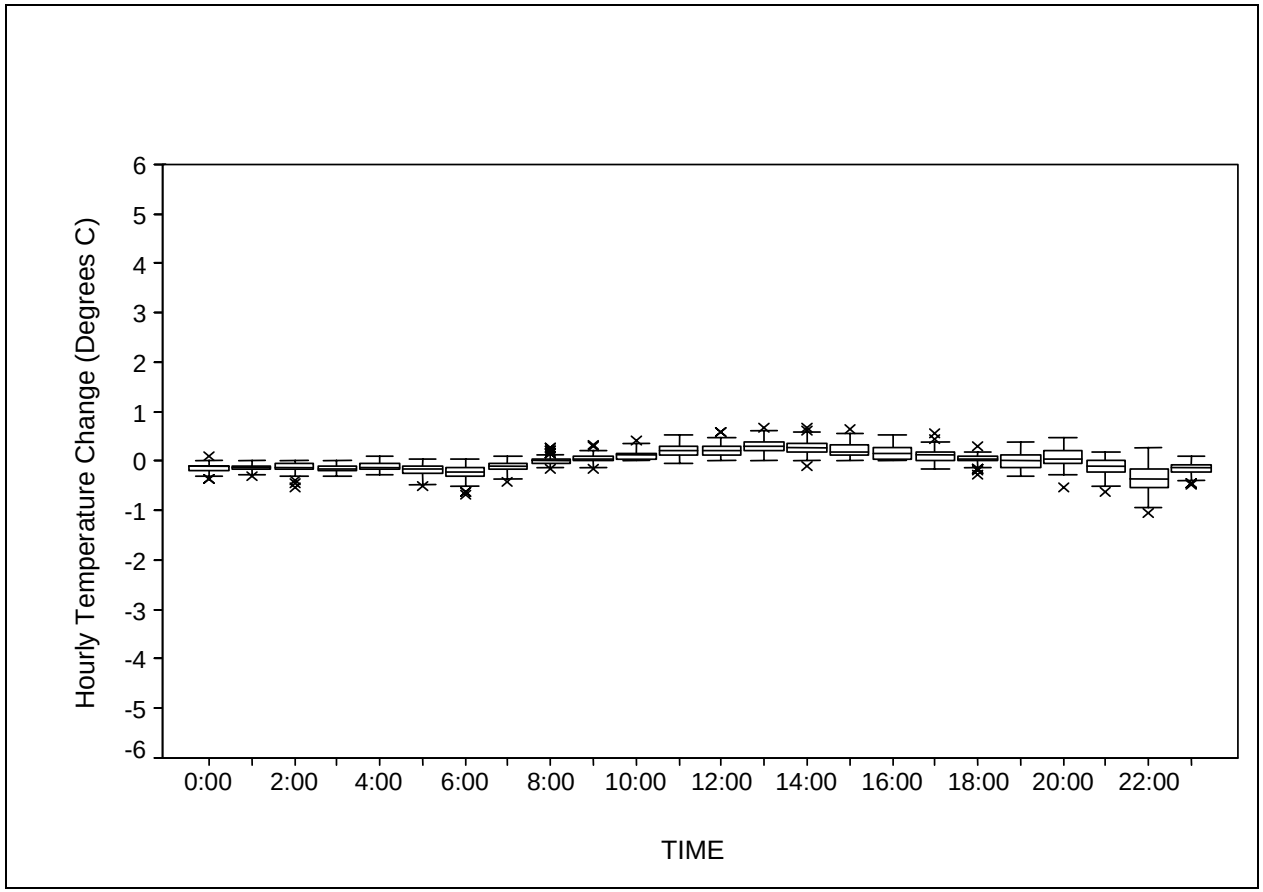

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FIGURE C-44C: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (TM-19)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

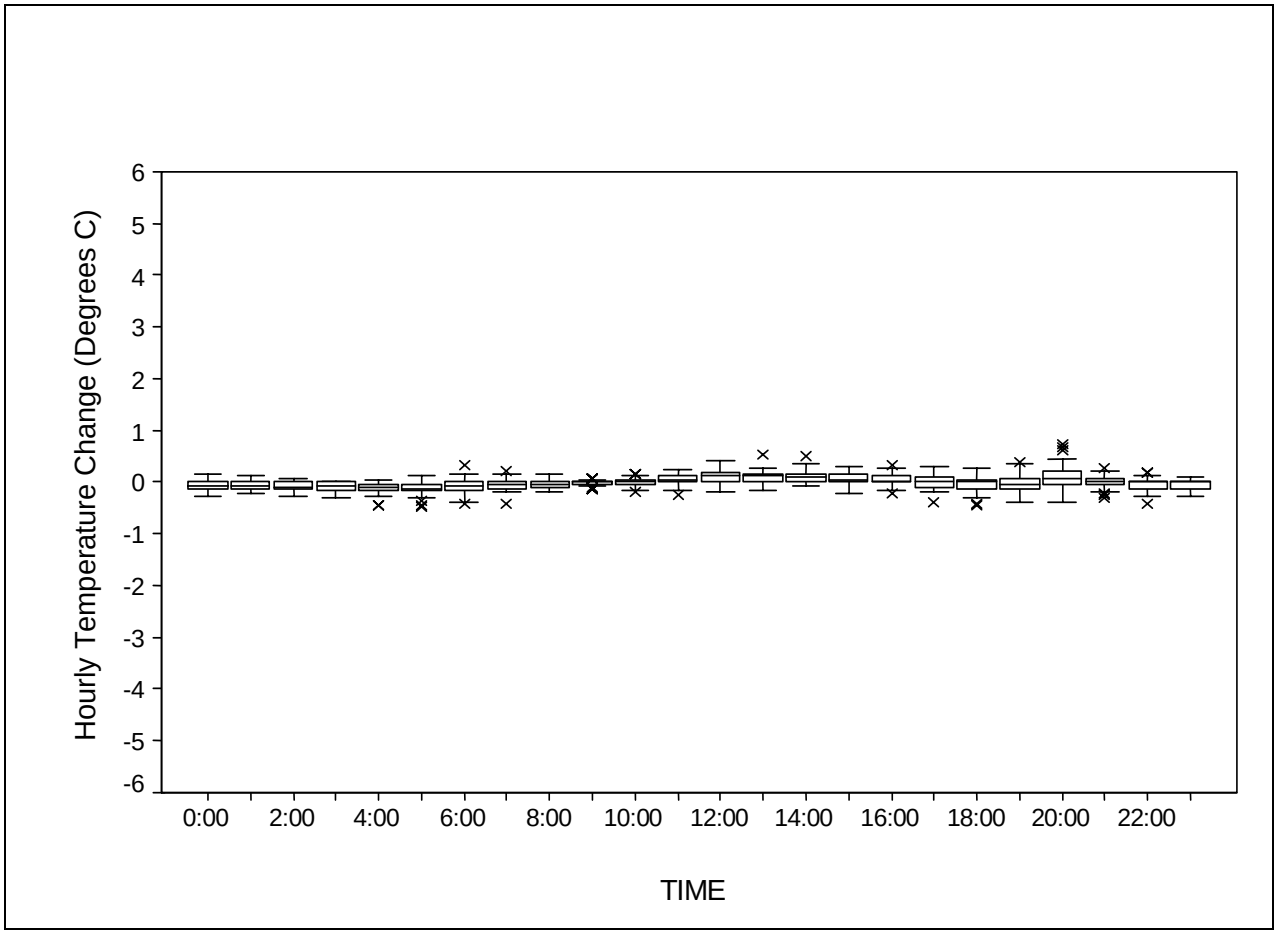

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FIGURE C-45: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (TM-10)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

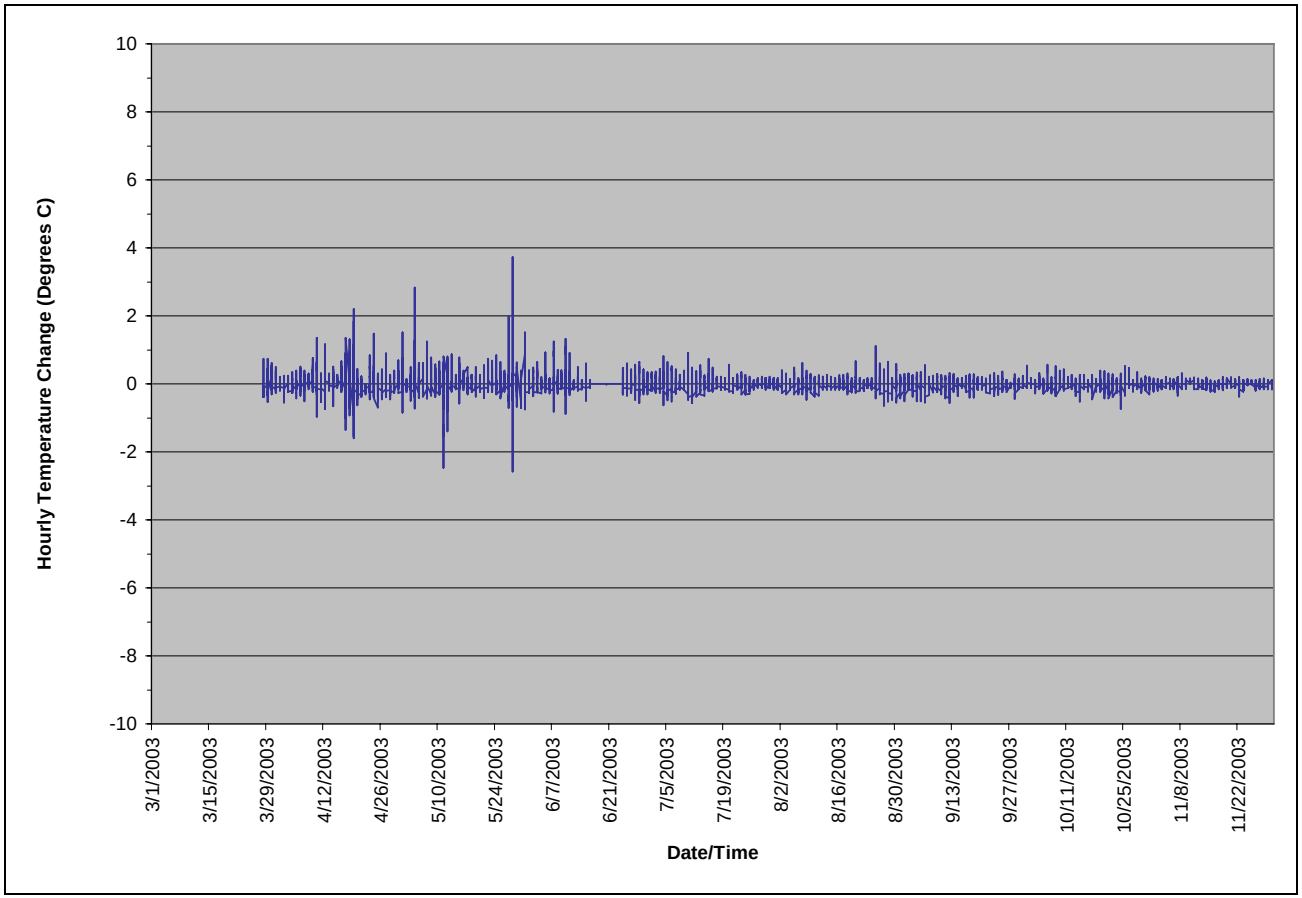

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FIGURE C-46A: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (TM-10)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

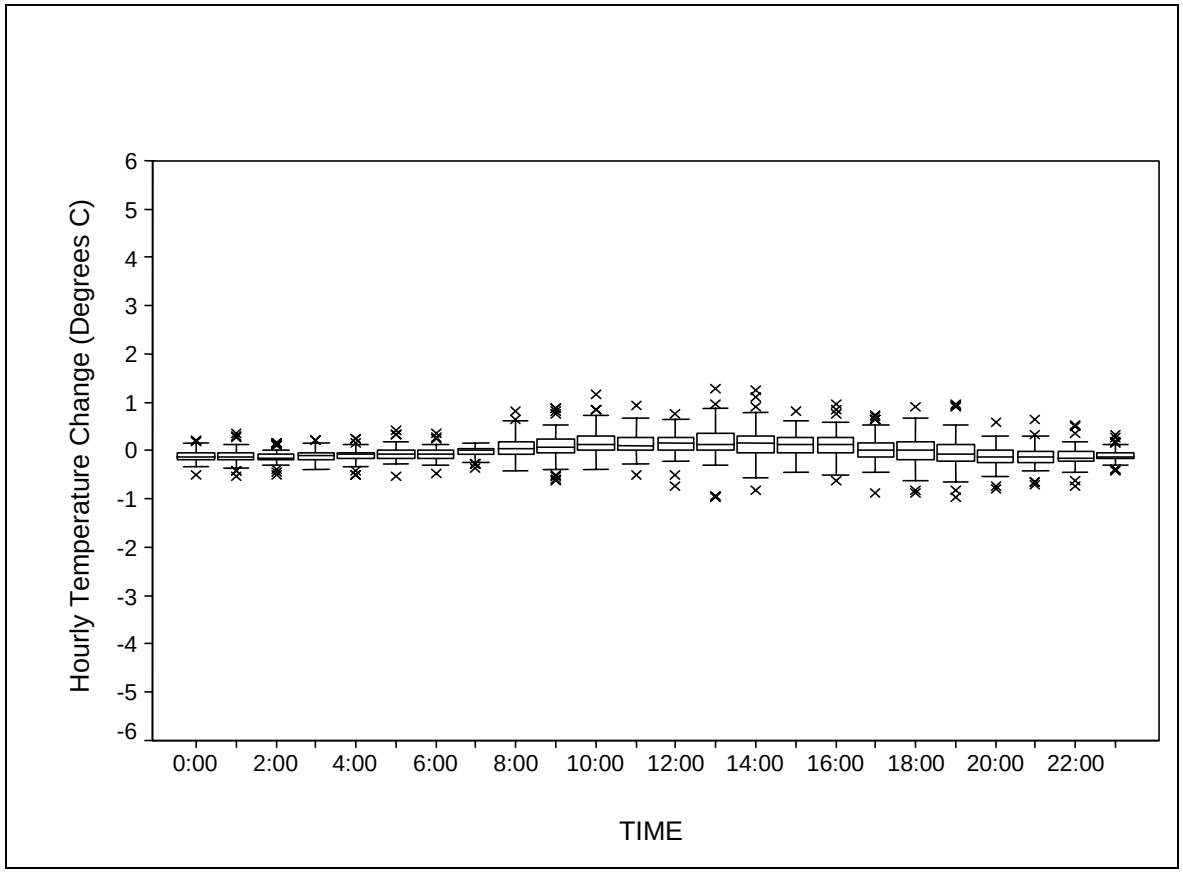

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FIGURE C-46B: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (TM-10)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

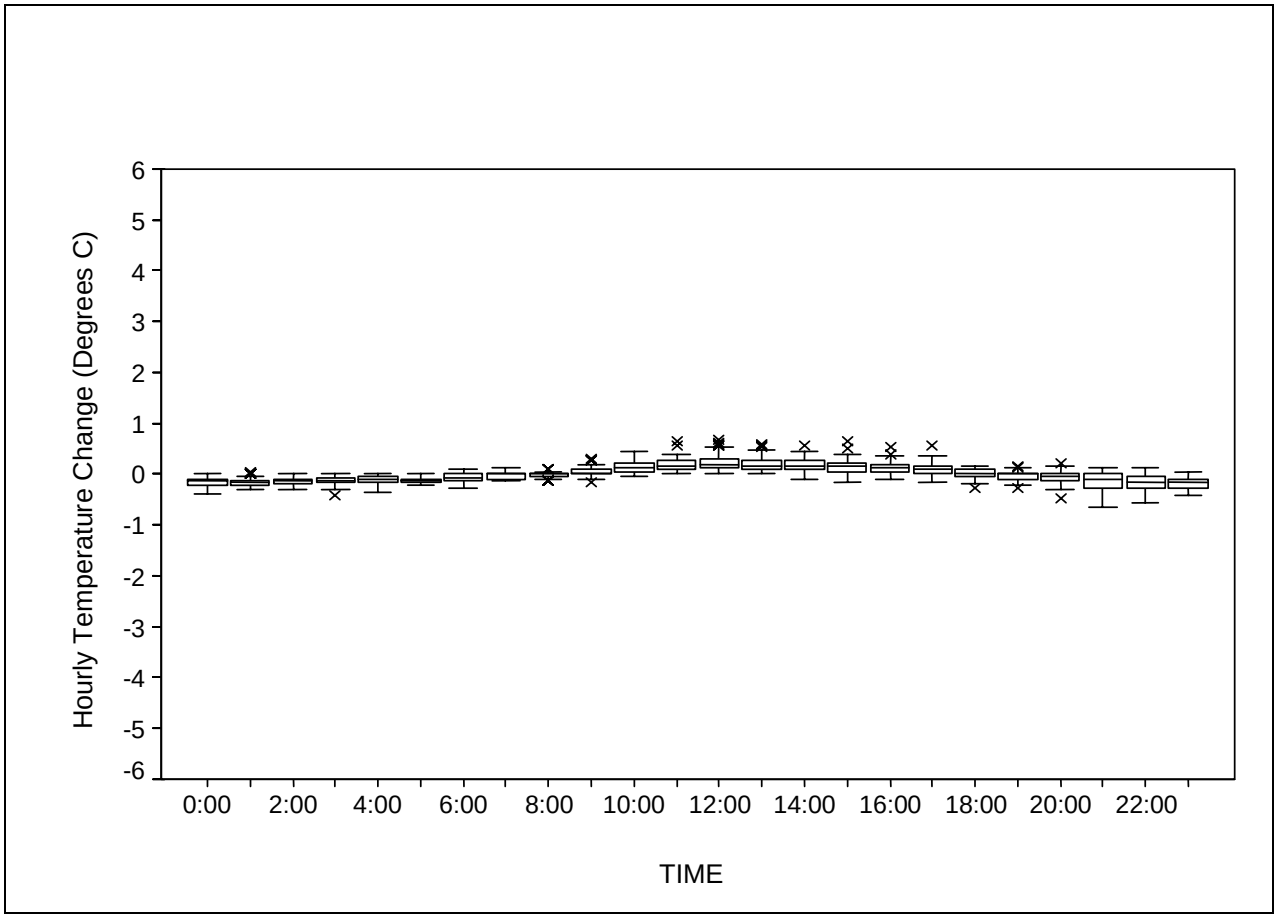

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FIGURE C-46C: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (TM-10)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

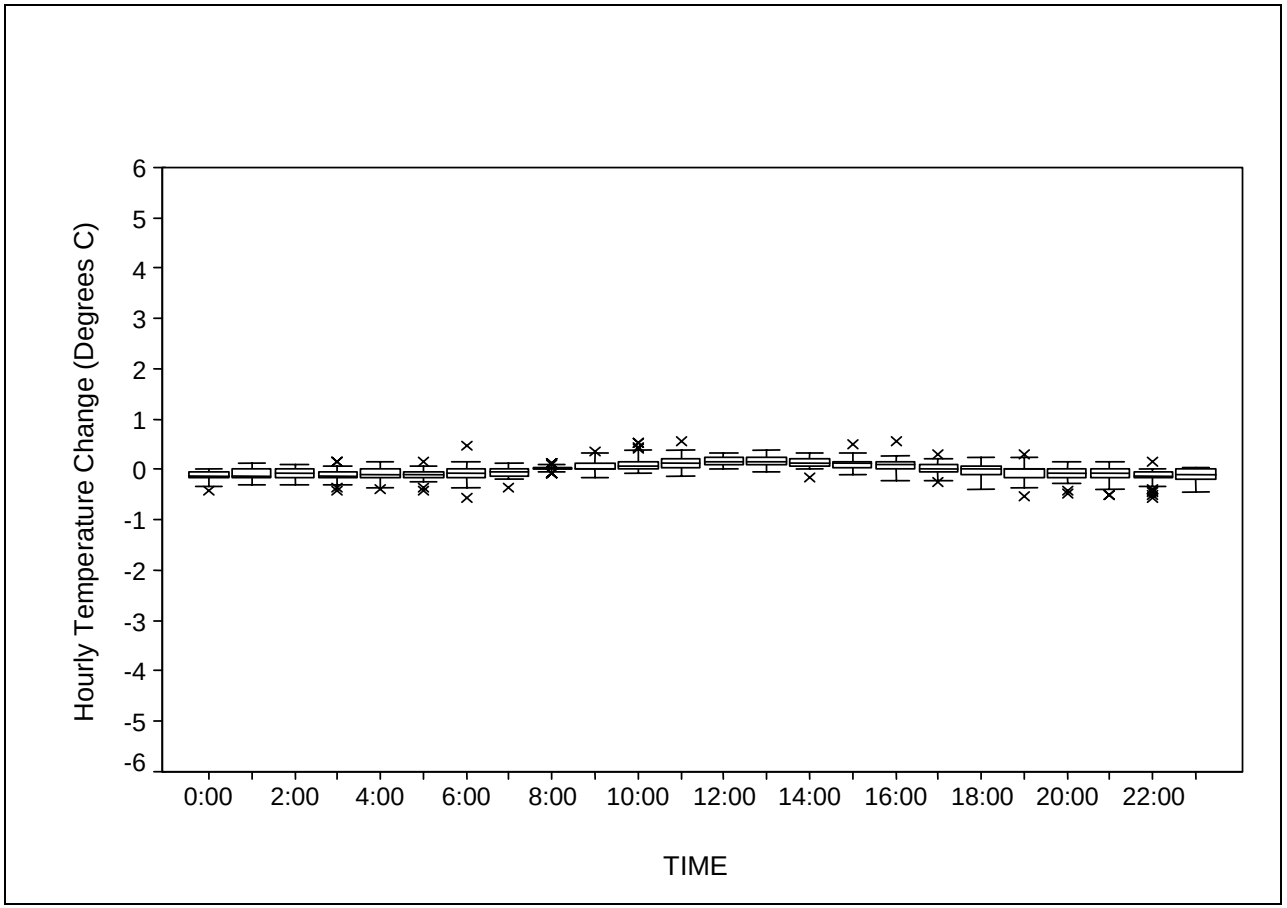

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FIGURE C-47: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (SMC-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

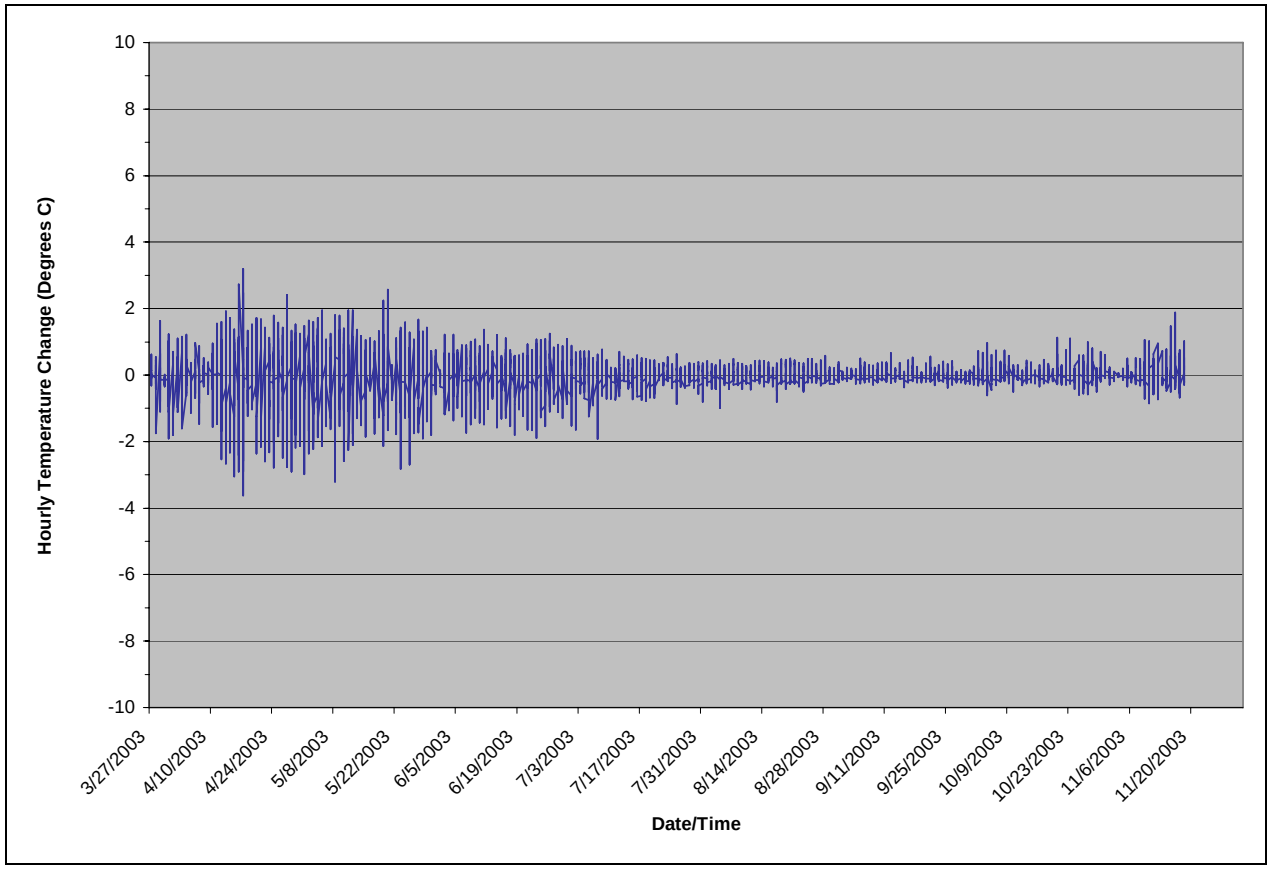

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FIGURE C-48A: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (SMC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

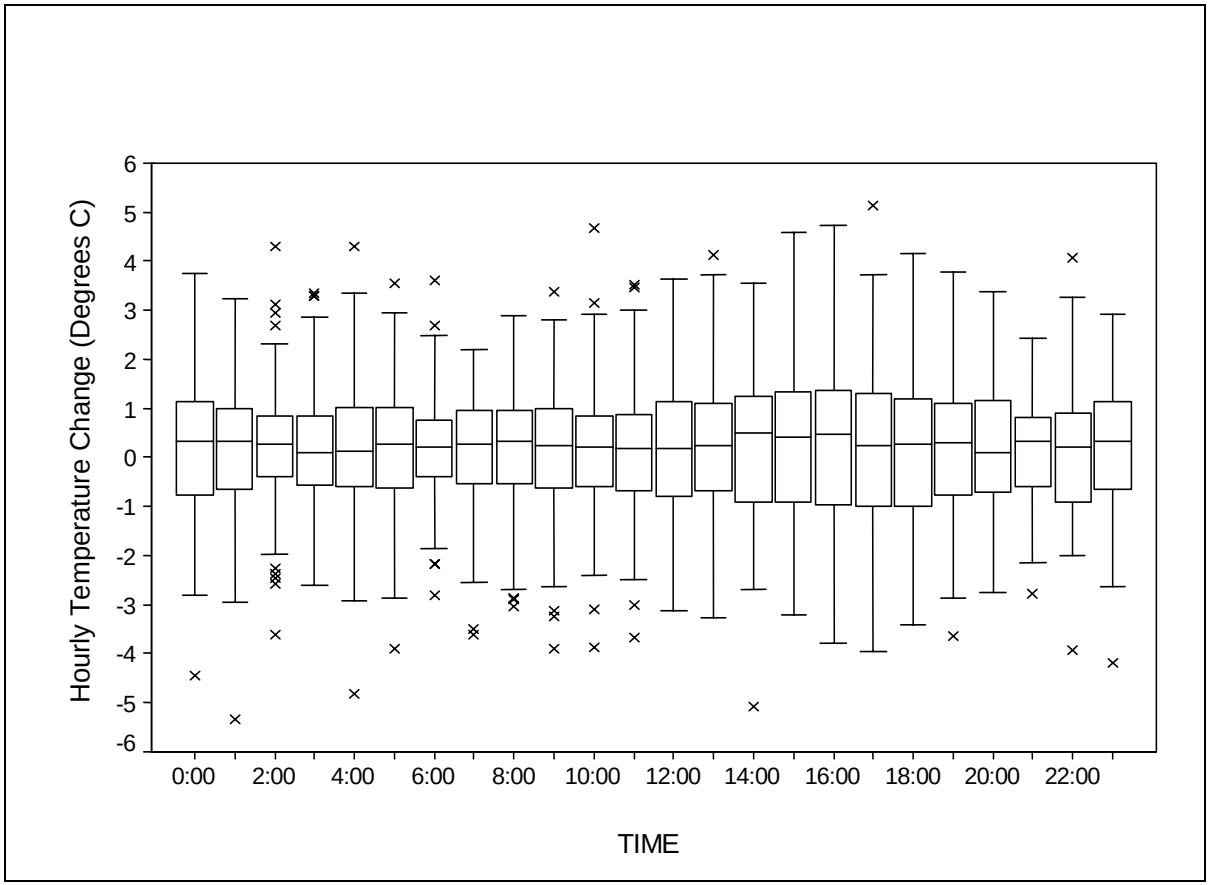

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FIGURE C-48B: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (SMC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

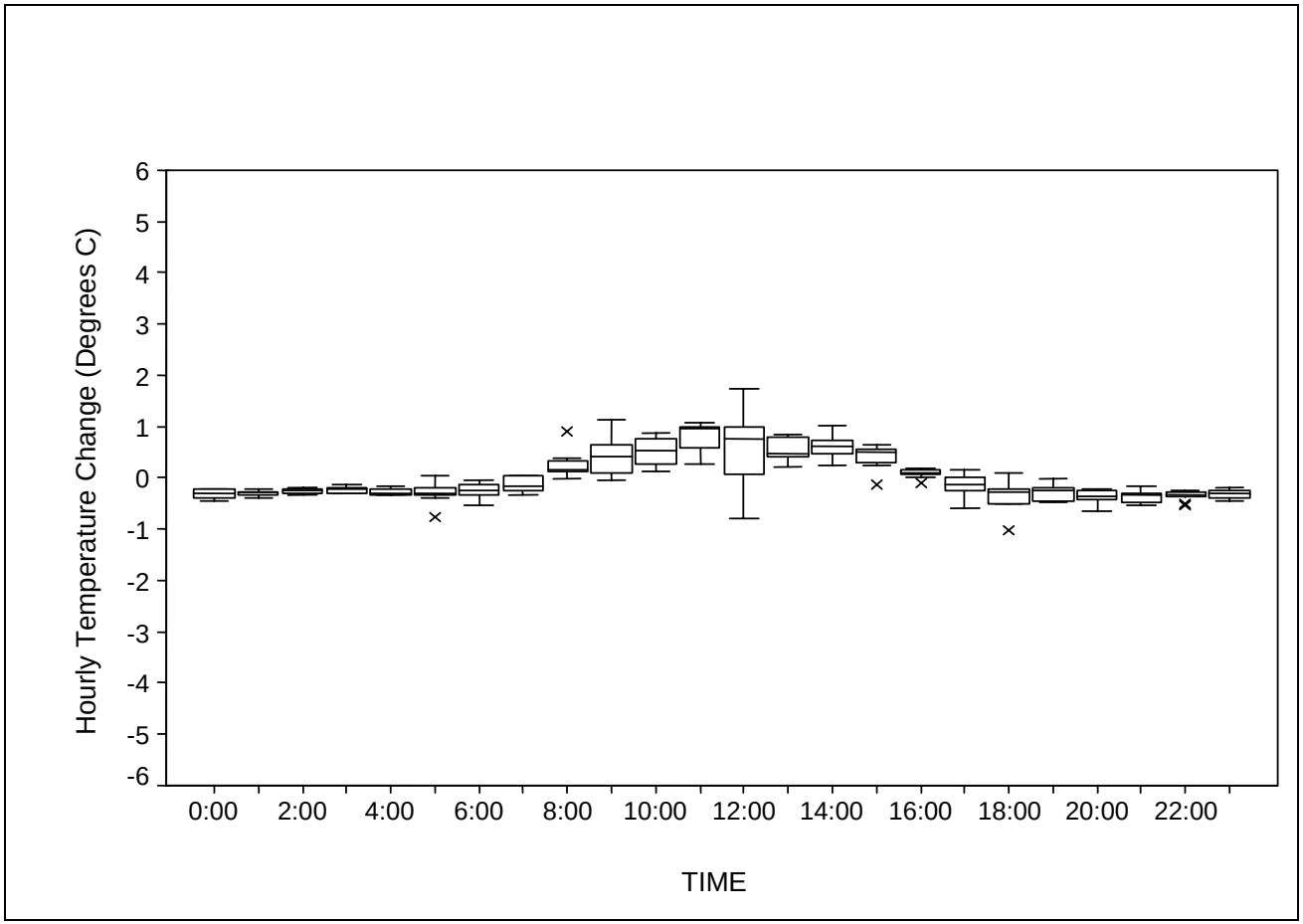

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FIGURE C-48C: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (SMC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

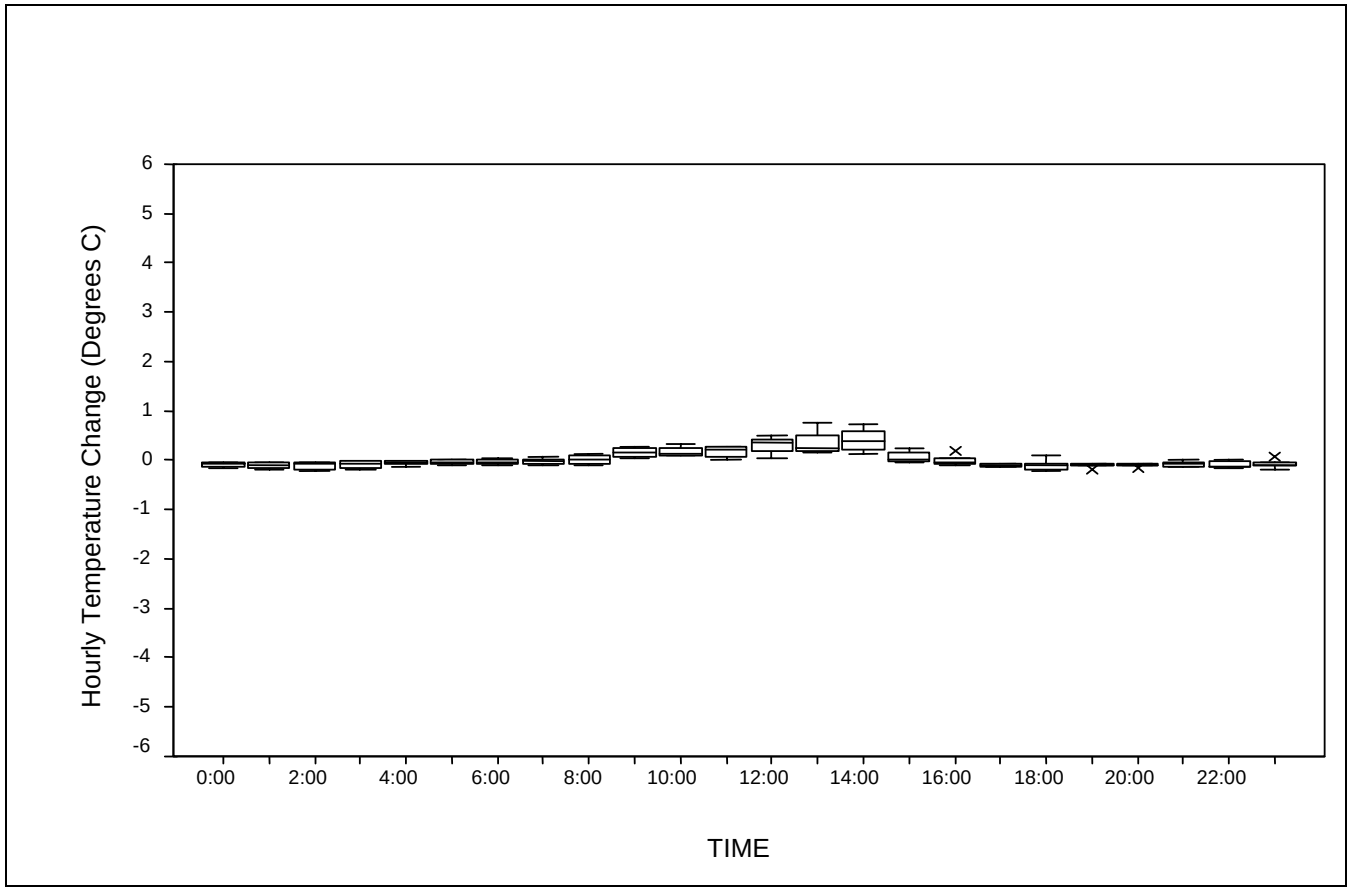

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FIGURE C-49: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (TSMC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

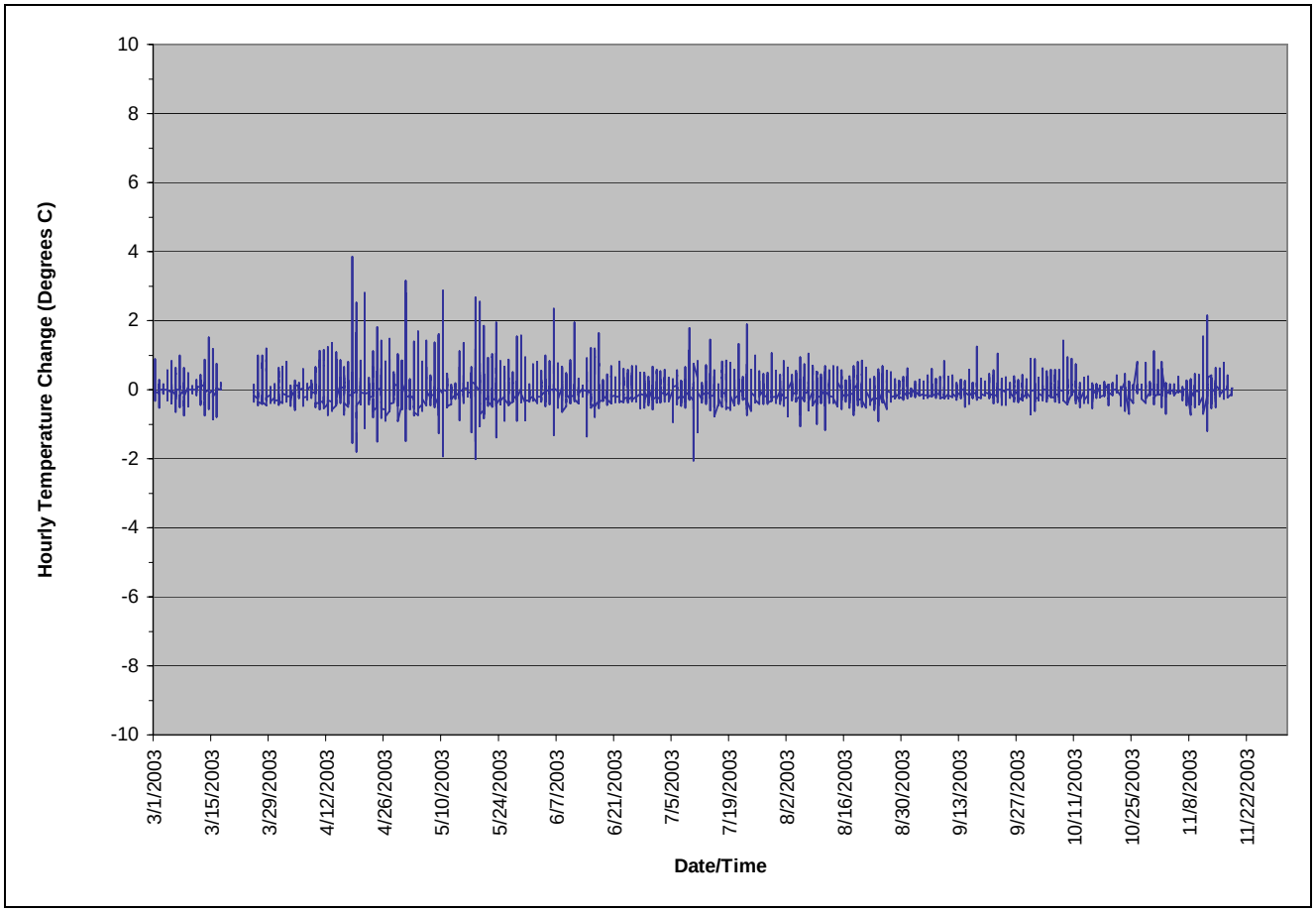

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FIGURE C-50: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (SMC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

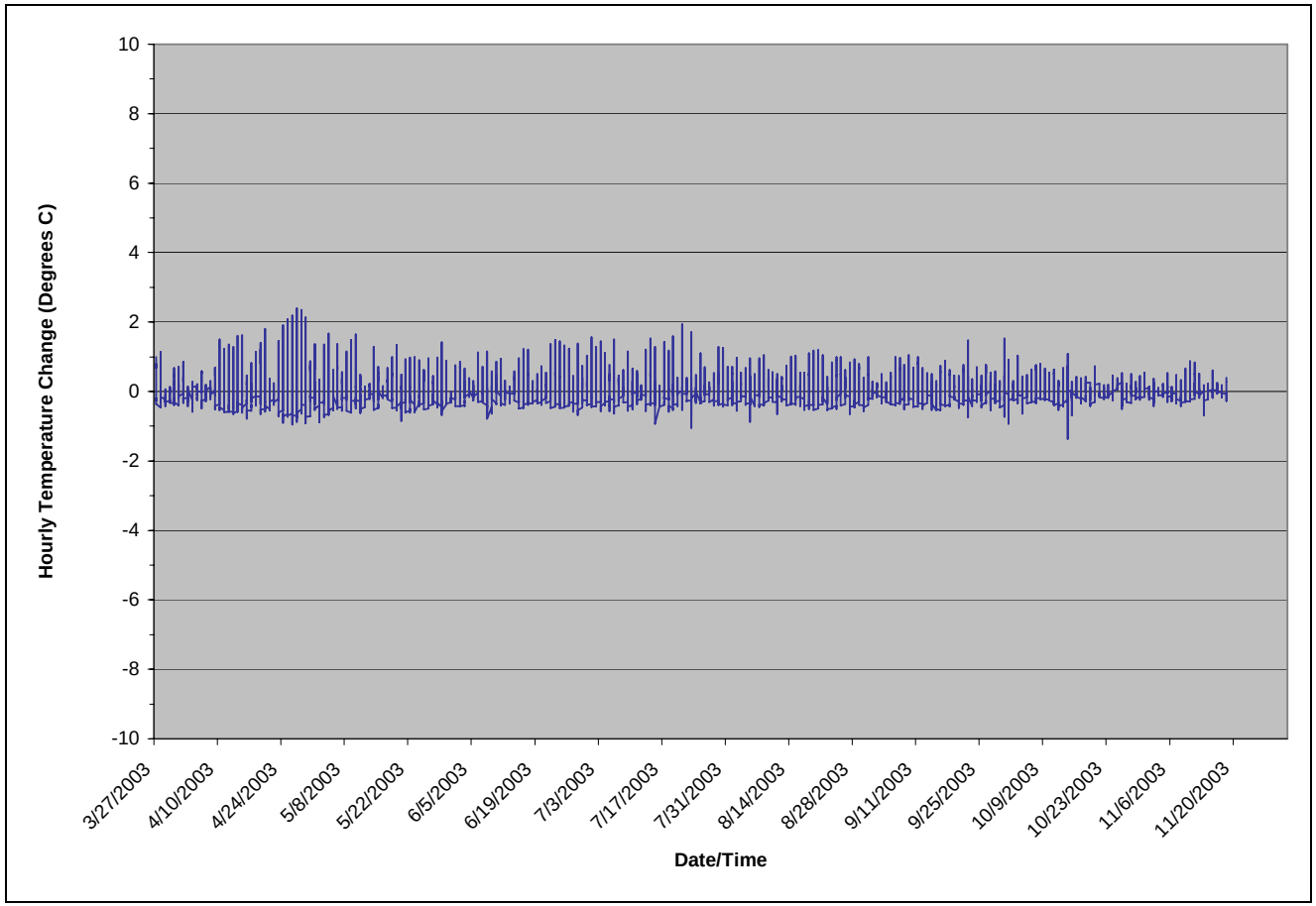

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FIGURE C-51A: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (SMC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

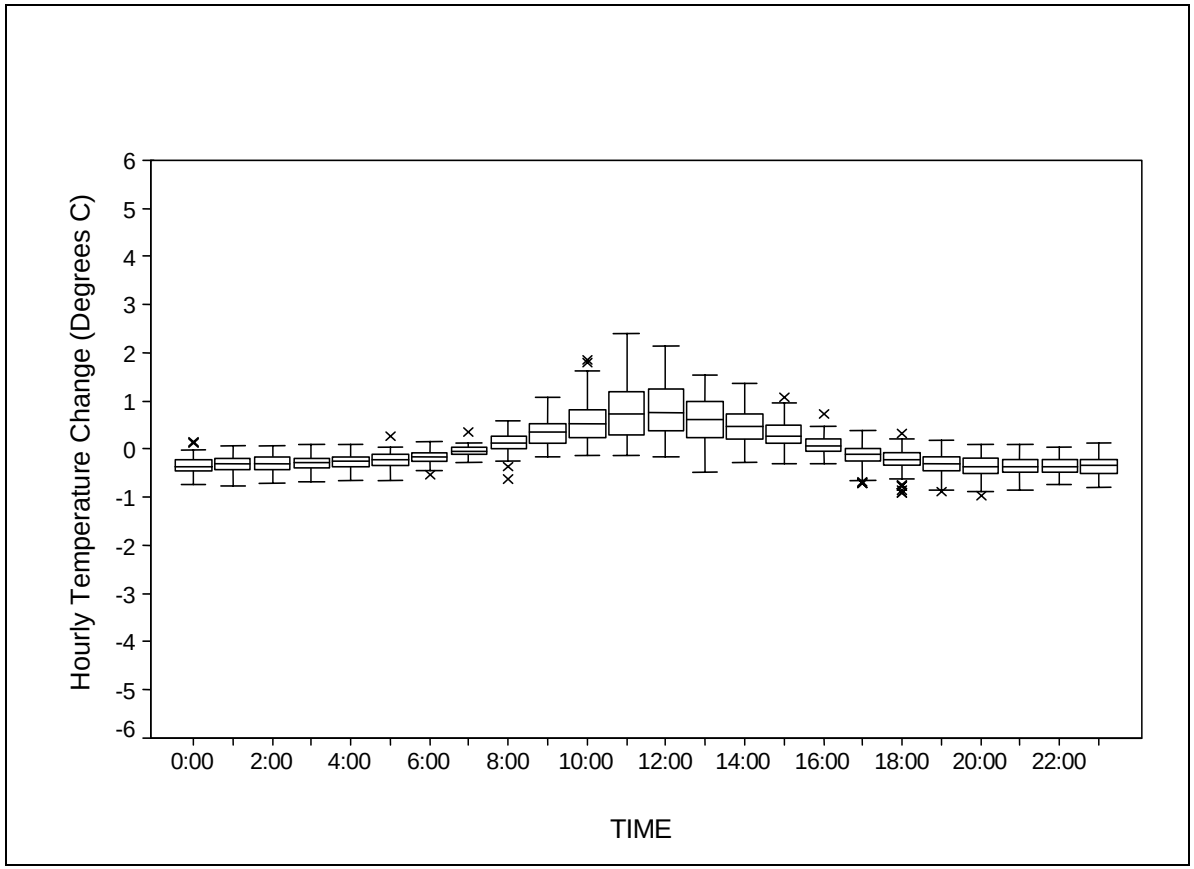

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FIGURE C-51B: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (SMC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

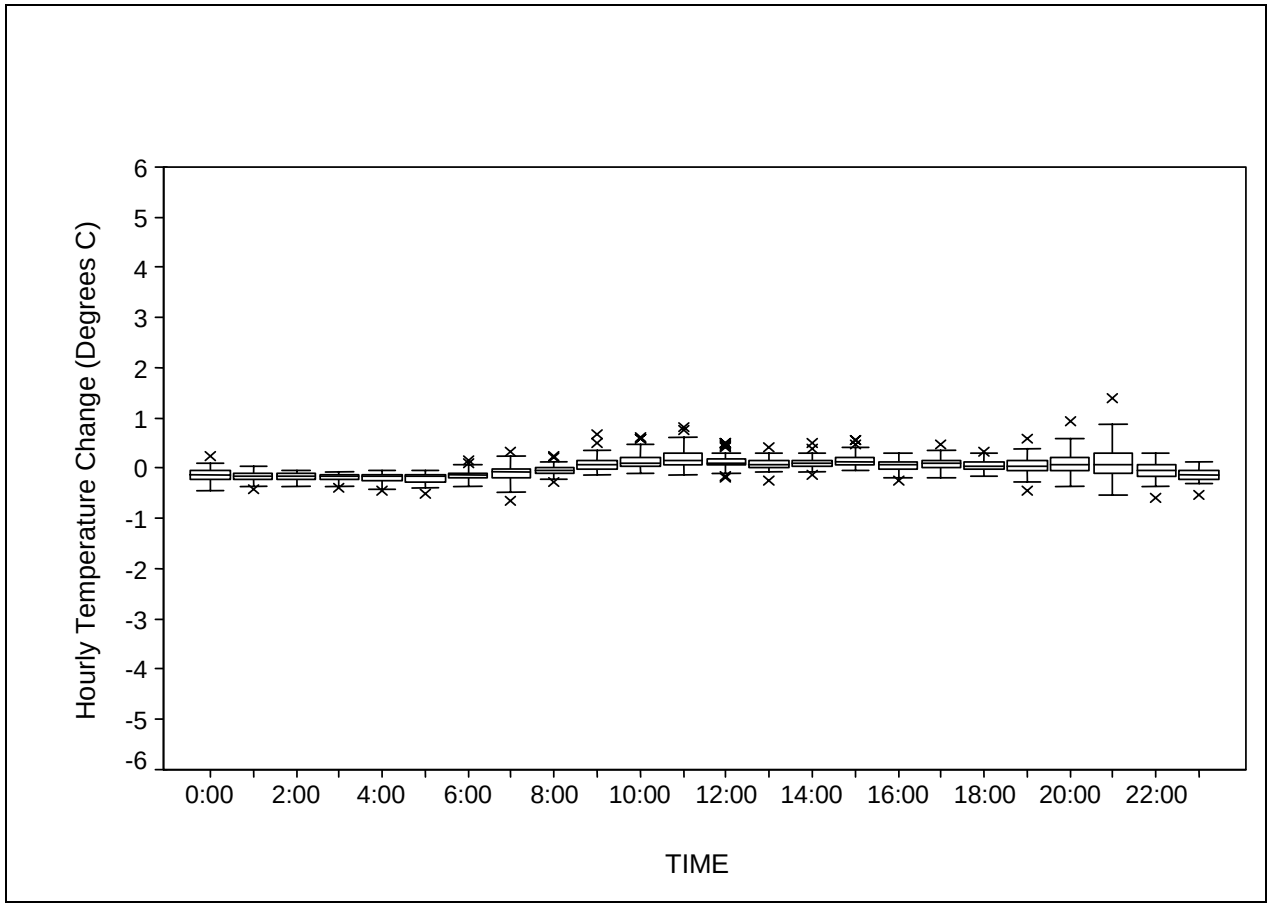

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FIGURE C-51C: ANALYSIS ZONE 1 – BIG SIXMILE CREEK (SMC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

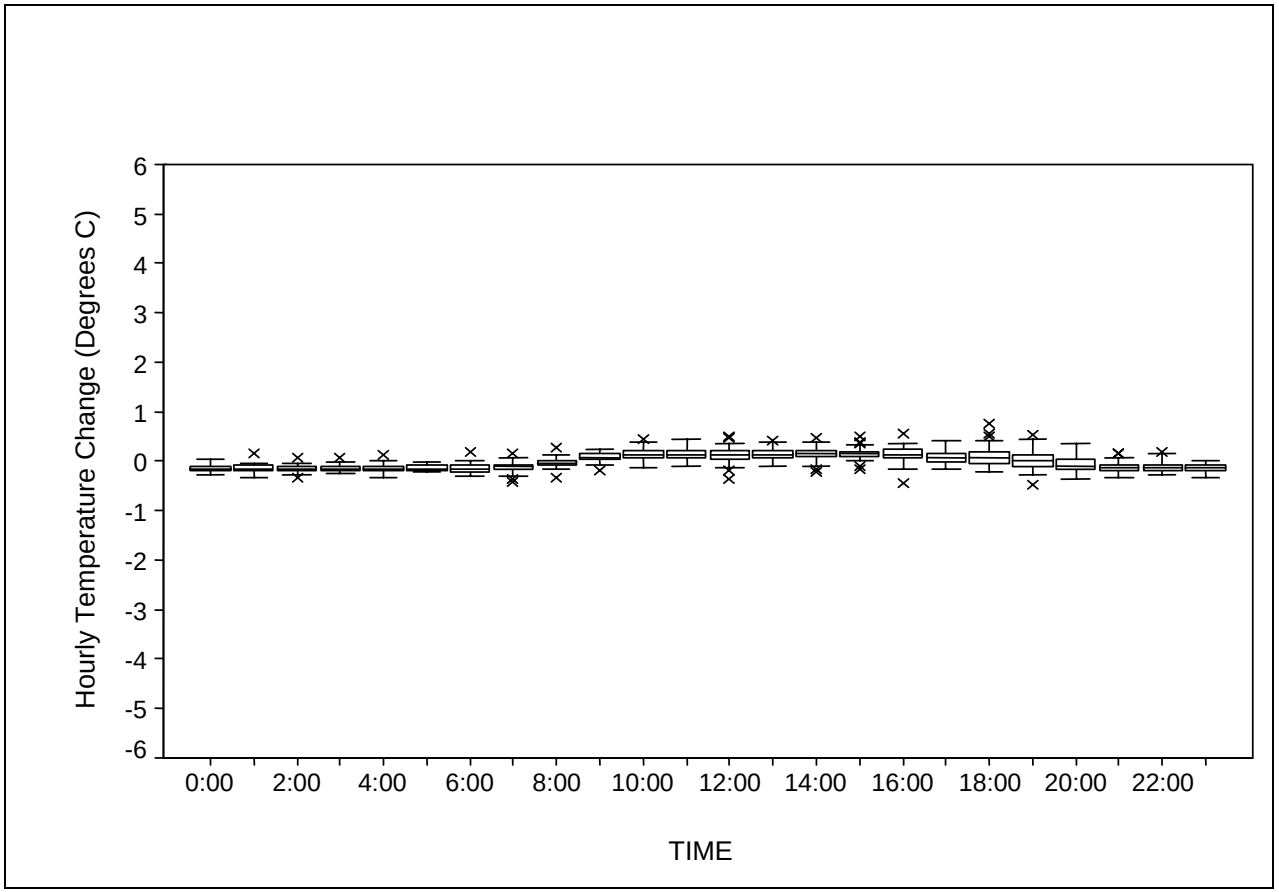

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FIGURE C-52: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

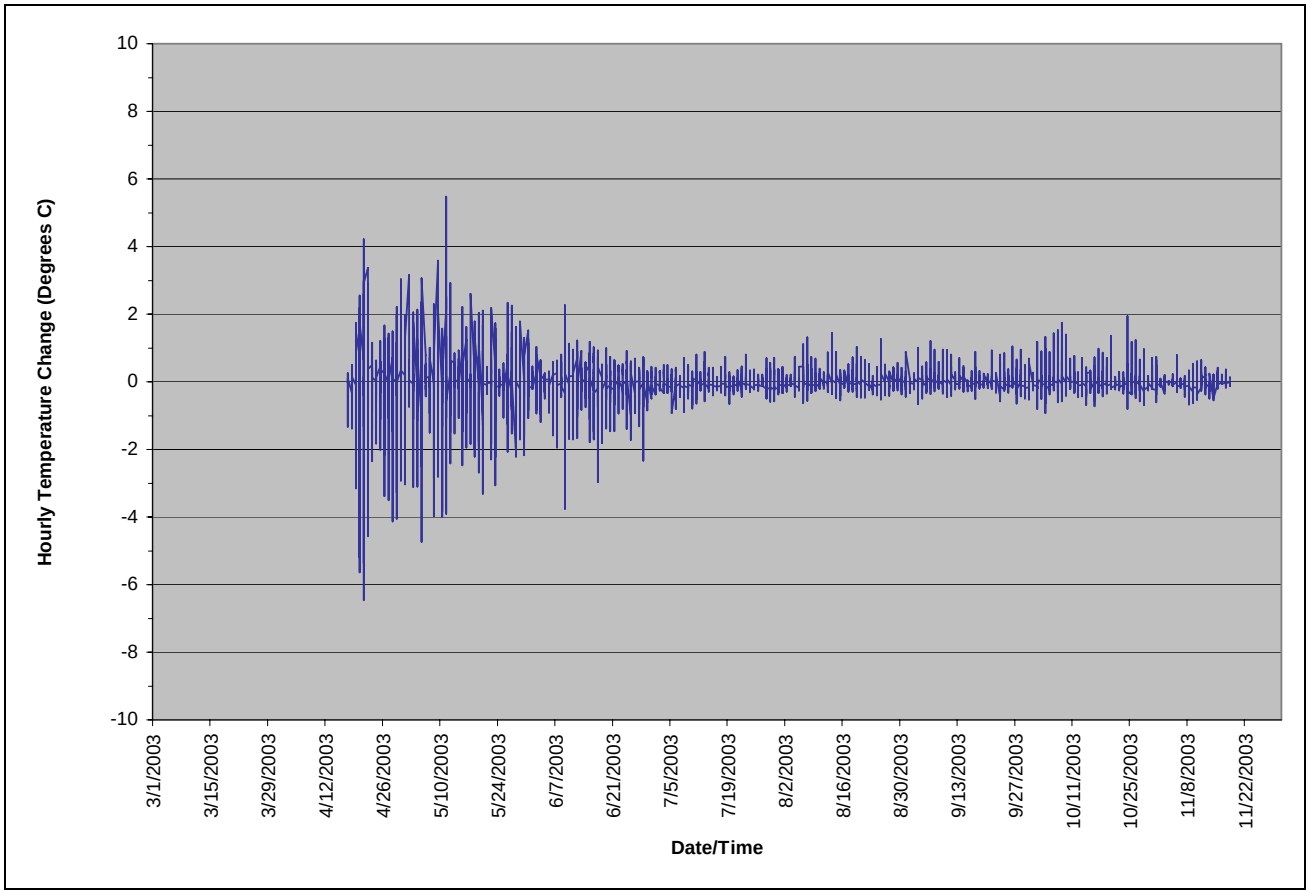

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FIGURE C-53A: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

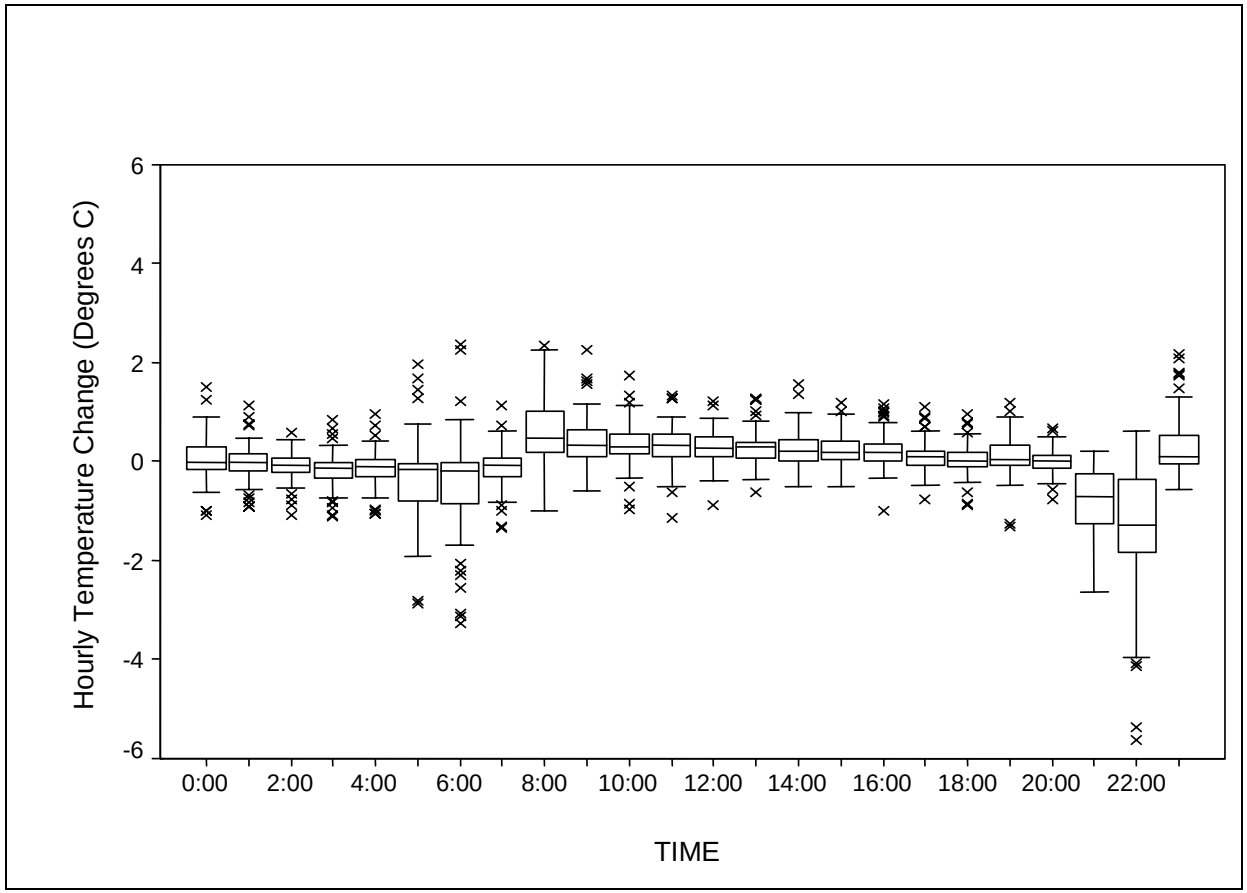

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FIGURE C-53B: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

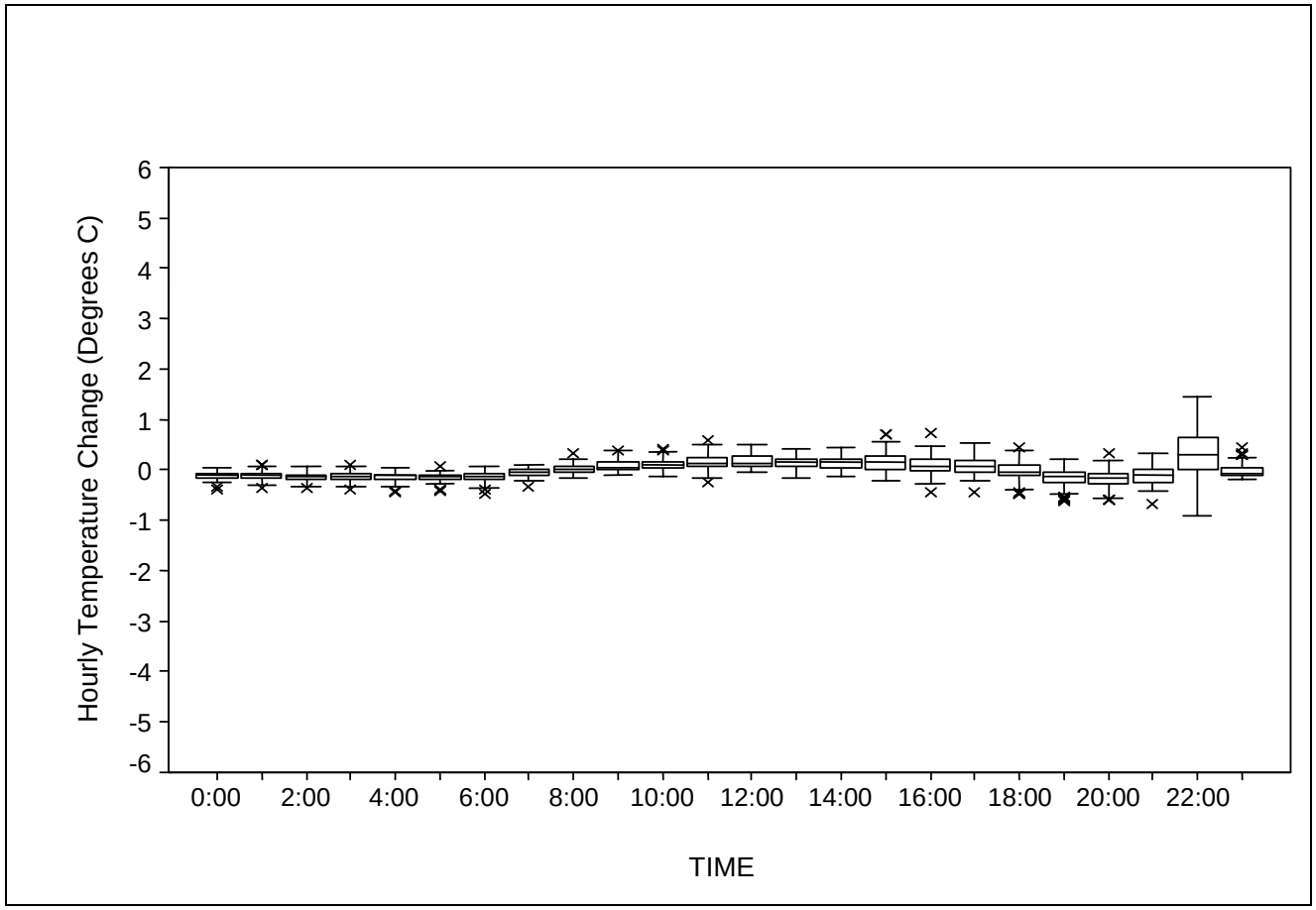

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FIGURE C-53C: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

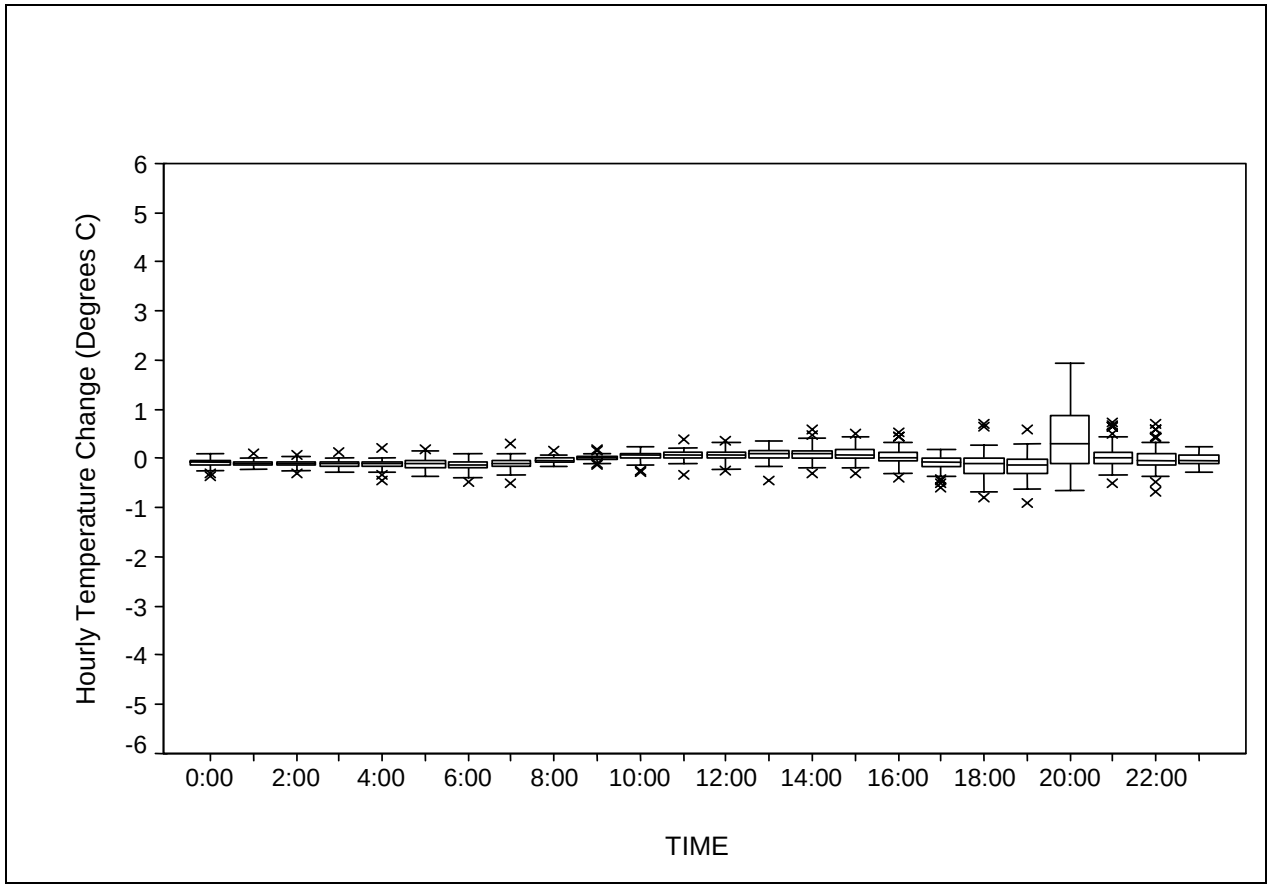

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FIGURE C-54A: ANALYSIS ZONE 1 - GN-RIVER_INT

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

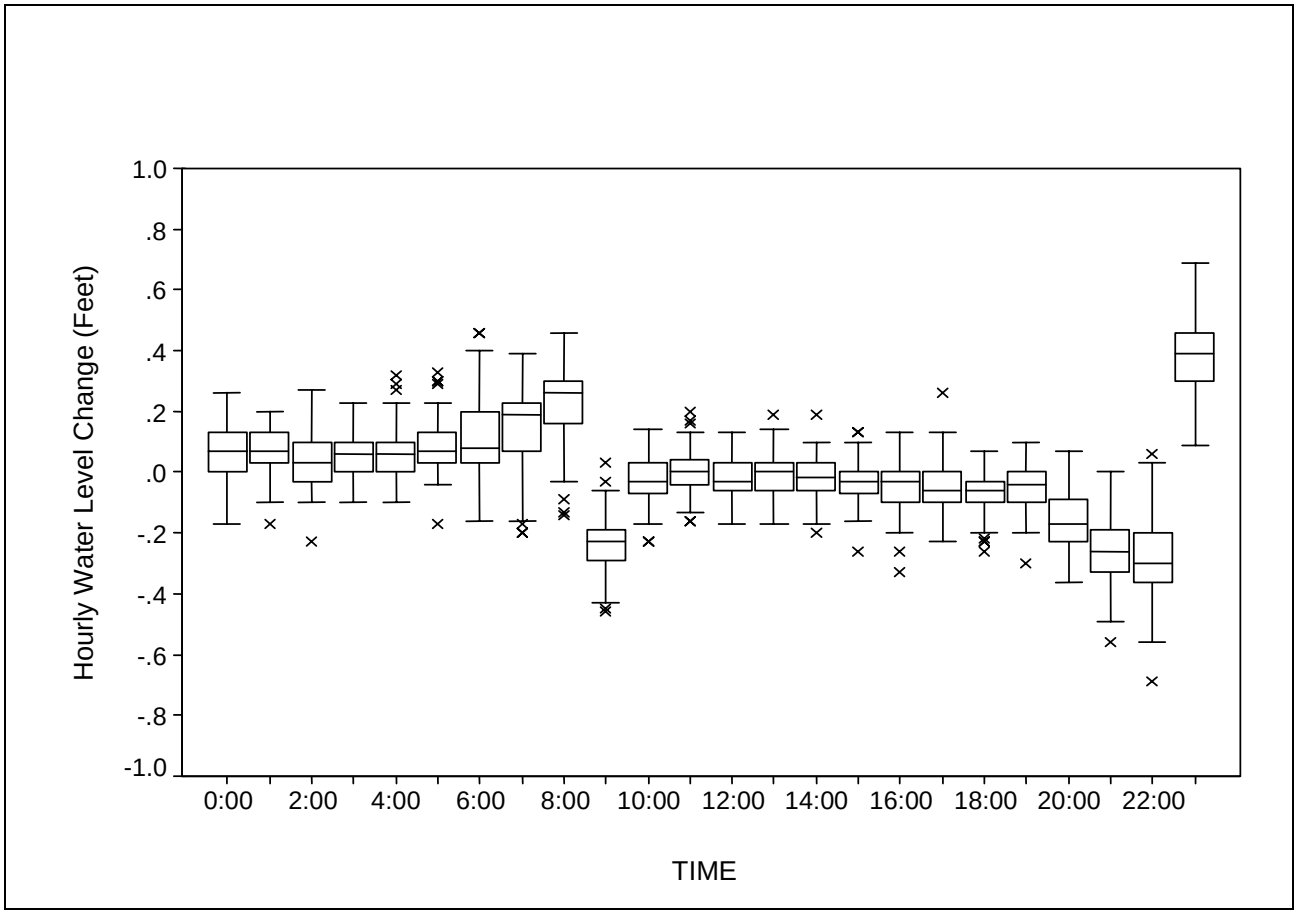

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FIGURE C-54B: ANALYSIS ZONE 1 - GN-RIVER_INT

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

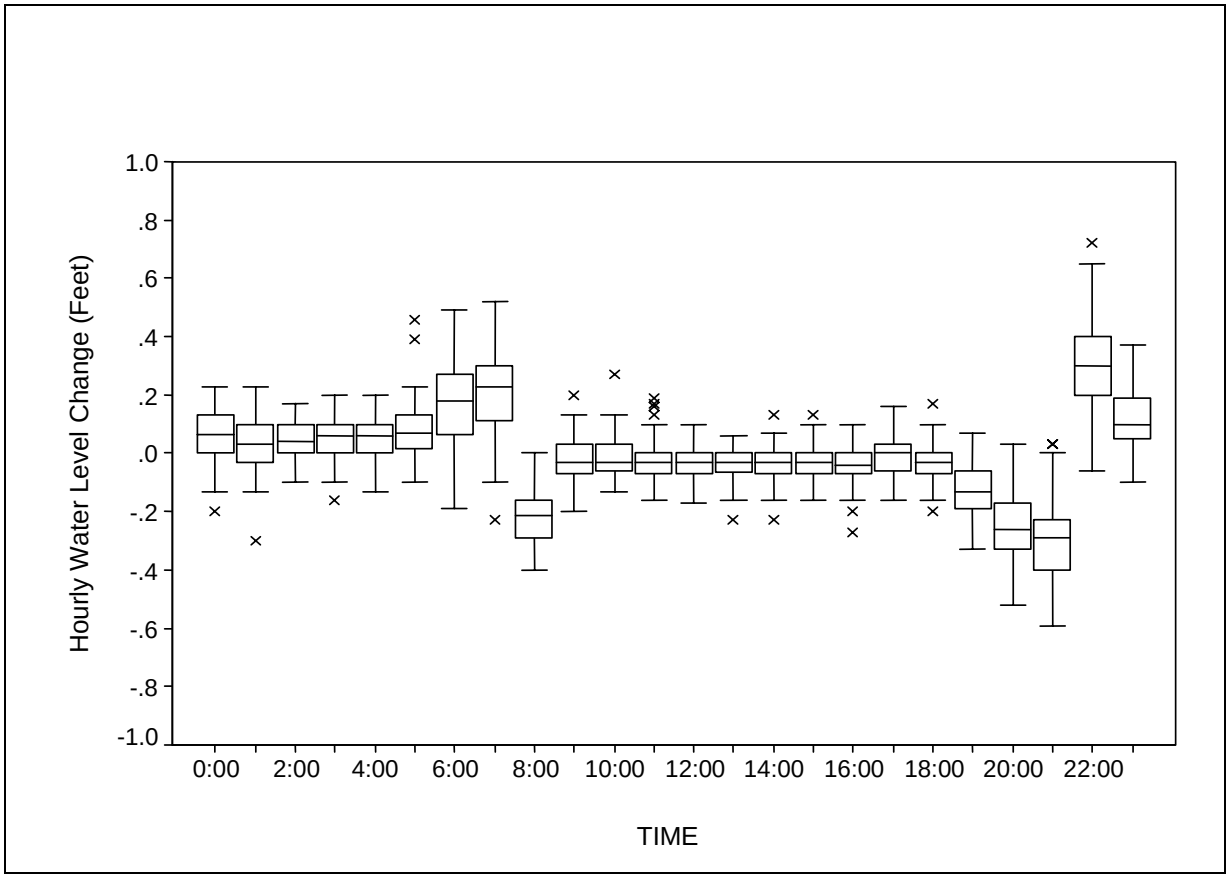

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FIGURE C-54C: ANALYSIS ZONE 1 - GN-RIVER_INT

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

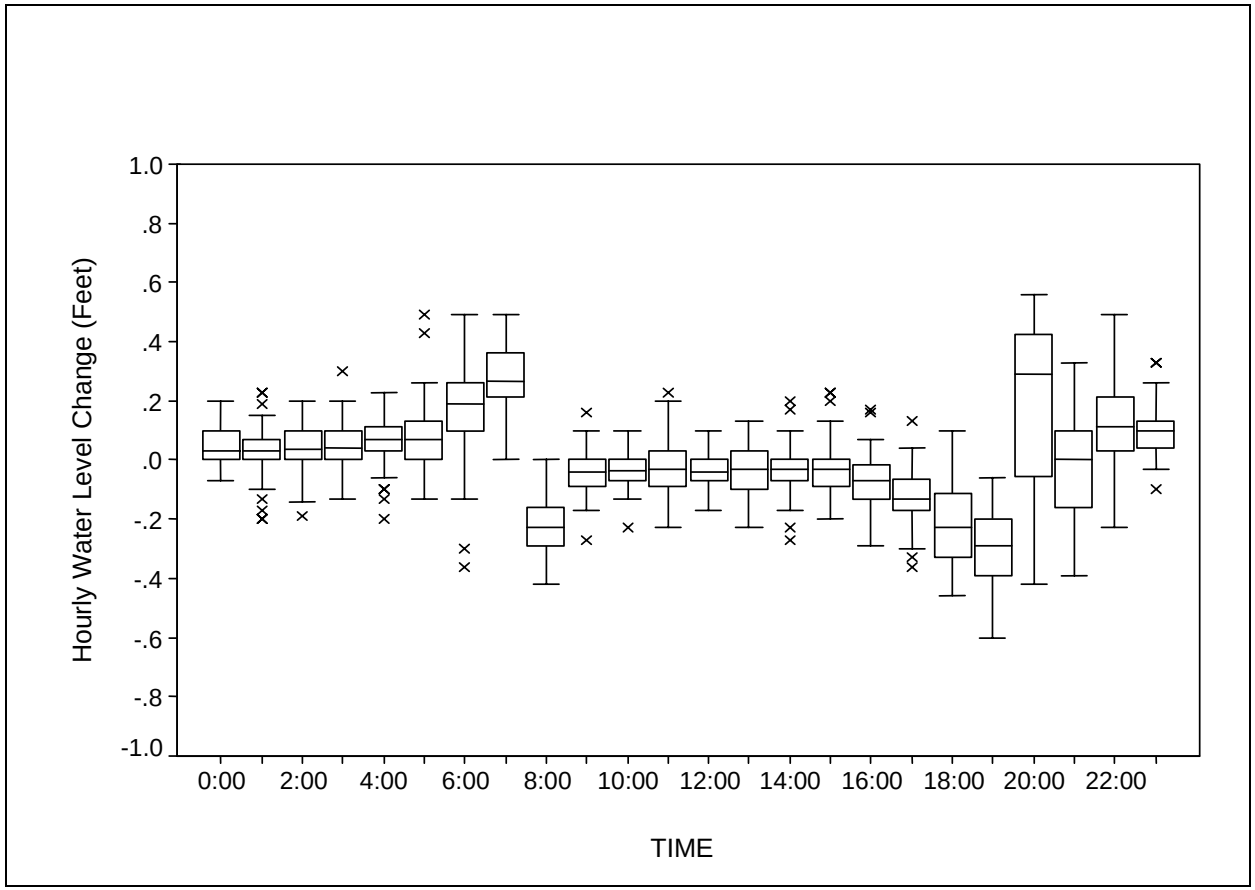

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FIGURE C-55: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

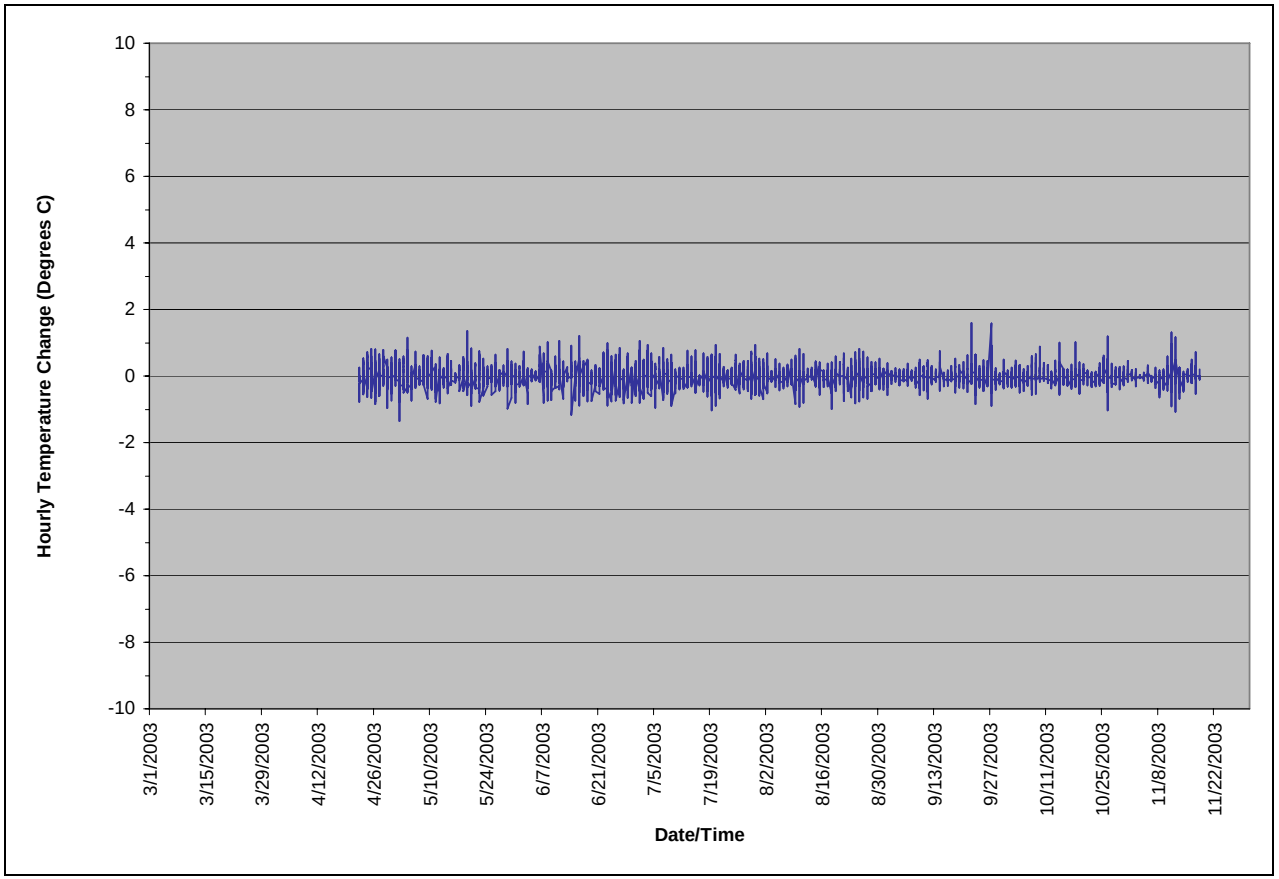

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FIGURE C-56A: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

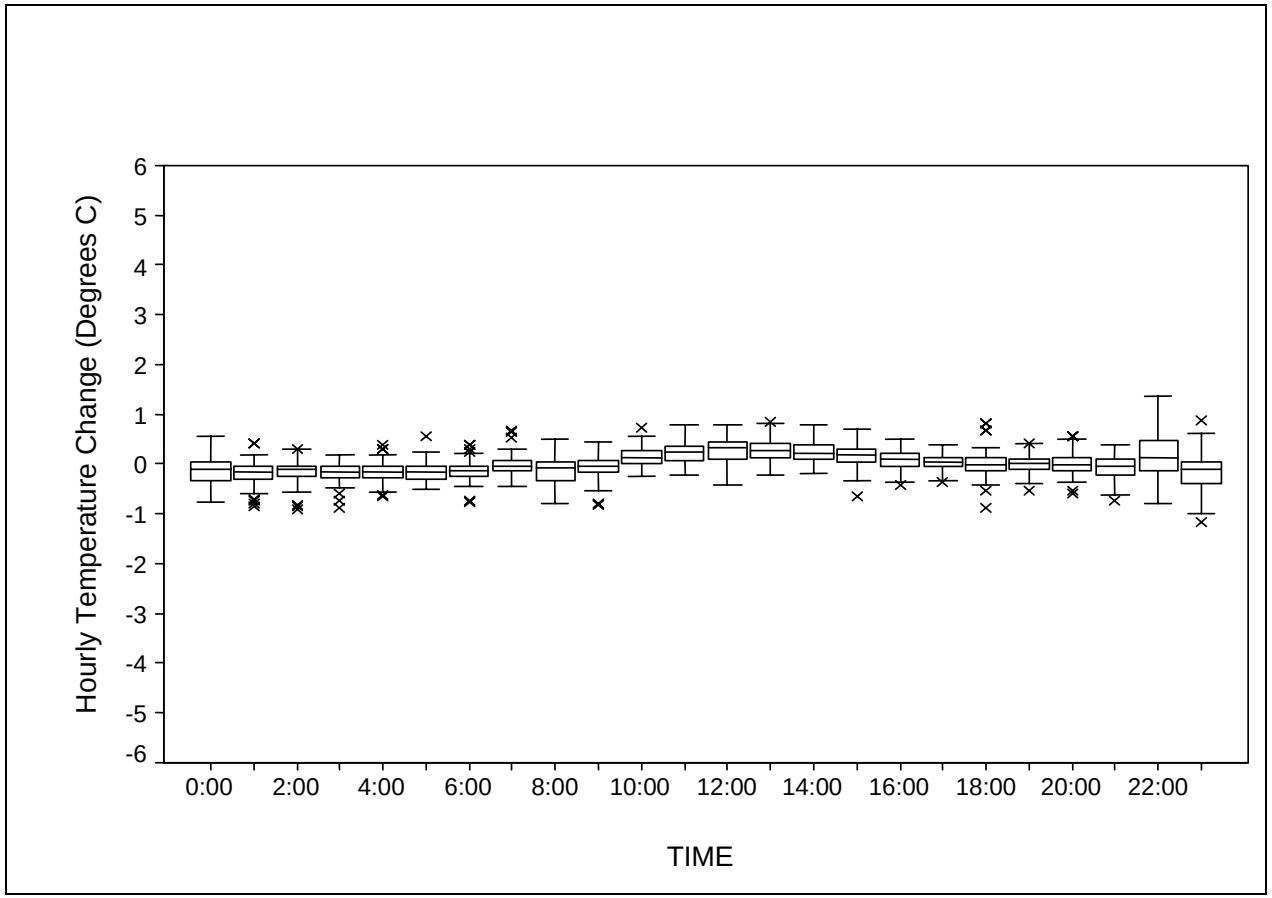

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FIGURE C-56B: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

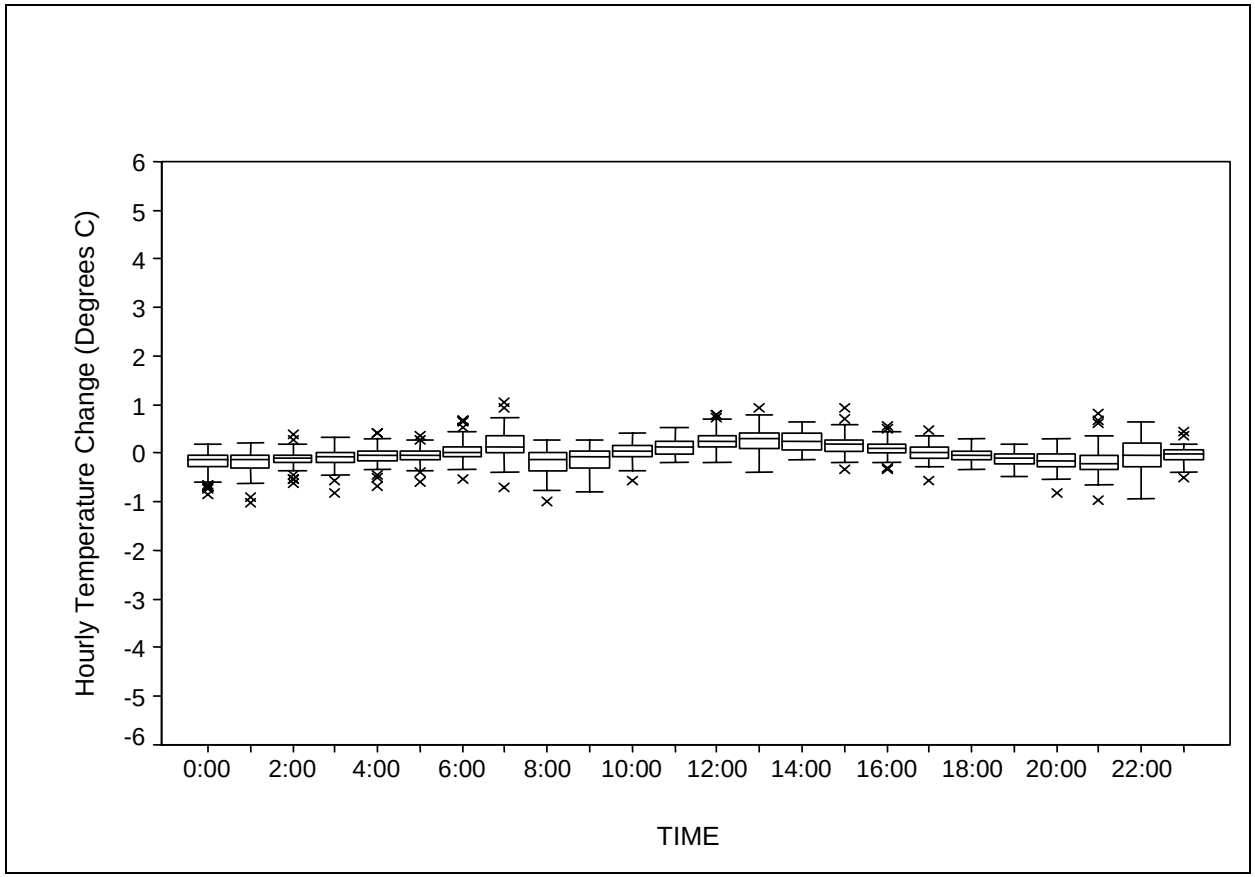

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FIGURE C-56C: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

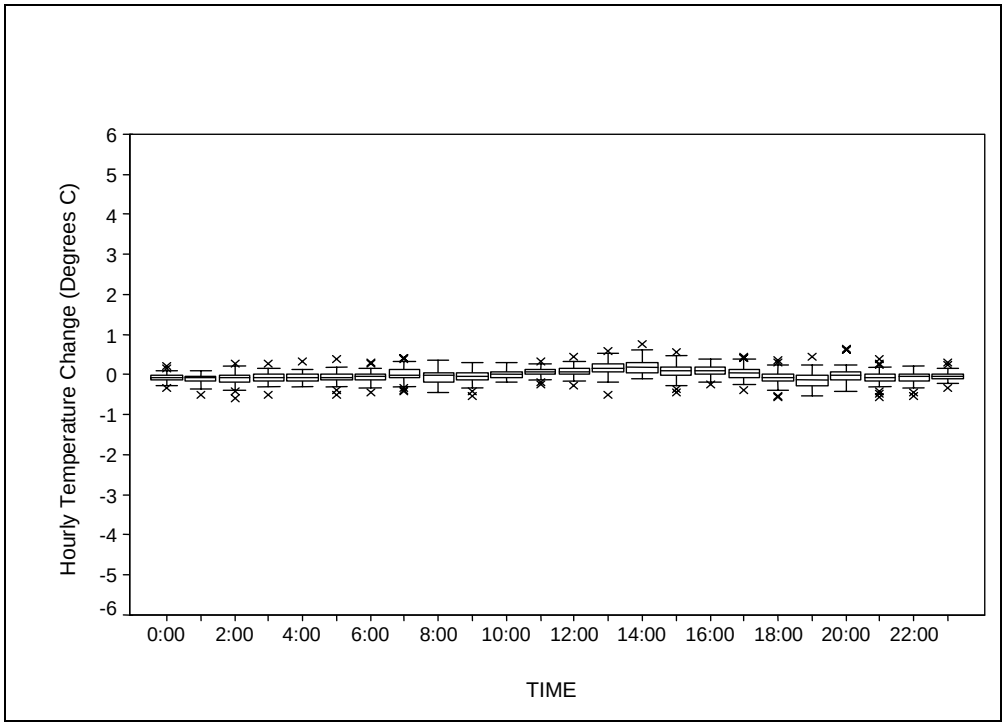

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FIGURE C-57: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-03)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

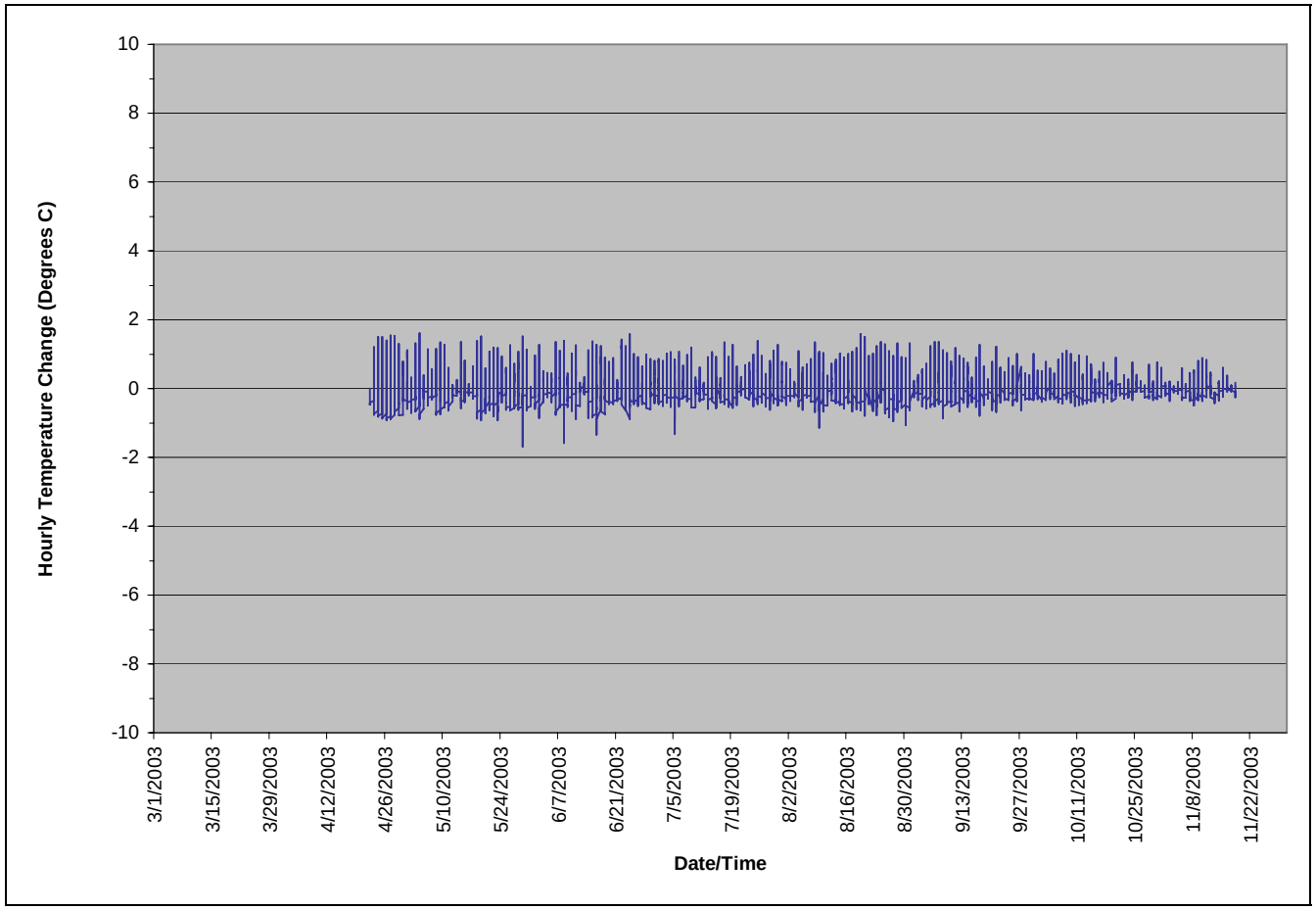

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FIGURE C-58A: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-03)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

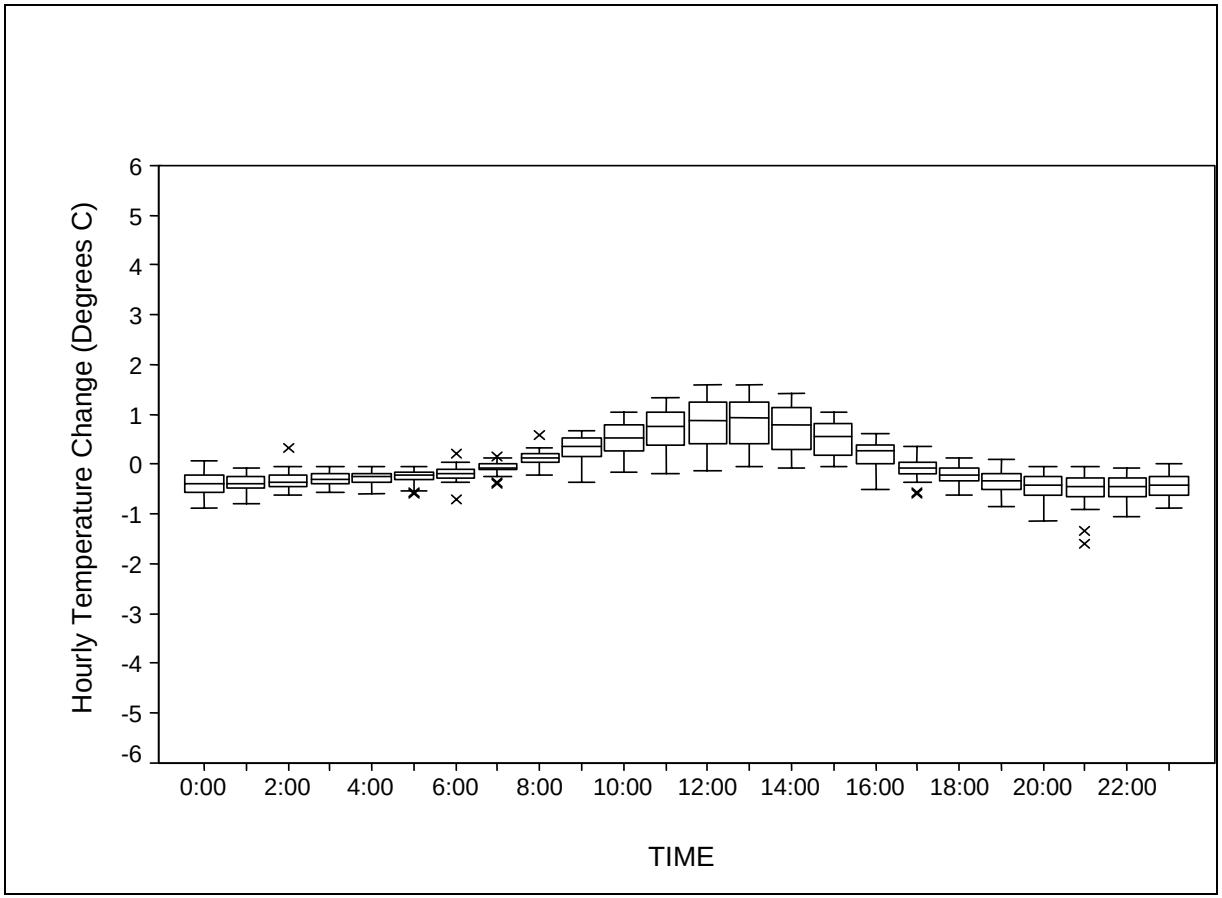

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FIGURE C-58B: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-03)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

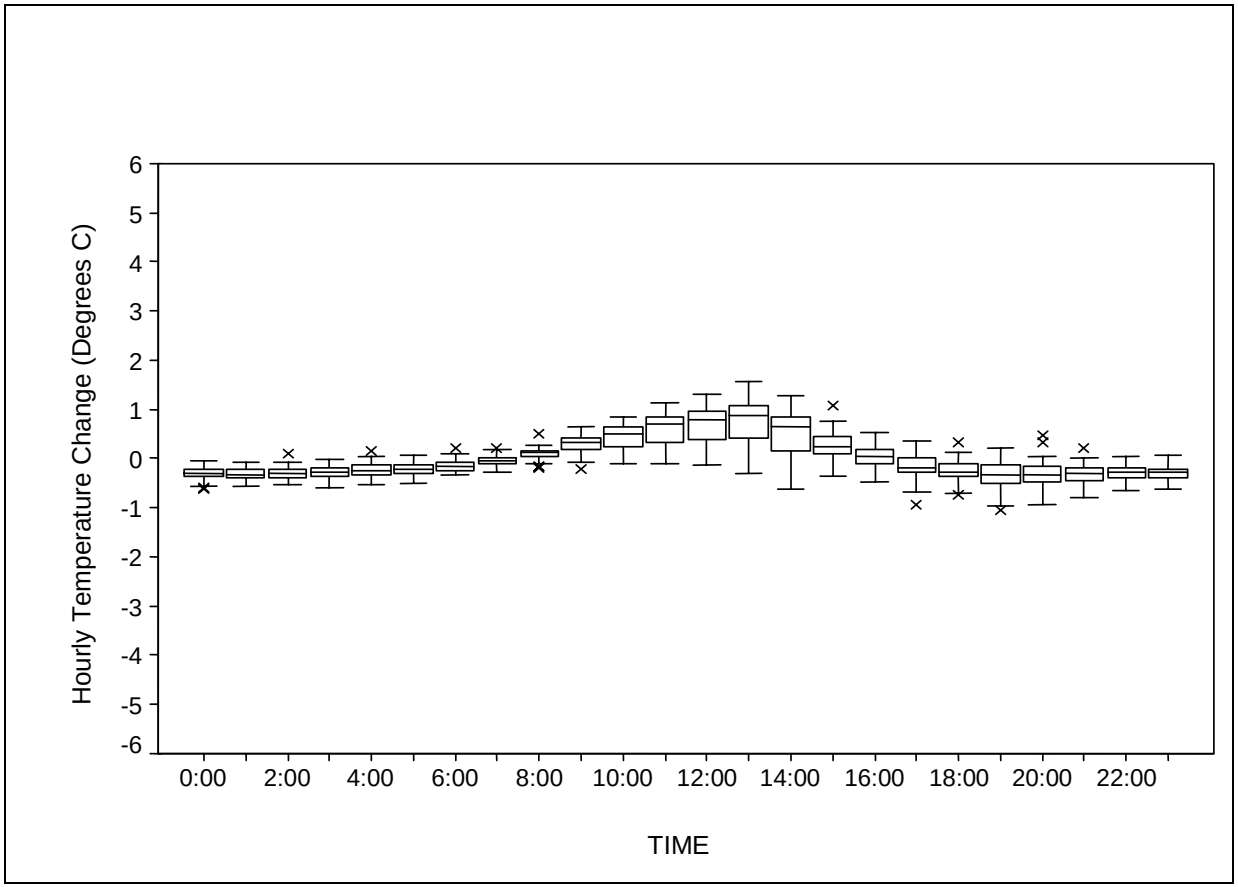

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FIGURE C-58C: ANALYSIS ZONE 1 – CAYUGA CREEK (CC-03)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

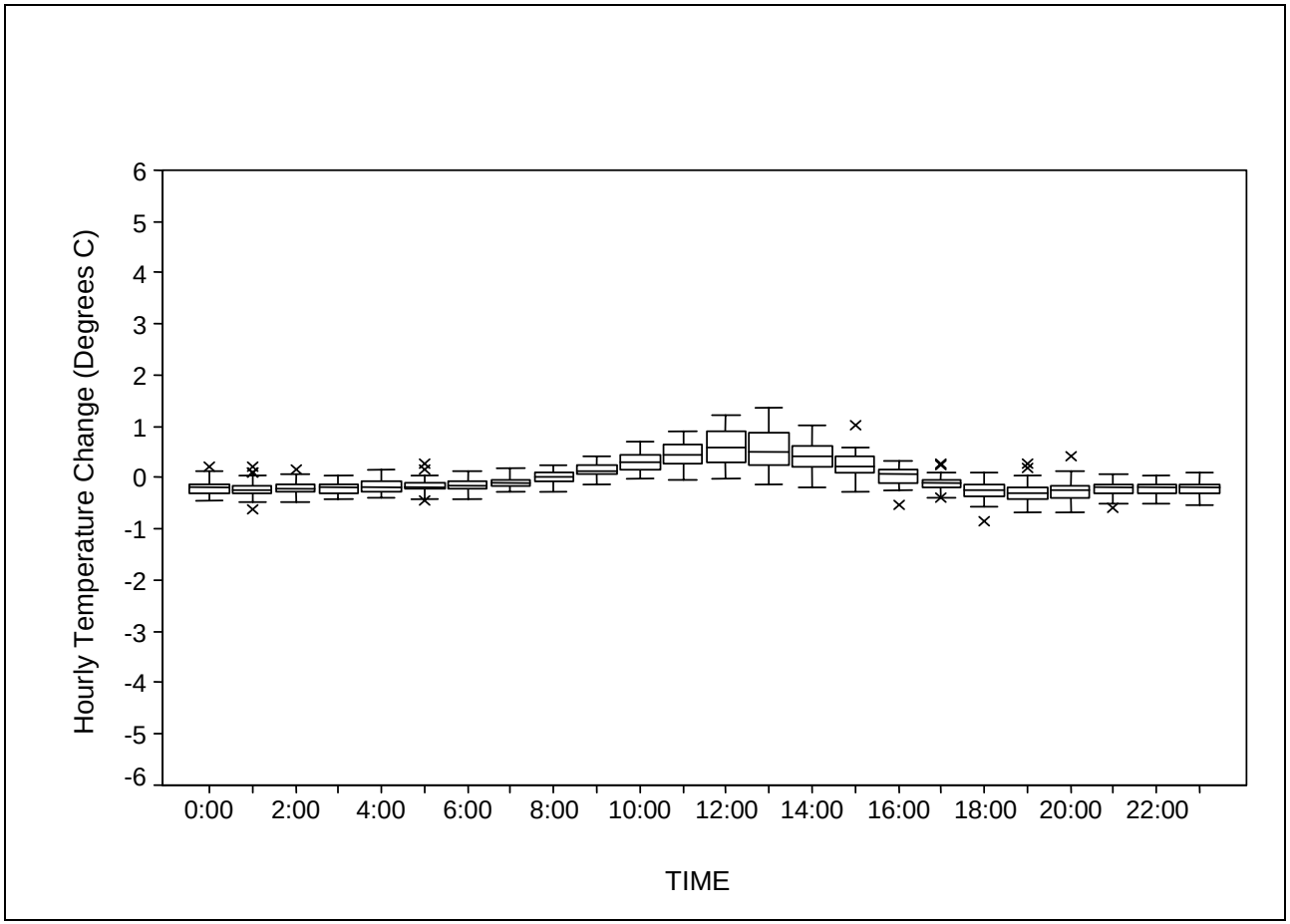

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FIGURE C-59: ANALYSIS ZONE 1 – TONAWANDA CREEK (TTC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

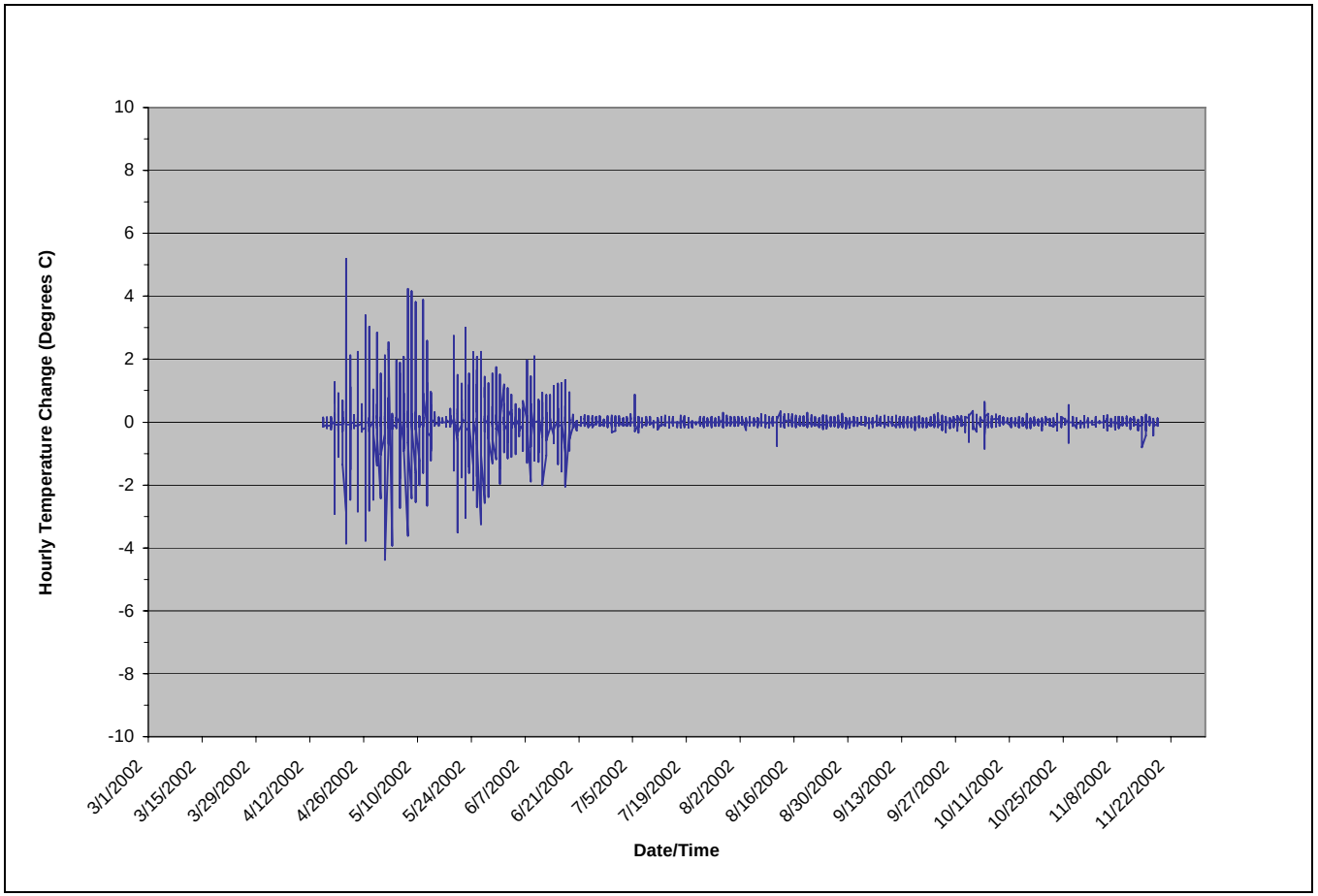

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FIGURE C-60A: ANALYSIS ZONE 1 – TONAWANDA CREEK (TTC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

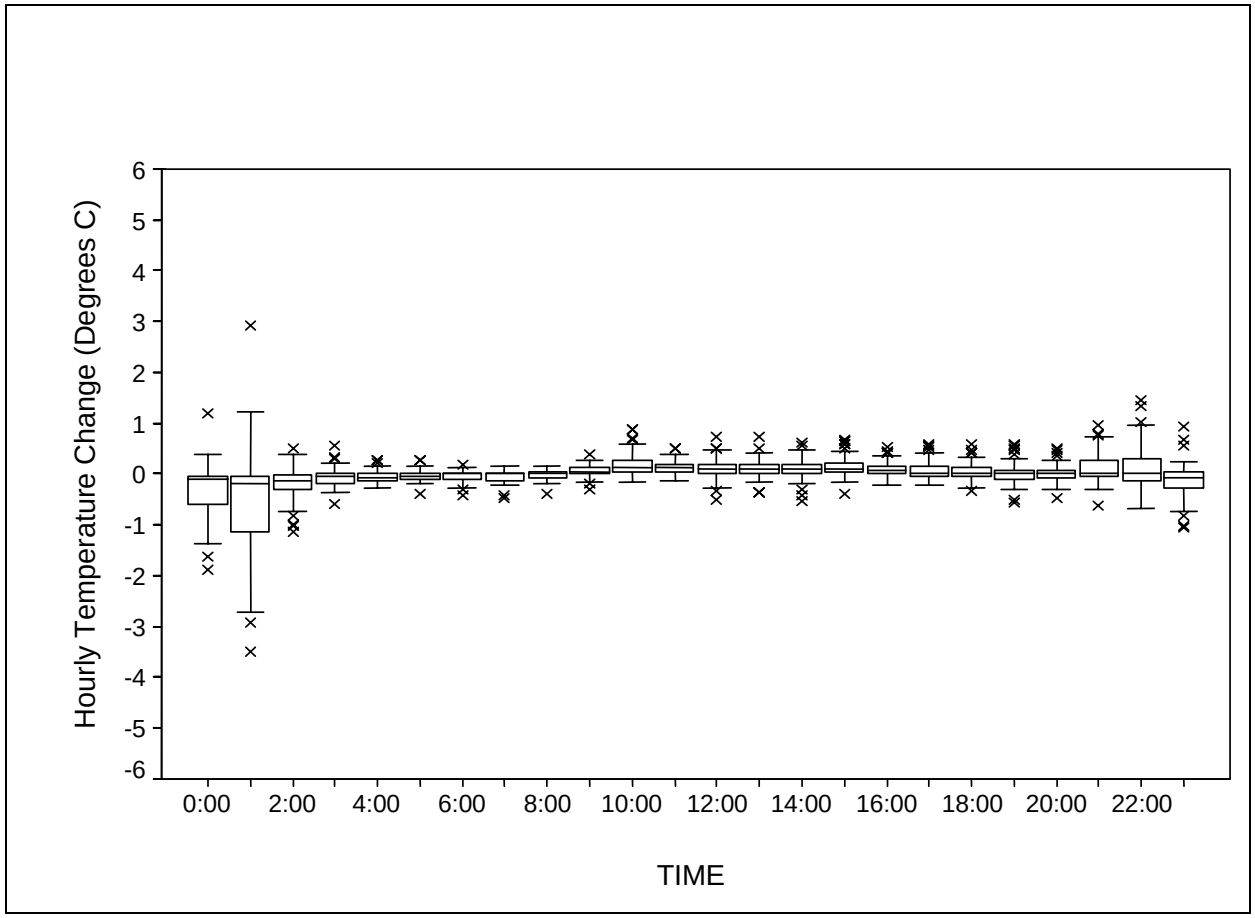

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FIGURE C-60B: ANALYSIS ZONE 1 – TONAWANDA CREEK (TTC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

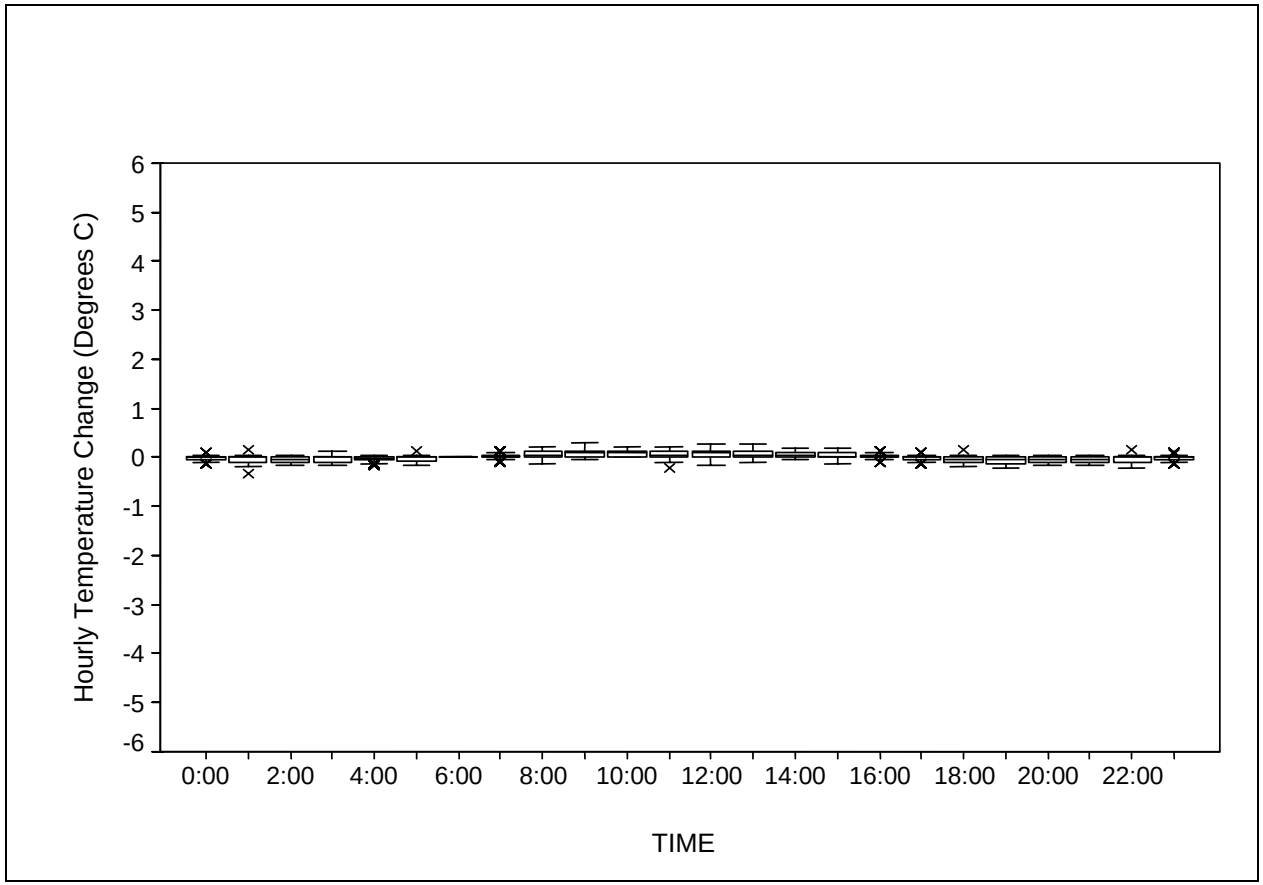

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FIGURE C-60C: ANALYSIS ZONE 1 – TONAWANDA CREEK (TTC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

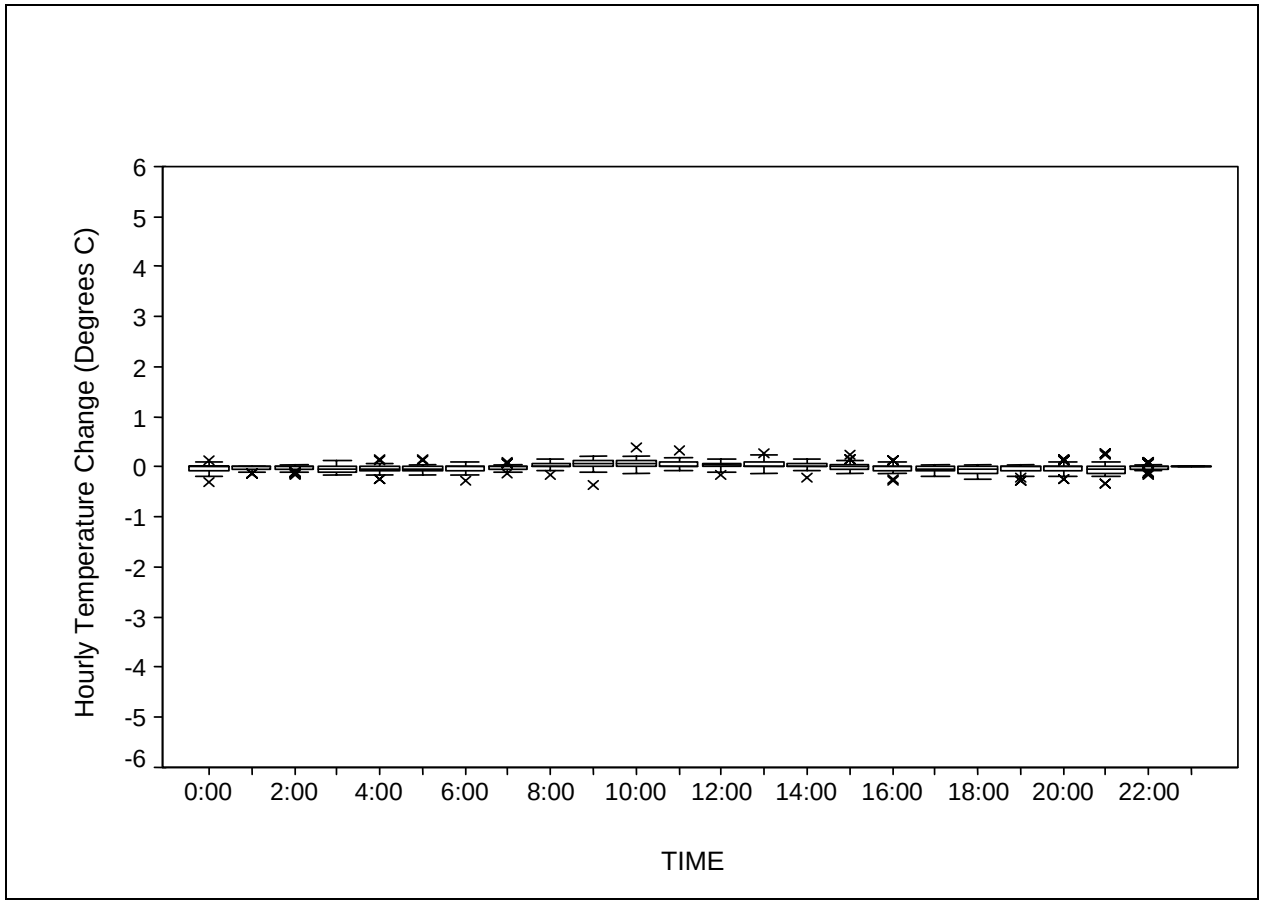

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FIGURE C-61: ANALYSIS ZONE 1 – ELLICOTT CREEK (EC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

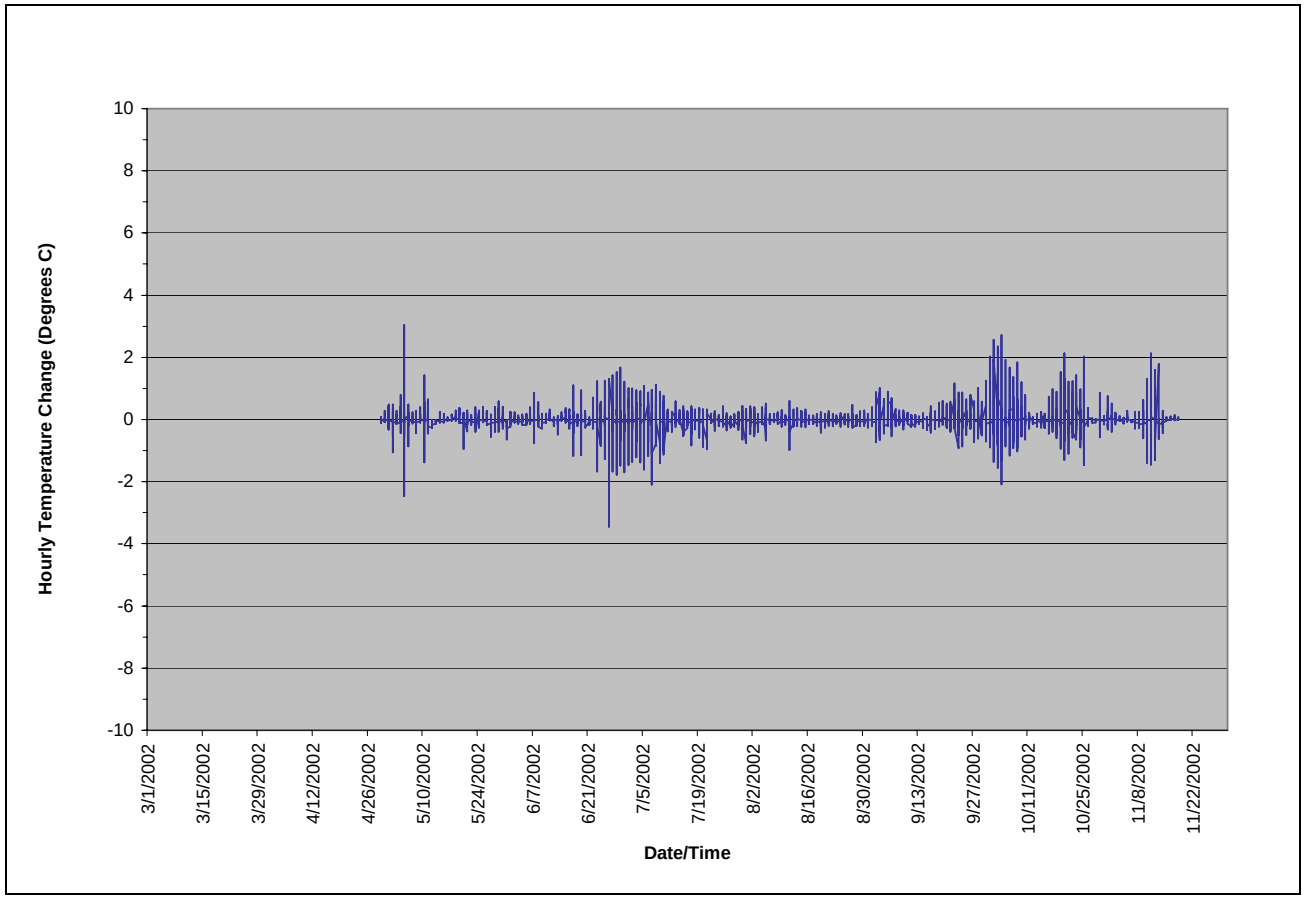

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FIGURE C-62A: ANALYSIS ZONE 1 – ELLICOTT CREEK (EC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

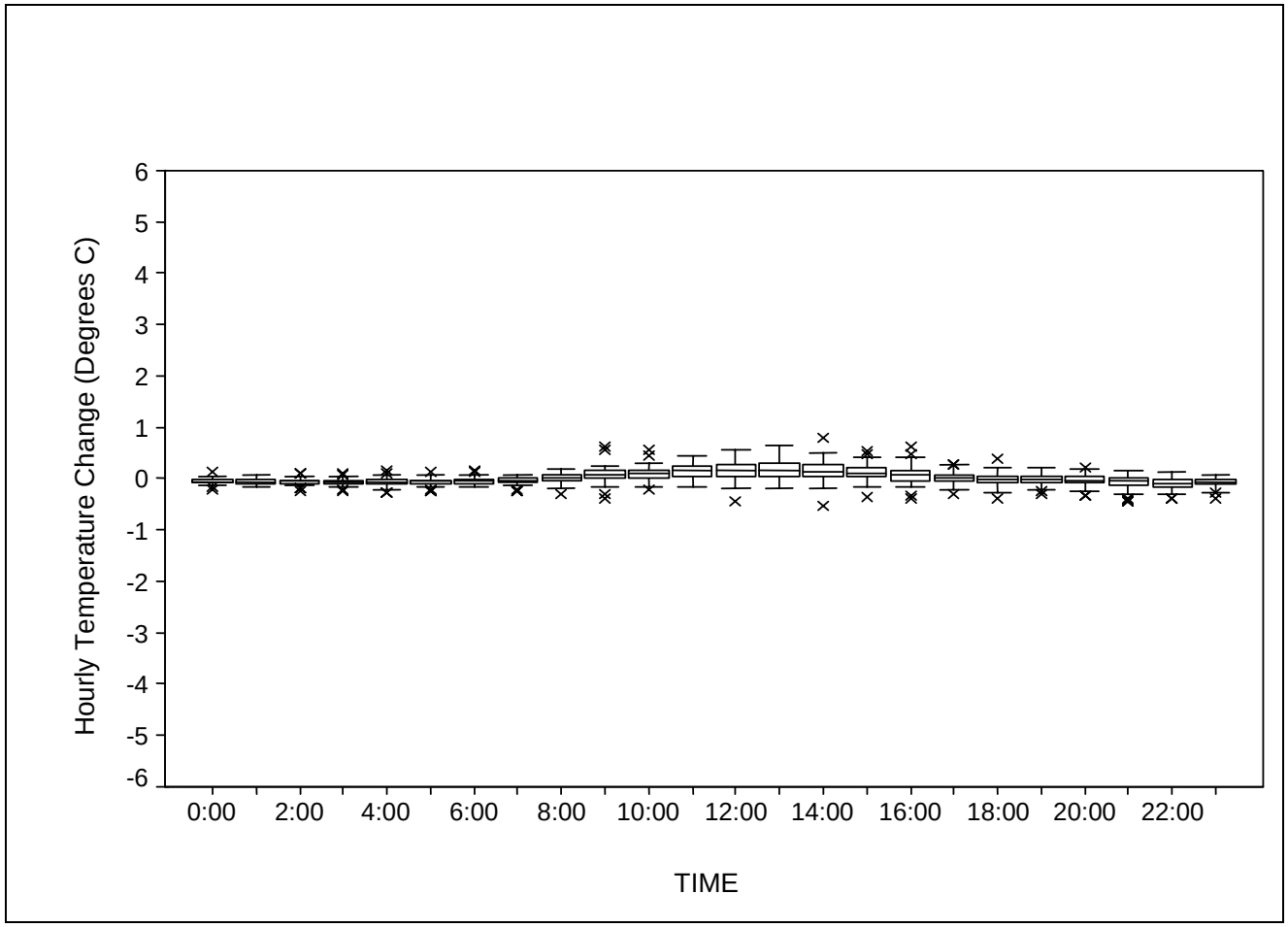

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FIGURE C-62B: ANALYSIS ZONE 1 – ELLICOTT CREEK (EC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

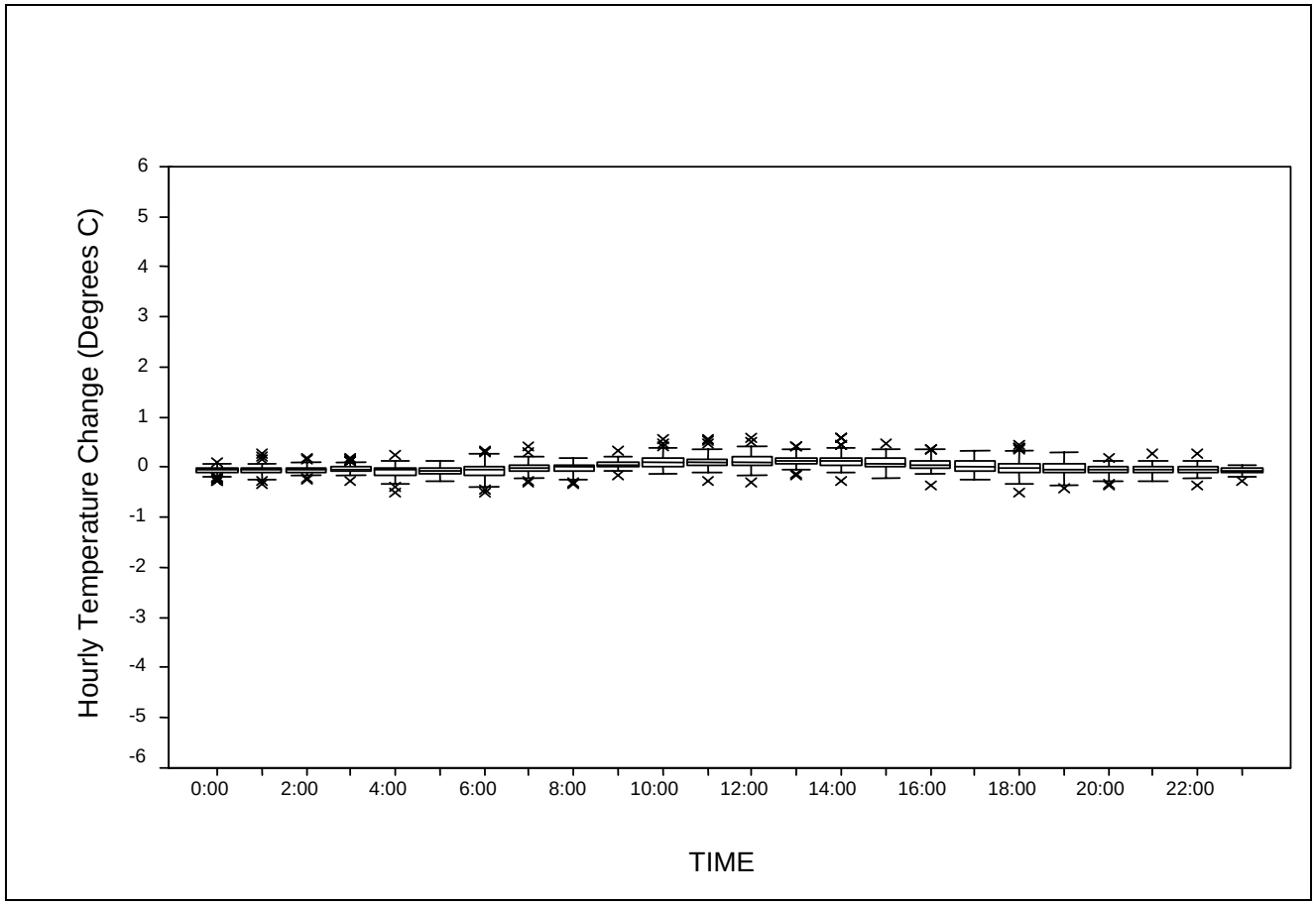

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FIGURE C-62C: ANALYSIS ZONE 1 – ELLICOTT CREEK (EC-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

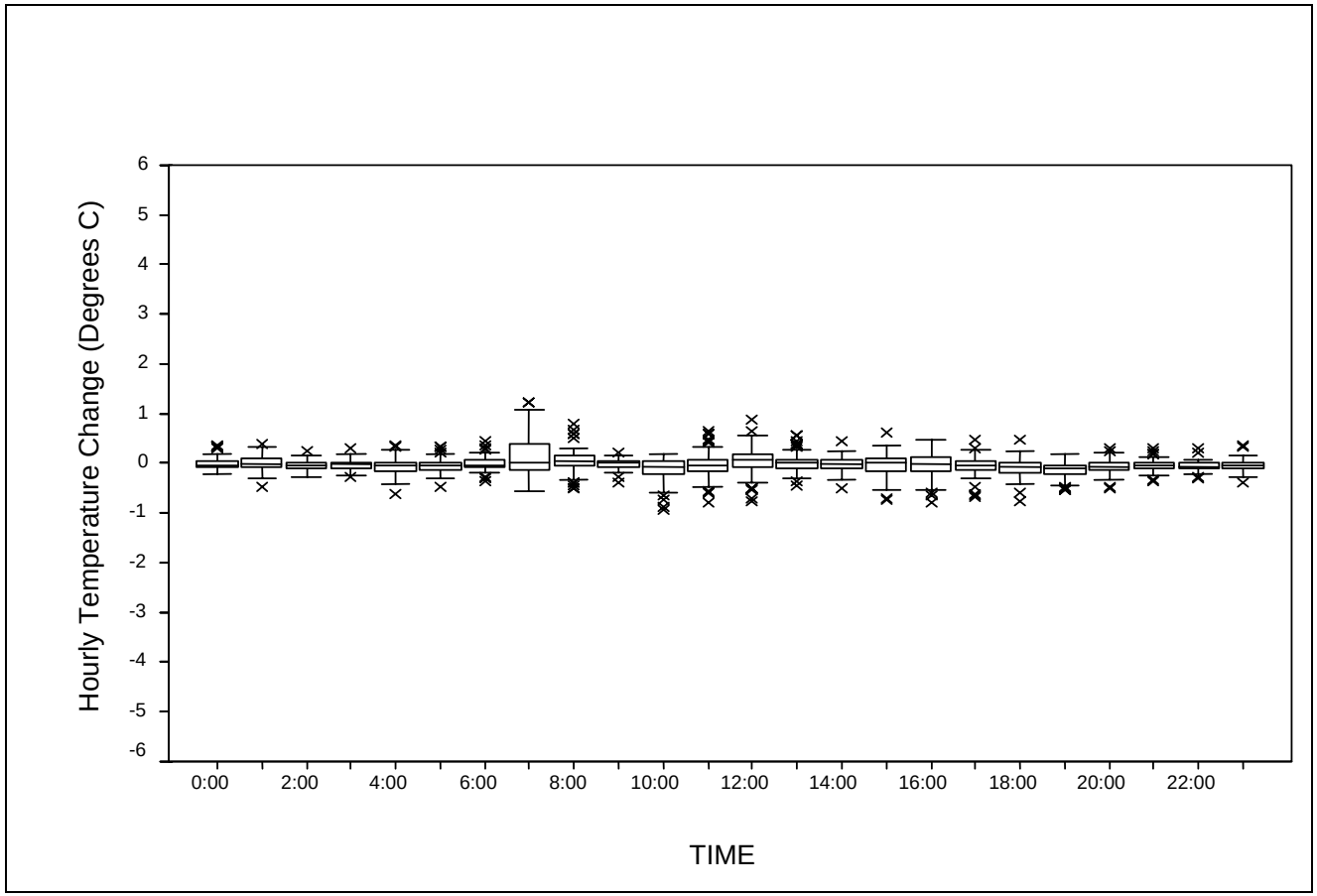

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FIGURE C-63: ANALYSIS ZONE 1 – ELLICOTT CREEK (EC-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

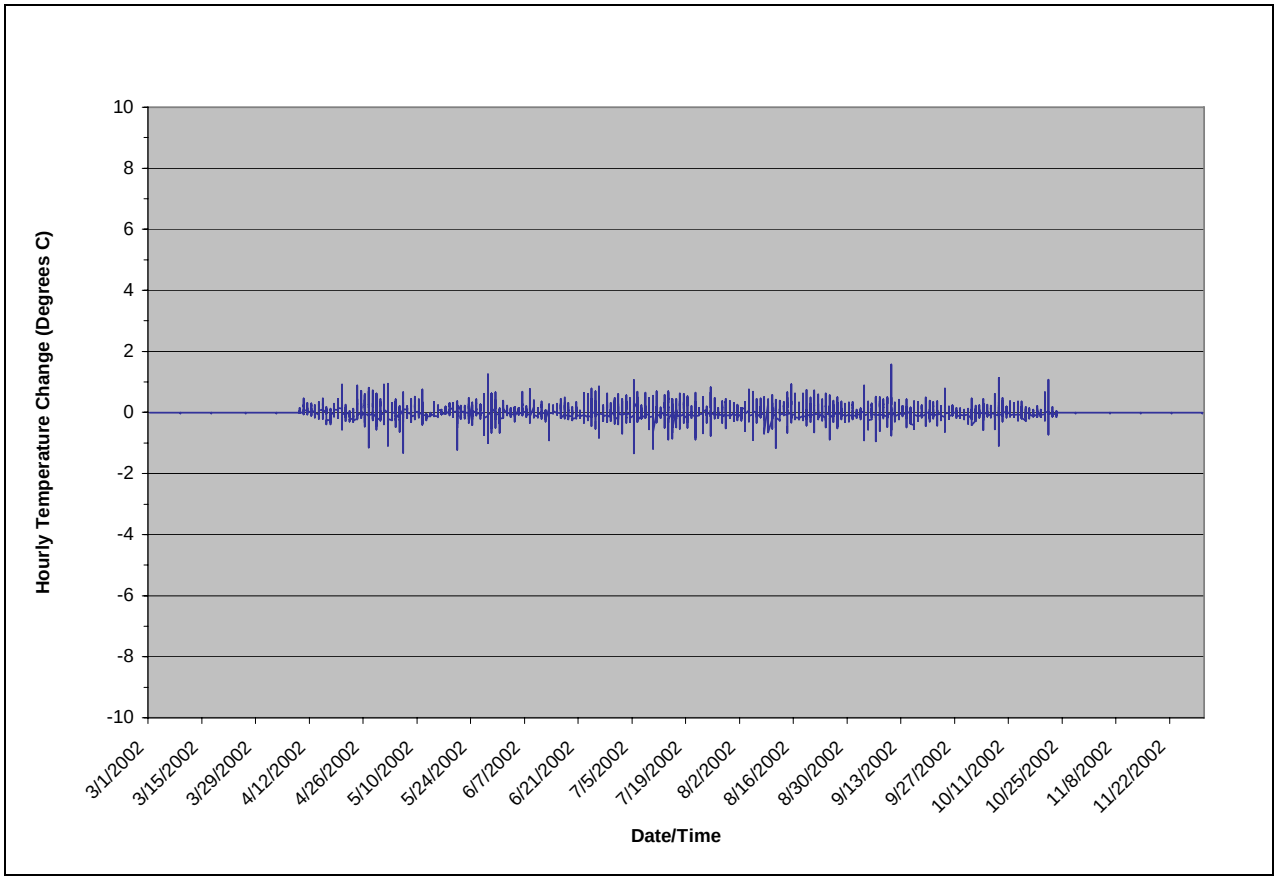

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FIGURE C-64A: ANALYSIS ZONE 1 – ELLICOTT CREEK (EC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

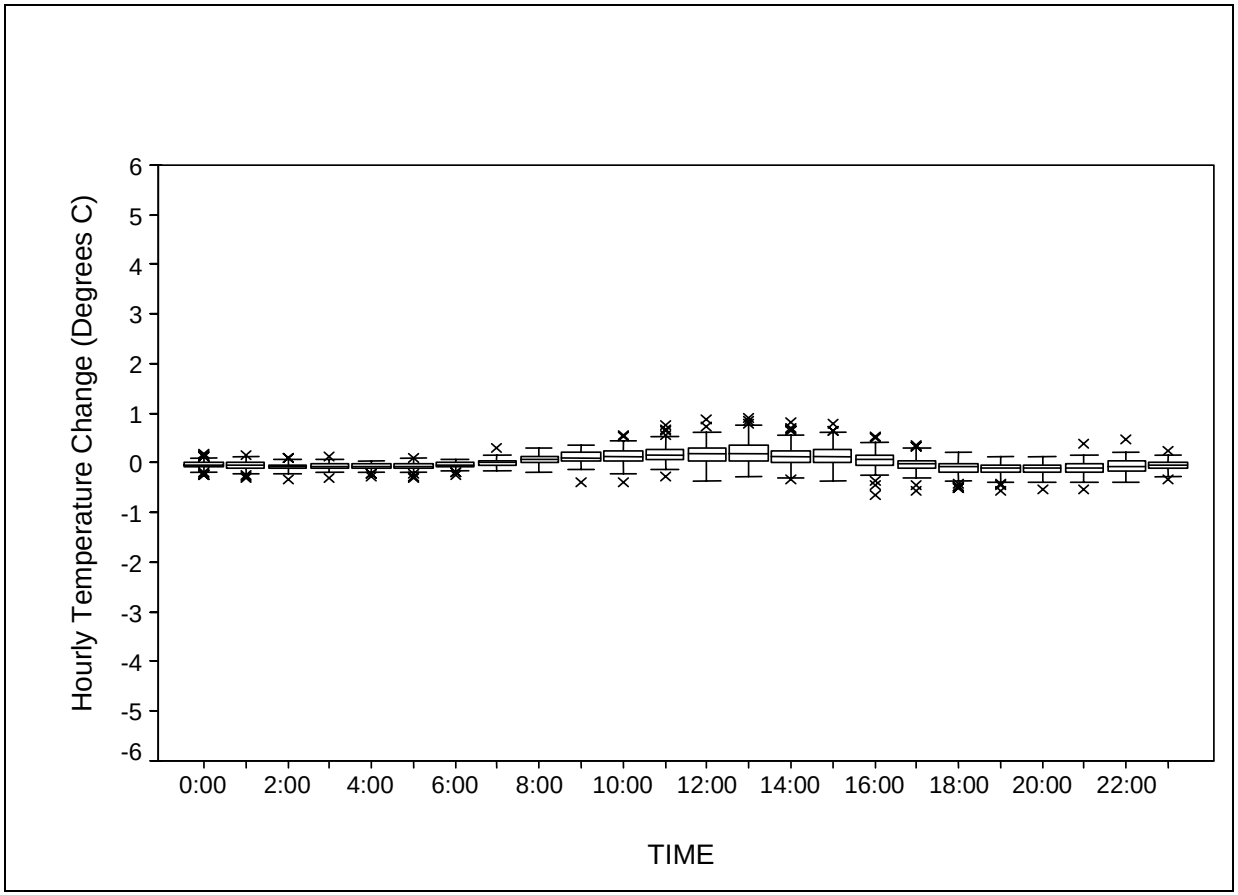

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FIGURE C-64B: ANALYSIS ZONE 1 – ELLICOTT CREEK (EC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

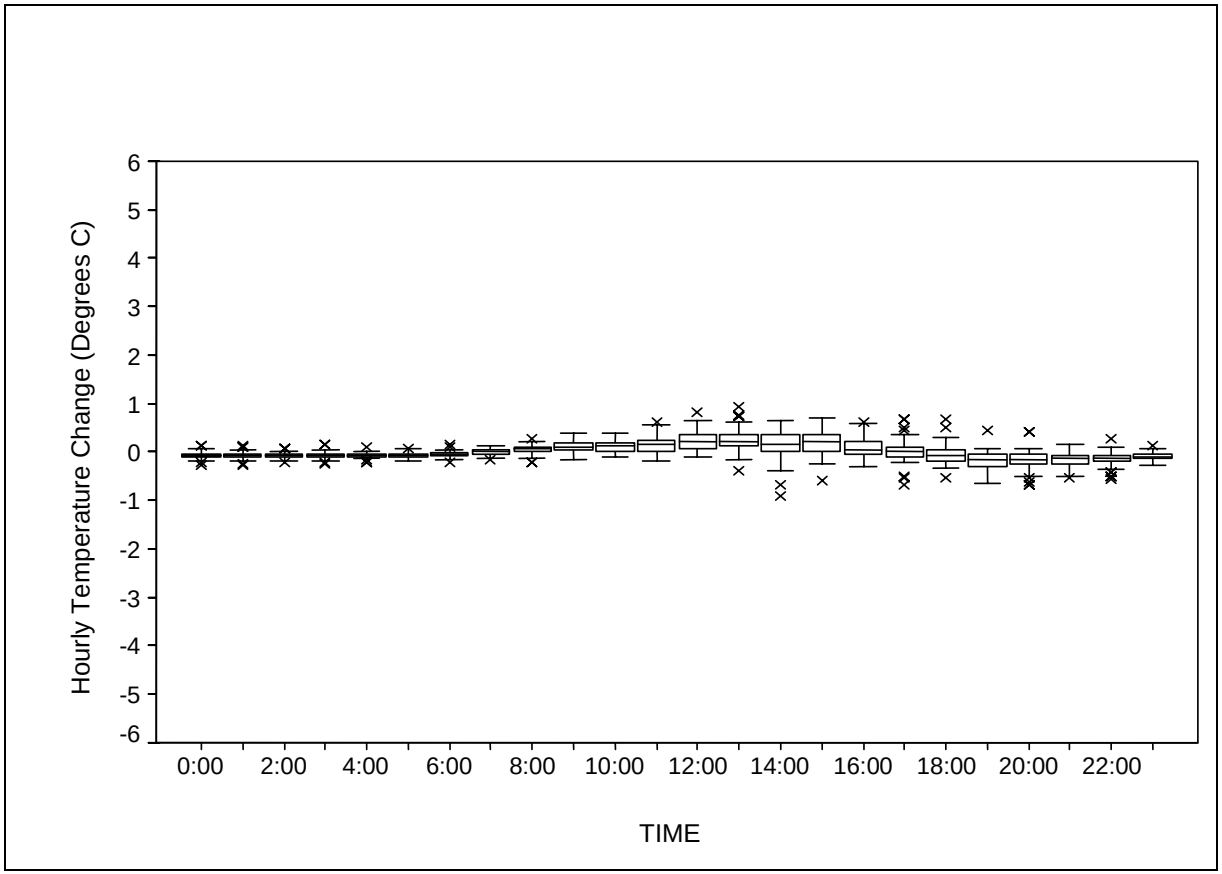

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FIGURE C-64C: ANALYSIS ZONE 1 – ELLICOTT CREEK (EC-02)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

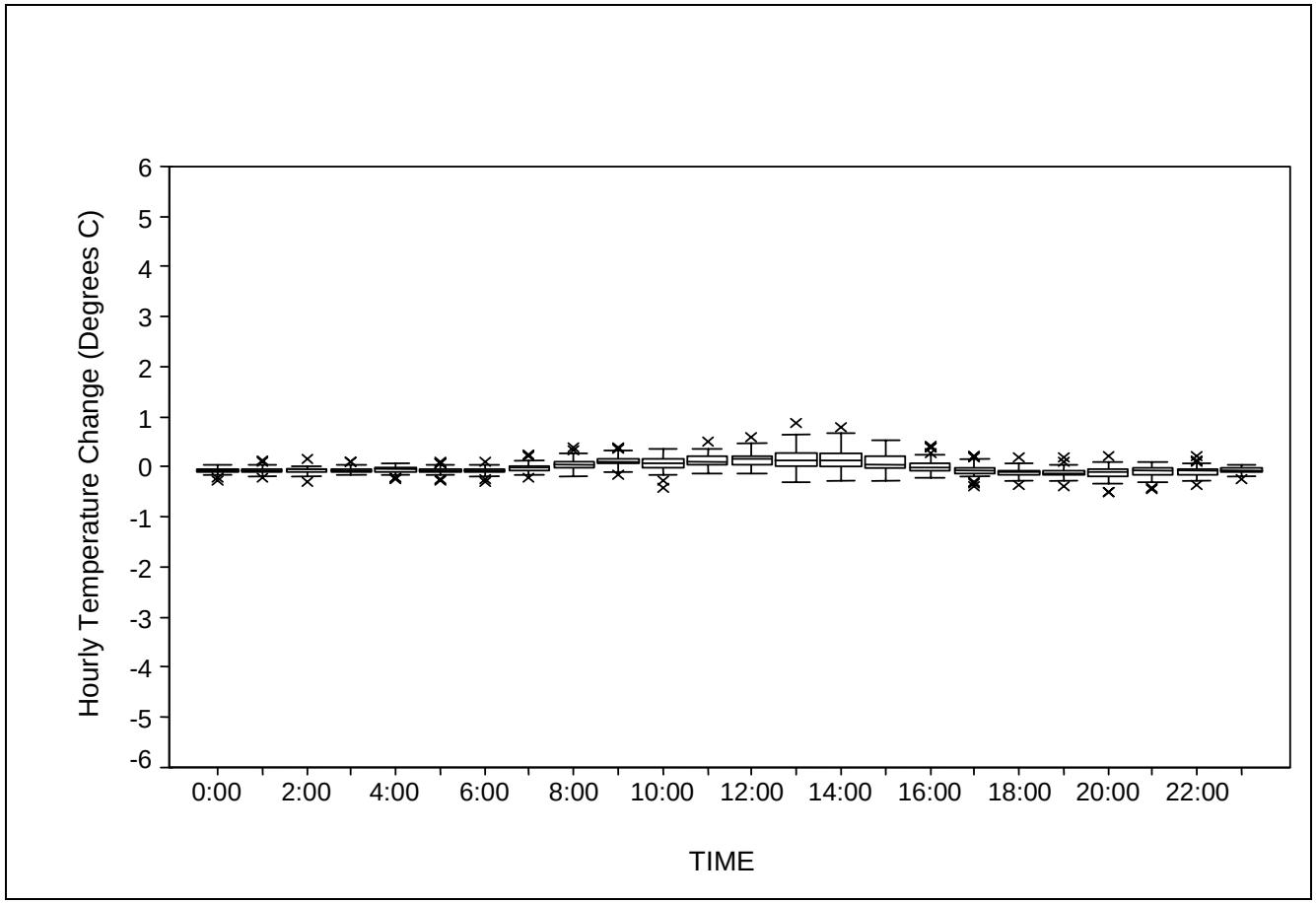

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FIGURE C-65: ANALYSIS ZONE 1 – ELLICOTT CREEK (EC-03)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

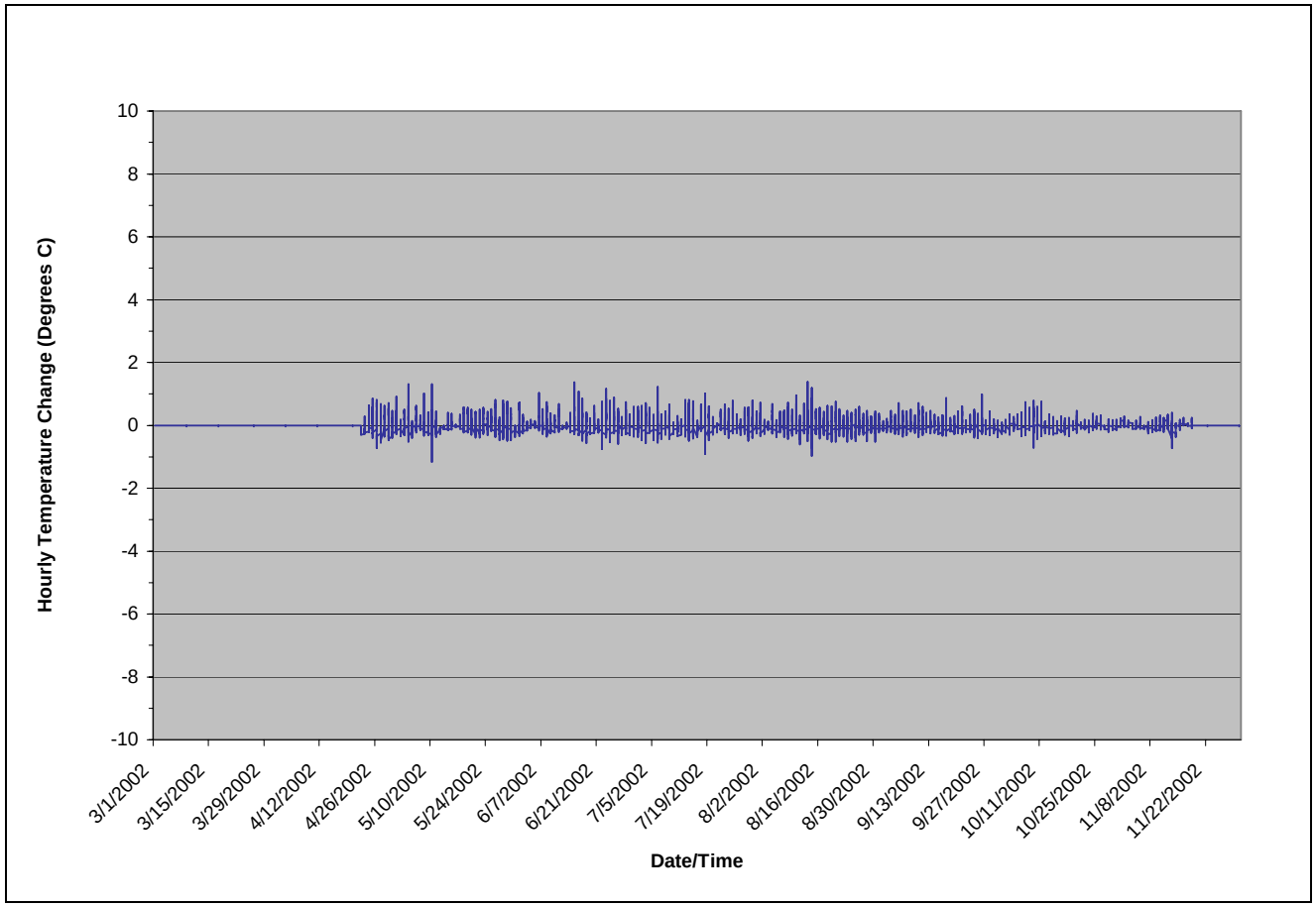

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FIGURE C-66: ANALYSIS ZONE 1 – TONAWANDA CREEK (TC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

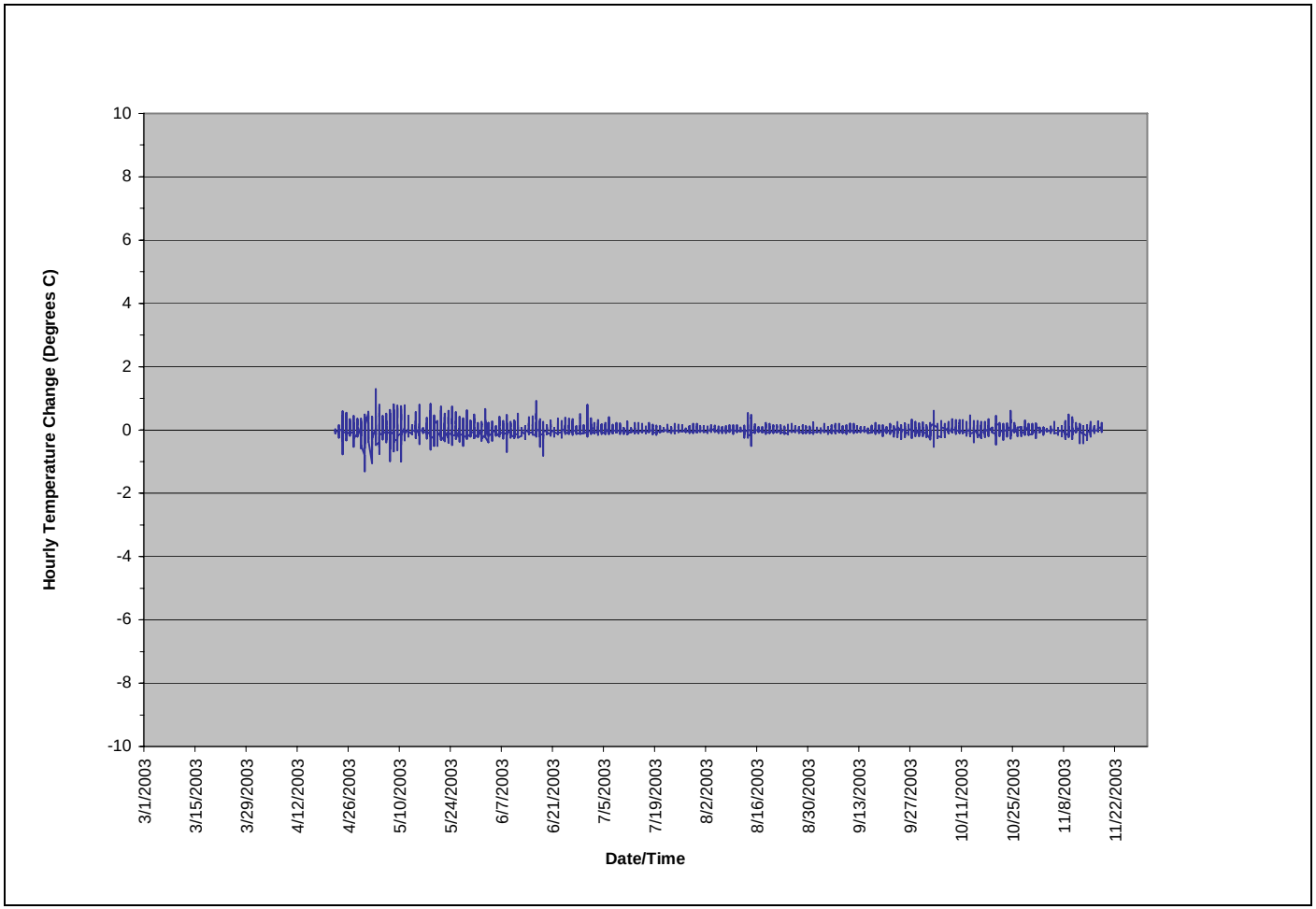

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FIGURE C-67: ANALYSIS ZONE 1 – FISH CREEK (TFC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

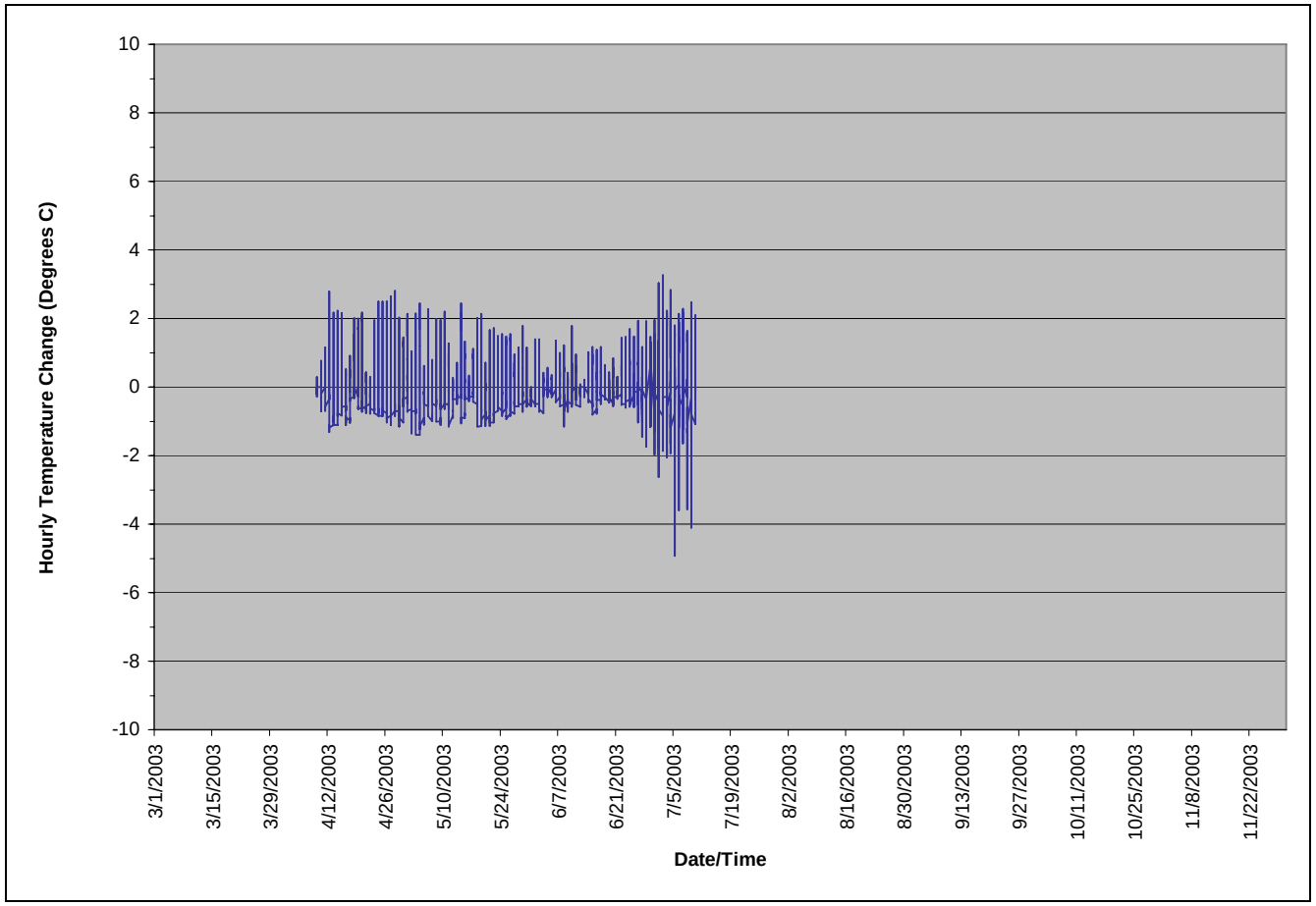

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FIGURE C-68: ANALYSIS ZONE 1 – FISH CREEK (TFC-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

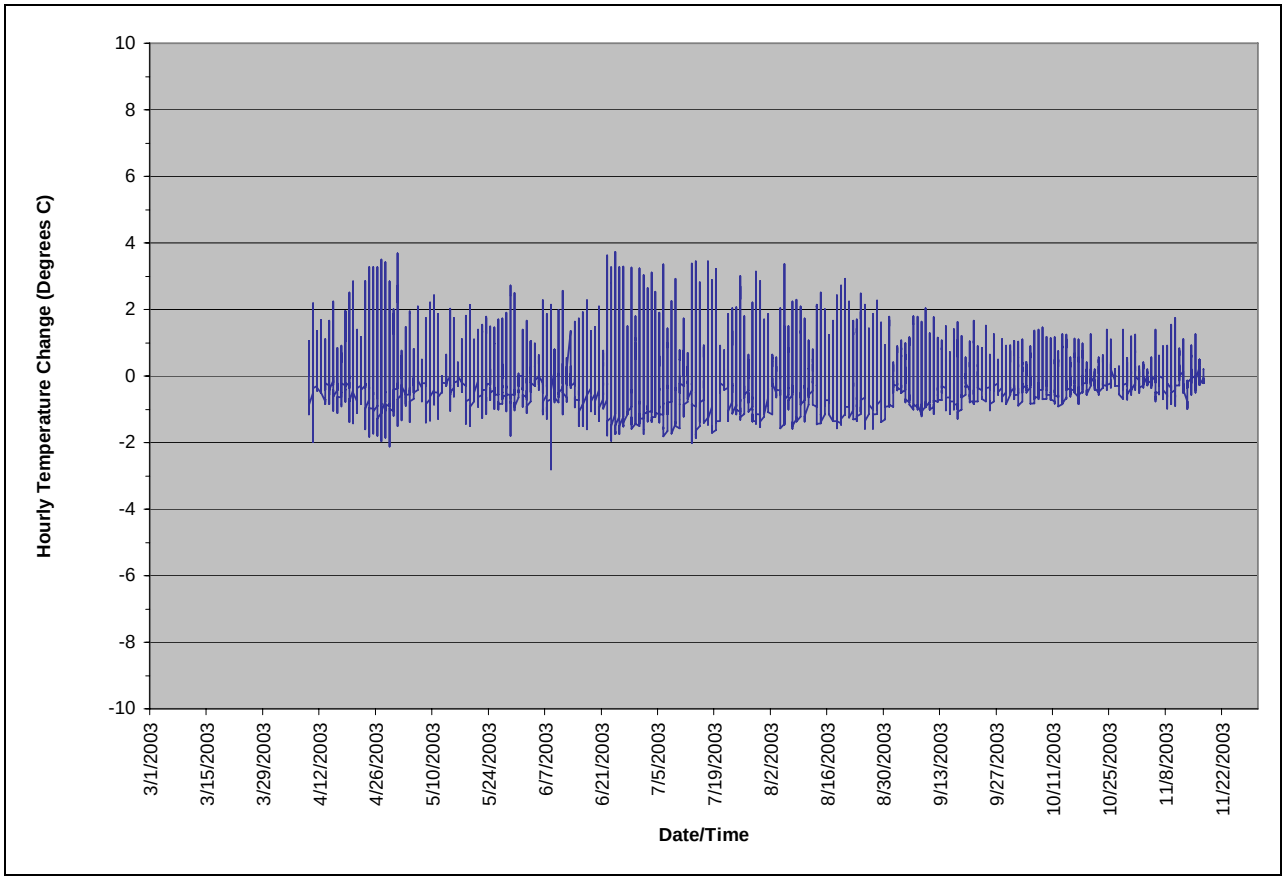

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FIGURE C-69: ANALYSIS ZONE 1 – GILL CREEK (TGLC-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

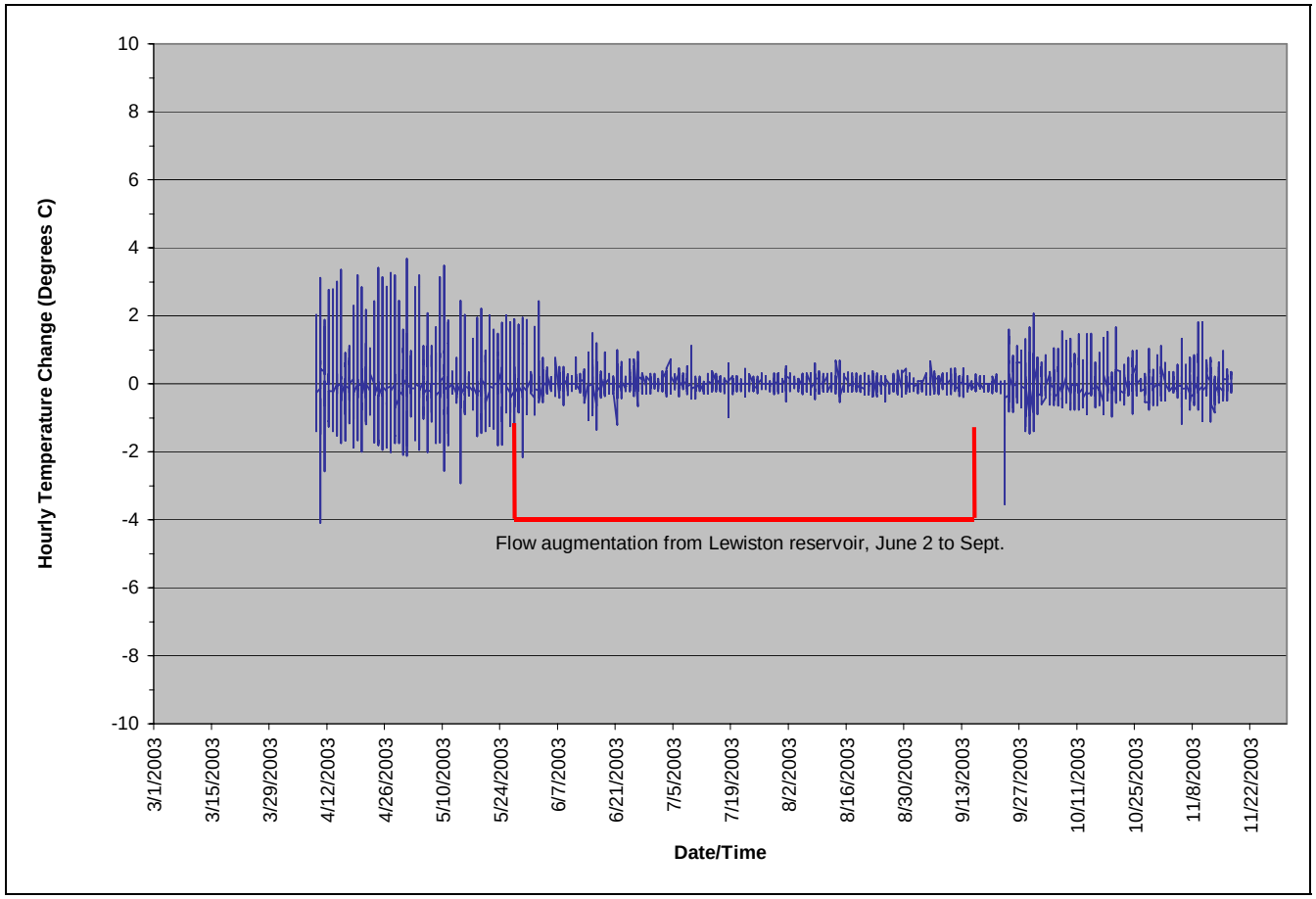

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FIGURE C-70: ANALYSIS ZONE 1 – GILL CREEK (TGLC-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

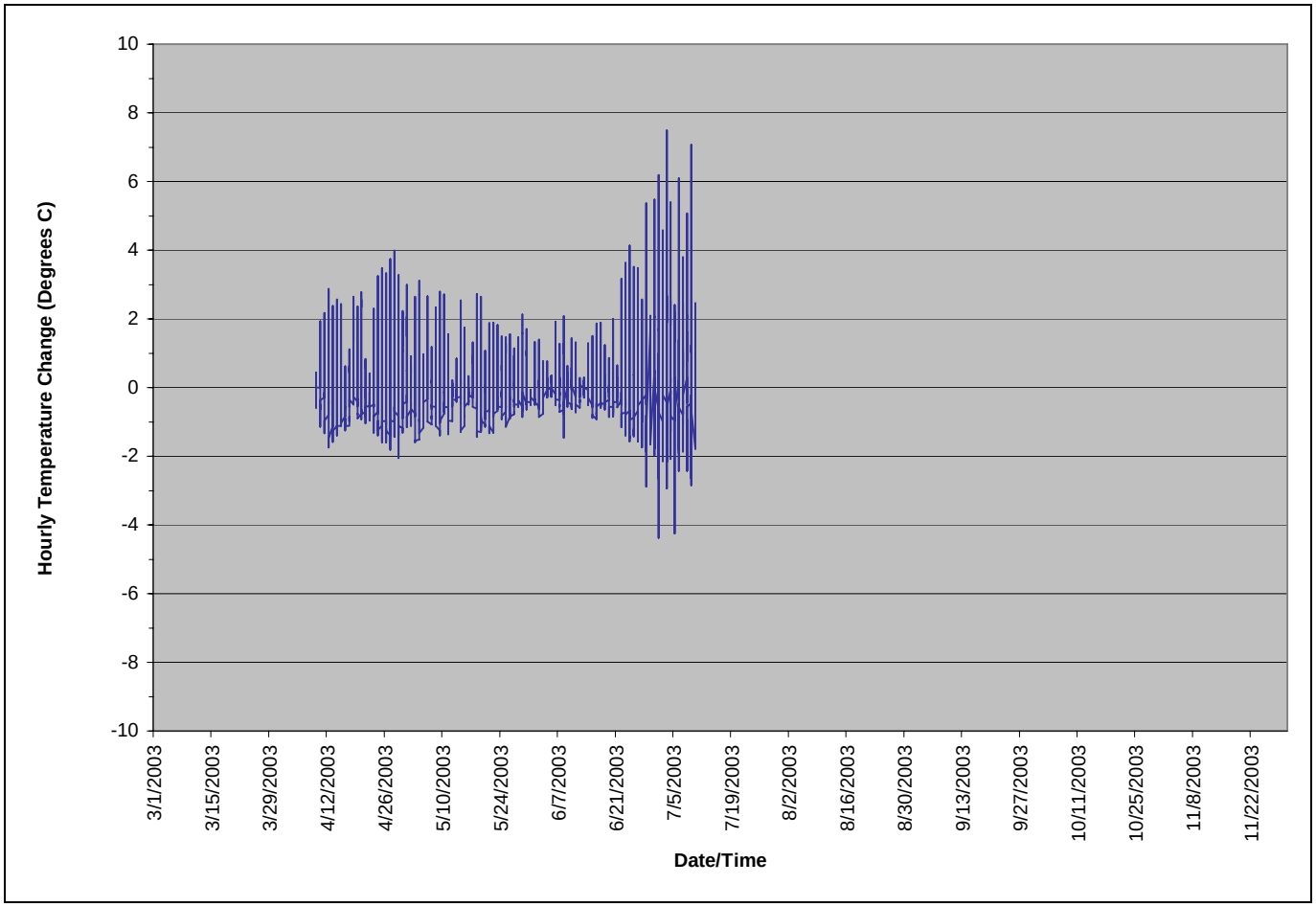

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FIGURE C-71: ANALYSIS ZONE 1 – GILL CREEK (TGLC-03)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

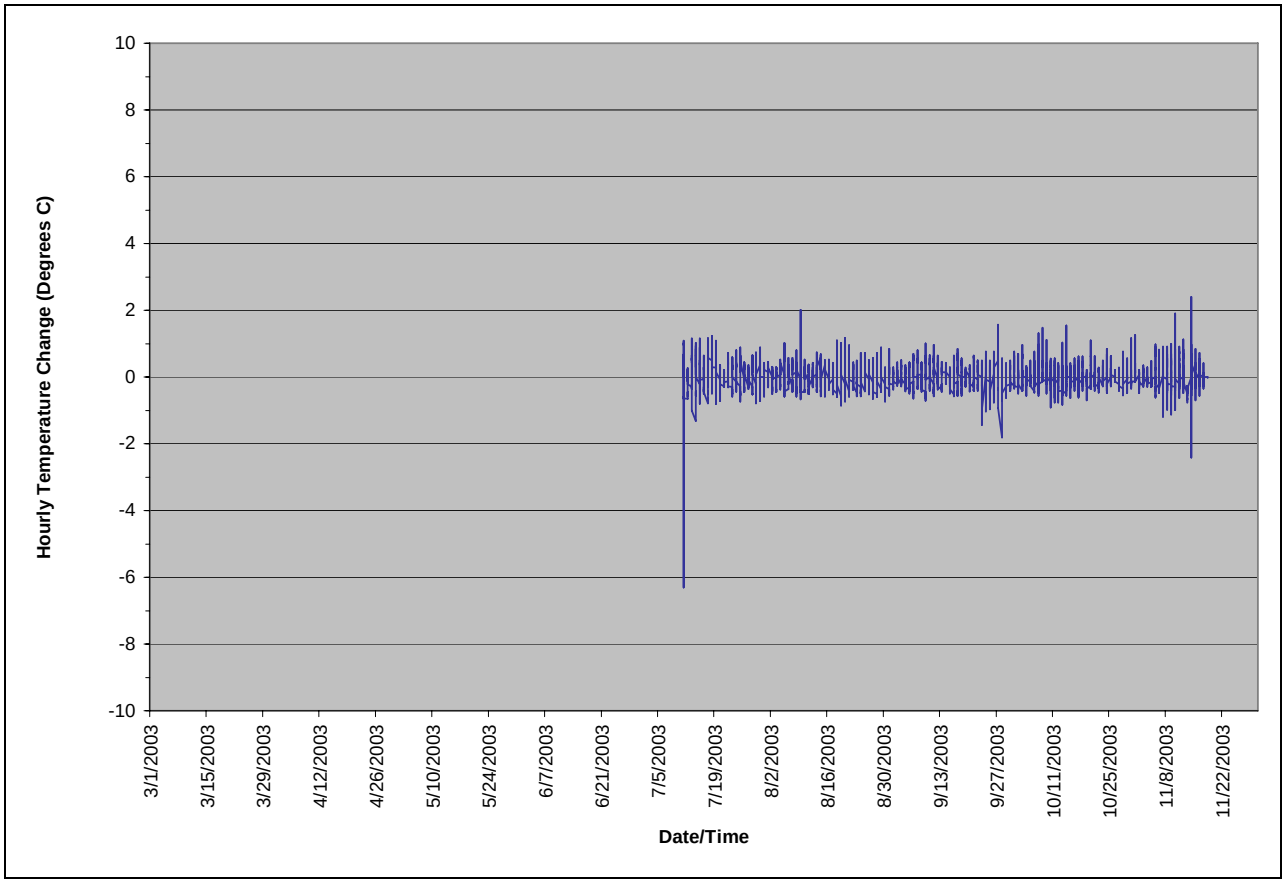

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FIGURE C-72: ANALYSIS ZONE 2 – UPPER NIAGARA RIVER (TM-17)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

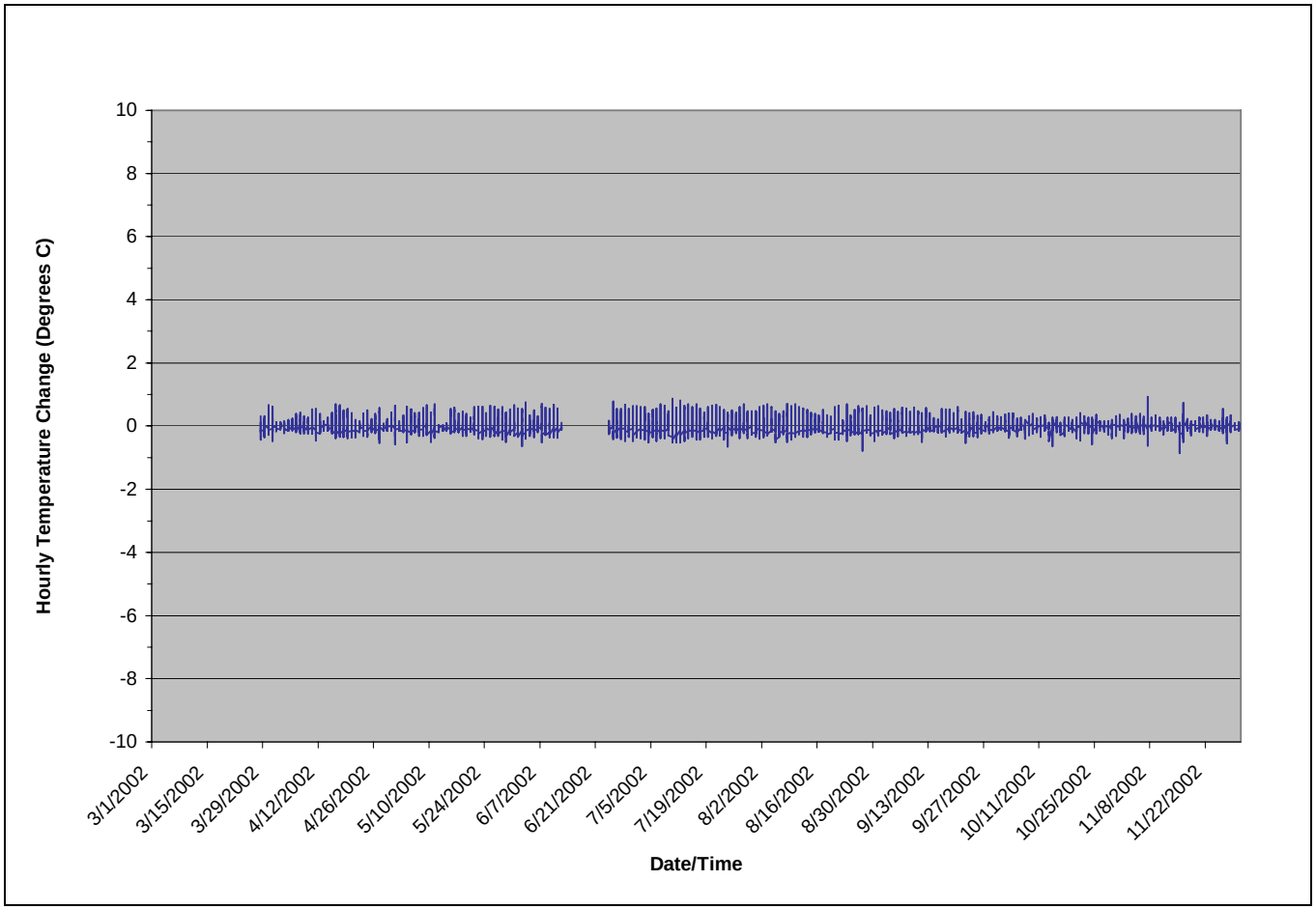

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FIGURE C-73: ANALYSIS ZONE 2 – UPPER NIAGARA RIVER (TUNR-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

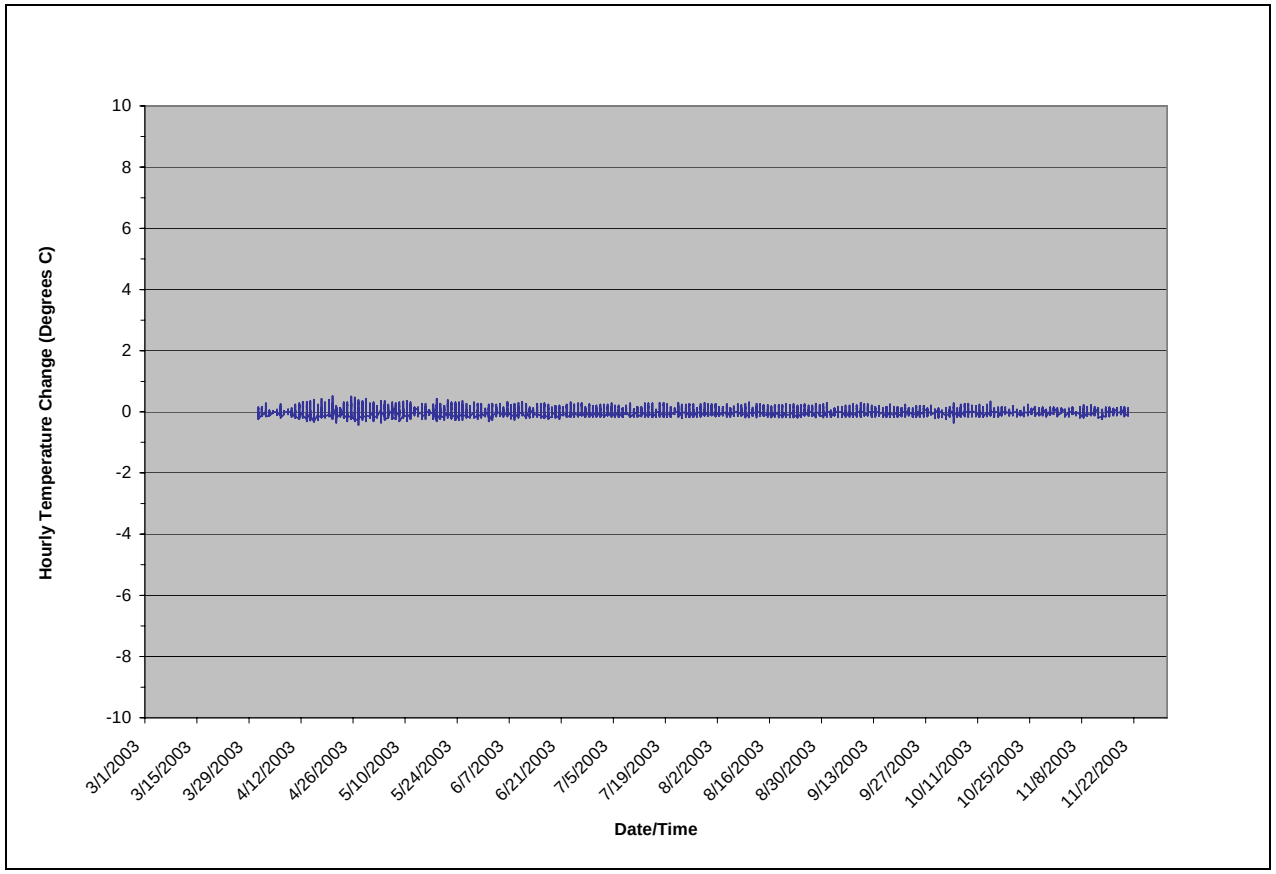

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FIGURE C-74: ANALYSIS ZONE 2 – UPPER NIAGARA RIVER (TUNR-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

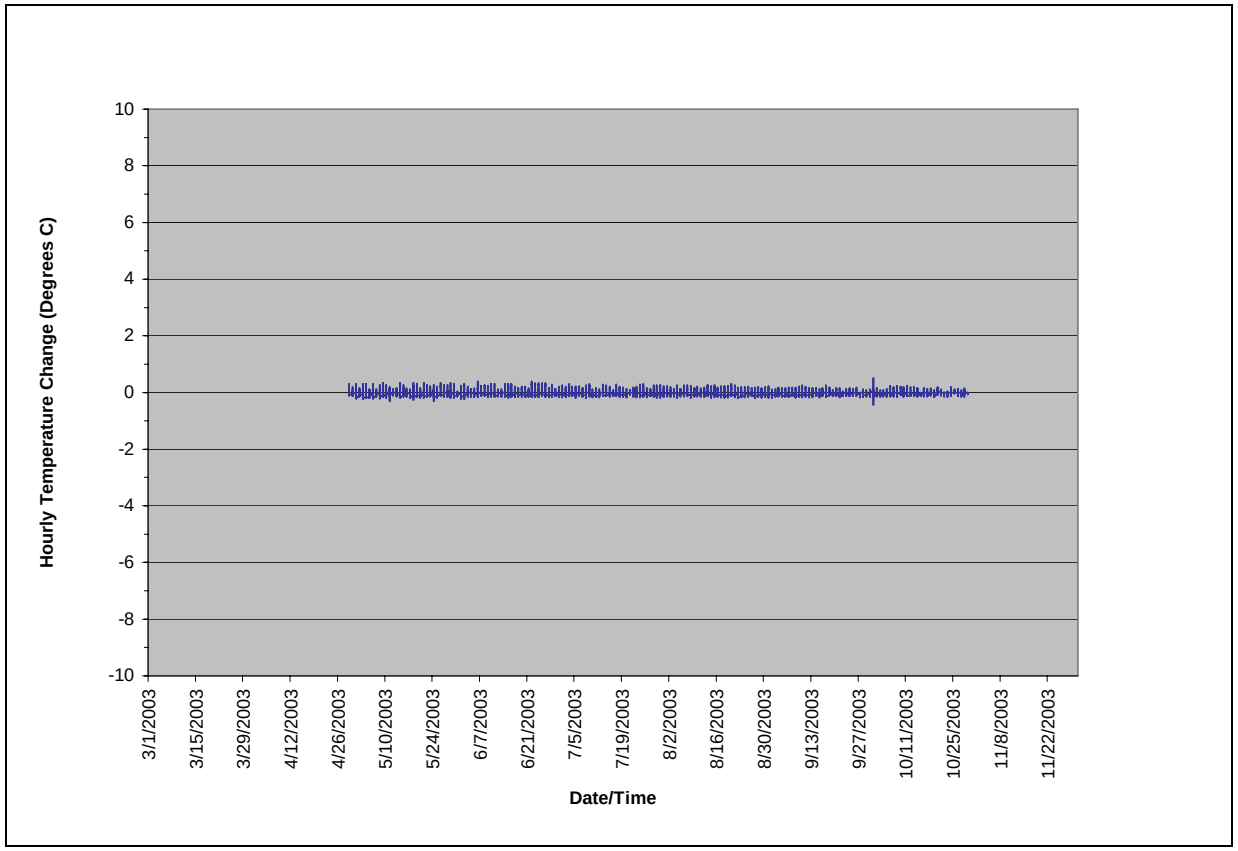

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FIGURE C-75: ANALYSIS ZONE 2 – UPPER NIAGARA RIVER (TUNR-03)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

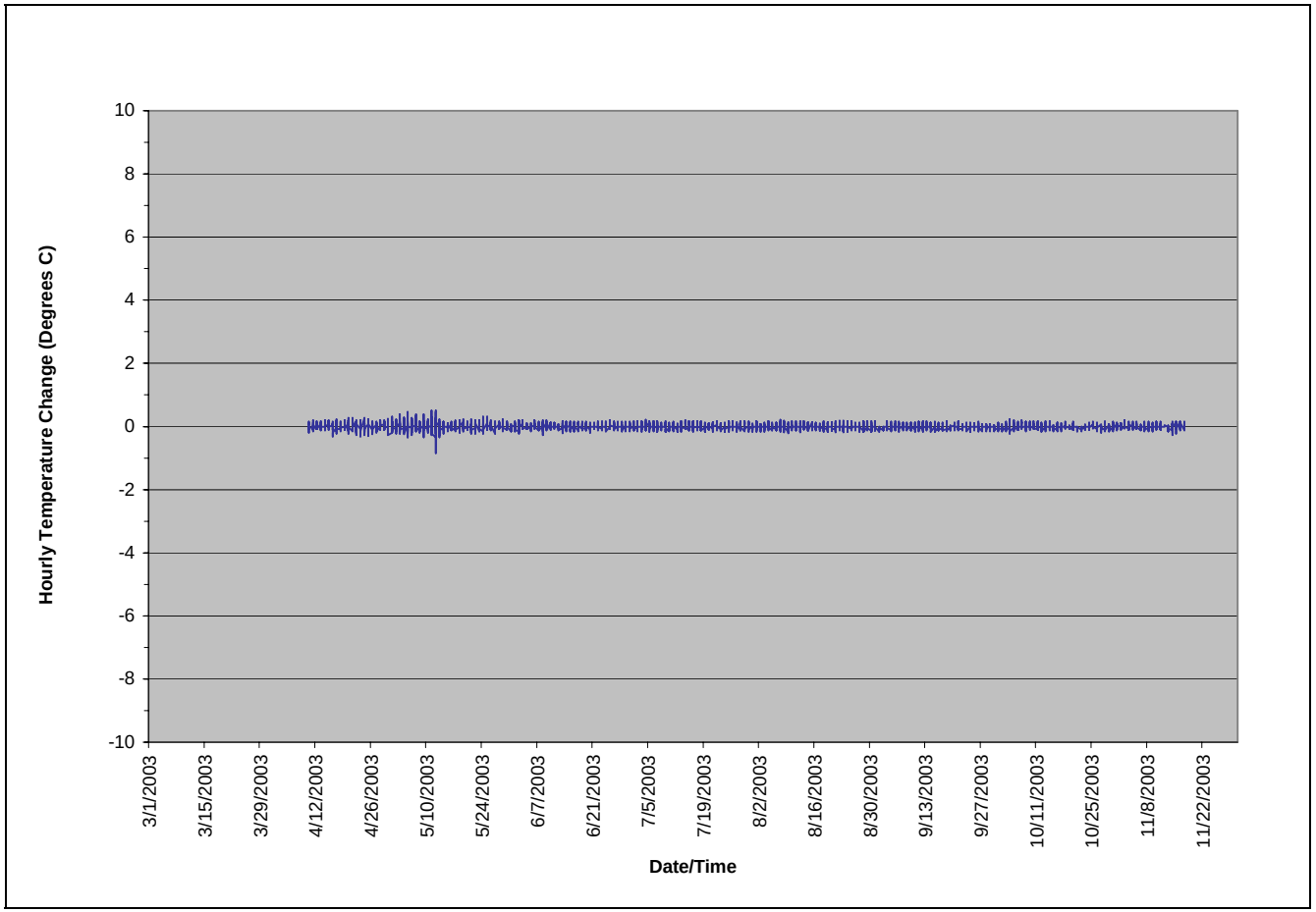

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FIGURE C-76: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-11)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

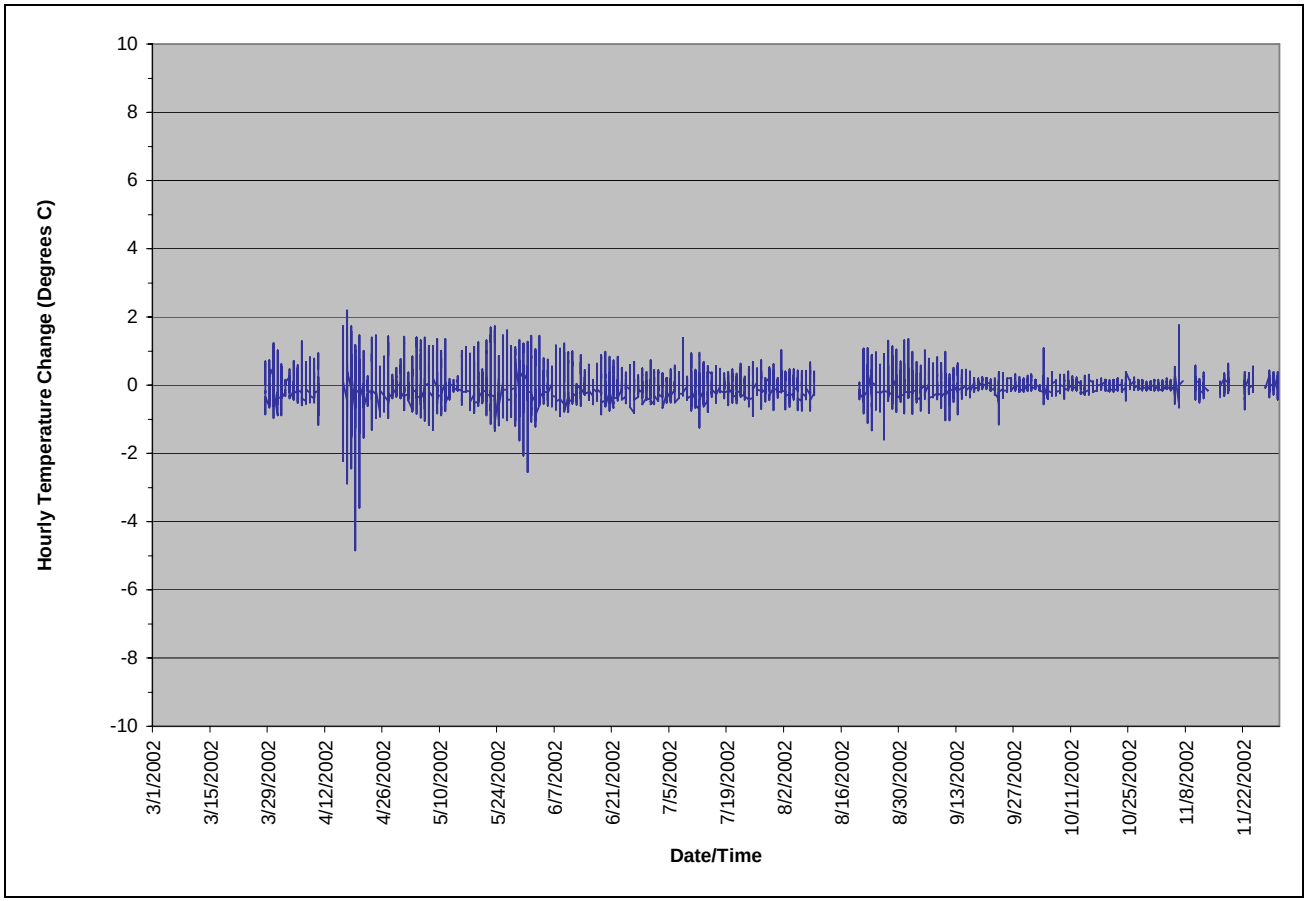

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FIGURE C-77A: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-11)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

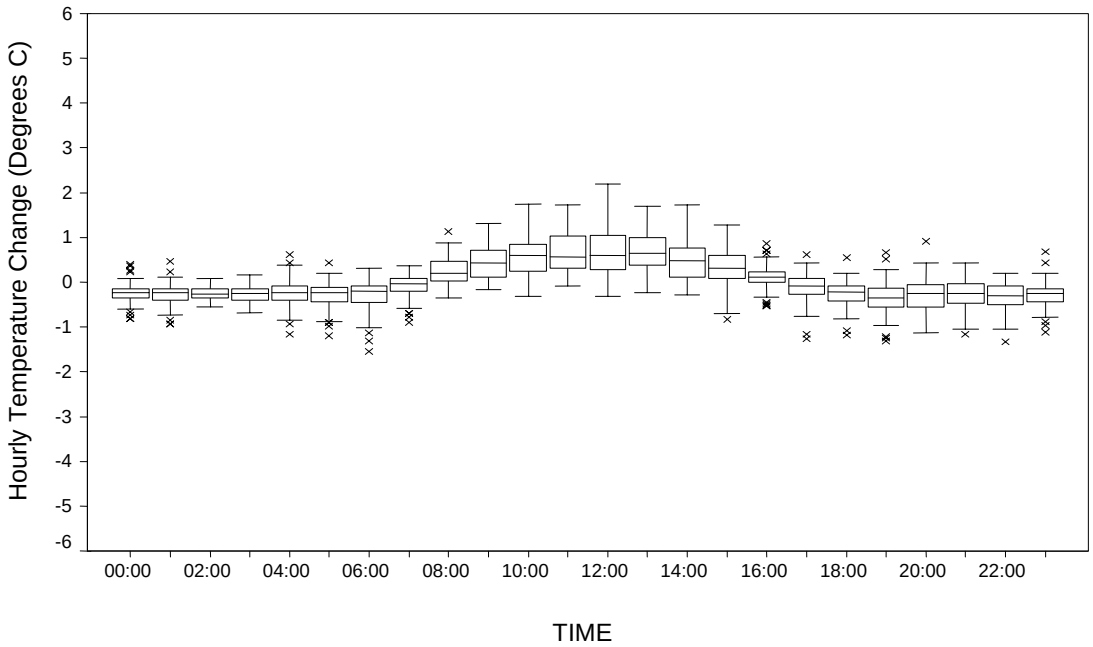

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FIGURE C-77B: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-11)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

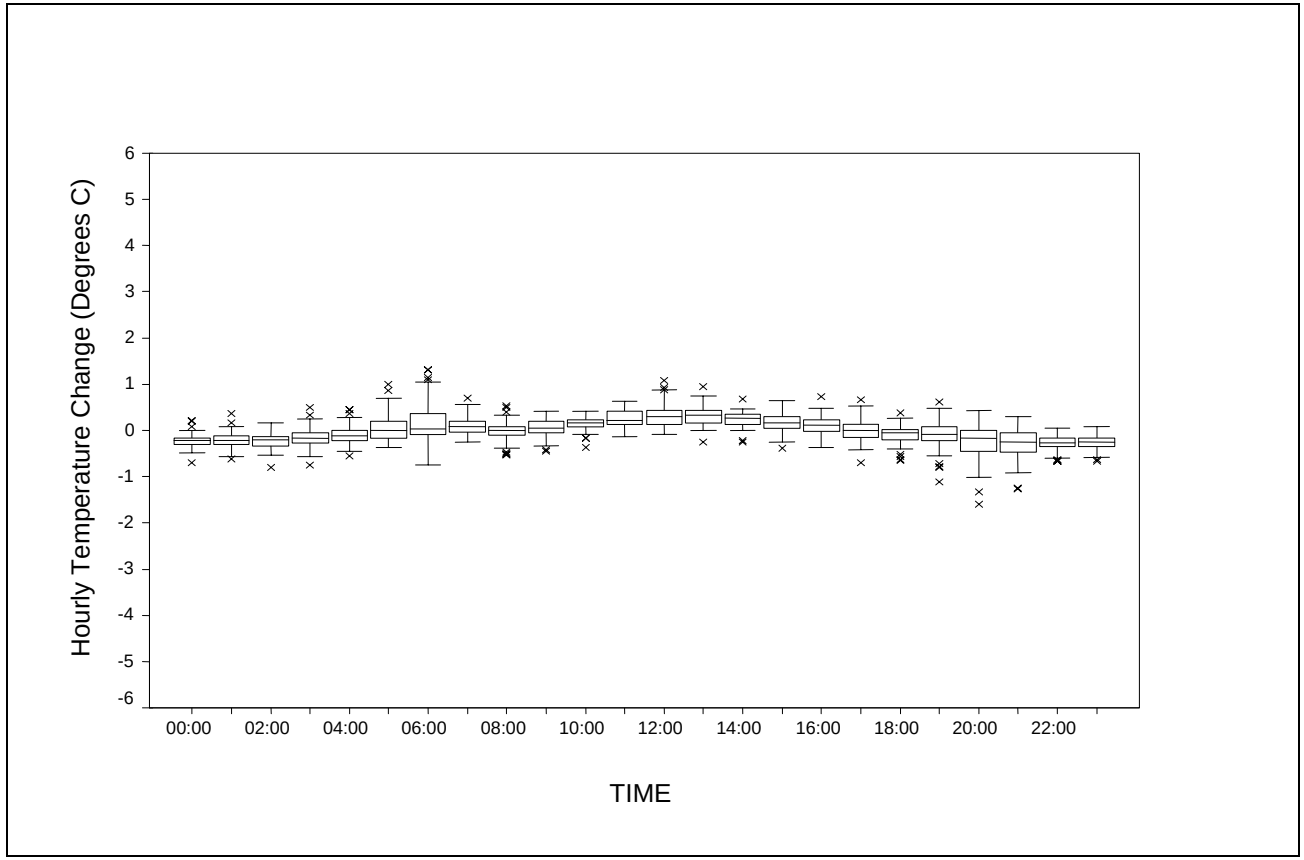

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FIGURE C-77C: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-11)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

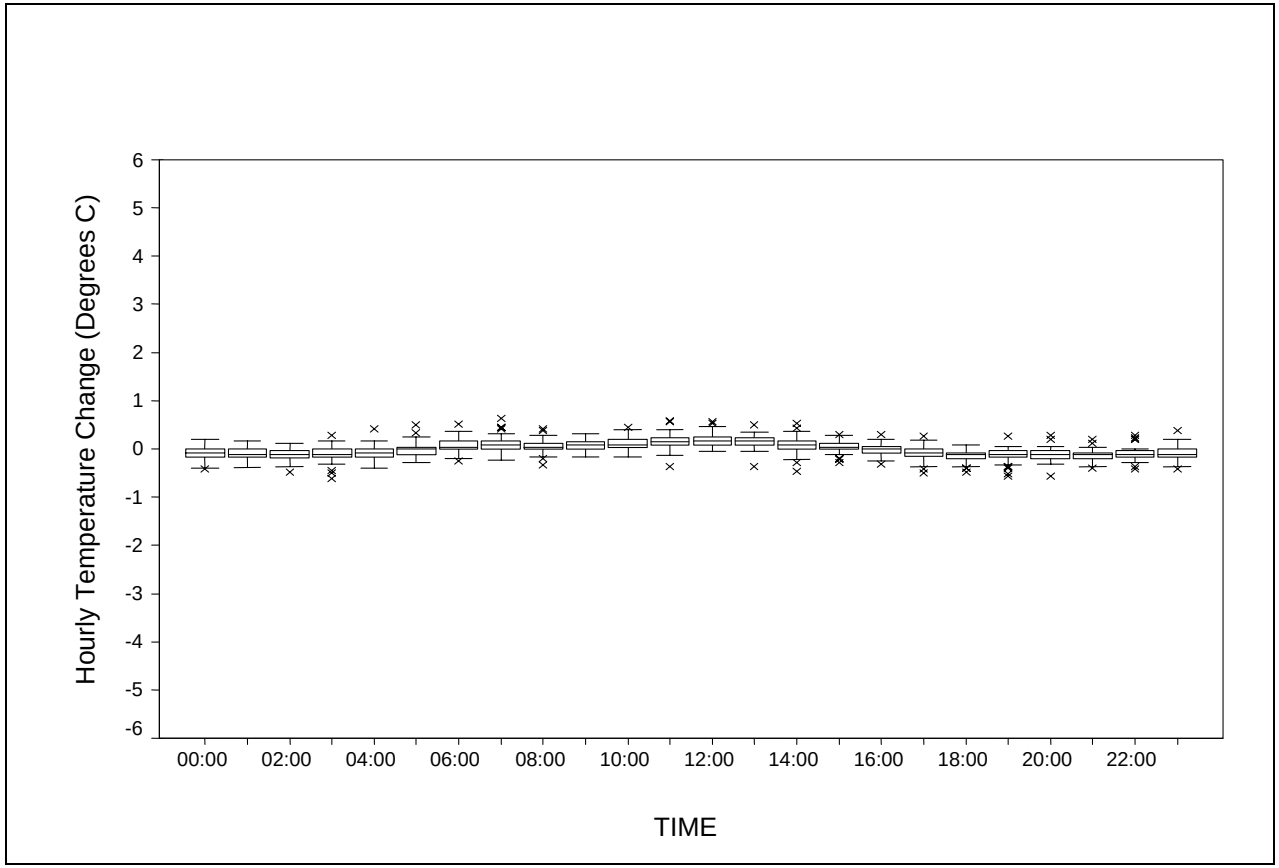

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FIGURE C-78: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-13)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

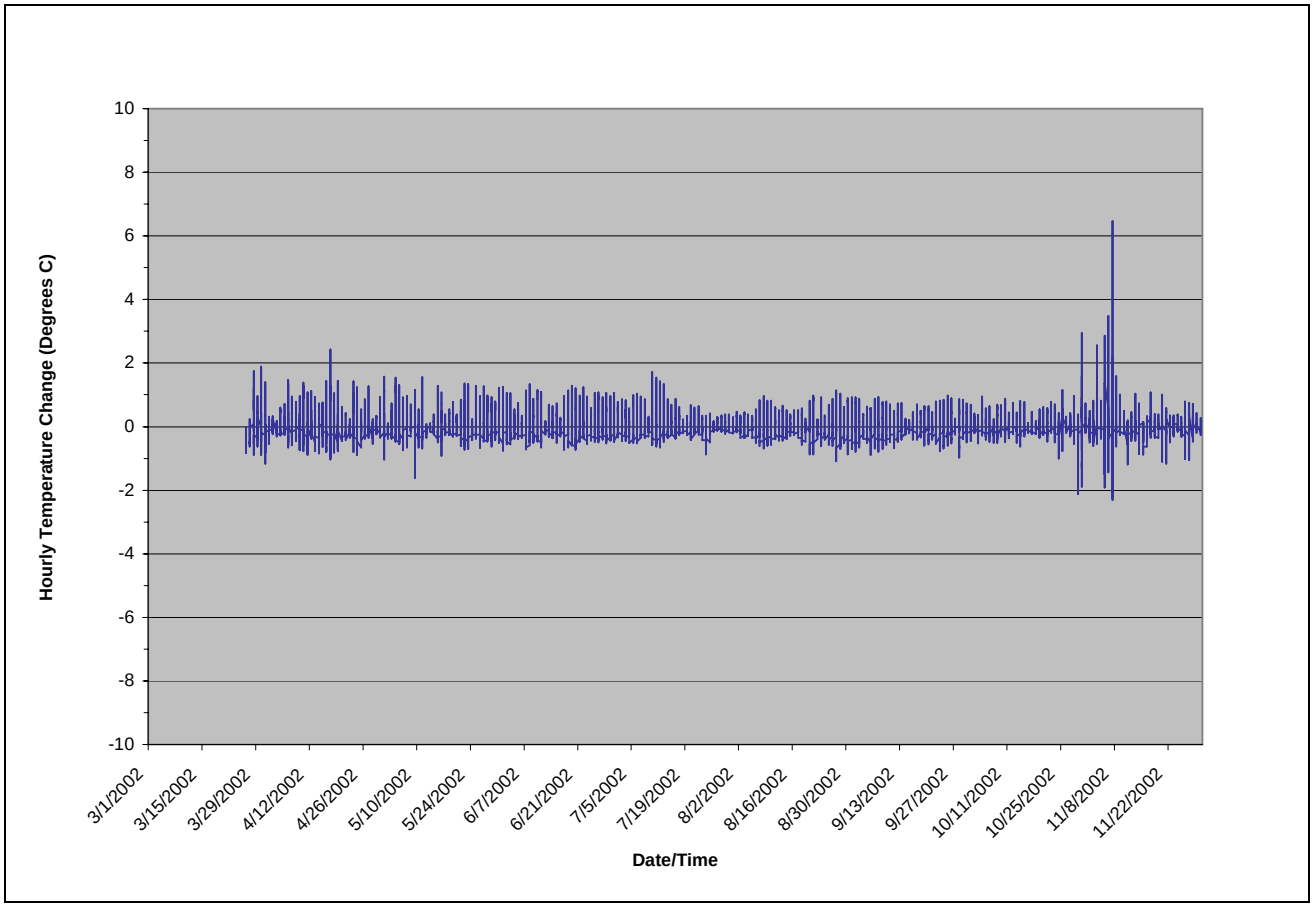

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FIGURE C-79: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-15)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

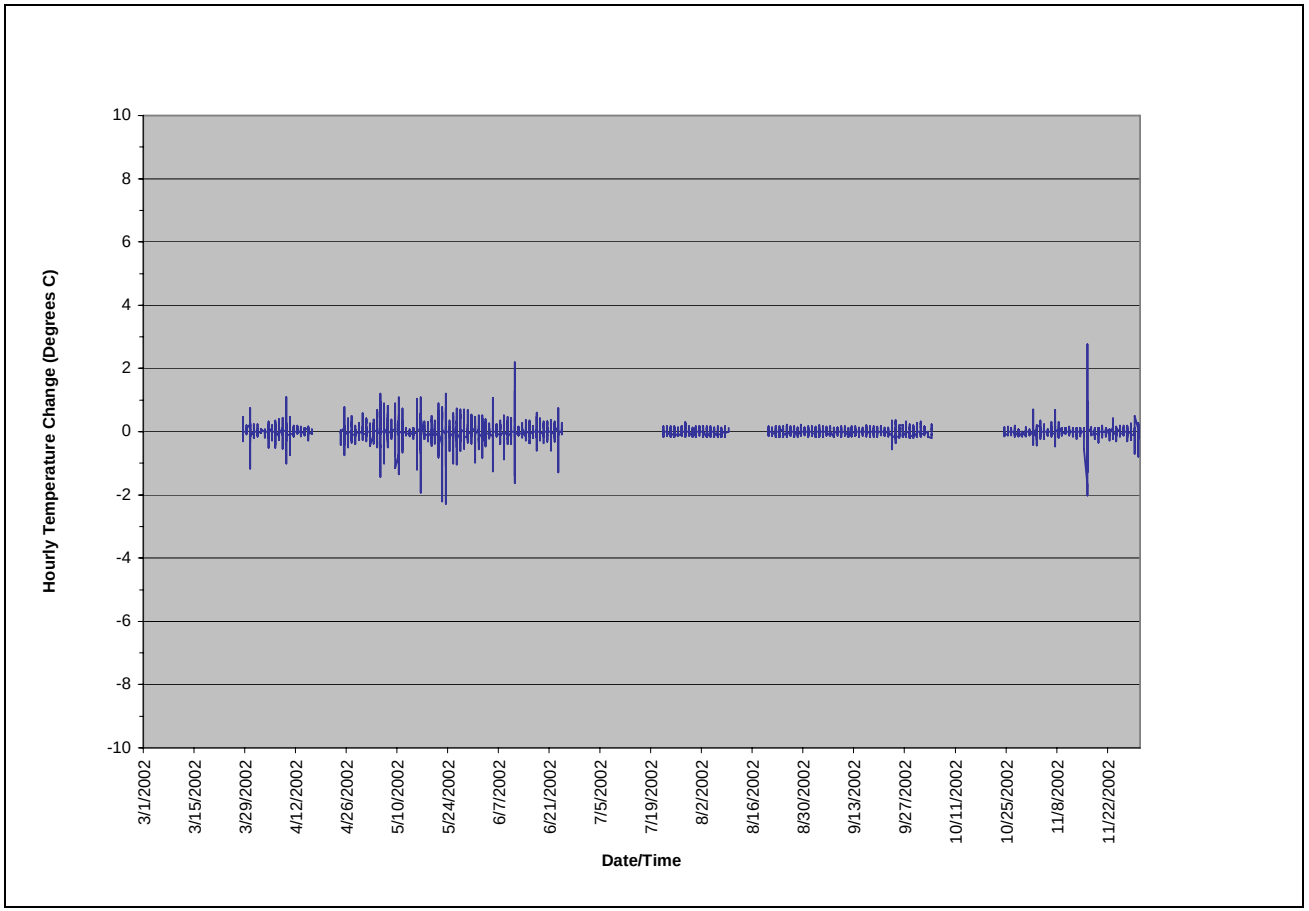

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FIGURE C-80A: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-15)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

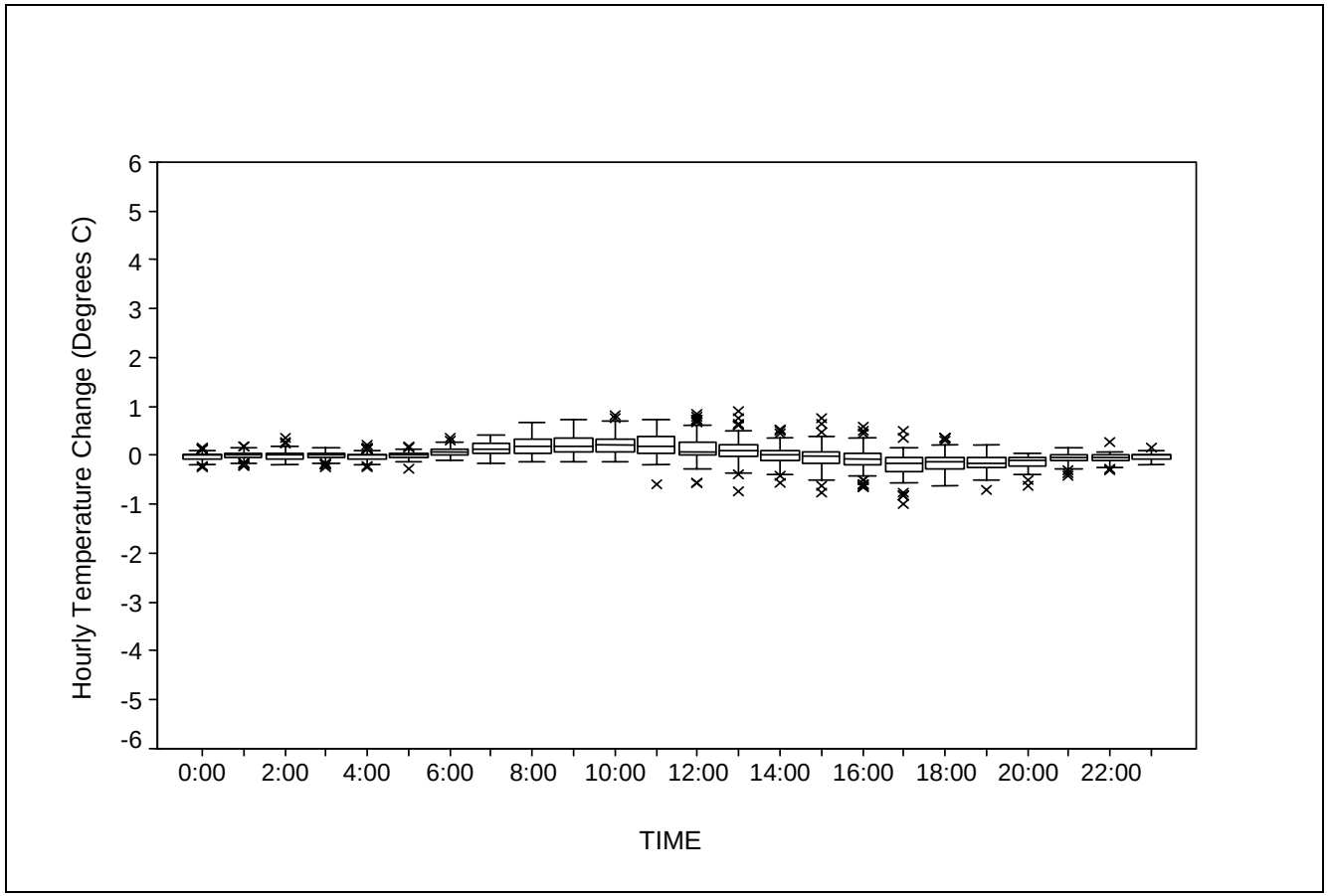

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FIGURE C-80B: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-15)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

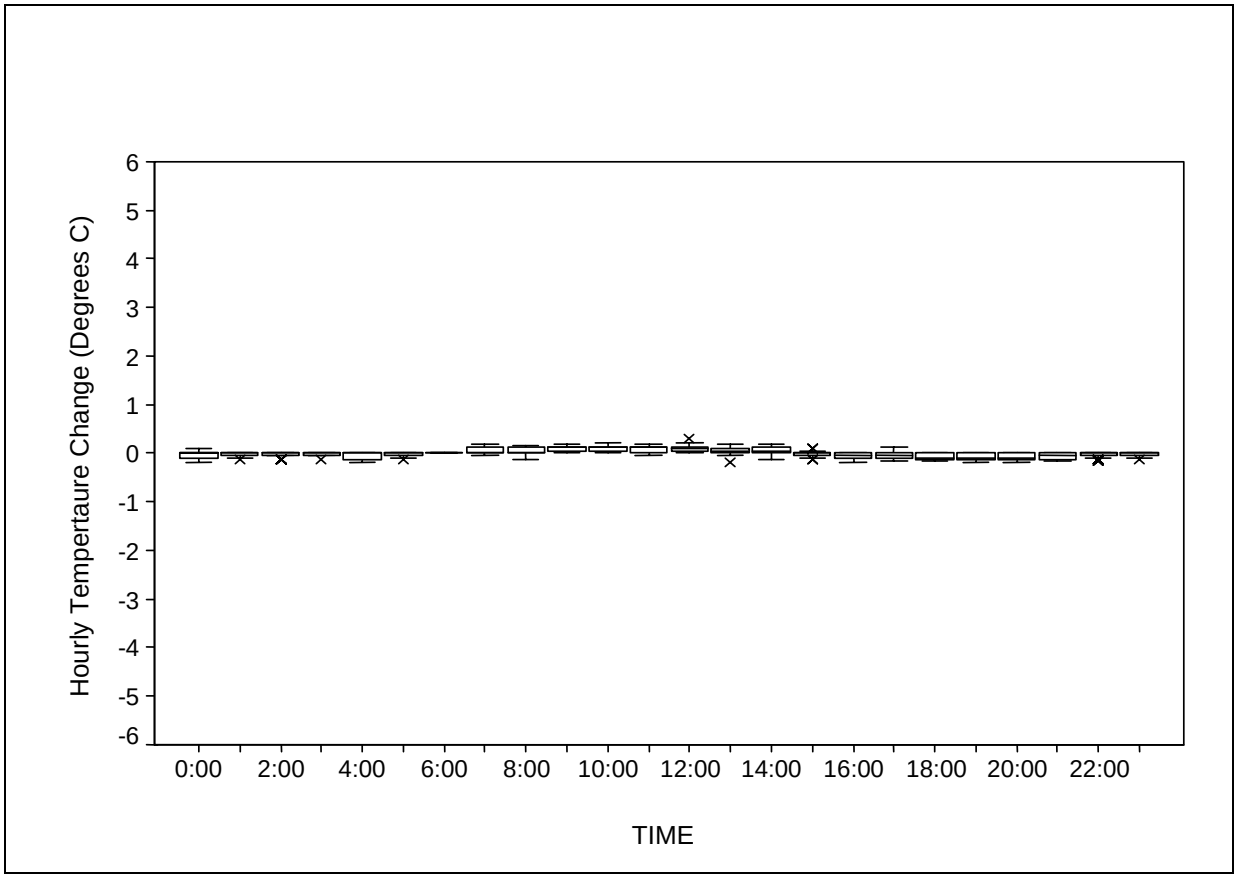

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FIGURE C-80C: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-15)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

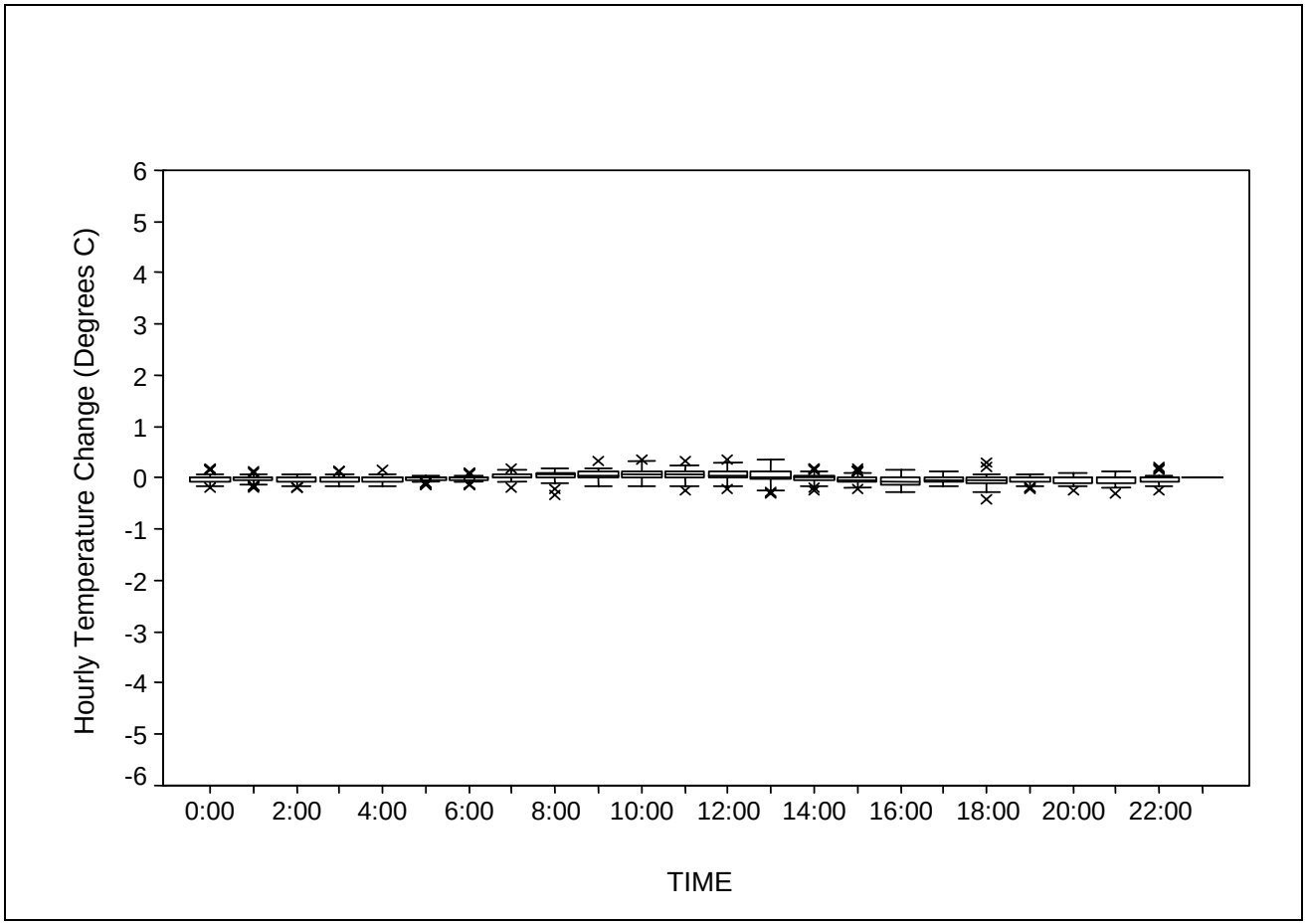

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FIGURE C-81: ANALYSIS ZONE 3 - UPPER NIAGARA RIVER (TM-16)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

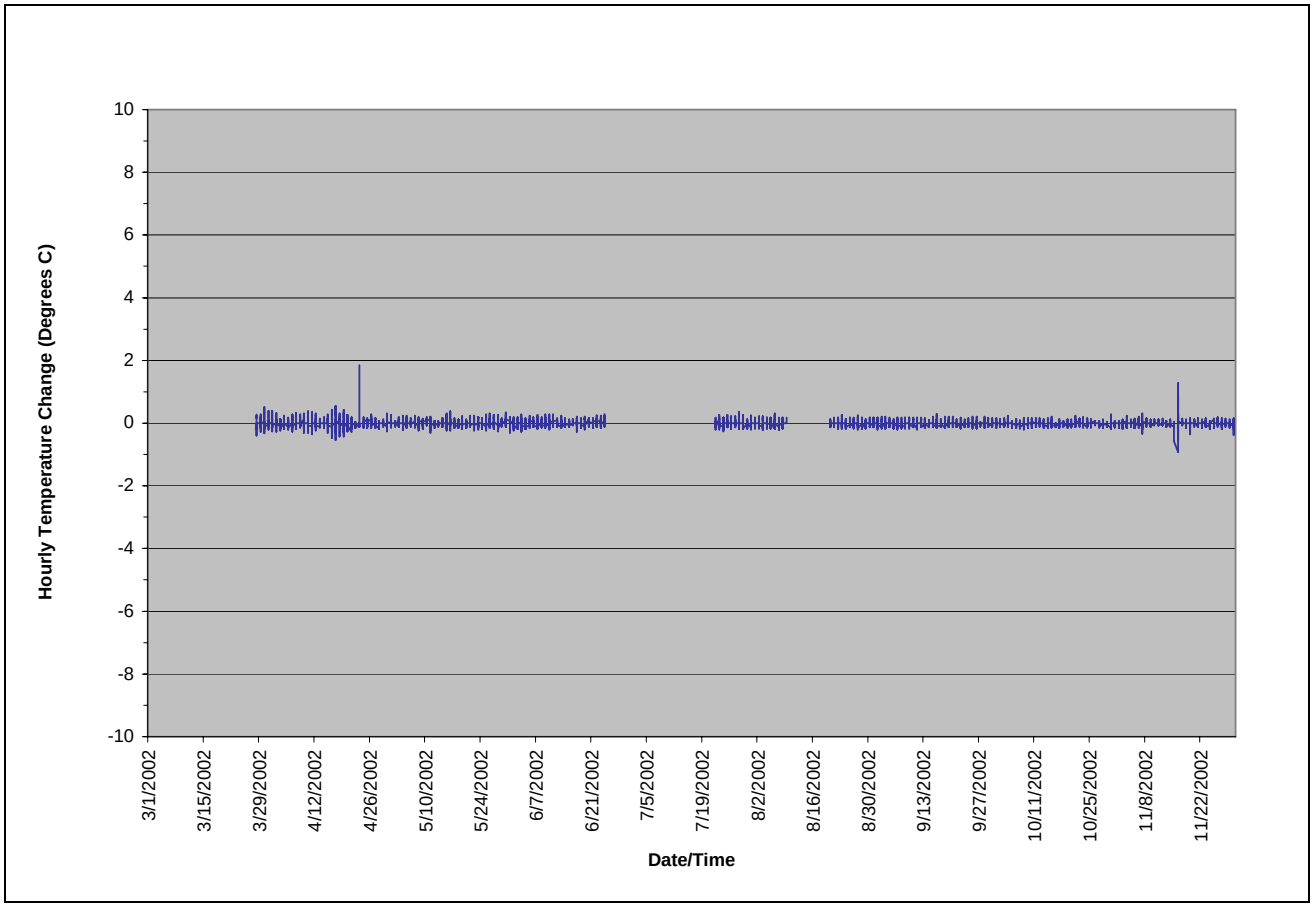

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FIGURE C-83: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-18)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

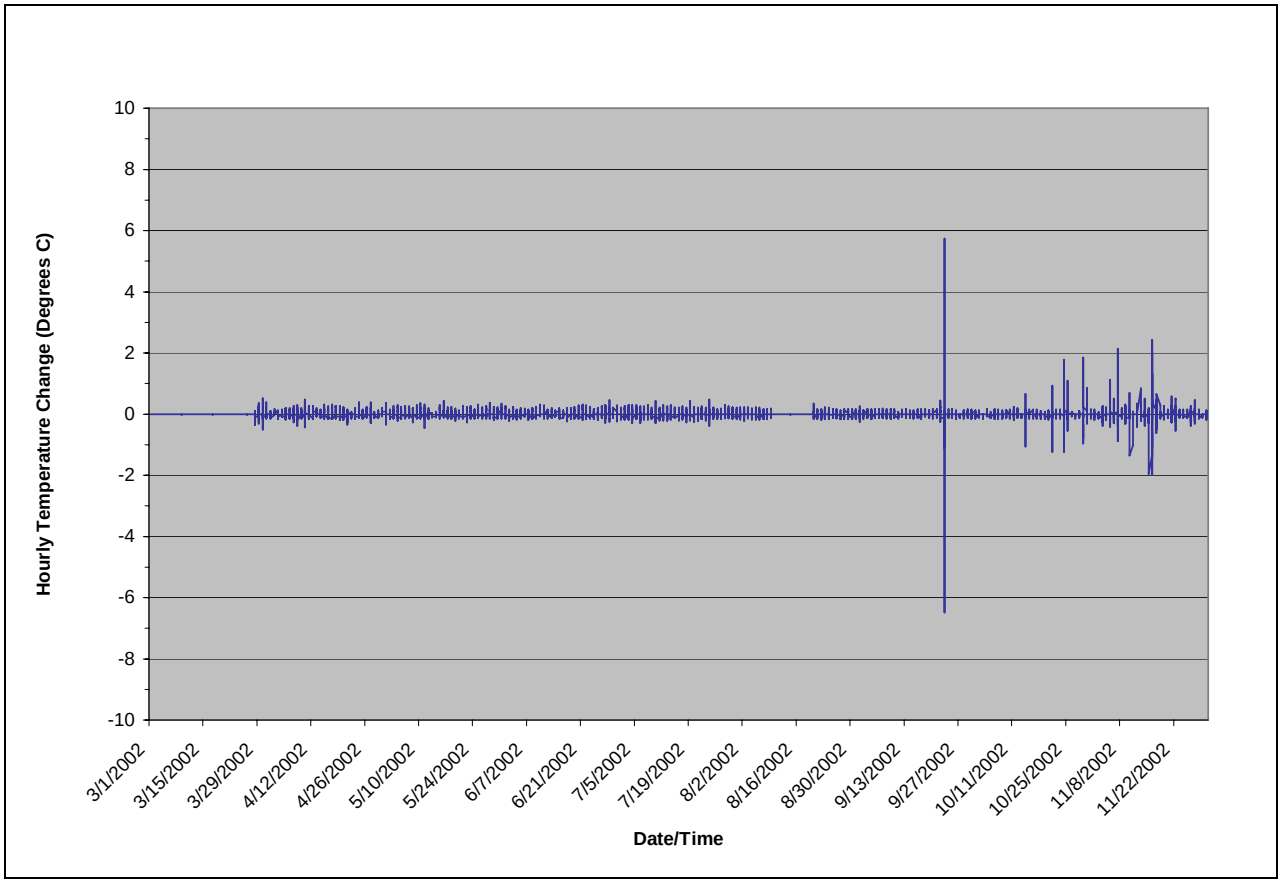

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FIGURE C-84: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TM-20)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

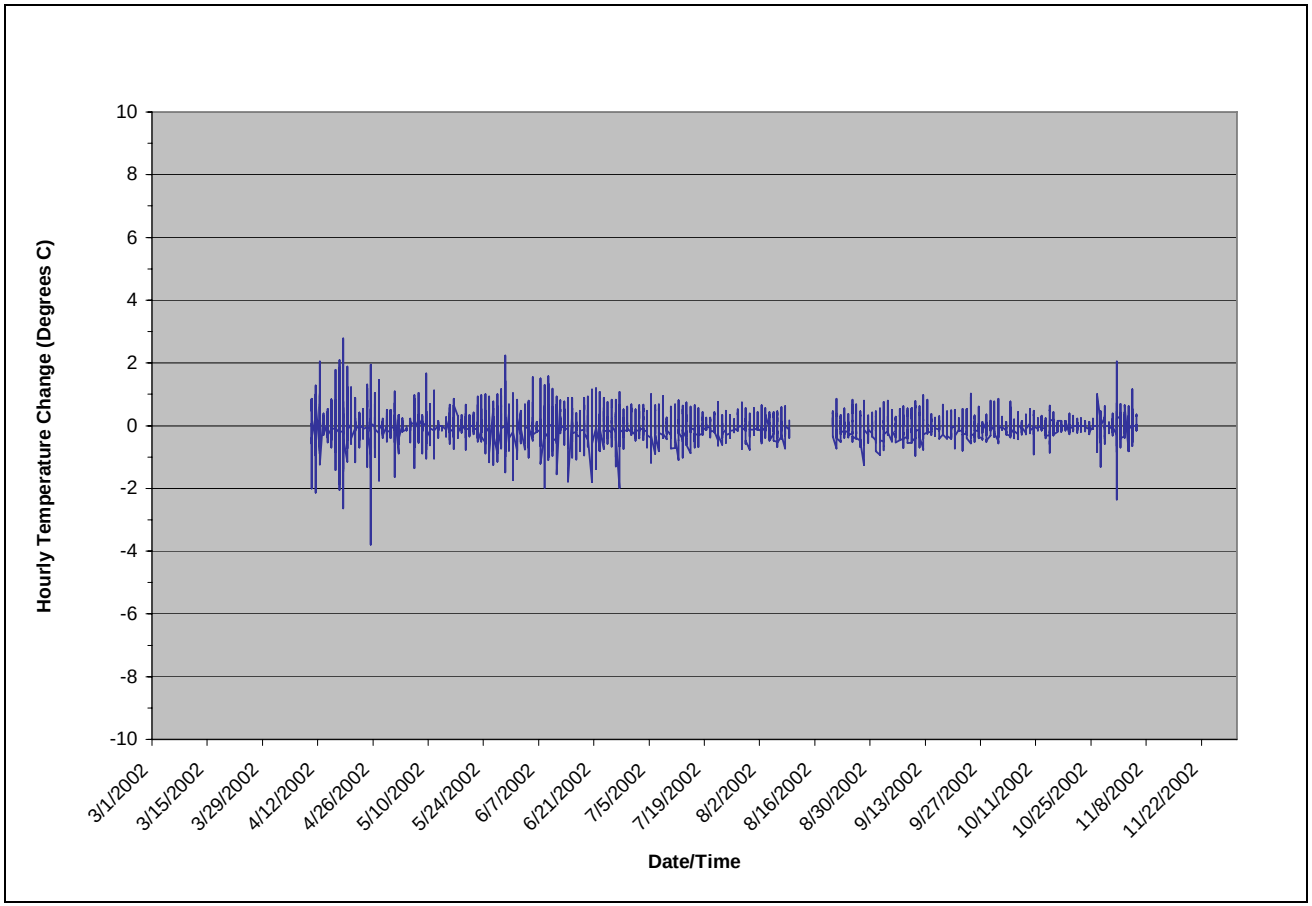

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FIGURE C-85A: ANALYSIS ZONE 3 – TM-20

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

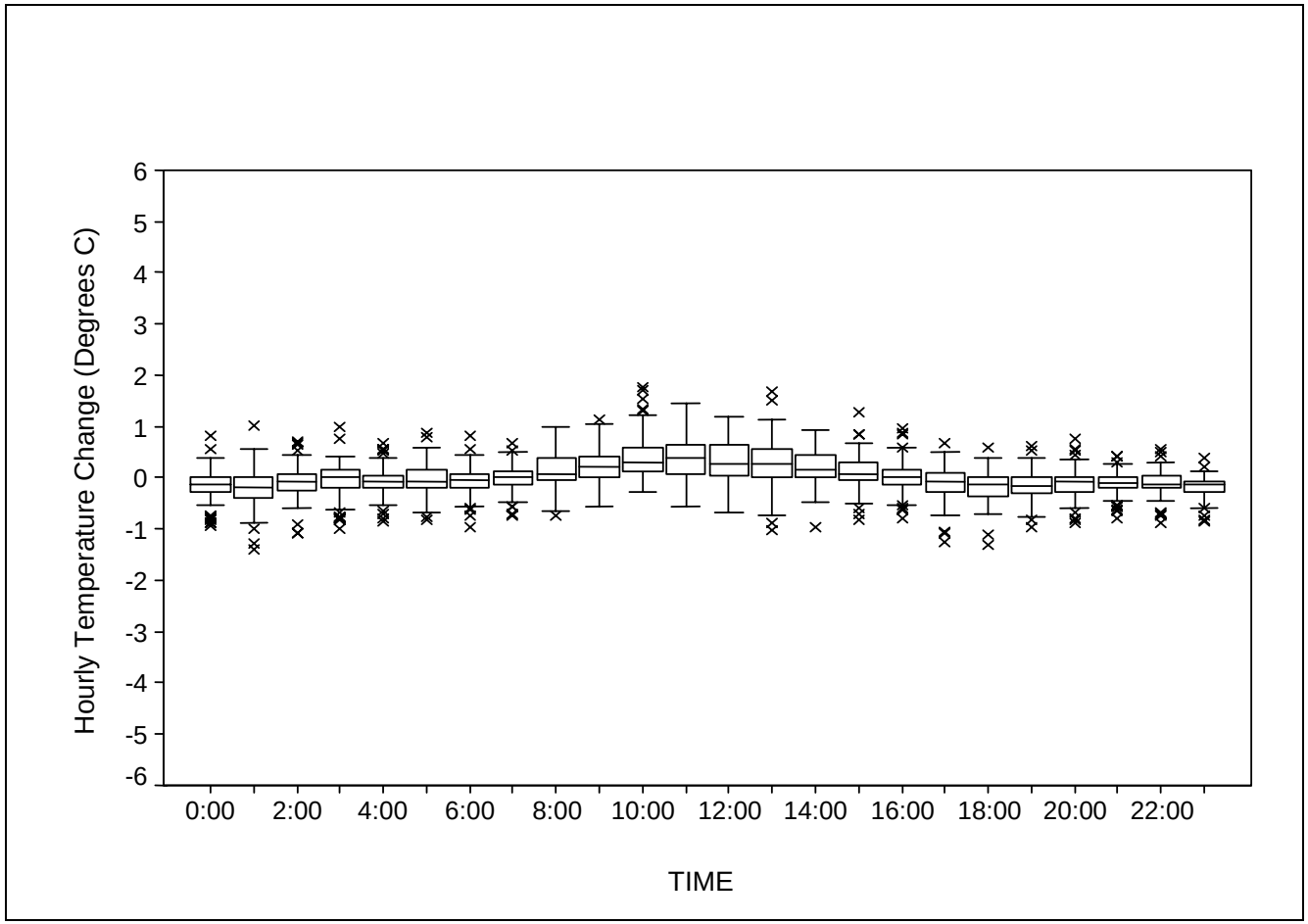

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FIGURE C-85B: ANALYSIS ZONE 3 – TM-20

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

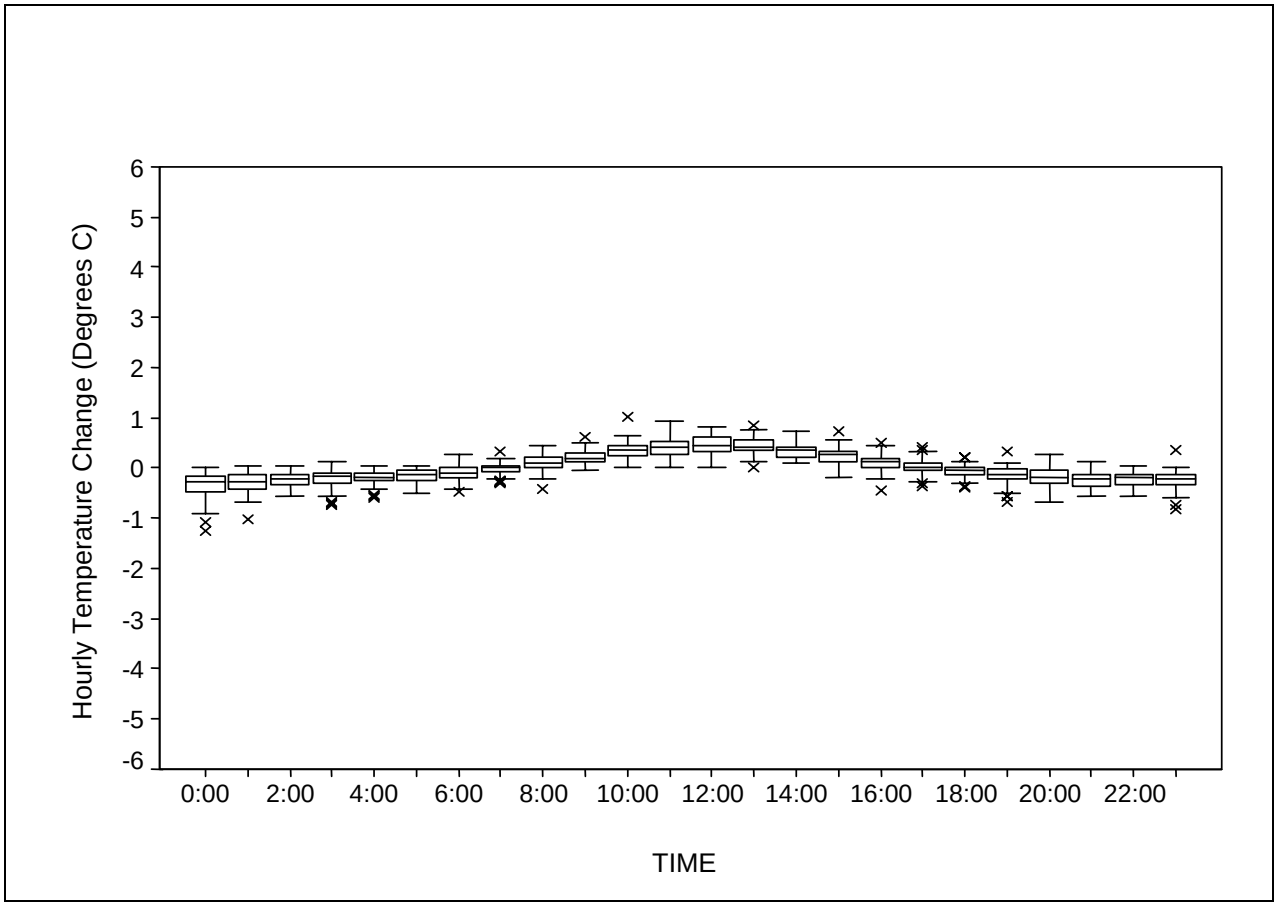

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FIGURE C-85C: ANALYSIS ZONE 3 – TM-20

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

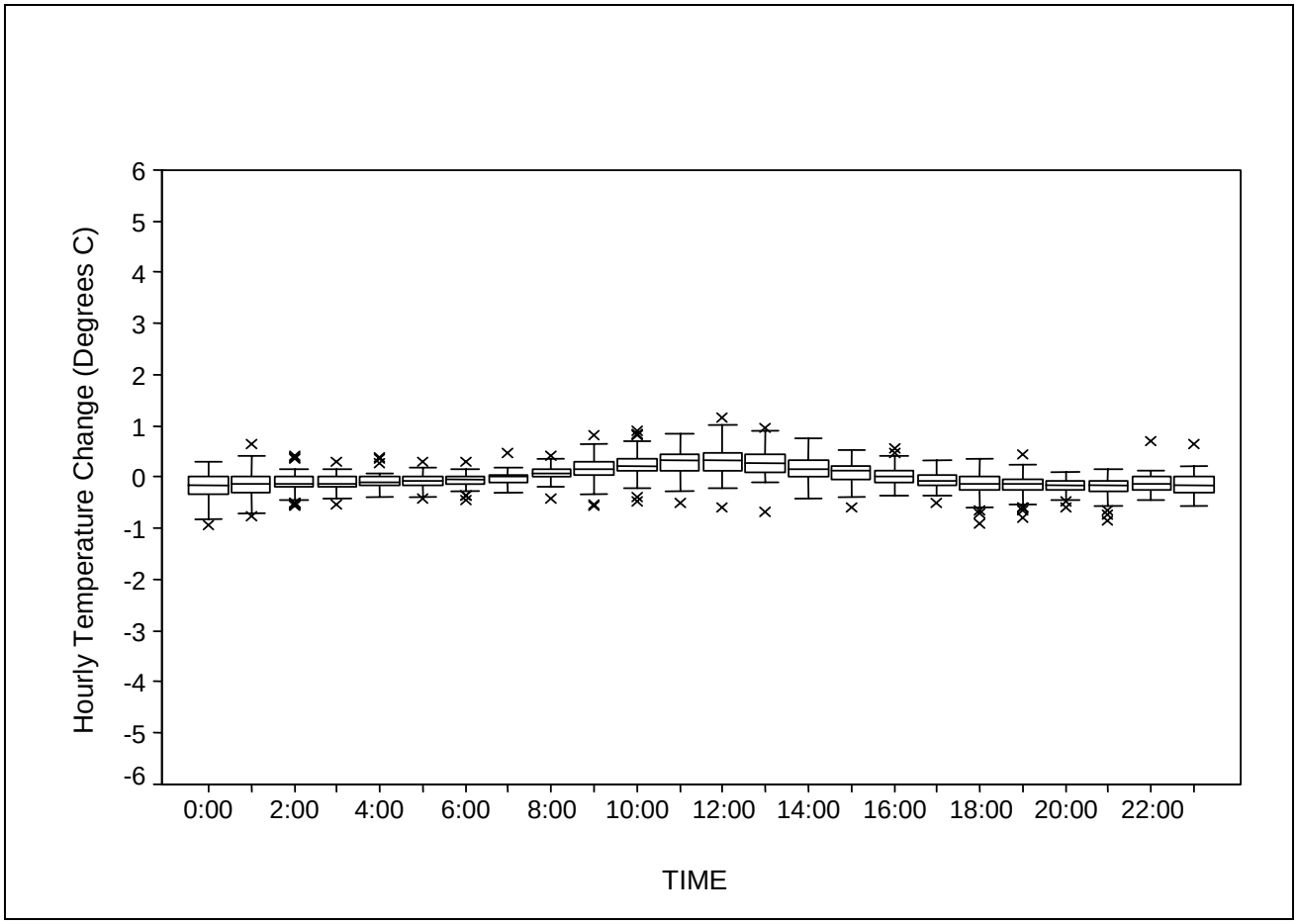

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FIGURE C-86: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TUNR-04)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

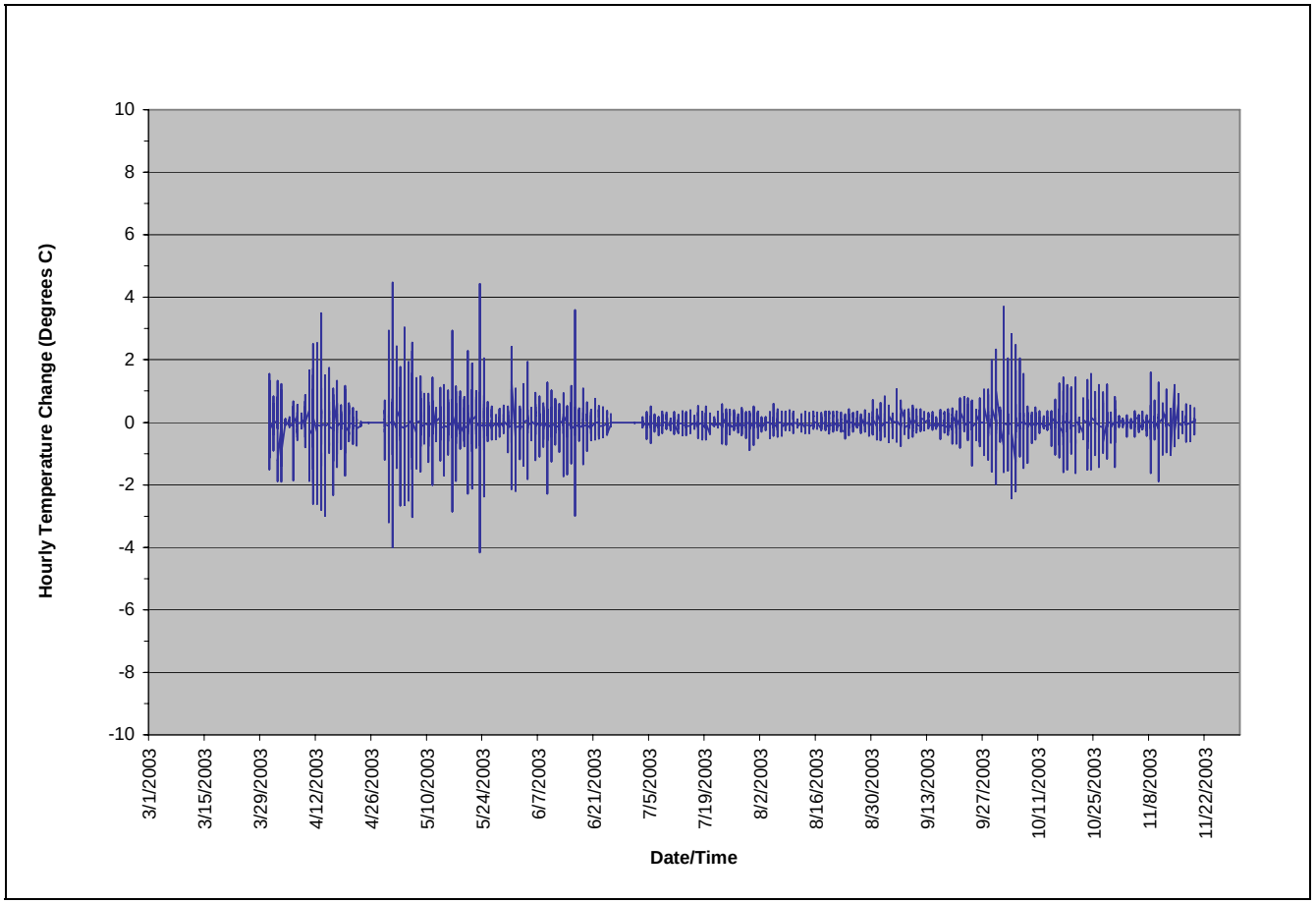

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FIGURE C-87A: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TUNR-04)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

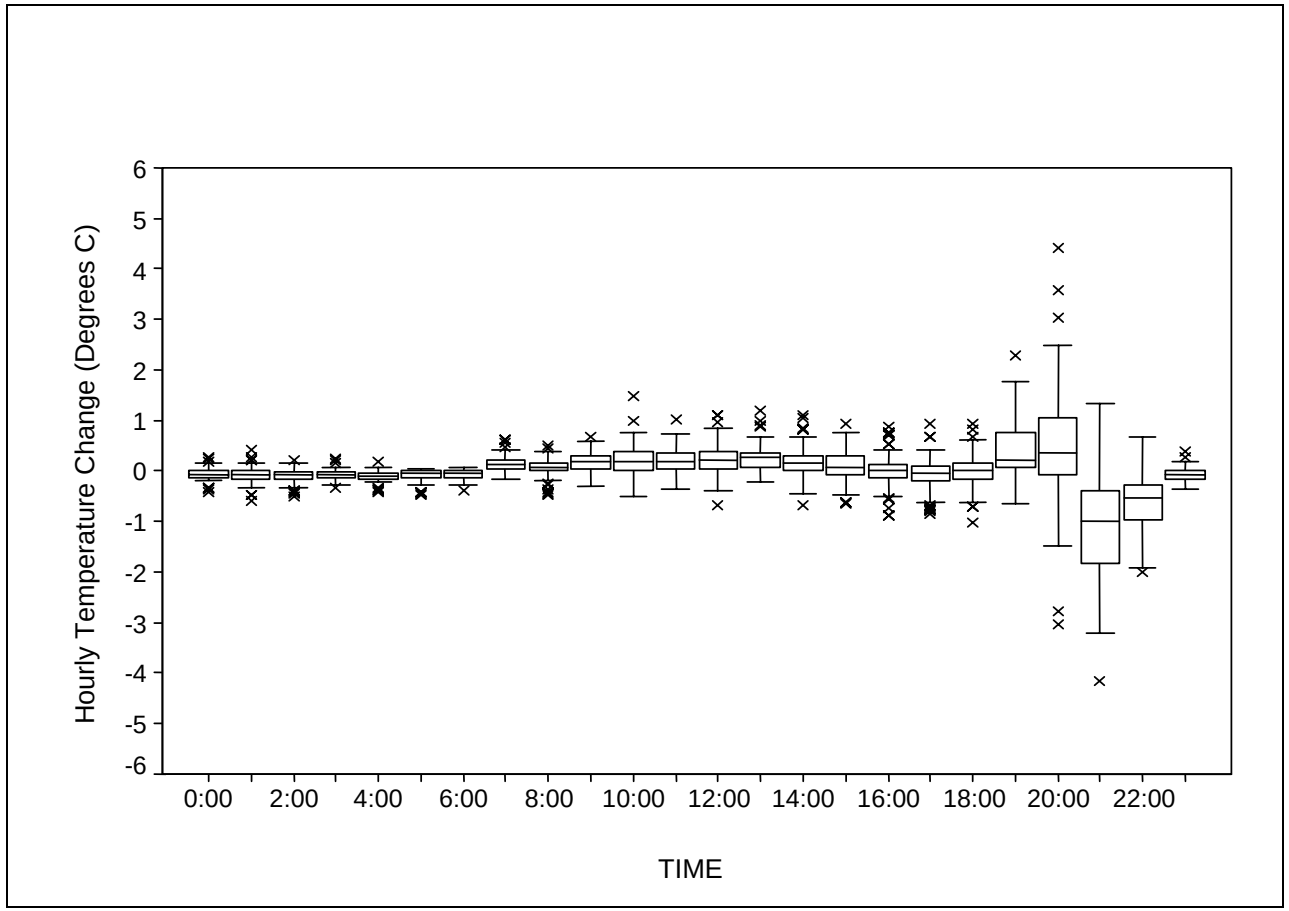

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FIGURE C-87B: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TUNR-04)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

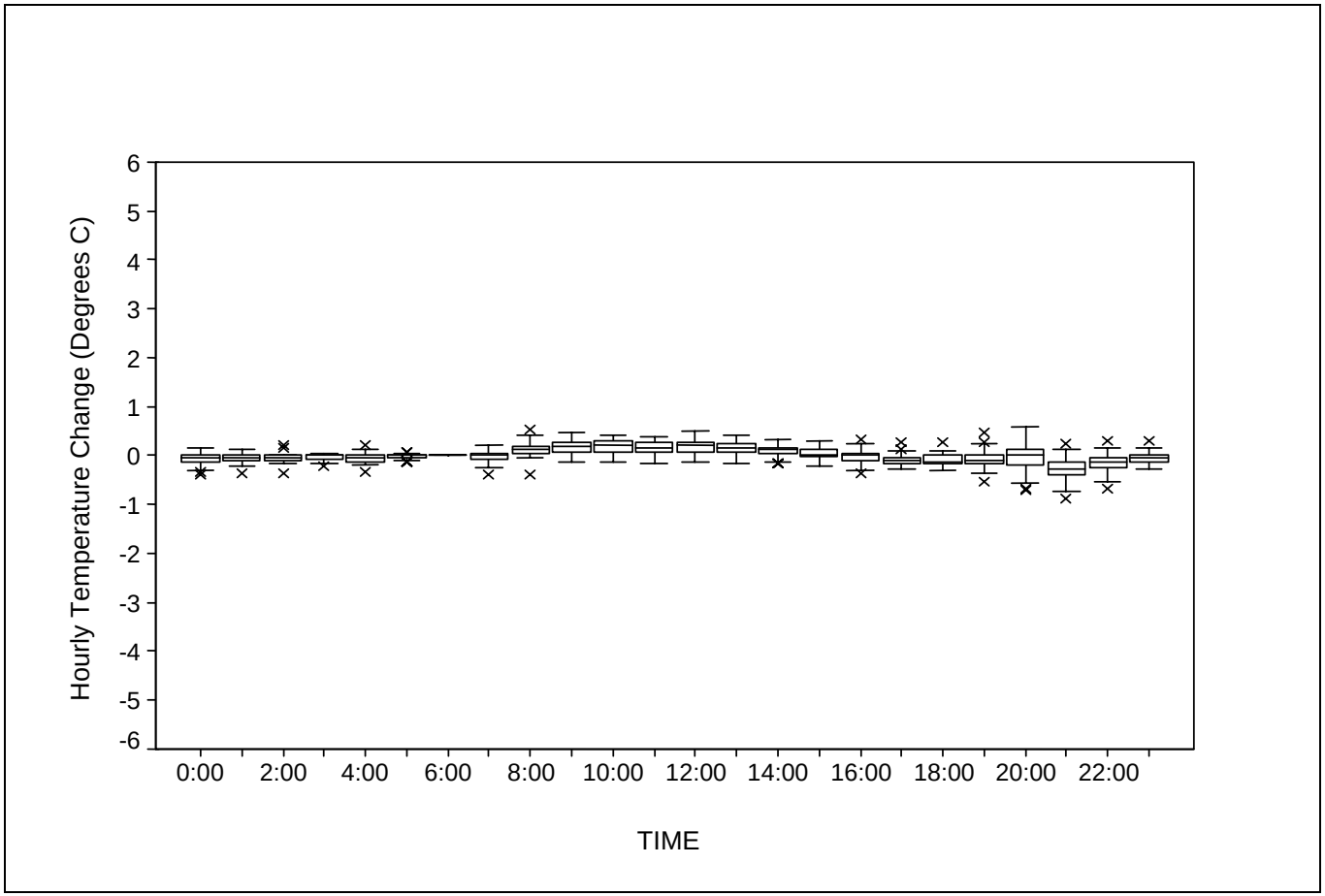

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FIGURE C-87C: ANALYSIS ZONE 3 – UPPER NIAGARA RIVER (TUNR-04)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

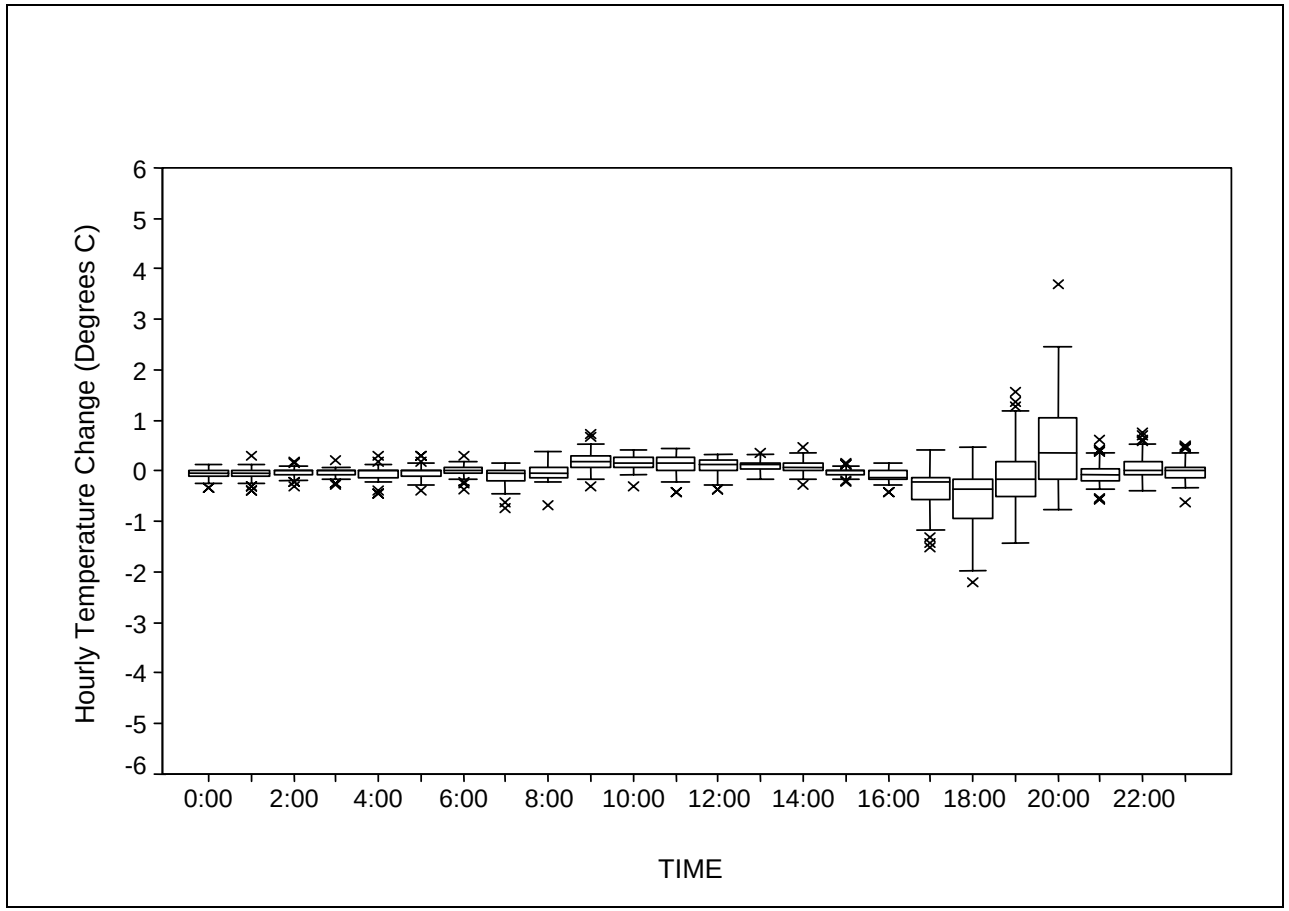

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FIGURE C-88: ANALYSIS ZONE 4 – LOWER NIAGARA RIVER (TLNR-03)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

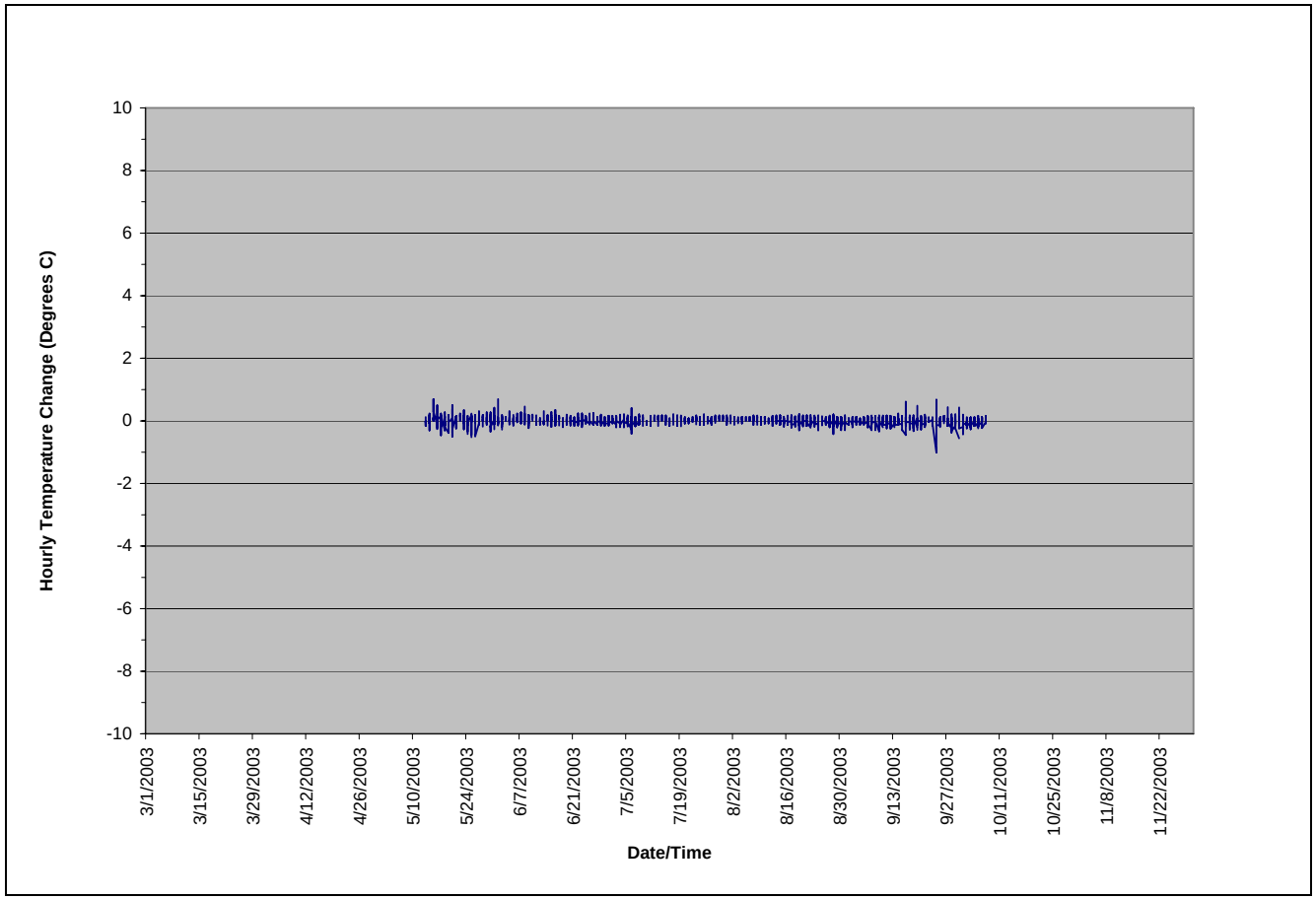

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FIGURE C-89: ANALYSIS ZONE 4 – LOWER NIAGARA RIVER (TLNR-03)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

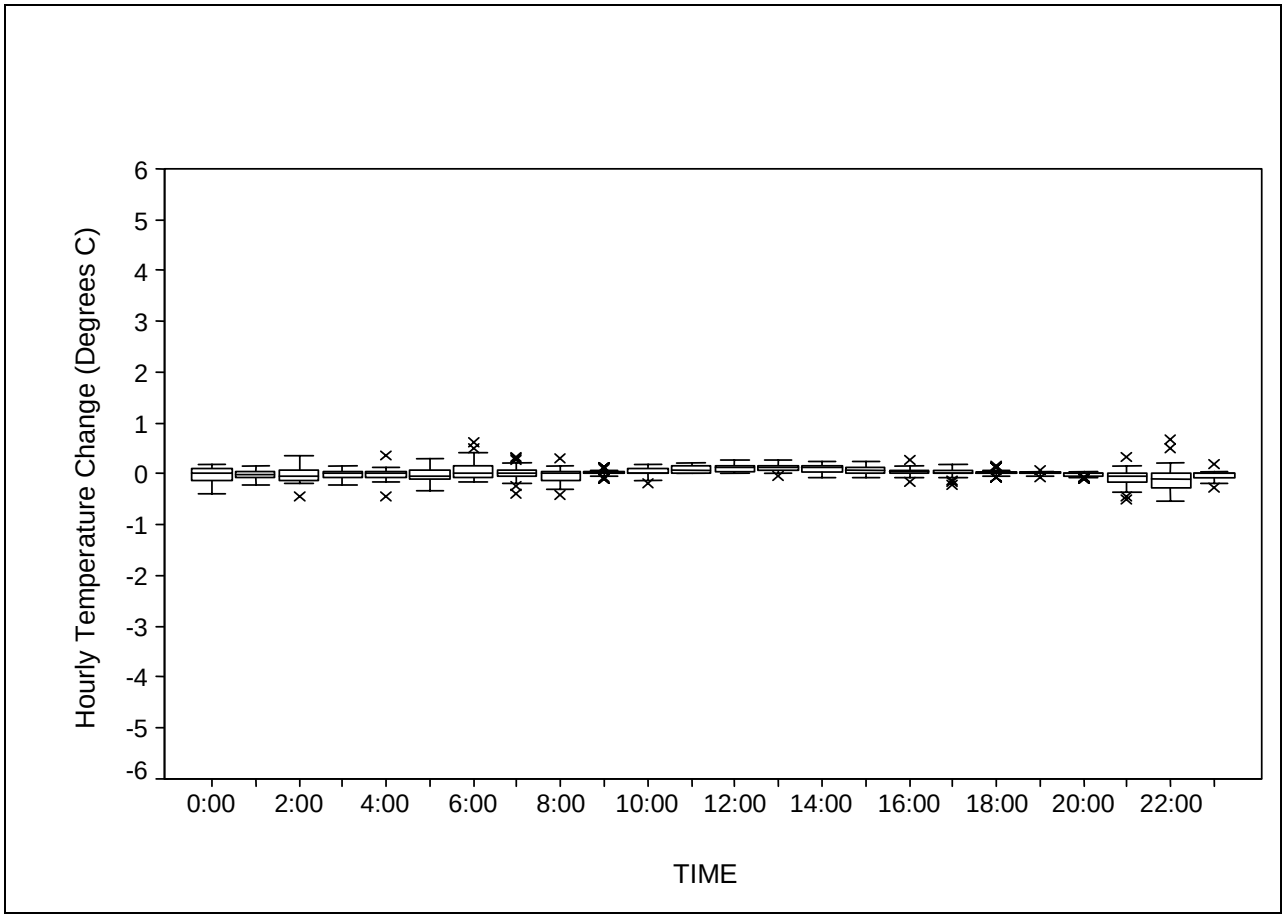

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FIGURE C-90: ANALYSIS ZONE 4 – LOWER NIAGARA RIVER (LNR-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

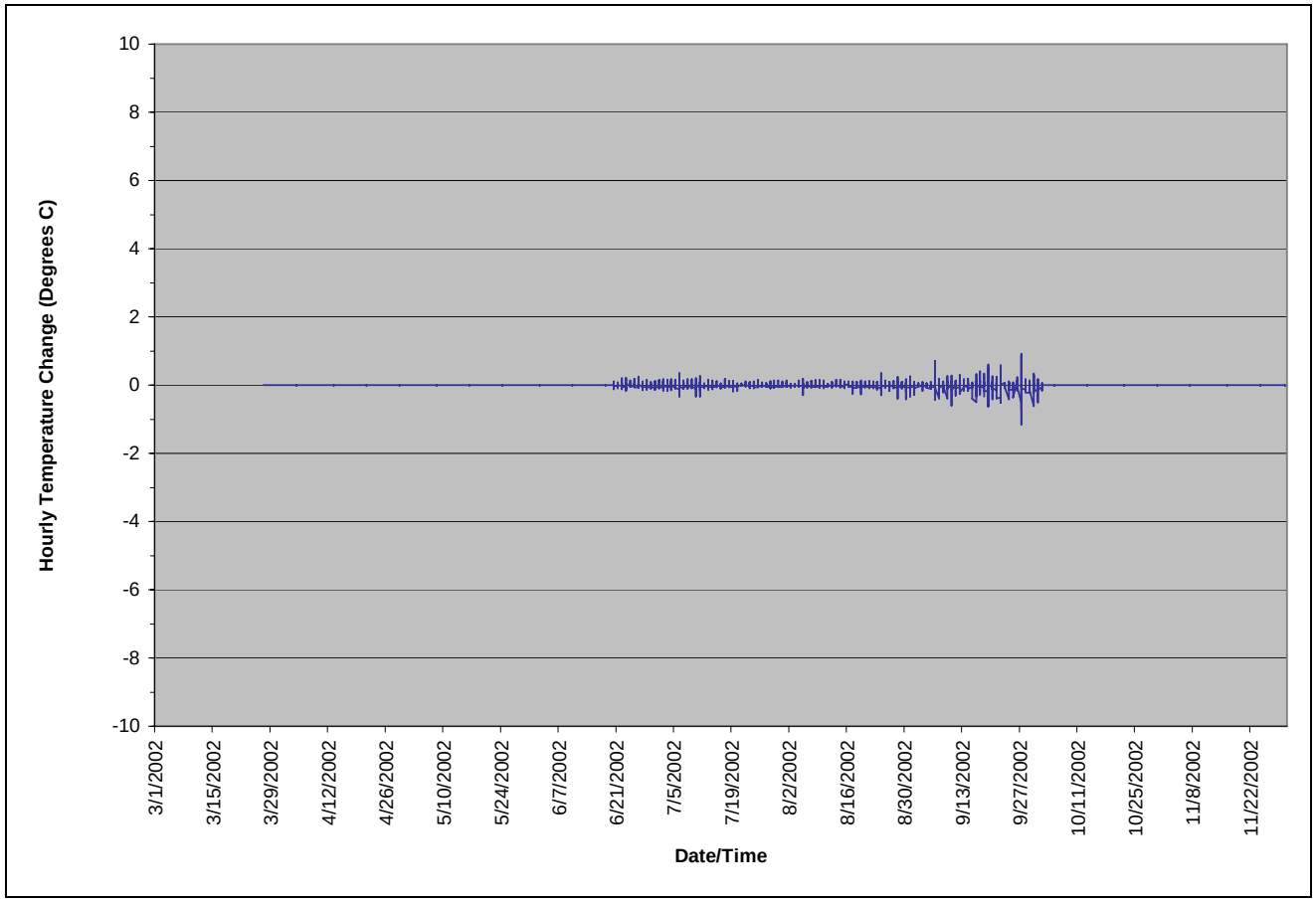

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FIGURE C-91A: ANALYSIS ZONE 4 – LOWER NIAGARA RIVER (LNR-01)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

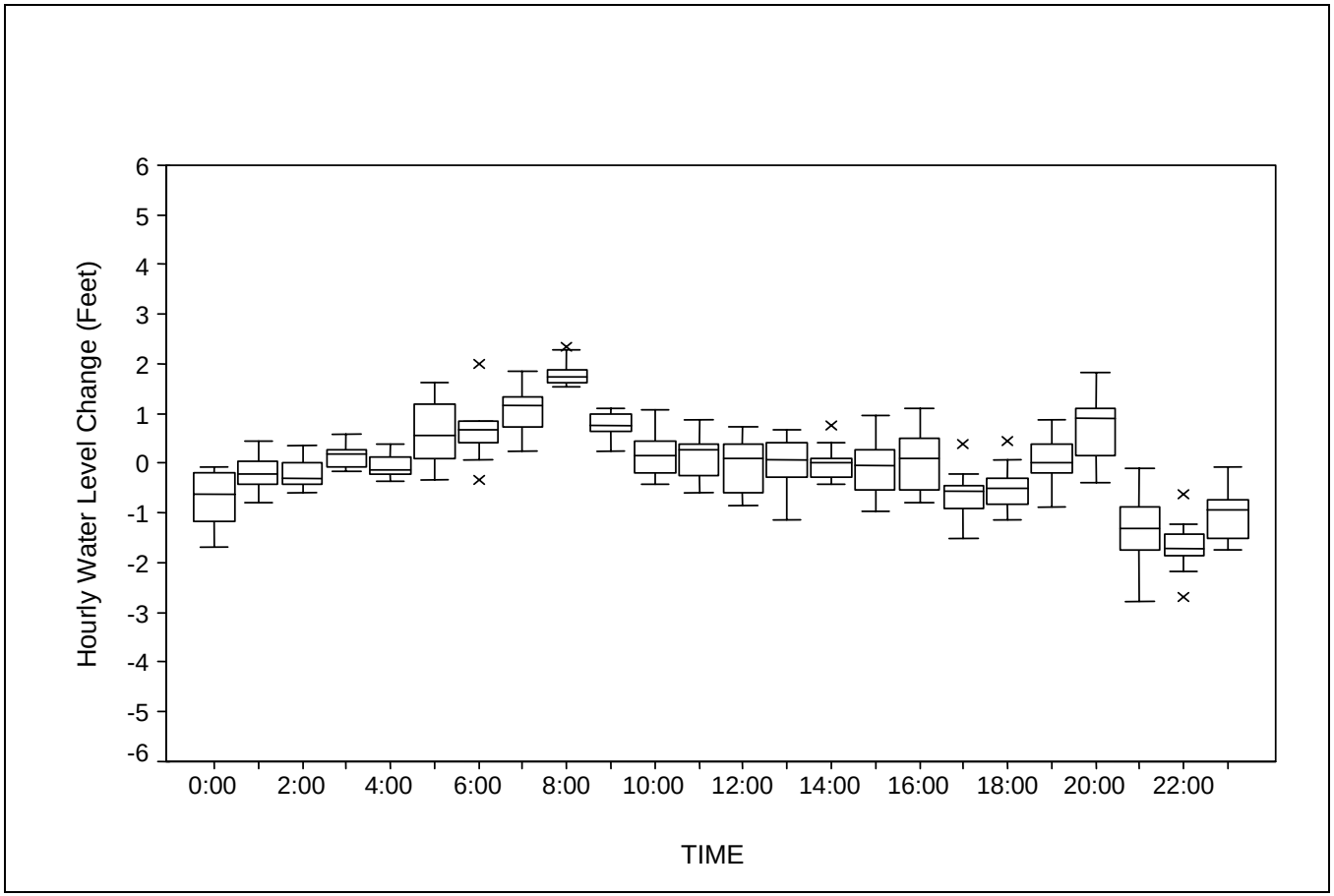

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FIGURE C-91B: ANALYSIS ZONE 4 – LOWER NIAGARA RIVER (LNR-01)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

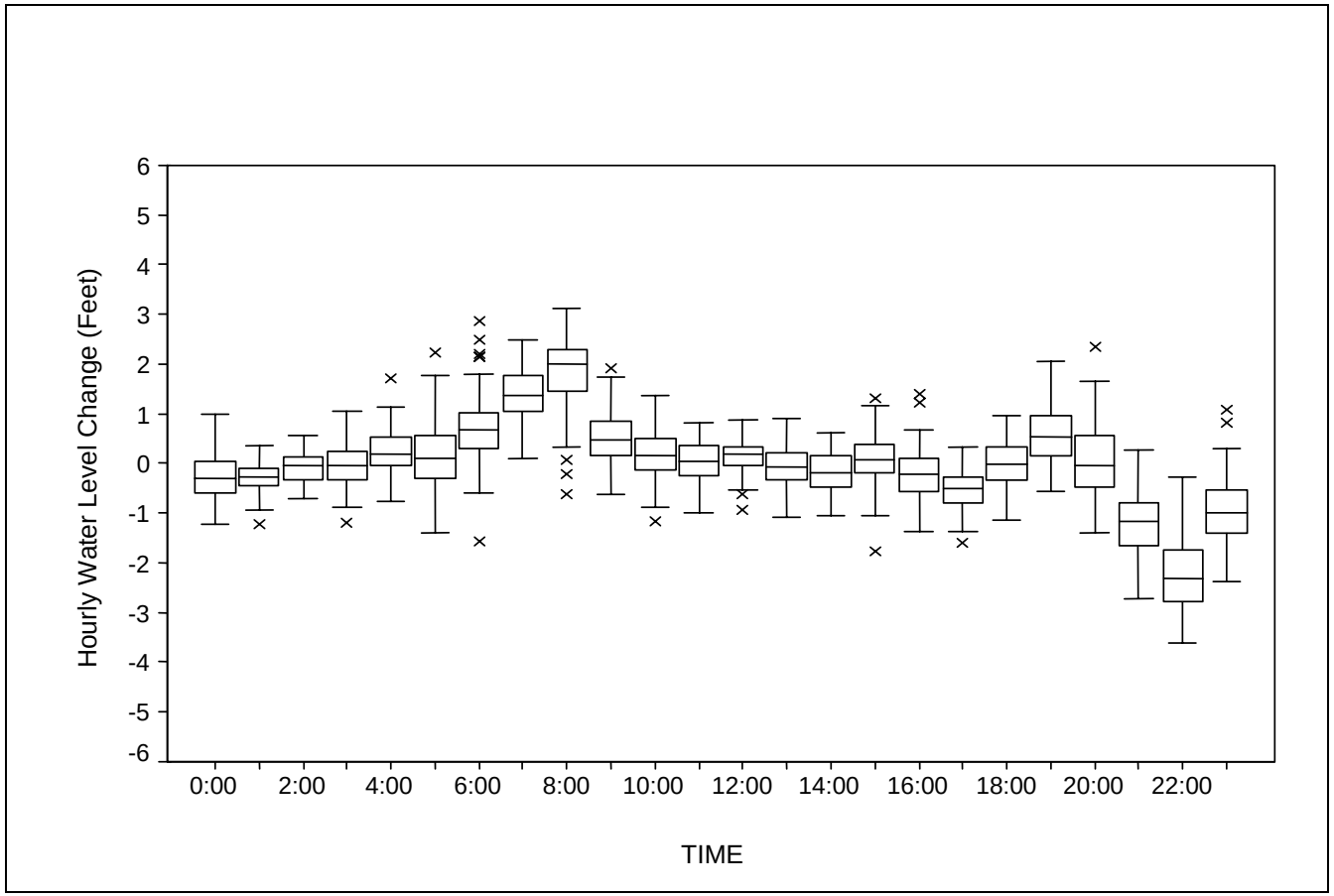

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FIGURE C-91C: ANALYSIS ZONE 4 – LOWER NIAGARA RIVER (LNR-01)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

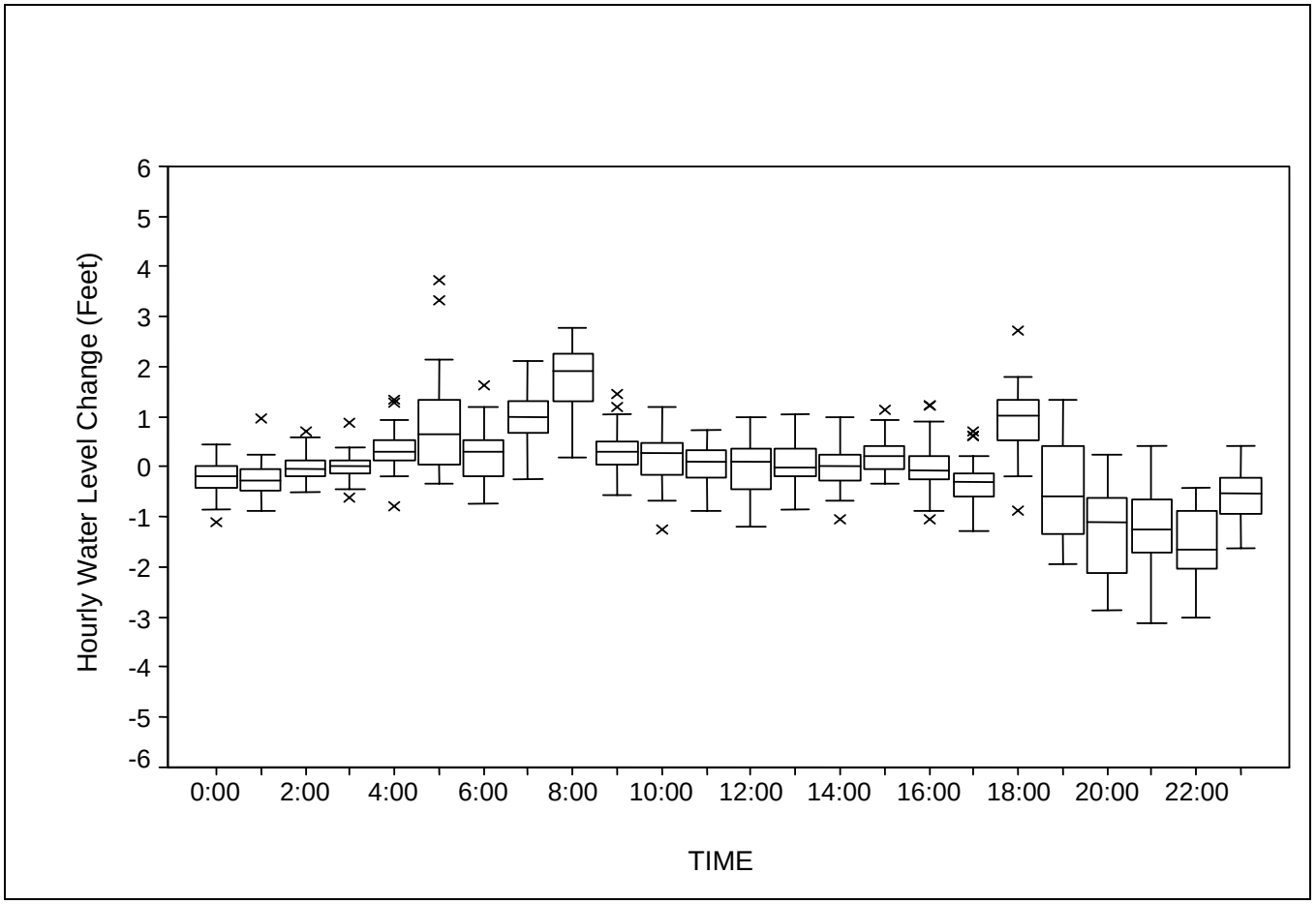

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FIGURE C-92: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TLNR-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

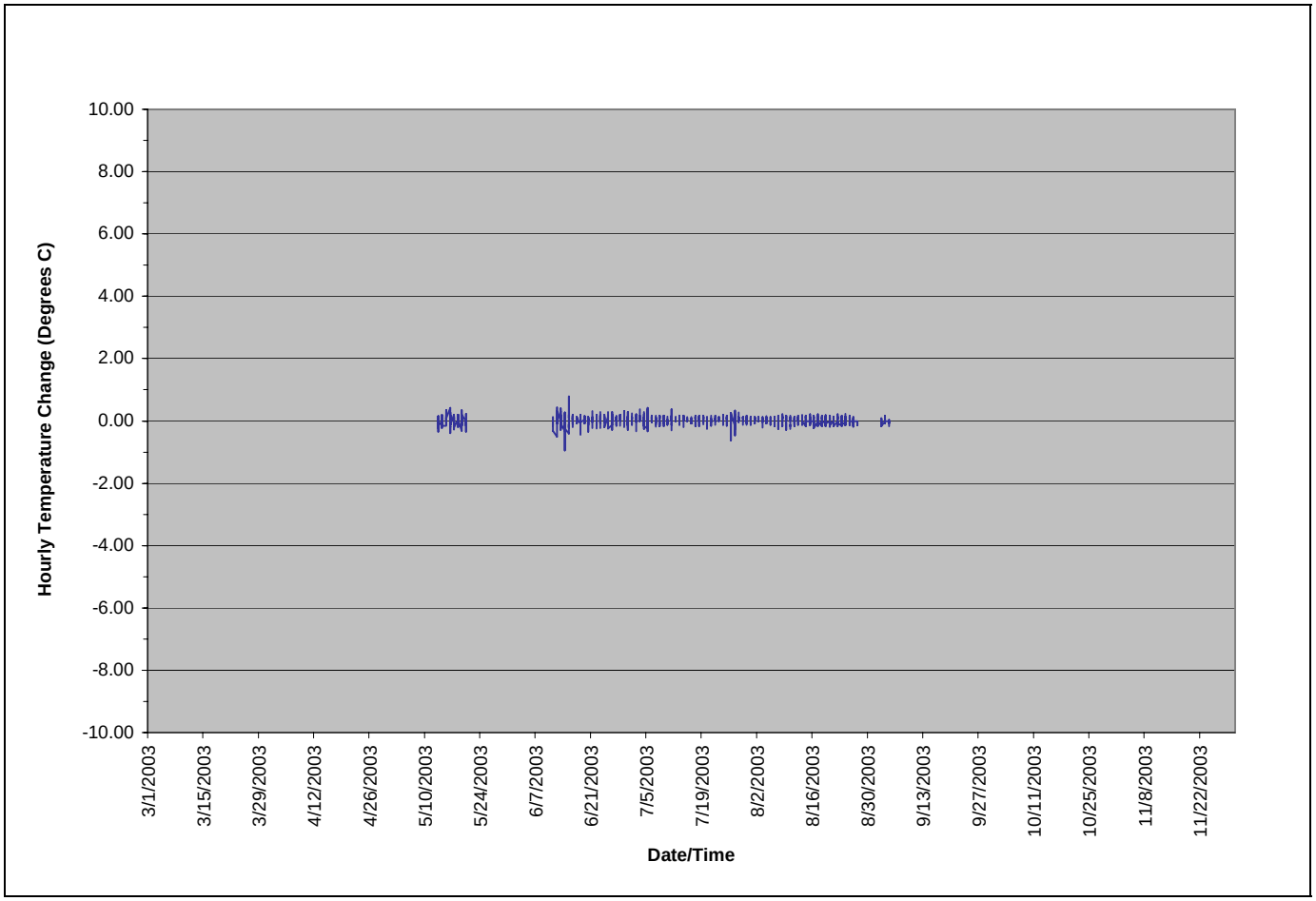

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FIGURE C-93: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TLNR-01)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

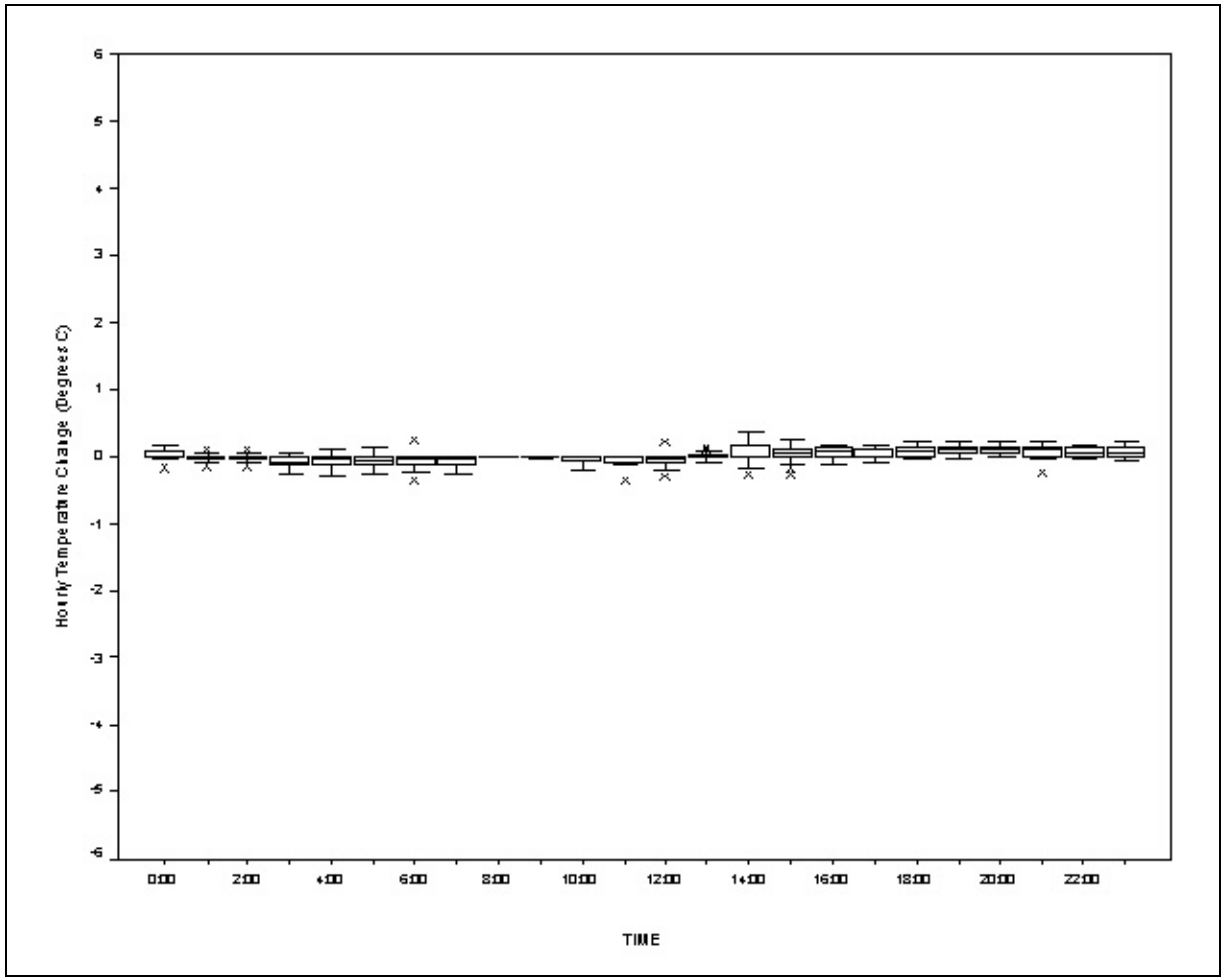

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FIGURE C-94: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TLNR-04)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

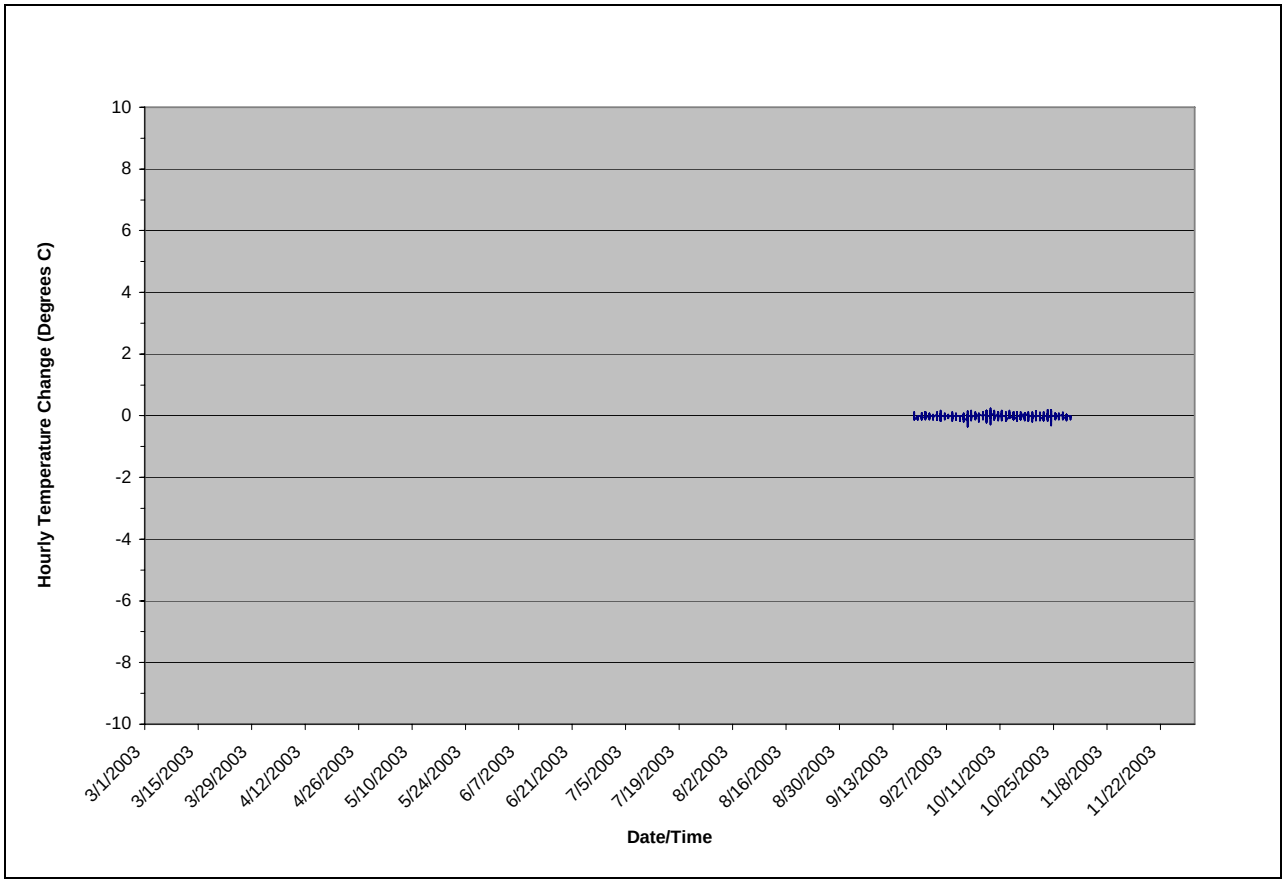

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FIGURE C-95: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TLNR-05)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

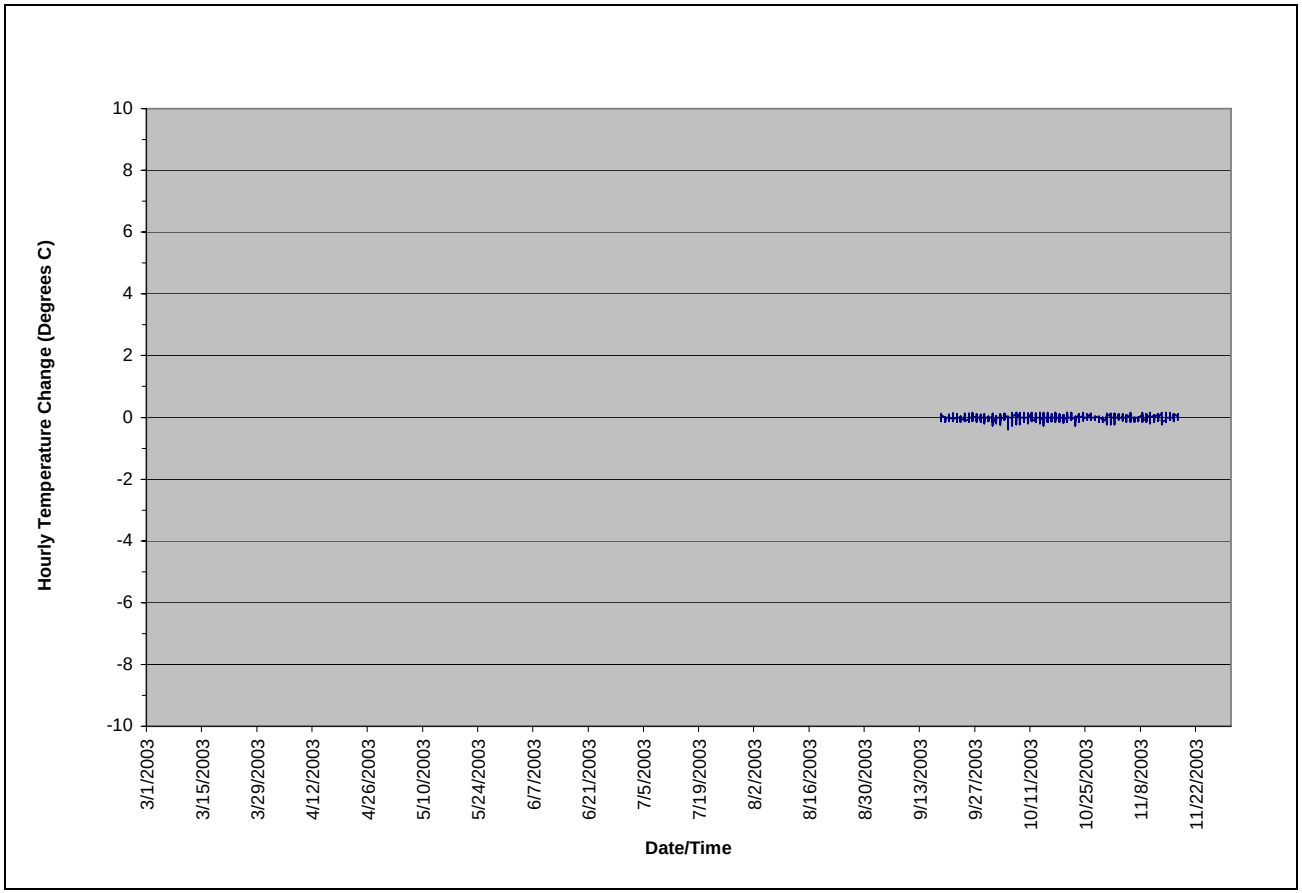

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FIGURE C-96: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TLNR-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

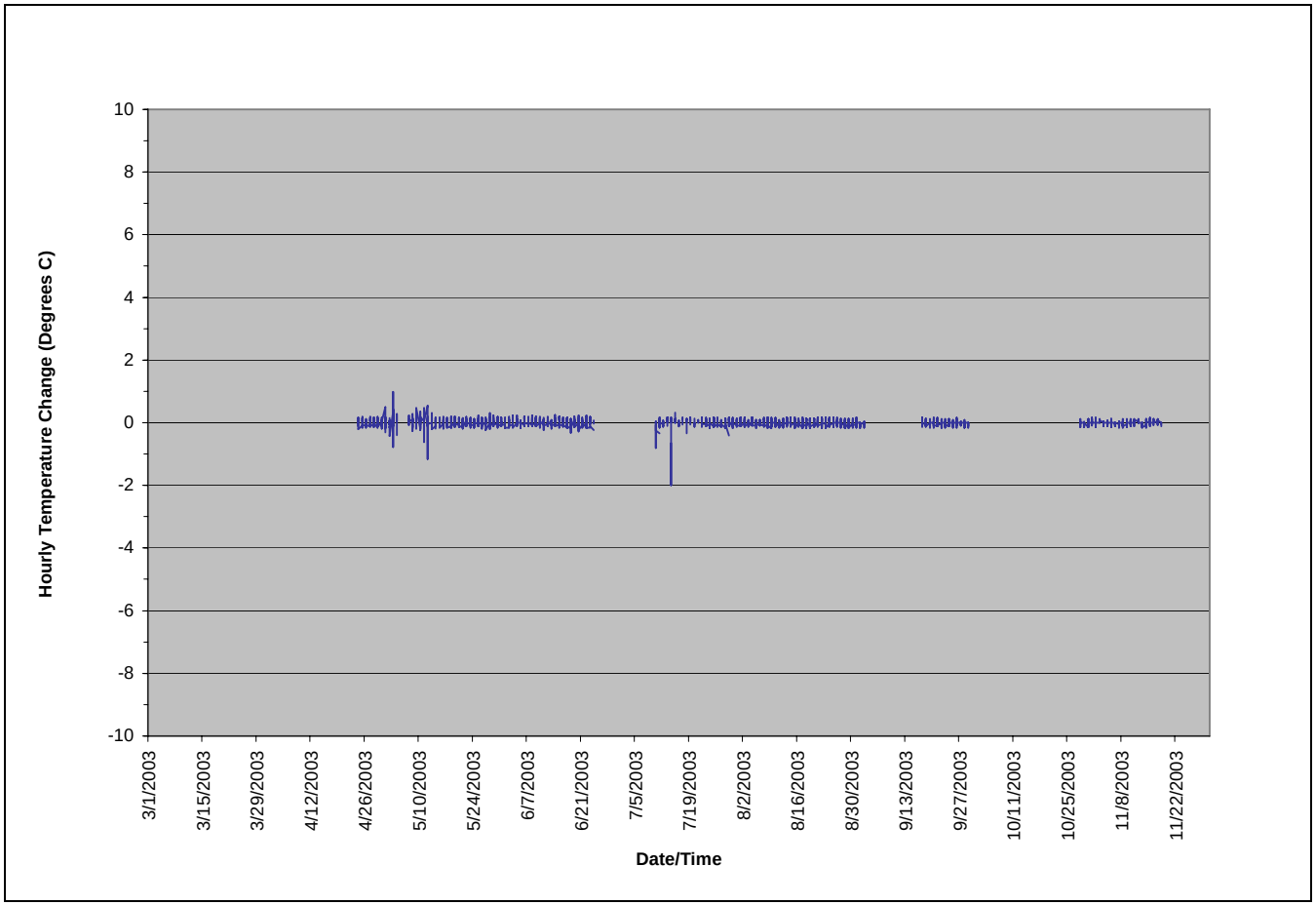

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FIGURE C-97: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (LNR-02)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

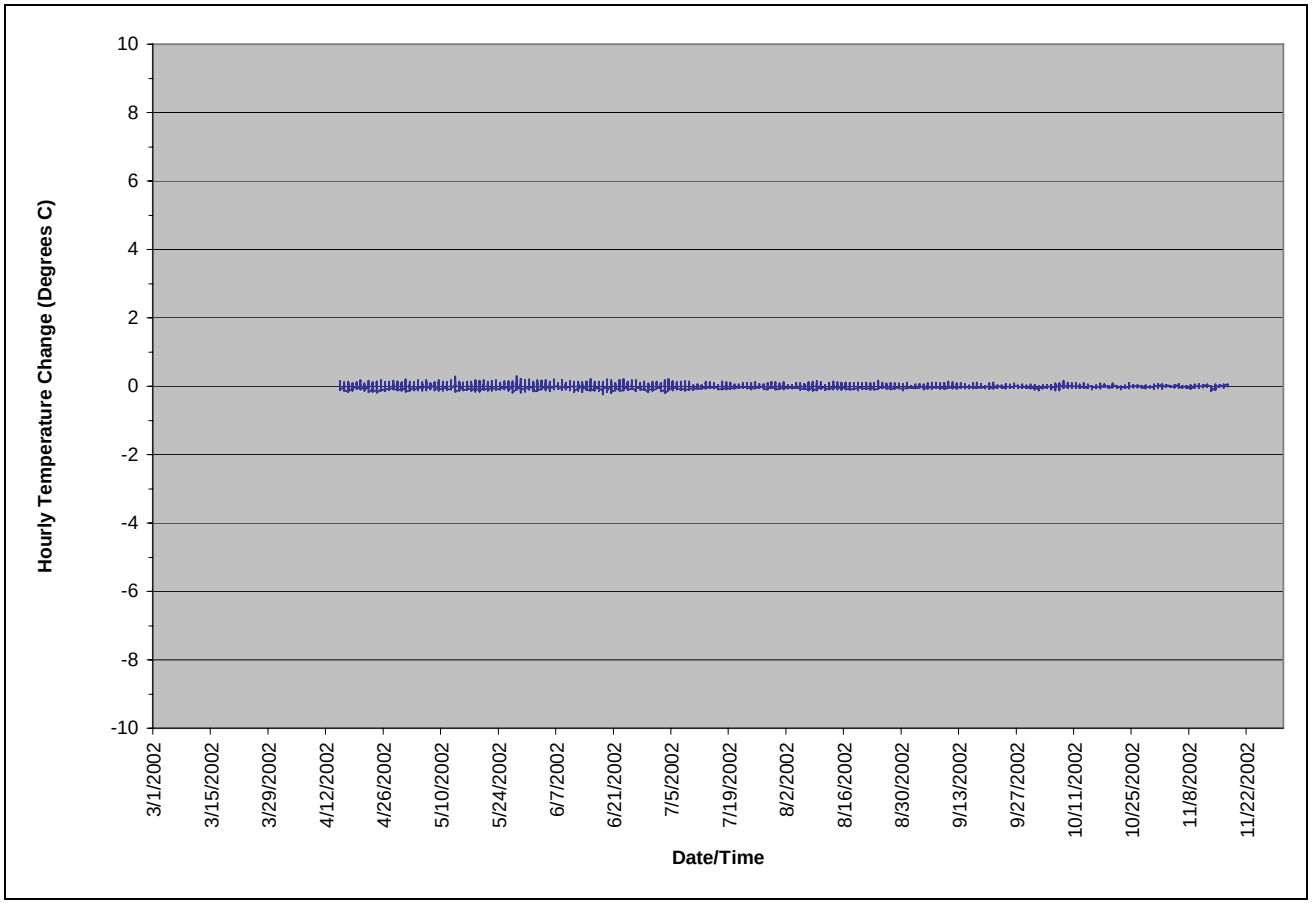

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FIGURE C-98A: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (LNR-02)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2003

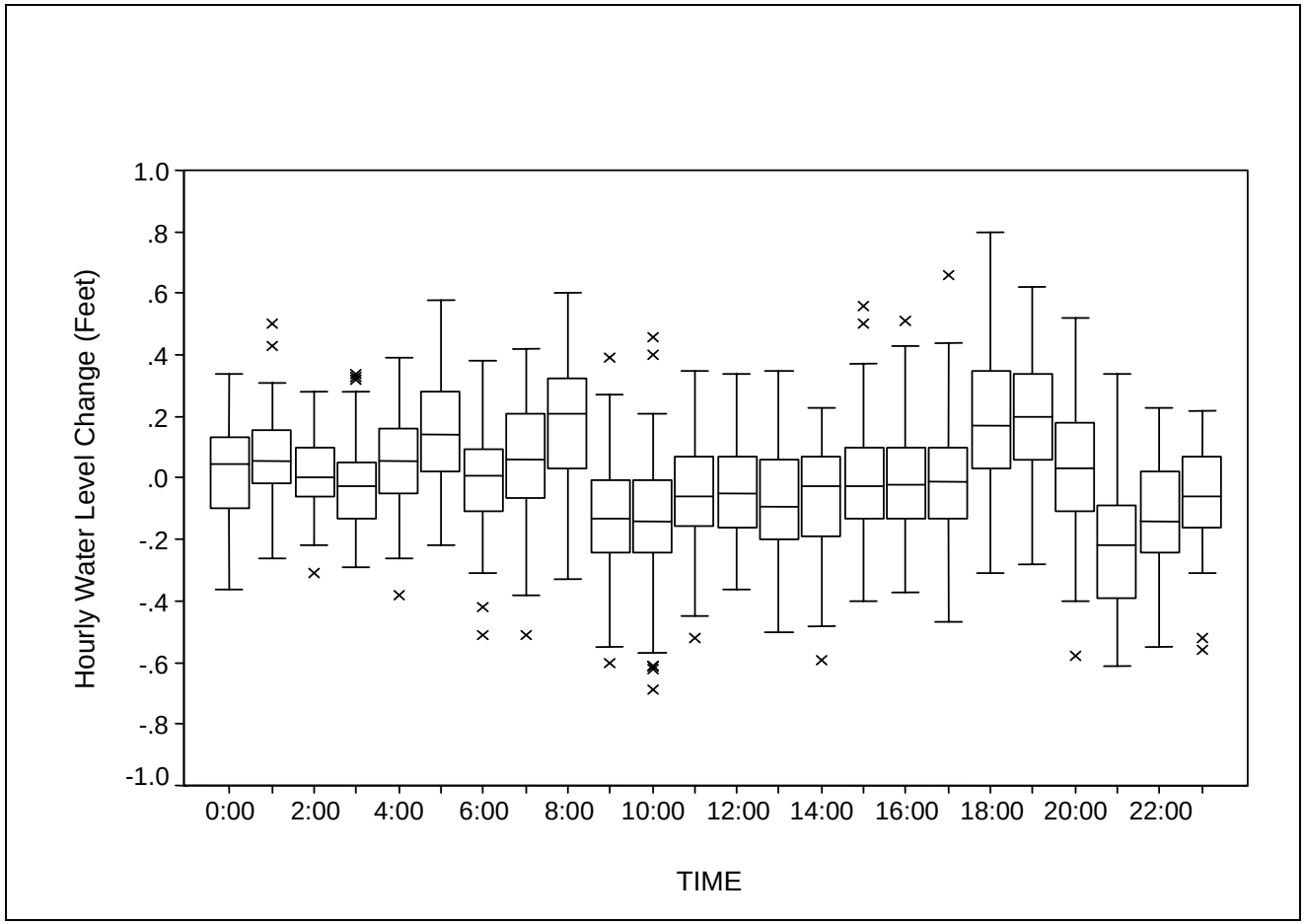

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FIGURE C-98B: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (LNR-02)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2003

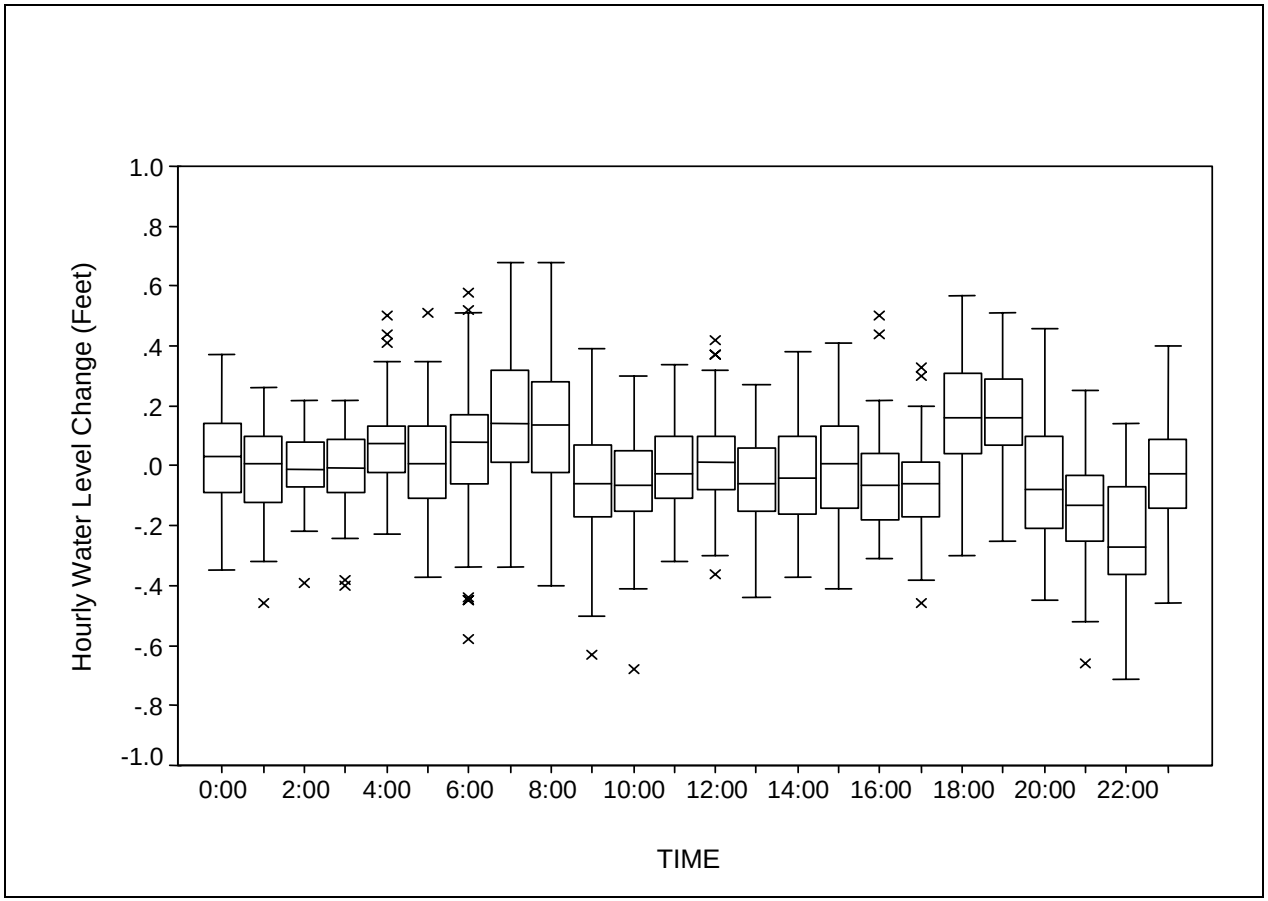

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FIGURE C-98C: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (LNR-02)

FREQUENCY DISTRIBUTION OF $\Delta°_{WL}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2003

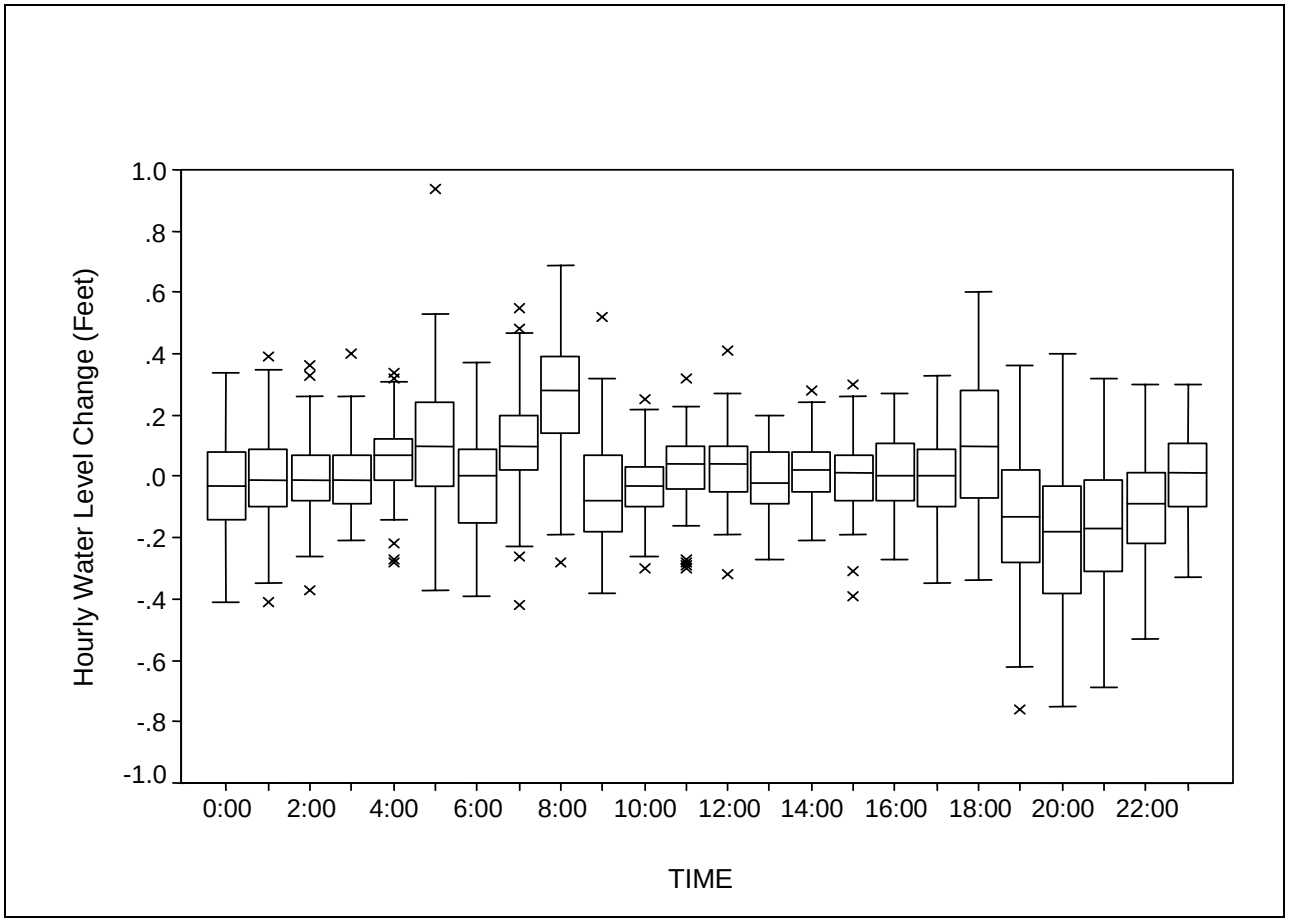

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FIGURE C-99: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TM-24)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

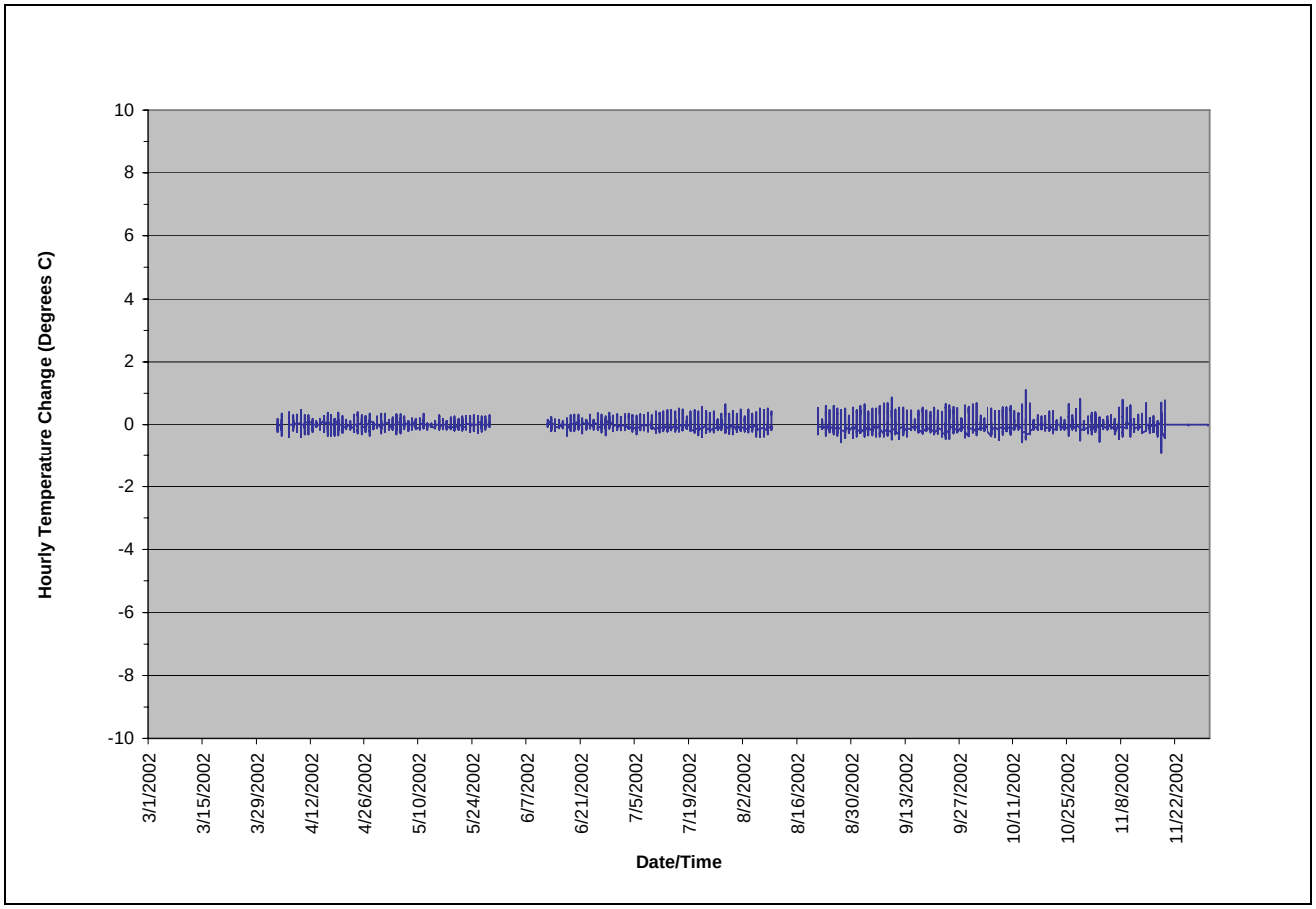

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FIGURE C-100A: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TM-24)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 4/1 TO 6/30, 2002

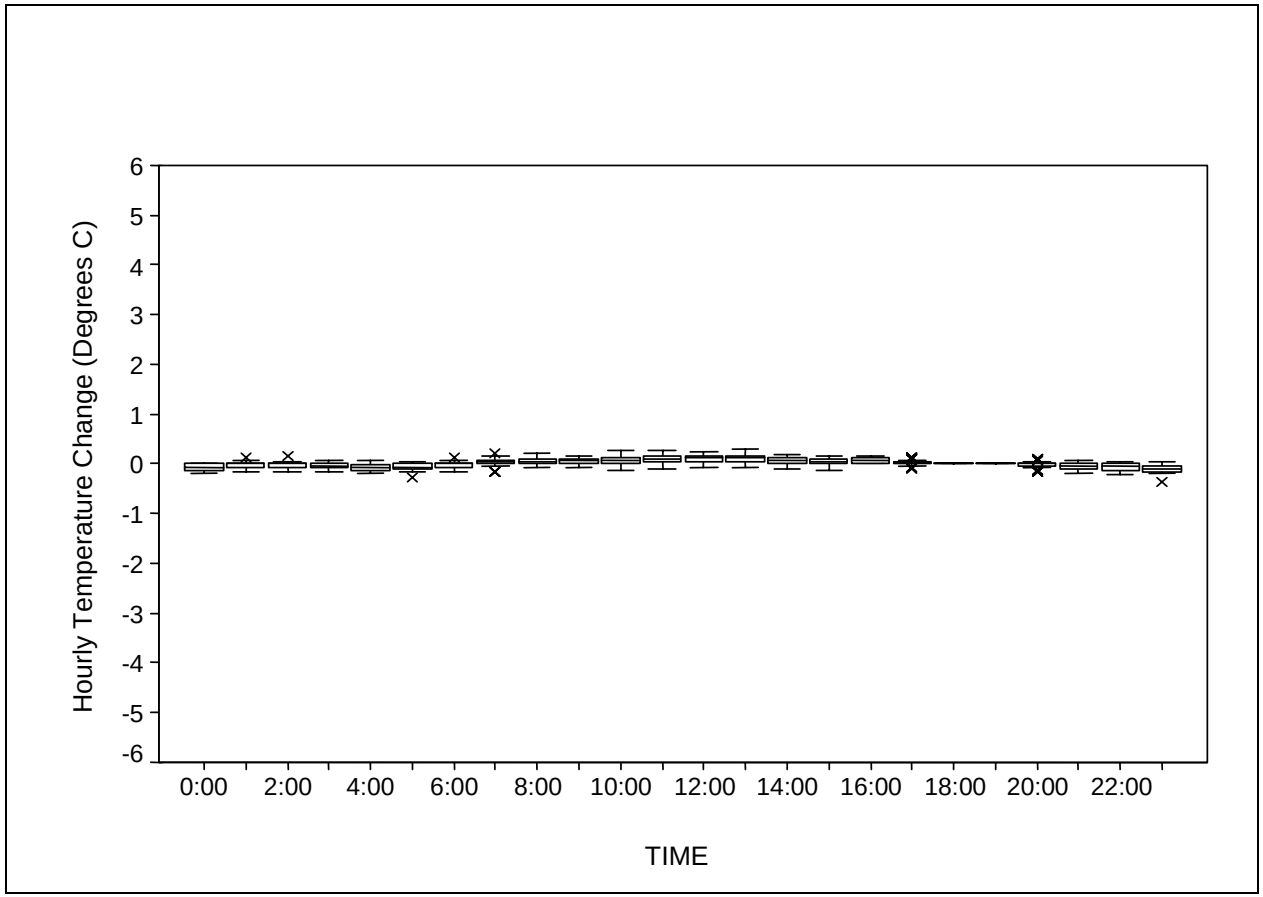

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FIGURE C-100B: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TM-24)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 7/1 TO 8/31, 2002

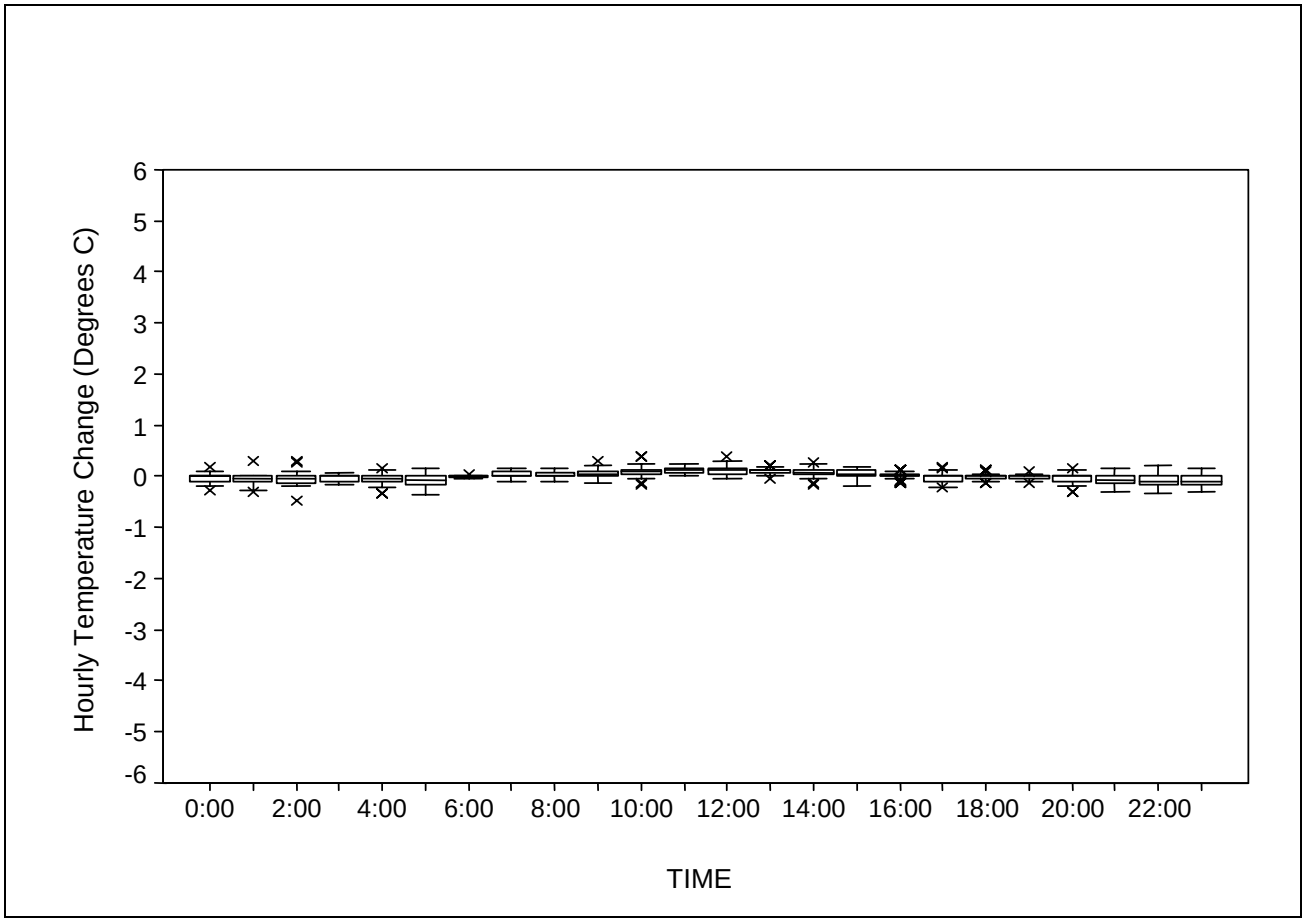

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FIGURE C-100C: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TM-24)

FREQUENCY DISTRIBUTION OF $\Delta°C_{WT}$ VALUES BY HOUR OF DAY FOR 9/1 TO 10/31, 2002

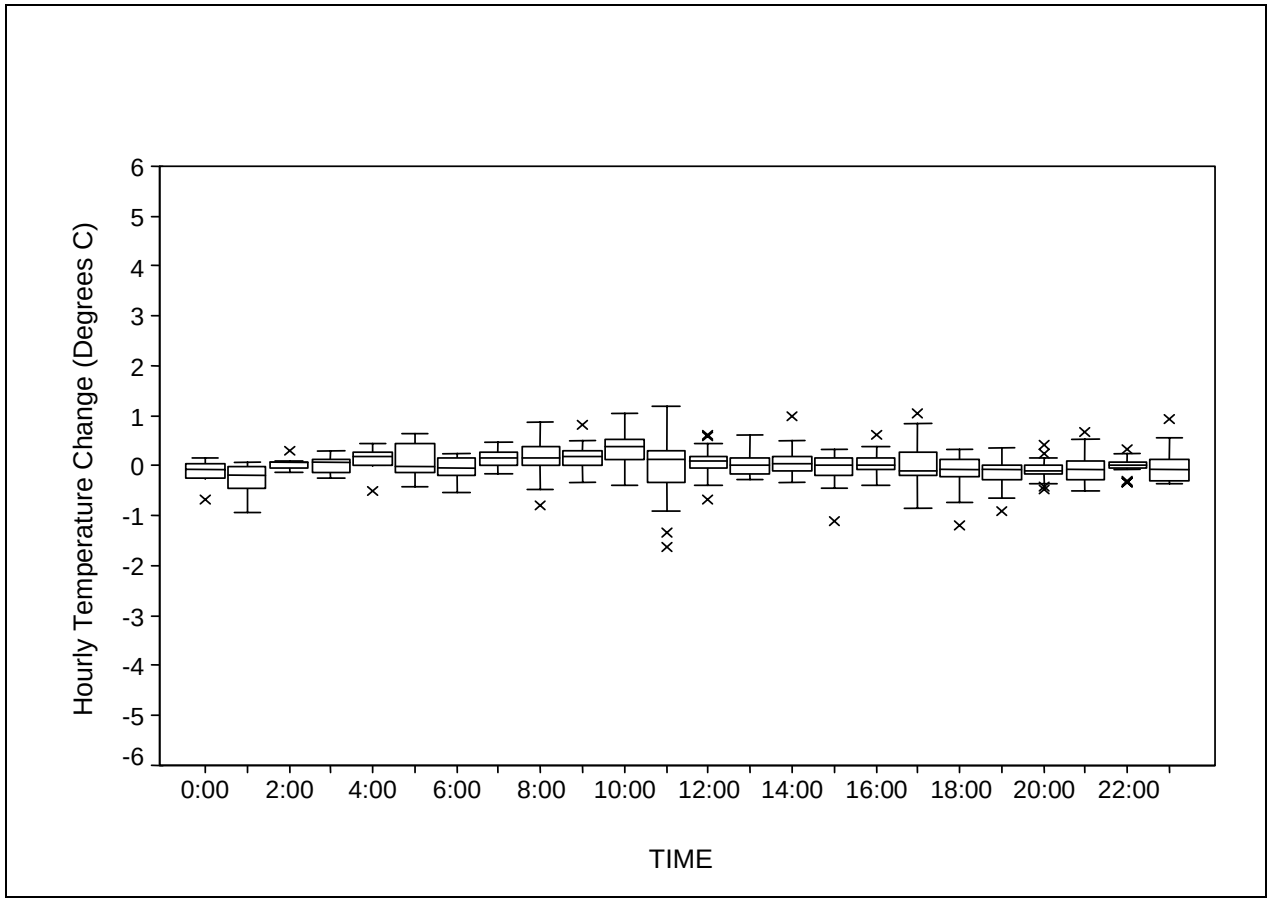

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FIGURE C-101: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (LNR-03)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

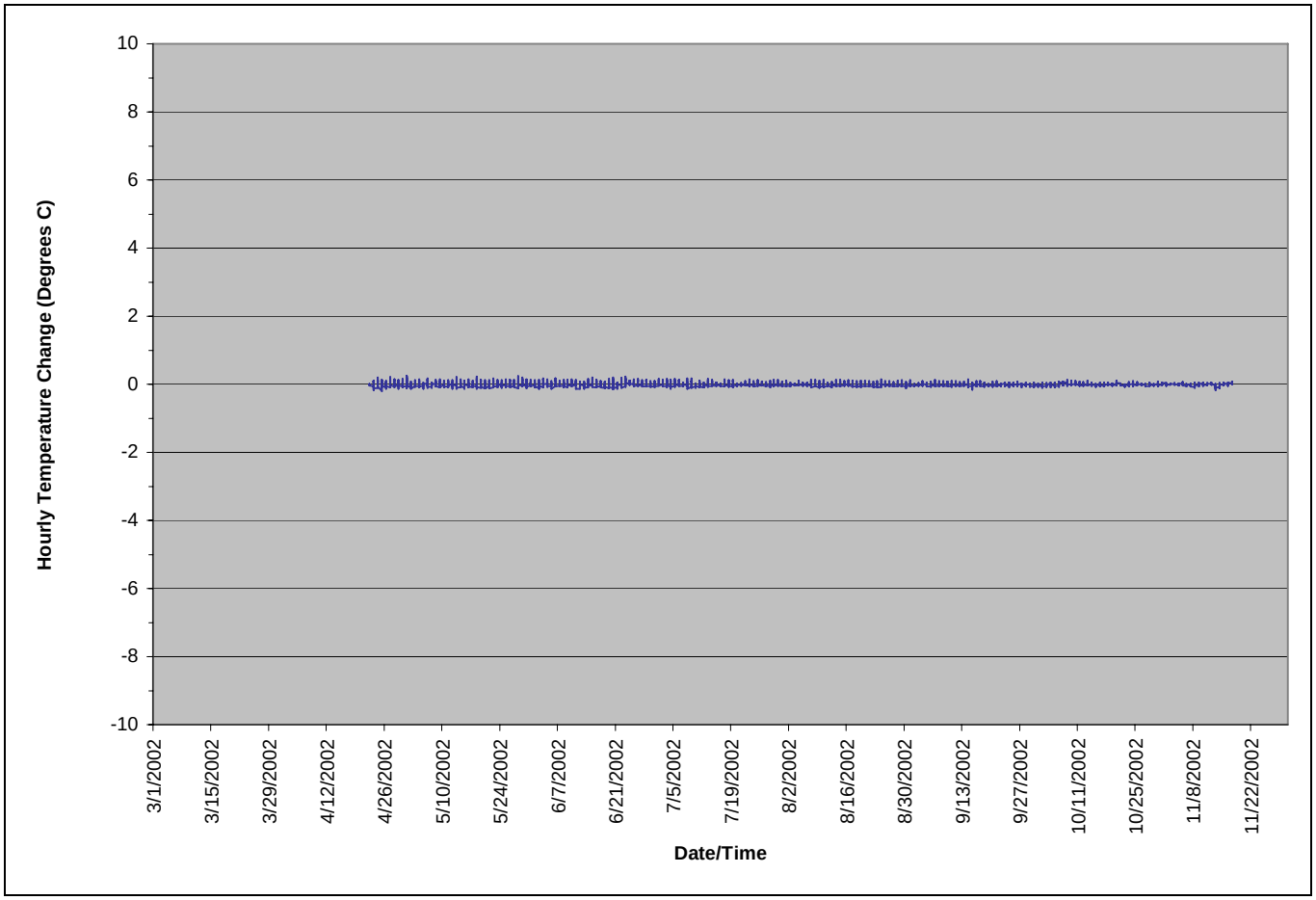

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FIGURE C-102: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (LNR-04)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

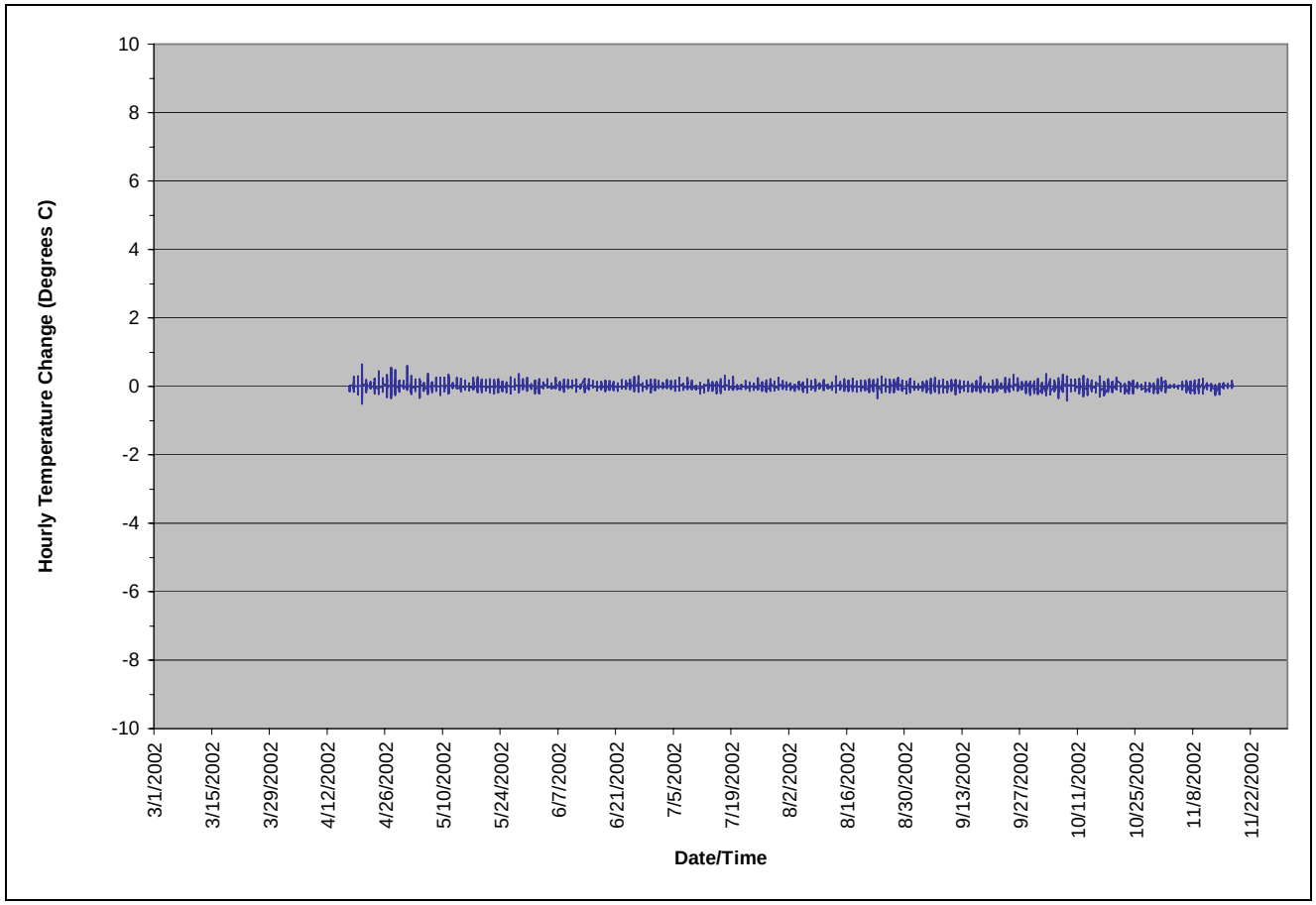

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FIGURE C-103: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (LNR-05)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003

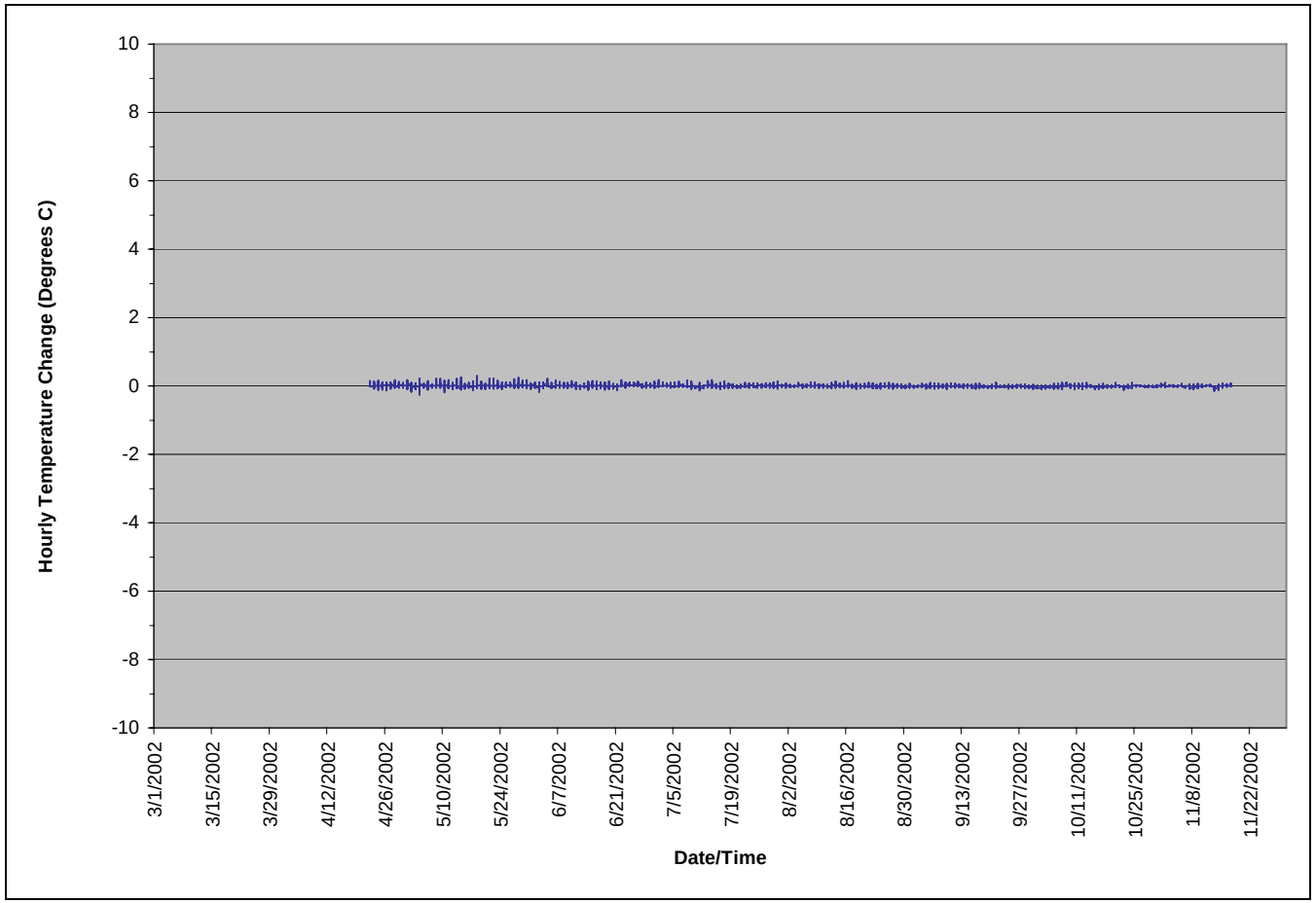

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FIGURE C-104: ANALYSIS ZONE 5 – LOWER NIAGARA RIVER (TM-25)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2002

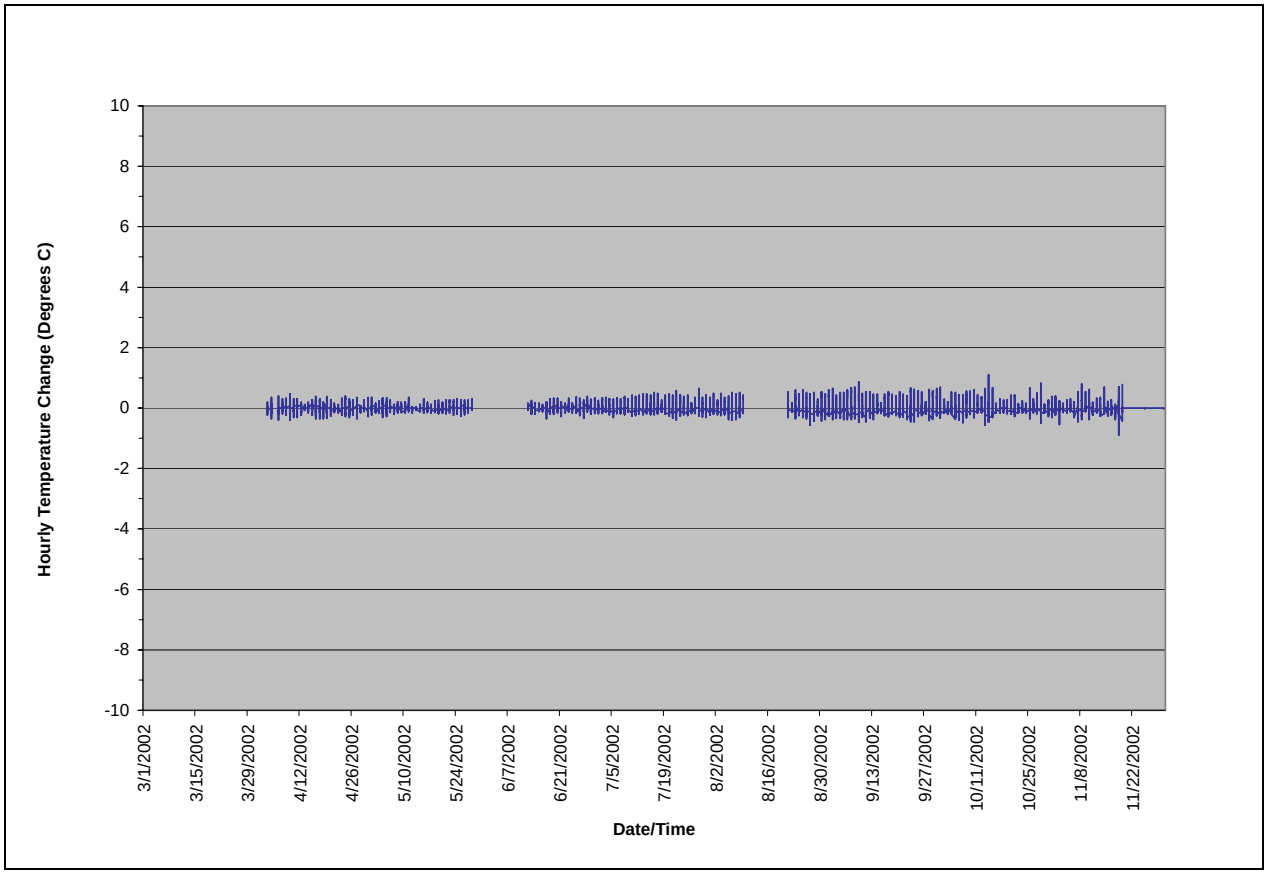

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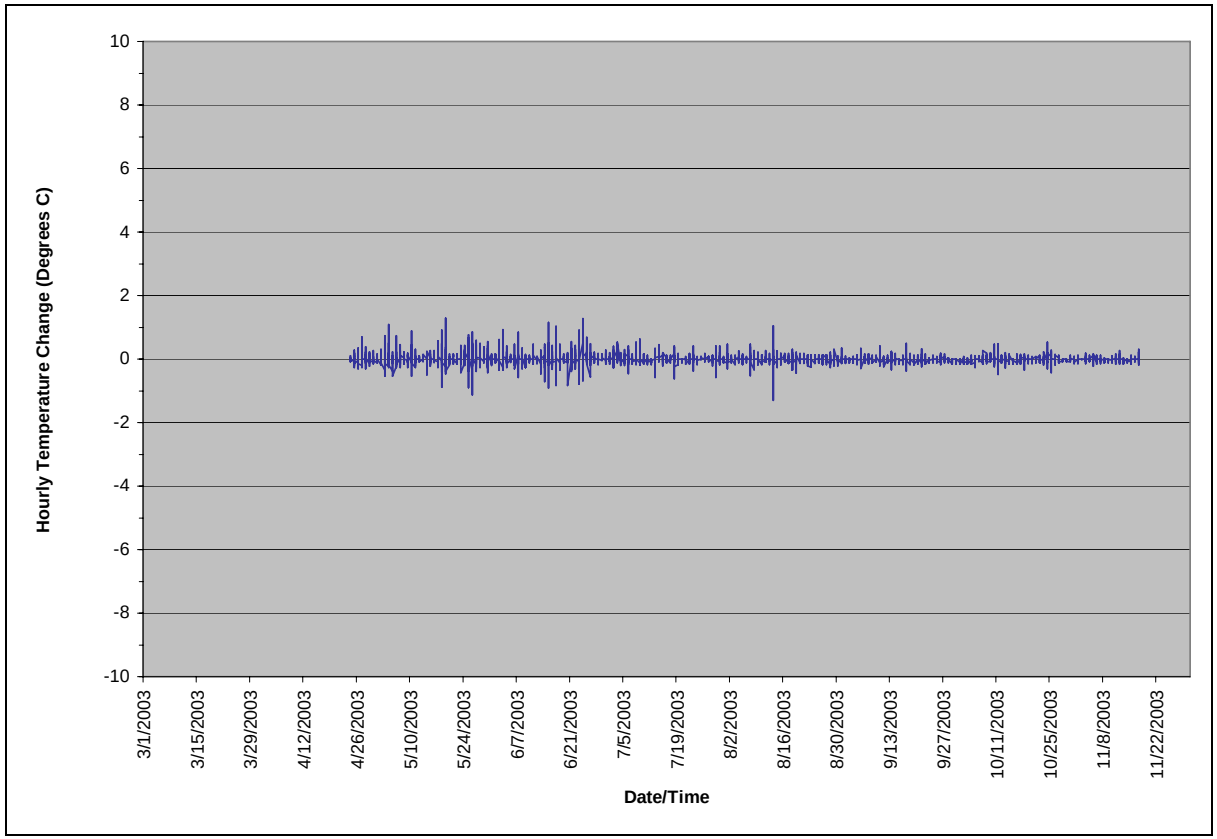
FIGURE C-105: ANALYSIS ZONE 6 – LEWISTON RESERVOIR (TLEW-01)

ANNUAL PATTERN OF $\Delta°C_{WT}$ VALUES FOR 2003



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APPENDIX D – FOCUS FISH SPECIES LIFE HISTORY AND HABITAT INFORMATION

To infer the outcomes of Project operations on water temperatures and subsequent effects on fish spawning, 18 species were chosen to represent the fish community of the upper Niagara River and its tributaries, the lower Niagara River, the Lewiston Reservoir. Following are summaries of the habitat requirements of each fish species, including the range of temperatures at which spawning occurs in northern populations. Tables 2.4-1, 2.4-2, 2.4-3, and 2.4-4 in Section 2.4 of the main body of this document summarize this information in tabular format. Many references give multiple values for preferred and optimum temperatures, velocities, and habitat depths. Individual references give observed values for local populations of fish, but do not always represent the full range of optimum or utilized temperatures throughout the northern range of a species. Wherever possible, the full range of these values for northern populations are given in Tables 2.4-1 through 2.4-4.

The following terms are used in this appendix and report:

- Upper incipient lethal temperature (UILT): The upper thermal range of a species.
- Lower incipient lethal temperature (LILT): The lower thermal range of a species.
- Heat Shock: The temperature threshold at or near the UILT causing death or sufficient incapacitation that death is likely to occur.
- Cold Shock: The temperature threshold at or near the LILT causing death or sufficient incapacitation that death is likely to occur.
- Behavioral effect/Avoidance behavior: A temperature effect insufficient to cause cold shock or heat shock, but large enough to cause a focus species life history stage to abandon the affected habitat.

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American Eel

American eels are catadromous species, living most of their lives in freshwater and migrating to the ocean to spawn (Facey and Van Den Ayle 1987, Scott and Crossman 1979). Spawning is believed to occur from February to April in the Sargasso Sea east of the Bahamas and south of Bermuda (DFOC 2004). Larval American eels, or leptocephali, are transported by ocean currents to estuaries where they transform into juveniles (glass eels and elvers) and enter tributaries (Facey and Van Den Ayle 1987, Scott and Crossman 1979). Juvenile eels migrate upstream to where they spend the majority of their lives as yellow eels (subadults) in rivers, streams, or lakes (Wallus et al. 1990). Mature, or silver, eels migrate downstream to the ocean and back to the Sargasso Sea where they spawn and eventually die (Facey and Van Den Ayle 1987, Scott and Crossman 1979). Maturation occurs in 8 to 24 years, with northern populations maturing later (ASMFC 2000).

American eels in the Niagara River are yellow eels that have migrated up the St. Lawrence River and across Lake Ontario. These eels are three to eight years old as they pass over the Moses-Saunders Dam at Massena, New York (Reid 2001). No other life stage of eel is found in the Niagara River other than the perhaps the silver downstream migratory life stage. American eels in the Niagara River historically are restricted to the lower river, although there may be access to the upper river through the Welland Canal and the New York State Barge Canal System. American eels are reported in Lake Erie, although rarely (Smith 1985, Scott and Crossman 1979). All American eels in Lake Ontario and upstream are female, males remain in estuarine waters of St. Lawrence River (AFS-SOC 2004).

Yellow eels are bottom oriented, feeding primarily on demersal fishes and invertebrates (crayfish, snails, worms and insects) (ASMFC 2000). They are primarily nocturnal, spending daylight hours buried in soft sediments or under larger rocks (Smith 1985, Scott and Crossman 1979).

Adult American eels are tolerant of a range of temperatures, preferring water temperatures between 10°C and 32.2°C. The optimum temperature range for juvenile growth is 25°C (Wismer and Christie 1987).

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The decline in the Lake Ontario basin eel catch is linked to the long-term decline in the number of eels being passed upstream at hydroelectric dams on the upper St. Lawrence River (DFOC 2004, Haro et al. 2000). This decline may be linked to the apparent decline in elver abundance in the lower St. Lawrence River, which has been linked to recent increased demand of juvenile eels (glass eels and elvers) for the overseas aquaculture industry (primarily Asia) resulting in increases in directed fishing effort for this life stage in Canada and Maine (DFOC 2004, Haro et al. 2000). American eels are panmictic, with random mating at the oceanic spawning area (Haro et al. 2000). Dispersal of the larvae from the open ocean to coastal habitat occurs largely by passive drift, with recruitment to any single habitat (e.g., a watershed or estuary) not dependent on the number of adults that emigrate from that specific water body (Haro et al. 2000).

Bluntnose Minnow

Bluntnose minnows are nest building spring and summer spawners that deposit eggs underneath the surface of flat boards, stones, or other objects providing a suitable surface (Scott and Crossman 1979). The male hollows out a nest underneath the object creating a shallow depression. The adhesive eggs are deposited on the underside of the sheltering object. Nests are typically constructed at depths from 0.5 to three feet in depth. Spawning begins in late May to June at temperatures of about 20°C and may continue until August when water temperatures reach approximately 26.1°C (Scott and Crossman 1979; Smith 1985; Becker 1983). Males guard the nest and aerate the eggs by providing water flow through the nest. Males are extremely efficient in guarding nests and serious losses of eggs or fry due to nest abandonment occur only when the nest is repeatedly disturbed by large animals, such as man or wading cattle (Hubbs and Cooper 1936). Females can spawn multiple times during a season (Scott and Crossman 1979; Becker 1983). Eggs hatch in approximately 7-14 days depending on water temperature (Scott and Crossman 1979; Smith 1985).

Adult bluntnose minnows prefer sandy to gravely substrate in clear, shallow lakes and ponds, but are also found in slow moving rock or gravel bed streams (Scott and Crossman 1979). They appear to avoid dense heavy beds of macrophytes. They are bottom oriented, feeding on algae, detritus, insect larvae, and zooplankton (Scott and Crossman 1979; Smith 1985).

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Bluntnose minnows have not been documented to abandon their nests during sudden drops in water temperature and they spawn over such an extended period with multiple spawning by females, that it is unlikely that nest abandonment is a factor in recruitment. Bluntnose minnow fry can survive cold shock (sudden negative change in water temperature sufficient to cause direct or indirect mortality) of -14°C to –17.5°C at acclimation temperatures of 15°C and 25°C (Table 2.4-1). They can also survive heat shock of 19°C to 8.3°C at acclimation temperatures of 5°C to 25°C (Table 2.4-1). Adult bluntnose minnows exhibit avoidance behavior at lower ΔT of -6°C to –3°C at acclimation temperatures of 30°C and 12°C or upper ΔT of 9°C and 3°C at acclimation temperatures of 12°C and 30°C (Table 2.4-1).

Brown Bullhead

Brown bullhead spawn in the late spring and summer as water temperatures approach 21°C (Scott and Crossman 1979). Smith (1985) reported that spawning occurs from late May through June. Spawning occurs in nests cleared by the adults, in relatively shallow areas (less than 4.0 feet), with little or no current, and on preferred substrates of mud, sand, or gravel (Scott and Crossman 1979; Auer 1982). Brown bullhead will nest under and in cover such as boards, hollow stumps, and tires, or in burrows (Scott and Crossman 1979). Spawning occurs during daylight hours usually around the shoreline, in coves, bays, or in creek mouths. The eggs are demersal and adhesive. Either parent or both may guard the nest. Eggs typically hatch in six to nine days at temperatures between 20.6°C and 23.3°C (Scott and Crossman 1979).

Brown bullhead yolk sac fry emerge and remain immobile in the nest for approximately seven days, after which they begin to swim and actively feed (Scott and Crossman 1979). Either or both parents guard the fry for approximately two weeks, during which time they reach approximately 2 inches in length (Scott and Crossman 1979; Smith 1985). Brown bullhead fry prefer shallow areas (less than one foot deep), little to no flow, primarily fine substrates, and are sometimes associated with vegetation (Adams and Hankinson 1928).

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Juvenile brown bullhead initially use similar habitat as fry and then gradually shift to habitats preferred by adults as they grow. They generally prefer shallow areas with little or no flow, soft substrates, and abundant vegetation or other cover types (Raney and Webster 1940; Becker 1983).

Adult brown bullhead are bottom oriented and occur primarily in shallow, warm water areas of lakes and rivers with abundant vegetation and sand to mud substrates (Scott and Crossman 1979). Adults are found in both lentic and lotic environments and, while preferring shallow waters, have been reported at depths up to 40 feet. Brown bullheads are tolerant of warm temperatures, low dissolved oxygen levels, and pollutants that may limit other species (Scott and Crossman 1979).

Brown bullhead have not been documented to abandon their nests during sudden drops in water temperature. Brown bullhead adults can survive cold shock of -20°C to –29.5°C at acclimation temperatures of 20°C and 36°C (Table 2.4-1). They can also survive heat shock of 24.9°C to 13.4°C at acclimation temperatures of 5°C to 20°C (Table 2.4-1). Fry and juveniles can survive heat shock of 13.2°C and 11.9°C at acclimation temperatures of 25°C and 24°C (Table 2.4-1). Juvenile brown bullhead exhibit avoidance behavior at lower ΔT of –3.5°C to –6°C at acclimation temperatures of 3.5°C and 28°C or upper ΔT of 11.1°C and 16.5°C at acclimation temperatures of 25°C and 35°C (Table 2.4-1).

Chinook Salmon

Chinook salmon are anadromous salmonids indigenous to the west coast of North America. They were first introduced into Lake Erie from 1873-1878 by Michigan and Ohio and into Lake Ontario from 1874-1881 by Ontario (Scott and Crossman 1979). New York State began stocking Chinook salmon into Lake Ontario in 1969. Currently the Lake Ontario population is maintained through annual stockings by New York and Ontario.

Chinook salmon are, for the most part, a fall spawning species in the Great Lakes (Smith 1985). In their native range they exhibit at least three spawning strategies with spring, summer, and fall spawning runs depending on river size and distance covered during migration (Beauchamp et al. 1983). Spawning in New York waters begins in late August, but usually occurs from September through October

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(Smith 1985). Spawning can occur between 4.4°C and 13.9°C (Beauchamp et al. 1983; Raleigh et al. 1986). Chinook salmon build nests (redds) in clear, well-oxygenated streams (Beauchamp et al. 1983; Raleigh et al. 1986; Scott and Crossman 1979). They prefer gravel substrates at depths greater than one foot, and water velocities between 1.5 and 2.4 fps (Raleigh et al. 1986). The eggs are demersal and are typically deposited at the center of the redd (nest) where they fall within the interstitial spaces in the gravel substrate (Scott and Crossman 1979).

Incubation and hatching are temperature-dependent. Eggs require an average of 882 to 991 temperature units for hatching (1 temperature unit = 1 degree Fahrenheit above freezing for a period of 24 hours) (Beauchamp et al. 1983). Successful hatching occurs at temperatures of 3.9°C to 16.1°C (Allen and Hassler 1986). Scott and Crossman (1979) reported that the eggs hatch in the spring and the fry remain in the in the gravel for 2 to 3 weeks.

Fry and juveniles remain in their natal rivers from 1 to 18 months (Beauchamp et al. 1983; Allen and Hassler 1986). Fry prefer velocities of less than 1.6 fps, depths greater than 0.5 feet, and gravel substrates (Raleigh et al. 1986). Juveniles tend to prefer deeper, faster water with larger substrates (Raleigh et al. 1986).

Adult Chinook salmon in the Great Lakes are pelagic, mid-lake inhabitants and therefore do not show a preference for substrate type, depth, or water velocity. Depth distribution is related to temperature, dissolved oxygen, and prey abundance. Adult Chinook salmon are known to remain in the marine environment from one to six years with the average being three and four years (Beauchamp et al. 1983).

Although Chinook salmon may stop laying eggs in redds during sudden increases in water temperature, they will resume spawning when water temperatures drop again and dig new redds (Healey 1991). Eggs that have been laid before leaving redds, are in gravel and protected from predators. Chinook salmon embryos can survive cold shock of -6°C to –15.5°C at acclimation temperatures of 7°C and 20°C (Table 2.4-1). Fry can survive cold shock of –9.2°C to –16.6°C at acclimation temperatures of 10°C to 24°C and heat shock of 15.5°C to 1.1°C at acclimation temperatures of 5°C to 24°C (Table 2.4-

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1). Juveniles and adults can survive heat shock of 5°C and 4°C at acclimation temperatures of 17°C and 18°C. Adult Chinook salmon exhibit avoidance behavior at lower ΔT of -3°C or upper ΔT of 21°C (Table 2.4-1). Juvenile Chinook salmon exhibit avoidance behavior at upper ΔT greater than 19.5°C – 22.8°C (Table 2.4-1). Adults stop upstream migration at temperatures of 21°C (McCullough 1999). When stream temperatures drop below 4°C, fry and juveniles enter stream gravels until the water temperature increases (Raleigh et al. 1986).

Emerald Shiner

Limited information exists on emerald shiner spawning. Evidence suggests they have a prolonged spawning season in late spring to early summer with some spawning reported as late as mid-August (Scott and Crossman 1979; Smith 1985). Water temperatures during spawning are around 23.9°C (Smith 1985). Emerald shiners appear to be broadcast spawners, most likely in mid-water areas.

Hatching occurs quickly, within 24 to 32 hours after fertilization, followed by rapid growth. Emerald shiners can reach 8.9 mm (0.35 inches) in approximately 11 days and young-of-year can average 50 mm (1.96 inches) by mid-November (Scott and Crossman 1979).

Emerald shiner juveniles and adults are primarily pelagic, inhabiting large lakes and rivers. They are an offshore schooling species that stays near the surface during the summer months, moving into shallow inshore waters in autumn and spring (Scott and Crossman 1979; Smith 1985).

Emerald shiners do not care for their eggs or young. Emerald shiner embryos can survive cold shock of –12.5°C (Table 2.4-1). Fry can survive cold shock of –13.4°C to –17°C at acclimation temperatures of 15°C to 25°C and heat shock of 5.7°C to 18.3°C at acclimation temperatures of 25°C to 5°C (Table 2.4-1). Juveniles can also survive heat shock of 12.6°C at acclimation temperatures of 20°C to 25°C (Table 2.4-1). Adult emerald shiners exhibit avoidance behavior at a lower ΔT of -14°C at an acclimation temperature of 20°C and an upper ΔT of 22°C at an acclimation temperature of 20°C (Table 2.4-1).

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Greater Redhorse

Greater redhorse spawn from May to July in high gradient runs and riffles when water temperatures are between 12.8°C and 18.9°C (Healy 2002; Scott and Crossman 1979). They prefer shallow depths (0.3-3 feet), moderate velocities (0.1-3.8 fps), and gravel or cobble substrates (Healy 2002). After spawning the adults are known to move downstream to lower velocity runs (Bunt and Cooke 2000).

Larval and juvenile greater redhorse in Minnesota rivers prefer lower velocity pools (Healy 2002). Age-0 fish prefer depths of 0.7 feet and velocities of 0.69 fps (Healy 2002). Juvenile greater redhorse (greater than age-0) prefer slightly deeper pools (2-5 feet deep) and slightly higher velocities (1.2 fps) (Healy 2002).

Adult greater redhorse prefer large clear streams and rivers with coarse substrates such as gravel, cobble, and boulders (Healy 2002, Trautman 1981). Bunt and Cooke (2002) in the Grand River, Ontario, Canada reported the adult's summer range was in low velocity runs (depths of 1.5 ft and velocities of less than 0.6 fps). Like other redhorses they are bottom oriented feeding on insects, invertebrates, worms, and mollusks (Scott and Crossman 1979).

Greater redhorse ΔT shock or ΔT avoidance temperatures have not been documented, nor have these values for any other species of redhorse been documented. The white sucker is the most closely related species with extensive documentation of these values. White suckers have similar spawning requirements and exhibit similar spawning behavior to the greater redhorse and ΔT values for white suckers are likely to closely approximate the values for the greater redhorse. White suckers broadcast their eggs over stream substrates and do not care for their eggs or young. White sucker embryos can survive cold shock of –18.3°C at an acclimation temperature of 21.2°C (Table 2.4-1). They can also survive heat shock of 10.4°C to 20.1°C at acclimation temperatures of 21.1°C to 8.9°C (Table 2.4-1). White sucker fry can survive cold shock of –10.4°C to –15°C at acclimation temperatures of 15.2°C and 21°C and juveniles can survive cold shock of –18°C to –19°C at acclimation temperatures of 20°C and 25°C (Table 2.4-1). White sucker fry can also survive heat shock of 18°C to 9°C at acclimation

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temperatures of 10°C and 21°C and juveniles can survive heat shock of 19°C to 4°C at acclimation temperatures of 5°C and 25°C (Table 2.4-1). Adult white suckers have been documented to exhibit avoidance behavior at an upper ΔT of 12.2°C at an acclimation temperature of 17.2°C (Table 2.4-1).

Lake Sturgeon

Lake sturgeon spawn from early-May to late-June in swift water, rapids, the tailraces of hydroelectric projects, or the bases of small falls in water two to 25 feet deep (Hayes 2000; Knights et al. 2002). Preferred water velocities are between 0.32 fps and 2.29 fps (Threader et al. 1998). Spawning depends on temperature, with peak spawning occurring at temperatures between 10°C and 14.1°C (Kempinger 1988). Clean rock, gravel, and stone bottom substrates are used for spawning by mature adults (Houston 1987; Bouton 1994; Auer 1996; Hay-Chmielewski and Whelan 1997; Borkholder et al. 2002; Knights et al. 2002; Hughes 2002). Where suitable spawning streams are unavailable, lake sturgeon may spawn in wave action over ledges or around rocky islands (Scott and Crossman 1979). The eggs are demersal and adhesive and adhere to stones and vegetation. In general, females spawn every three to seven years and males may spawn every other year (Hay-Chmielewski and Whelan 1997).

Lake sturgeon eggs hatch in 8-14 days at temperatures between 15.6°C and 17.8°C (Kempinger 1988); MacNeill and Busch 1994). The time to hatching depends on water temperature (Kempinger 1988). The yolk sac is absorbed in 9-18 days, and within two-weeks the fry resemble the adult lake sturgeon (Scott and Crossman 1979). At emergence, and from the fry and through the juvenile life stage, lake sturgeon are nocturnal drifters that move downstream in riverine systems (Kempinger 1988, MacNeill and Busch 1994).

In the Niagara River, juvenile and adult lake sturgeon were studied by Mr. Chris Lowie and Mr. Thomas Hughes as part of a Great Lakes native fish restoration project (USFWS 1999; USFWS 2002). To determine movement patterns and habitat preferences in the Niagara River, sturgeon were captured and fitted with ultrasonic tags (Hughes 2002; USFWS 2002). Tagged sturgeon showed some preference for a back eddy area known as Peggy's Eddy below Joseph Davis State Park and the Queenston Long Drift near Lewiston. Sturgeon preferred areas with bottom velocities between 0.62 and 1.2 fps and depths

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between 30 and 35 feet. Juvenile lake sturgeon seemed to prefer nearshore, slow-water currents (mean bottom velocity 0.62 fps) in Peggy's Eddy and the Queenston Long Drift. Subadults preferred areas with currents of approximately 0.88 fps, and adults seemed to prefer the faster currents (mean bottom velocity 1.2 fps) of the river and the area of the river's confluence with the lake. Juveniles, subadults, and adults all occupied similar depths between 30 and 35 feet (USFWS 2002). Threader et al. (1998) reported that juvenile lake sturgeon preferred foraging on substrates of silt, sand, gravel, and cobble, foraging depths of between 6.6 feet and 23.0 feet, and foraging velocities between 0.16 fps and 1.3 fps.

Sturgeon are known to use activity centers (Borkholder et al. 2002) or core areas (Knights et al. 2002). Borkholder et al. (2002) found that 80% of daytime observations were concentrated in four activity centers, and all tagged fish showed some affinity for specific pools. Like Peggy's Eddy and the Queenston Drift, the preferred habitat for sturgeon were areas along transition zones from high current to low current where deposition may occur, such as back eddies. All studies found sturgeon to preferentially use areas over soft substrates such as silt or sand (Borkholder et al. 2002, Knights et al. 2002, Hughes 2002). Sturgeon activity centers generally have low current velocities (Seyler 1997, Borkholder et al. 2002, Hughes 2002). Current velocities under 1.3 fps were preferred by sturgeon in a Minnesota study (Borkholder et al. 2002). Seyler (1997) found that adult lake sturgeon did not prefer habitats with current velocities exceeding 2.0 to 2.3 fps, and Hughes (2002) suggested that juvenile sturgeon prefer areas where current velocities are even lower. The preferred habitats of sturgeon in the lower Niagara River were characterized by sand and gravel, and relatively few zebra mussels. Adults appeared to prefer the lake or main river whereas juveniles preferred back eddy environments (Hughes 2002). In the upper Niagara River, young-of- year sturgeon appear to concentrate in the waters around Buckhorn Island State Park, where currents are lower than in the main river channel (USFWS 1999). Historically, lake sturgeon were believed to spawn in the fast flowing water upstream of the Peace Bridge at the head of the upper Niagara River near the southern end of the Black Rock canal (Goodyear et al. 1982).

Lake sturgeon broadcast their eggs over stream substrates and do not care for their young. While the ΔT shock and ΔT avoidance temperature values for lake sturgeon have not been extensively documented, embryos acclimated at 14°C and suddenly subjected to 10°C temperatures do not experience mortalities (Table 2.4-1). Adult lower ΔT avoidance behavior has been documented at a Δ T of –1.5°C to -3°C at acclimation temperatures of 10°C - 14°C (Table 2.4-1). Spawning behavior resumes when

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temperatures increase. Most fish species can tolerate temperature shifts of 15°C to 18°C, provided the exposure temperature is within the tolerance range (UILT and LILT) of the species, which are well within the range of any temperature shifts likely to occur during the spawning season in the lower or upper Niagara River.

Lake Trout

Lake trout spawn in the Great Lakes from September though November at temperatures ranging from 8.9°C to 13.9°C (Scott and Crossman 1979; Marcus et al. 1984; Sly and Schneider 1984). Spawning occurs over rubble and boulders at depths of one to 40 feet, with reports of fish spawning at 100 to 200 feet in Seneca and Cayuga Lakes (Scott and Crossman 1979; Smith 1985), and in the Great Lakes at depths of < 120 feet. In the Great Lakes, spawning typically occurs in water of <~46 feet deep (Marsden et al. 1995). Lake trout spawn primarily in lakes and rarely in rivers (Scott and Crossman 1979; Marcus et al. 1984). Sly and Schneider (1984) reported lake trout spawning over a cobble-gravel beach in eastern Lake Ontario. The eggs are demersal, falling into the interstitial areas of the substrate.

Hatching time varies; it can range from 15-21 weeks at temperatures between 0.3°C and 1°C (Scott and Crossman 1979). Fry typically seek out deeper water within a month after hatching.

Adult lake trout are typically found near the bottom of cool, well oxygenated lakes at depths ranging from 40 to 175 feet (Scott and Crossman 1979). Their preferred temperatures range between 10°C and 17.2°C (Scott and Crossman 1979; Smith 1985).

Lake trout are fall spawners that broadcast their eggs over lake (and rarely stream) substrates and do not care for their young. Although river spawning may occur in a few tundra rivers of Alaska or Canada, the only documented spawning of lake trout in rivers are a few populations that spawn in Canadian tributaries of Lake Superior (Eschenroder et al. 1995). It has been suggested that the riffles used by lake trout to spawn in were formerly lake shallows that these fish continued to use when lake levels receded (Loftus 1958, Eschenroder et al. 1995). In the rare cases where stream spawning has been documented, lake trout broadcast their eggs over stream substrates of large boulders, cobble and coarse

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gravel and do not care for their young (Loftus 1958). Spawning in rivers occurs in September and is over quickly, with spawning finished by early October, while lake spawning occurs between October and November (Loftus 1958). Lake trout avoid bright light and spawn in rivers at night, entering soon after dark and quickly migrating upstream to spawning areas (Loftus 1958). By midnight, most of the fish have returned to the lake and remain in deep water off river mouths until the next evening when they repeat the process until finished spawning (Loftus 1958). Lake trout inhabit the lower Niagara River during all of the colder fall through spring months and probably treat the river as an extension of lake habitat. Suitable lake type spawning habitat exists in the deeper portions of both the upper and lower Niagara River (Stantec et al. 2005). The native lake trout of Lake Ontario and Lake Erie are extirpated, and the lakes are currently being stocked with various strains of hatchery lake trout stocks (Perkins et al. 1995, Krueger and Ihssen 1995, Hansen and Peck 1995). The Seneca Lake stock has shown the highest success in spawning in Lake Ontario and because of this is the most heavily planted (Perkins et al. 1995). The Seneca Lake stock spawns in deep water at subthermocline depths, beginning at a 9°C temperature, which would indicate a relatively late spawning date (Nov.-Dec.) if spawning occurs in the lower Niagara River (Casselman 1995). The higher rate of egg survival of a deep water spawning stock in Lake Ontario is likely due to higher oxygen saturation at the lower water temperature below the thermocline (Marsden et al. 1995).

Lake trout embryos, juveniles, and adults can survive heat shock of 6°C, 8.5°C, and 4.5°C at acclimation temperatures of 8.8°C, 15°C, and 20°C (Table 2.4-1). They are coldwater adapted salmonids, whose eggs and fry can survive extremes of cold temperatures (Becker 1983). Adult lake trout exhibit avoidance behavior at lower ΔT of -5°C and upper ΔT of 5°C and 3°C (Table 2.4-1).

Largemouth Bass

Largemouth bass typically spawn late spring to early summer, with peak spawning early to mid-June as water temperatures reach 16.1°C – 22.2°C (Stuber et al. 1982; Smith 1985; Scott and Crossman 1979). Optimum weekly mean temperatures for spawning are between 20°C and 22.2°C (Stuber et al. 1982). Optimum water velocities are between 0 and 0.09 fps (Stuber et al. 1982). Largemouth bass spawn on nests constructed by the male in 0.5-26 feet of water, with an average of 1.6-2.9 feet (Stuber et al. 1982). Gravel is the preferred substrate, although largemouth bass will construct nests on other

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substrates, including vegetation, roots, sand, mud, and cobble (Stuber et al. 1982; Scott and Crossman 1979). Where largemouth and smallmouth bass coexist, largemouth bass will spawn sooner, since they nest in shallower, protected waters that warm sooner (Scott and Crossman 1979). The eggs are demersal and adhesive and are typically laid over the entire nest bottom (Scott and Crossman 1979). Males guard the nest during incubation.

At the preferred spawning temperatures, eggs hatch in three to five days (Scott and Crossman 1979; Smith 1985). Fry remain in the nest until the yolk sac is absorbed (6-7 days) then emerge and begin feeding. Optimal water velocities for largemouth bass fry are 0-0.02 fps, with a maximum tolerance of 0.88 fps (Stuber et al. 1982). Fry require 40-80% cover with greater than 3.3 feet water depth for optimal survival (Stuber et al. 1982). Optimal temperatures for fry growth are between 26.7°C and 30°C (Stuber et al. 1982).

Specific habitat requirements for juvenile and adult largemouth bass are the same. Adult largemouth bass inhabit the upper levels of warm water in lakes and rivers and are rarely found in depths greater than 20 feet (Scott and Crossman 1979). Largemouth bass adults and juveniles are usually found associated with extensive growths of EAV and SAV, particularly water lilies, cattails, and various species of pondweed (Scott and Crossman 1979; Stuber et al. 1982; Smith 1985). Optimum cover is between 40% and 60% coverage of the littoral area. Adults are more prevalent in slower waters, with optimum velocities of less than or equal to 0.2 fps (Stuber et al. 1982). Soft to fine substrates are preferred over rocky substrates.

Largemouth bass have been documented to abandon their nests during sudden drops in water temperature of -10°C when mean daily temperatures are approximately 19°C (Table 2.4-1). Largemouth bass juveniles can survive cold shock of -15°C to –19°C at acclimation temperatures of 20°C and 30°C (Table 2.4-1). Largemouth bass adults can survive cold shock of –14.5°C to –18.2°C at acclimation temperatures of 20°C and 30°C (Table 2.4-1). Adults can also survive heat shock of 12.5°C to 6.4°C at acclimation temperatures of 20°C to 30°C (Table 2.4-1). Adult largemouth bass exhibit avoidance behavior at lower ΔT of -3°C at acclimation temperatures of 12°C and 24°C or upper ΔT of 12°C and 11°C at acclimation temperatures of 12°C and 24°C (Table 2.4-1).

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Muskellunge

Muskellunge typically spawn in shallow (less than 6.0 feet deep) lentic waters during the spring at water temperatures between 9.4°C and 15°C (Scott and Crossman 1979; Cook and Solomon 1987). Optimum spawning temperature is 12.8°C (Cook and Solomon 1987). These conditions typically occur between May and mid-June. Harrison (1978) reported that spawning in the Niagara River took place in heavily vegetated lotic areas at depths of 3-7 feet and at higher than the reported optimal temperatures (16.1°C – 17.8°C). Harrison concluded that the limited amount of shallow lentic waters on the Niagara River may have required muskellunge to spawn in the faster and deeper waters than those they normally preferred. Muskellunge prefer abundant vegetation and fine or organic substrates, however no type of vegetation, depth, or cover is critical to reproduction (Cook and Solomon 1987). Muskellunge eggs are semi-demersal, non-adhesive, and are randomly broadcast over submerged vegetation (Scott and Crossman 1979). Eggs are intolerant of sedimentation, low dissolved oxygen, and high hydrogen sulfide levels (Cook and Solomon 1987). Spawning typically continues for one week.

Hatching occurs 8-14 days after spawning at water temperatures between 12.2°C and 16.7°C (Cook and Solomon 1987). Yolk sac fry are inactive, remaining within the spawning vegetation until the yolk sac is absorbed, in approximately 10 days. Muskellunge fry typically remain in or near the spawning area where the submerged vegetation provides cover (Cook and Solomon 1987). Preferred vegetation is a mix of dense and sparse SAV and EAV. These areas are typically 3.3 feet deep, have little to no current, and have substrates consisting of sand, muck, silt, and detritus (Cook and Solomon 1987).

In sampling for juvenile muskellunge on the Niagara River, NYSDEC (1994 and 1995;) found that juveniles were most prevalent at water depths of 2-5 feet, substrates dominated by consolidated silt-clay or sand, and in moderate to dense vegetation. Another observation was that almost every site where juvenile muskellunge were observed, wild-celery was a dominant or significant component of the SAV. No water velocity preferences were discussed. The area with the highest catch rate, however, was an embayment upstream of the Niagara Parks Marina. It is assumed to have relatively slow water velocities (NYSDEC 1994; NYSDEC 1995).

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Adult muskellunge utilize a variety of water depths and cover types associated with their foraging patterns (Cook and Solomon 1987). They are regularly found associated with dense growths of several species of pondweed (*Potamogeton* spp.) and typically inhabit areas less than 15 feet deep (Scott and Crossman 1979). Larger muskellunge are often found in less vegetated water at depths up to 50 feet, particularly during the summer and winter months (Scott and Crossman 1979). Low-velocity waters are preferred, along with sand, gravel, fines, or organic substrate. Optimum water temperature for adults is 25.6°C (Scott and Crossman 1979), with a reported summer range of between 23.9°C and 27.2°C (Smith 1985).

Muskellunge are broadcast spawners that do not exhibit parental care for their eggs or young. Juveniles can survive heat shock of 7.25°C to 3.25°C at acclimation temperatures of 25°C and 30°C (Table 2.4-1). Most fish species can tolerate temperature shifts of 15°C to 18°C, provided the exposure temperature is within the tolerance range (UILT and LILT) of the species, which are well within the range of any temperature shifts likely to occur during the spawning season in the lower or upper Niagara River. The known tolerance levels of muskellunge juveniles to heat shock are similar to those of northern pike and it is likely that the two species have similar tolerances for heat and cold shock.

Northern Pike

Spawning typically occurs in shallow (less than 20 in.) lentic waters over submerged vegetation soon after ice-out (Casselman and Lewis 1996; Inskip 1982; Clark 1950; Scott and Crossman 1979), but spawning has been documented to occur in water up to 16 feet deep (Farrell 2001) with deeper water being used as the spawning season progresses. Harrison and Hadley (1978) found that 97% of the northern pike collected during spawning season in the upper Niagara River waters were collected in its tributaries despite extensive mainstem river sampling. Movement into the spawning areas (i.e., tributaries, flooded marshes, and wetlands) occurs shortly after ice-out as water temperature rise to 7.8°C – 12.2°C (Casselman and Lewis 1996; Inskip 1982; Clark 1950). Spawning typically occurs from late-March to late-April, depending on water temperatures (Clark 1950; Scott and Crossman 1979; Franklin and Smith 1963). Optimal spawning substrates are in shallow flooded areas with moderately dense vegetation such as grasses and sedges. Type or species of vegetation does not appear to be a limiting factor with the exception of cattails, which appear to be unsuitable spawning substrate for northern pike

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(Casselman and Lewis 1996; Inskip 1982). Northern pike eggs are demersal and very adhesive. They are broadcast randomly across the vegetation where they quickly sink and attach to the vegetation (Scott and Crossman, 1979).

Maximum hatching success occurs at temperatures between 8.9°C and 15°C (Inskip 1982). Eggs hatch within 12-14 days at 17.8°C - 20°C (Scott and Crossman 1979). Northern pike yolk sac fry have small papillae on the front of their heads that allow them to attach to the vegetation. This keeps them suspended above the bottom and potential areas with low oxygen or high hydrogen sulfide levels (Inskip 1982). Yolk sac fry may stay attached for 6-10 days. Fry average 0.28-0.35 inches in length at hatching, growing to 0.59-0.79 inches within 10-24 days (Inskip 1982; Franklin and Smith 1963). Habitat requirements are the same as those for spawning.

Emigration of fry from the spawning area takes place from one to six weeks after hatching, and possibly depends on temperature, light intensity, food supply, or water levels (Inskip 1982; Franklin and Smith 1963). Juvenile northern pike move to deeper water, preferably adjacent to the spawning area (Casselman and Lewis 1996). Preferred habitat is dense submergent and emergent vegetation, with 40-90% coverage or other cover such as snags or submerged brush (Casselman and Lewis 1996). A positive correlation exists between depth and juvenile size for the first growing year (Casselman and Lewis 1996). Casselman and Lewis (1996) reported that for the first year, water is approximately 0.32 feet deep for every 0.46 inches of body length up to 5.9 inches in length. Depth preferences during the first year would then range between 0.32 and 4.0 feet. Growth is rapid, with juveniles reaching approximately 1.6 inches by the first month and approximately 5.9 inches by the end of the first growing season. Optimum temperature for juvenile growth is 19.9°C – 22.8°C (Casselman and Lewis 1996; Inskip 1982). Preferred substrates are mostly gravels, sands, fines, or organic muck, as these substrates are most typically associated with SAV/EAV beds (Inskip 1982).

Adult northern pike generally prefer shallow vegetated areas (usually less than 13 feet), but sometimes are found as deep as 39 feet (Casselman and Lewis 1996). Larger adults will utilize open water or the open water macrophyte interface more than smaller adults or juveniles. Chapman and Mackay (1984) found that larger northern pike were found in deep, unvegetated waters more frequently than smaller individuals. Northern pike in the St. Lawrence River have been caught with downriggers in

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water as deep as 60 feet. Very dense vegetation appears to be suboptimal for larger fish whereas the macrophyte-open water interface zone may provide important foraging habitat for larger adults (Casselman and Lewis 1996). Macrophyte growth and density may affect northern pike density and size distributions. Lakes with dense macrophytes tend to have larger populations of smaller northern pike than lakes with more open water-macrophyte interface areas (Casselman and Lewis 1996). Optimum water temperature for adult growth is reported to be between 19.9°C and 21.1°C (Inskip 1982, Casselman and Lewis 1996).

Northern pike are broadcast spawners that do not exhibit parental care for their eggs or young. Northern pike embryos can survive cold shock of –16.9°C at an acclimation temperature of 21.8°C and cold shocks of over –10°C at lower temperatures (Table 2.4-1). They can also survive heat shock of 14.5°C to 12.3°C at acclimation temperatures of 6.1°C to 11.8°C (Table 2.4-1). Fry can survive cold shock of –15°C at an acclimation temperature of 18°C and heat shock of 18.5°C at an acclimation temperature of 16°C (Table 2.4-1). Juvenile northern pike can survive heat shock of 3.25°C to 7.25°C at acclimation temperatures of 30°C and 25°C (Table 2.4-1). Adults can survive cold shock of –16.9°C at an acclimation temperature of 21.6°C and heat shock at 3°C to 7°C at acclimation temperatures of 30°C and 25°C. Adult northern pike have been documented to exhibit avoidance behavior at lower ΔT of -11°C (Table 2.4-1).

Rainbow Smelt

Rainbow smelt are typically anadromous and run up streams and rivers from the sea or large lakes (in the case of landlocked forms) in the spring to spawn (Scott and Crossman 1979). They are indigenous to the Atlantic coastal drainage from New Jersey to Labrador. They have been successfully introduced into many inland waters, including the Great Lakes (Buckley 1989). Rainbow smelt begin their spawning migrations in March though April soon after ice-out and spawn at water temperatures between 8.9°C and 17.8°C (Buckley 1989; Scott and Crossman 1979; Jilek et al. 1979). In the Great Lakes, they typically spawn in streams and along offshore gravel shoals from late-April to early-May (Scott and Crossman 1979; Jilek et al. 1979). Spawning can occur over a period of three weeks, but one week is more typical. Spawning takes place in water with velocities ranging from 1.97-2.62 fps and depths ranging from 0.3 to

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4.3 feet, with higher egg deposition in areas with the highest velocities (Buckley 1989). Rainbow smelt prefer sand and gravel substrates for spawning, with eggs deposited over gravel having a higher survival rate (Scott and Crossman 1979; Banner and Hayes 1996; Buckley 1989). The eggs are demersal and adhesive and quickly become attached to the substrate, which allows the egg to sway (balloon-like) in the current (Scott and Crossman 1979; Buckley 1989).

Hatching may occur anywhere from 2 to 3 weeks after fertilization (Scott and Crossman 1979). On hatching, the yolk sac larvae drift downstream with the current and concentrate near the surface (Buckley 1989; Scott and Crossman 1979). As the fry grow, they tend to concentrate near the bottom during the day in inshore areas along sand and gravel beaches, and move near the surface at night, apparently to feed (Scott and Crossman 1979; Buckley 1989).

Juvenile and adult smelt are pelagic, schooling fish that inhabit the midwater areas of lakes and rivers, with their depth in the water column depending on light and temperature. They have been found near the bottom of Lake Erie in 80 feet of water during daylight hours (Scott and Crossman 1979). Banner and Hayes (1996) report the optimal temperature preference range for adults and juvenile is between 3.9°C and 20°C. Being pelagic, adult and juvenile rainbow smelt have no distinct substrate preference. Coastal populations of juveniles have, however, been reported in and have a high preference for wild-celery (Buckley 1989; Banner and Hayes 1996).

Rainbow smelt are spring broadcast spawners that do not exhibit parental care for their eggs or young. Rainbow smelt adults can survive cold shock of –8.5°C at an acclimation temperature of 17°C and heat shock of 11.3°C to 13.5 at acclimation temperatures of 19.2°C and 15°C (Table 2.4-1). Most fish species can tolerate temperature shifts of 15°C to 18°C, provided the exposure temperature is within the tolerance range (UILT and LILT) of the species, which are well within the range of any temperature shifts likely to occur during the spawning season in the lower Niagara River.

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Rainbow Trout

Rainbow trout are anadromous salmonids indigenous to the west coast of North America. They were introduced in New York in 1874 or earlier (Scott and Crossman 1979). They are, for the most part, a spring spawner with two distinct migrations, an early run in the fall with the adults overwintering in the spawning river and a typically larger spring run just prior to spawning. Spawning can occur from March to August, but usually occurs from mid-April to late-June at temperatures between 10°C and 15.6°C (Scott and Crossman 1979; Raleigh et al. 1984). Rainbow trout build nests (redds) in clear, well-oxygenated streams (Barnhart 1986). Spawning rainbow trout prefer gravel substrates, depths between 1 and 8 feet, and water velocities between 1.6 and 3.0 fps (Raleigh et al. 1984; Barnhart 1986). The eggs are demersal and are typically deposited at the center of the nest where they fall within the interstitial spaces in the gravel substrate (Scott and Crossman 1979).

Hatching is temperature-dependent and incubation can take from approximately 19 days at 15°C to 80 days at 5°C (Barnhart 1986). The optimal temperature for embryo incubation is 7°C - 12°C (Raleigh et al. 1984). When spawning occurs in April or May, fry remain in the gravel for 2 to 3 weeks after hatching, then emerge from the nest in mid-June to mid-August (Scott and Crossman 1979; Barnhart 1986). Rainbow trout fry remain in the riffle areas of their natal streams, usually in the shallow waters along the streambank. They prefer water depths from 0.8 to 1.6 feet, velocities from zero to 0.5 fps, and cover in the form of rock crevices, vegetation, and debris piles (Raleigh et al. 1984). As the fry grow, they tend to move downstream to deeper and faster water. Stream-resident fry overwinter in shallow, low-velocity areas with substrate components from 4 to 16 inches in diameter (Raleigh et al. 1984).

Juvenile rainbow trout prefer velocities of zero to 0.98 fps, depths greater than 2.0 feet, and substrates of cobble and boulder (Raleigh et al. 1984). Preferred temperatures are between 10°C and 22.2°C. Juveniles in Lake Ontario and Lake Erie tributaries tend to migrate out to the lakes to avoid rising stream temperatures during the summer months. In other populations, however, juveniles may reside in the natal streams for one to four years (Barnhart 1986).

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Adult rainbow trout in the Great Lakes are pelagic, mid-lake inhabitants and therefore do not show a preference for substrate type. Depth distribution is related to temperature, dissolved oxygen, and prey abundance. Lake-resident rainbow trout adults prefer water between 7°C and 17.8°C at a preferred dissolved oxygen level of between 7 and 9 mg/l (Raleigh et al. 1984).

Although rainbow trout may stop laying eggs in redds during sudden decreases in water temperature, they will resume spawning when water temperatures drop again and dig new redds (Healey 1991). Eggs that have been laid before leaving redds, are in gravel and protected from predators. Rainbow trout adults can survive cold shock of –8.5°C at an acclimation temperature of 17°C and heat shock of 11.3°C to 13.5°C at acclimation temperatures of 10.2°C and 15°C (Table 2.4-1). Adult rainbow trout exhibit avoidance behavior at upper ΔT of 10°C (Table 2.4-1). Most fish species can tolerate temperature shifts of 15°C to 18°C, provided the exposure temperature is within the tolerance range (UILT and LILT) of the species, which are well within the range of any temperature shifts likely to occur during the spawning season in the lower Niagara River. Rainbow trout are more tolerant of temperature extremes than Chinook salmon and can be expected to survive greater upper ΔT (McCullough 1999).

Rock Bass

Rock bass spawn from late spring to early summer (mid-May to mid-June) at temperatures between 15.6°C and 21.1°C (Scott and Crossman 1979; Smith 1985). Spawning occurs in shallow nests built by the males in diverse areas ranging from swamps to gravel shoals (Scott and Crossman 1979). Preferred depths are between 2 and 4 feet (Bovee et al. 1994). Bovee et al. (1994) reported that rock bass in the Huron River, Michigan, showed a definite preference for spawning areas with little or no flow, and were most commonly found in areas with no current. Rock bass prefer gravel substrate and instream cover such as velocity shelters (logs, boulders, root wads) and emergent vegetation (Bovee et al. 1994, Smith 1985). The eggs are demersal and adhesive (Scott and Crossman 1979).

Hatching occurs within three to four days at temperatures between 20.5°C and 21°C (Scott and Crossman 1979). The male guards the nest and fry for up to 14 days (Smith 1985). Fry habitat requirements are the same as spawning habitat requirements.

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Juvenile rock bass prefer depths of between 1.1 and 2.5 feet for summer, and between 2.5 and 3.5 feet for winter (Bovee et al. 1994). They prefer waters with velocities from zero to 0.82 fps, and are often associated with instream cover such as logs, boulders, root wads, and emergent vegetation (Bovee et al. 1994). Smith (1985) reports that the young are frequently abundant in aquatic vegetation.

Rock bass adults generally inhabit rocky areas in shallow waters (Scott and Crossman 1979). Optimal depths for adults reported by Bovee, et al. (1994) ranged from 1.3 to 2.8 feet in summer and 2.5 to 3.5 feet in winter. Optimal velocities ranged from 0.16 to 0.92 fps in summer and zero to 0.66 fps in winter (Bovee et al. 1994).

Rock bass have not been documented to abandon their nests during sudden drops in water temperature. Rock bass juveniles can survive heat shock of 13.6°C to 18°C at acclimation temperatures of 23.9°C to 18°C (Table 2.4-1). Rock bass adults can survive heat shock of 5°C at an acclimation temperature of 30°C (Table 2.4-1). Juvenile rock bass exhibit avoidance behavior at lower ΔT of -3°C to -6°C at acclimation temperatures of 18°C and 33°C or upper ΔT of 9°C and 2°C at acclimation temperatures of 18°C and 33°C (Table 2.4-1).

Smallmouth Bass

Smallmouth bass spawn in the spring to early summer (mid-April to July) at water temperatures between 12.8°C and 25°C, with egg deposition occurring mostly between 16.1°C and 18.3°C (Edwards et al. 1983; Scott and Crossman 1979). Smallmouth bass build nests in areas with low currents (zero to 1.1 fps), generally at depths of 2 to 6 feet (range from 2-20 feet), and on coarse substrates (preferably gravel) (Edwards et al. 1983, Scott and Crossman 1979). Spawning nests are usually associated with instream cover such as logs, stumps, or boulders (used as velocity shelters in riverine environments). The eggs are demersal and adhesive and are usually attached to clean substrate in the center of the nest (Scott and Crossman 1979). The male guards the nest and newly hatched fry.

Hatching occurs in 4 to 10 days at temperatures typically found during the spawning period (Scott and Crossman 1979). The yolk sac is absorbed within 12 days and the fry typically remain on the nest

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another 5-7 days, still guarded by the male. Larval smallmouth bass remain on the nest for 5-7 days (Scott and Crossman, 1979). They prefer velocities of less than 0.5 fps and will use cover as velocity shelters (Edwards et al. 1983). Fry will utilize a variety of substrate types, with a preference for gravel or a gravel/cobble mix (Edwards et al. 1983). Optimal water temperature for fry growth is between 20°C and 30°C and their preferred depths are less than 2.4 feet (Edwards et al. 1983). Smallmouth bass fry may be found anywhere from late spring through summer.

Juvenile smallmouth bass prefer somewhat shallower waters than do the adults, with a preferred depth of 2.4 feet or greater. Adults prefer depths of 4.0 feet or greater (Edwards et al. 1983). Juvenile and adult smallmouth bass both prefer low current velocities, but are both found in lotic waters with adequate velocity shelters (Edwards et al. 1983). Optimal water velocities for juveniles and adults are between zero and 0.5 fps (Edwards et al. 1983). They both prefer coarse substrates (primarily cobbles and boulders) and are often associated with instream cover. Adult smallmouth bass will move to deeper water to avoid temperature extremes and become relatively inactive at less than 10°C (Scott and Crossman 1979).

Smallmouth bass have been documented to abandon their nests during sudden drops in water temperature of -10°C to –11.1°C when mean daily temperatures are approximately 15.6°C (Tables 2.4-1 and 2.4-3). Smallmouth bass juveniles can survive cold shock of -13°C to –16°C at acclimation temperatures of 15°C and 26°C (Table 2.4-1). They can also survive heat shock of 19.4°C to 12.8°C at acclimation temperatures of 12.8°C to 35°C (Table 2.4-1). Smallmouth bass adults can survive cold shock of -20°C and heat shock of 2°C at an acclimation temperature of 35°C (Table 2.4-1). Embryos and fry can survive heat shock of 12.8°C and 15°C at an acclimation temperature of 20°C (Table 2.4-1). Adult smallmouth bass exhibit avoidance behavior at lower ΔT of -10°C to –11.1°C when attending nests at an average mean water temperature of 15.6°C (Table 2.4-1). Juvenile smallmouth bass exhibit avoidance behavior at lower ΔT of -3°C to -6°C at acclimation temperatures of 18°C and 33°C or upper ΔT of 9°C and 2°C at acclimation temperatures of 18°C and 33°C (Table 2.4-1).

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Walleye

The scientific name of the walleye's genus was revised in 2003 from *Stizostedion* to *Sander* (pronounced *Zander*). The species name was changed from *vitreum* to *vitreus* to agree with the masculine gender of Sander (Nelson et al. 2003).

Walleye spawn in the spring shortly after ice-out at water temperatures between 6.1°C and 11.1°C (McMahon et al. 1984; Scott and Crossman 1979). Spawning occurs at preferred depths of 2.5 to 5.0 feet (McMahon et al. 1984; Beak 1992), with the reported range of less than 1.0 to 20 feet (Pitlo 1992). Water velocity preferences range from 2.0 to 3.6 fps, with optimal velocities between 2.5 and 3.0 fps (McMahon et al. 1984). Walleye will spawn on substrates sized from sand through cobble, however a gravel-cobble mix is the preferred substrate (McMahon et al. 1984). Beak (1992) found walleye spawning over gravel/cobble, cobble/rock, and cobble/boulder substrates on the Trent River, Ontario. Eggs are demersal and non-adhesive after hardening. They are broadcast and fall into the crevices of the substrate (Scott and Crossman 1979).

Eggs hatch within 12 to 18 days at temperatures reported for spawning (Scott and Crossman 1979). The yolk sac is quickly absorbed and within 10 to 15 days after hatching, the fry emerge from the substrate and are dispersed by drifting with the currents (Scott and Crossman 1979). Fry are typically found at water depths between 1 and 12 feet, over substrates ranging from silt to gravel, and in waters with velocities less than 0.25 fps (McMahon et al. 1984). They show no strong preference for cover and become primarily demersal after the brief pelagic stage (Nobel 1972; Scott and Crossman 1979). Walleye fry typically inhabit nearshore areas and move to deeper waters as juveniles (Scott and Crossman 1979). The optimum water temperature for growth is near 22.2°C (McMahon et al. 1984).

Juvenile walleyes prefer depths of 4.0 to 6.0 feet, little or no current, substrates of silt through gravel, and sparse vegetation (McMahon et al. 1984). Depth preferences increase with size and lateness of the season, with larger juveniles inhabiting waters as deep as 20 feet by the fall months (Festa et al. 1987).

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Adult walleyes have similar habitat preferences as larger juveniles. They prefer calm water, but are found in water with velocities up to 3 fps (McMahon et al. 1984). Adults prefer water depths greater than 4.0 feet with depth preferences increasing with increased water clarity (McMahon et al. 1984). Walleyes are sensitive to light and use deeper waters and objects as cover from light. Preferred substrates include silt through cobble/boulders, sometimes associated with vegetation-open water interface zones, although there is no strong requirement for vegetation (McMahon et al. 1984; Beak 1992).

Walleye broadcast their eggs over stream substrates and do not care for their young. Walleye embryos can survive cold shock of –8.8°C at an acclimation temperature of 11°C and heat shock of 20.2°C at an acclimation temperature of 11°C (Table 2.4-1). Fry can survive cold shock of –16°C at an acclimation temperature of 18°C (Table 2.4-1). Juveniles can survive heat shock of 5.8°C to 19°C at acclimation temperatures of 25.8°C to 8°C (Table 2.4-1). Adult walleye can survive cold shock of –17°C and heat shock of 21.7°C at acclimation temperatures of 25°C and 7.2°C (Table 2.4-1). A change of temperature during the incubation of walleye embryos of ±19ºC over a 2-hour period causes neither "excessive mortality nor any immediate adverse effect." Walleye fry tolerate temperature changes of 1.5ºC/minute, a relatively high rate compared with changes likely to occur in natural spawning areas (Schneider et al. 2002). On walleye spawning grounds in lakes and rivers, water temperature fluctuations high enough to reduce hatching success (±14-19º C) are very unlikely to occur (Schneider et al. 2002).

Fry must leave to reach a food source within 3 to 5 days, or they will perish (Becker 1983). Newly hatched fry drift passively for about four days until their yolk sac is absorbed (Olson et al. 1978). In rivers, they remain in pools (Olson et al. 1978). They are usually swept by water currents and carried down-river or to downstream lakes before the food supply in their yolk sac has been used up. Fry require temperatures >15ºC to begin to feed (McMahon et al. 1984). Larvae move in a vertical direction toward the surface of the water where the current is most rapid. Walleye larvae are unable to survive passage over dams, where they are either killed or trapped in the eddies below the dam (Becker 1983). Although suitable spawning habitat exists for walleye in the upper Niagara River, it is likely that any fry produced are carried downstream and over the falls, which are unlikely to survive. Spawning in the upper Niagara River would not be precluded due to lack of survival of fry, because homing behavior of spawners appears to be weakly developed compared with that of Pacific salmon. It has been proposed that walleye homing is an adult-learned behavior, which is reinforced by repeated migrations. Younger mature adults

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learn migratory spawning behavior from older fish with established movement patterns. Natal imprinting, as in salmon, is also learned behavior during the stream rearing period (Olson et al. 1978).

White Sucker

White suckers begin upstream migrations to their preferred spawning areas usually from mid-April to early June when water temperatures reach 10°C (Scott and Crossman 1979; Smith 1985; Twomey et al. 1984). Spawning occurs on gravel substrates in shallow flowing waters. Optimum spawning depths are between 0.2 and 1.0 feet and optimum velocities are between 1 and 2 fps (Twomey et al. 1984). Eggs are broadcast and adhere to the gravel or drift downstream where they adhere to substrates in areas with slower water (Scott and Crossman 1979; Twomey et al. 1984).

The eggs hatch in approximately two weeks at temperatures of 10°C - 15°C (Scott and Crossman 1979). Fry emerge from the gravel approximately 9 to 11 days after hatching and drift downstream at night (Twomey et al. 1984). White sucker fry prefer waters deeper than 1 foot and with velocities less than 0.3 fps (Twomey et al. 1984).

Adult white suckers are habitat generalists and can tolerate a wide range of environmental conditions (Twomey et al. 1984). In New York they are commonly found in nearly every habitat type from small streams to large lakes and rivers (Smith 1985). They are bottom oriented and feed primarily on invertebrates (Scott and Crossman 1979; Smith 1985). White suckers are typically found in warm, shallow waters in lakes, streams, and rivers usually within the top 20-30 feet. Adults show a preference for waters with velocities between 0.16 and 0.66 fps and depths between 2.3 and 9.8 feet (Twomey et al. 1984).

White suckers broadcast their eggs over stream substrates and do not care for their eggs or young. White sucker embryos can survive cold shock of –18.3°C at an acclimation temperature of 21.2°C (Table 2.4-1). They can also survive heat shock of 10.4°C to 20.1°C at acclimation temperatures of 21.1°C to 8.9°C (Table 2.4-1). White sucker fry can survive cold shock of –10.4°C to –15°C at acclimation temperatures of 15.2°C and 21°C and juveniles can survive cold shock of –18°C to –19°C at acclimation

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temperatures of 20°C and 25°C (Table 2.4-1). White sucker fry can also survive heat shock of 18°C to 9°C at acclimation temperatures of 10°C and 21°C and juveniles can survive heat shock of 19°C to 4°C at acclimation temperatures of 5°C and 25°C (Table 2.4-1). Adult white suckers have been documented to exhibit avoidance behavior at an upper ΔT of 12.2°C at an acclimation temperature of 17.2°C (Table 2.4-1).

Yellow Perch

Yellow perch spawning takes place in the spring from mid-April to early-May at temperatures between 7.2°C and 12.7°C (Kreiger et al. 1983; Scott and Crossman 1979). Hokanson (1977) reported that the most frequently found water temperatures during spawning are between 6.1°C and 8.9°C. Preferred spawning habitat has water depths of 1.2 to 3.0 feet, velocities less than 0.25 fps, substrates of mud or silt, and aquatic vegetation or submerged brush (Scott and Crossman 1979; Kreiger et al. 1983). Eggs are extruded as an adhesive gelatinous accordion-folded string or mass that is semi-buoyant. This egg mass is easily transported by wave action until it adheres to the submerged vegetation or sometimes the bottom (Scott and Crossman 1979).

The eggs hatch approximately 8-10 days after spawning, but have been reported to take as long as 27 days at 8.3°C (Scott and Crossman 1979). The yolk sac fry are inactive for approximately five days until absorption of the yolk, when they become pelagic and drift with the current. Yellow perch fry are generally found in the upper 5.0 feet of the water column but have been found at depths to 20 feet (Nobel 1968). Because of their pelagic nature, fry may be found offshore as well as nearshore. When occurring in the nearshore area they are typically associated with vegetation, little to no water currents, and silt or silty-sand substrates (Kreiger et al. 1983). As the fry grow, they become less pelagic and move into littoral areas where they become demersal (Carlander 1997). Yellow perch fry may be found from spring through mid-summer.

Young juvenile yellow perch prefer shallower waters as compared to older juveniles and adults. The preferred depth range for young juveniles is between 1.6 and 2.0 feet and from 5.0 to 20.0 feet for older juveniles and adults. Beak (2000) found numerous yellow perch adults in Lake Michigan at depths

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of up to 95 feet (deepest water sampled) and had reliable reports of numerous adults captured in commercial bottom-set gill nets as deep as 200 feet. Juveniles and adults prefer little to no current; silt, gravel and cobble substrates; and moderate amounts of vegetation (Kreiger et al. 1983; Robillard and Marsden 2001).

Yellow perch broadcast their eggs over vegetation and do not care for their young. Yellow perch embryos have been documented to survive cold shock of –4.4°C with no mortalities occurring (Becker 1983). Yellow perch embryos are likely to survive cold shock of at least –8.8°C. Fry can survive heat shock of 16.4°C to 19.8°C at acclimation temperatures of 7.6°C and 15.8°C (Table 2.4-1). Adults can survive cold shock of –9.9°C to –21.3°C at acclimation temperatures of 11°C and 25°C. Adults can also survive heat shock of 7.3°C to 16°C at acclimation temperatures of 25°C to 5°C (Table 2.4-1). The juvenile stage is the most thermally tolerant stage in the life cycle of percids (Hokanson 1977). Juvenile yellow perch have been documented to exhibit avoidance behavior at lower ΔT of –3°C to -6°C at acclimation temperatures of 15°C and 24°C and upper ΔT of 5°C to 6 at acclimation temperatures of 24°C and 15°C (Table 2.4-1).

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