NIAGARA POWER PROJECT

RELICENSING

NIAGARA RIVER WATER LEVEL AND FLOW FLUCTUATION STUDY FINAL REPORT

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1993 Directive of the International Niagara Board of Control 11

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ABBREVIATIONS

Agencies

CHS	Canadian Hydrographic Service
EC	Environment Canada
FERC	Federal Energy Regulatory Commission
IJC	International Joint Commission
INBC	International Niagara Board of Control
NOAA	National Oceanic and Atmospheric Administration
NRCC	Niagara River Control Center
NYISO	New York Independent System Operator
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

Units of Measure

cfs	cubic feet per second
E.S.T.	Eastern Standard Time
E.D.S.T.	Eastern Daylight Savings Time

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El.	elevation
fps	feet per second
IGLD 1985	International Great Lakes Datum 1985
mph	miles per hour
MW	megawatt, or one million watts
NGVD	National Geodetic Vertical Datum
USLSD	U.S. Lake Survey Datum 1935

Miscellaneous

ADCP	Acoustic Doppler Current Profiler
LPGP	Lewiston Pump Generating Plant
NYPA	New York Power Authority
OPG	Ontario Power Generation

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EXECUTIVE SUMMARY

In preparation for relicensing of the Niagara Power Project (the Project) an engineering analysis was performed for the New York Power Authority (NYPA) to determine: 1) the magnitude, frequency and spatial extent of water level and flow fluctuations in the Niagara River and 2) the magnitude and frequency of water level fluctuations in Lewiston Reservoir associated with power generation at the Project.

It was known at the investigation's outset that water level fluctuations in both the upper and lower Niagara River (i.e., the portions of the river above Niagara Falls and below it, respectively) 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 regulation of Niagara Falls flows for scenic purposes, operation of 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. Therefore, for many of the analyses, the reported water level fluctuations in the Niagara River include the influences from all the factors. One exception was the effects of storm and wind induced water level fluctuations that were differentiated through a combination of gauge data analysis and empirical calculation of surface wave height and wind setup.

The Niagara River Water Diversion Treaty of 1950 specifies that flow over Niagara Falls be at least 100,000 cfs during tourist-season (April 1 to October 31) daylight hours and at least 50,000 cfs at all other times. The purpose of regulation of water levels in the Chippawa-Grass Island Pool is to ensure the availability of sufficient flows to satisfy these treaty requirements while providing for power production and maintenance of water levels in the pool within the specifications of a 1993 Directive of the International Niagara Board of Control.

The Directive requires that the International Niagara Control Structure be operated to ensure an operational long-term average pool level of El. 562.75 feet (IGLD 1985 El. 561.55 feet) (Figure EX-1). It

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also establishes certain tolerances for the pool's water level as measured at the Material Dock gauge, permitting up to 1.5 feet fluctuation between daily maximum and minimum water levels. This daily allowable fluctuation must occur within a normal 3-foot range between El. 561.24 and El. 564.22 feet (IGLD 1985 El. 560.04 to 563.02 feet). Under extreme conditions (e.g., high flow, low flow, ice), the allowable range of Chippawa-Grass Island Pool water level fluctuation is extended to 4 feet between El. 560.75 and El. 564.75 (IGLD 1985 El. 559.55 to 563.55 feet).

The analysis was done using hourly water level and flow data from 15 permanent water level gauges and 3 flow gauges in the upper and lower Niagara River during the years 1991 through 2002, hourly water level data from four temporary gauges in the lower Niagara River below the Project discharge during 2001 and 2002, and six temporary gauges in the Buckhorn Marsh area of Grand Island during 2002.

Data were analyzed in various ways to produce a picture of daily fluctuation in the upper and lower Niagara River and to establish the upstream extent of such fluctuation in the upper Niagara River. These analyses included graphing of hourly water levels and river-water elevation profiles (plots of water elevation versus river mile), analysis of the timing of maximum and minimum water levels, duration-distribution analyses of hourly water level and daily fluctuations, extreme-events analysis, and wind analysis.

In the upper Niagara River, it was found that regulation of the Chippawa-Grass Island Pool water levels by means of the International Control Structure and Power Entity water withdrawals has a more pronounced effect during the tourist season rather than the non-tourist season. The reason for this is that 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. On a typical day during the tourist season, the water level in the upper Niagara River from the northern tip of Grand Island downstream (the Chippawa-Grass Island Pool) is at its maximum at 7 a.m. E.S.T. The water level in the pool is drawn down over the course of the day as water is diverted through the intakes for power generation. It is generally at its lowest level by 9 p.m. E.S.T. At night, when the flow over Niagara Falls and power generation are reduced, water is ponded in the pool.

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The effect of ponding in the Chippawa-Grass Island Pool is detectable upstream and varies with river conditions. If there is a flow surge traveling down the river, the influence does not extend far upstream. On the other hand, for calm conditions on Lake Erie, this influence can extend to somewhere between the Frenchman's Creek and the Peace Bridge gauges. Impact of water level regulation at the Chippawa-Grass Island Pool on Fort Erie water levels (immediately upstream of the Peace Bridge) is virtually undetectable. Water level fluctuations at Fort Erie appear to be wholly caused by prevailing weather conditions, particularly wind speed and direction.

Figure EX-2 compares the difference in daily median water level fluctuations for the tourist and non-tourist seasons at various gauges in the upper Niagara River. The amount of daily median water level fluctuation from all causes is highest at the gauges in the Chippawa-Grass Island Pool (NYPA Intake, Material Dock, LaSalle, and Slater's Point). The amount of daily fluctuation decreases as one proceeds upstream as the influence of regulation of water in the Chippawa-Grass Island Pool lessens. The amount of median daily water level fluctuation is lowest at Huntley, Frenchman's Creek, and Peace Bridge gauges. The amount of daily fluctuation then increases as one travels upstream towards Lake Erie as the influence of storm surges from the lake increases.

In the lower Niagara River downstream of Niagara Falls but upstream of the Project tailrace, the daily median water level change during the tourist season at the Ashland Avenue gauge (in the Maid of the Mist Pool immediately downstream of the Falls) is approximately 11 feet, based on data collected from 1991-2002. This is due to the treaty-mandated control of flow over Niagara Falls for reasons of tourism, with more water (100,000 cfs) being released during tourist season daytime and less (50,000 cfs) being released at all other times. Water level fluctuations downstream of the Niagara Power Project are much less. The average daily water level fluctuation during the 2002 tourist season 1.4 miles downstream of the Robert Moses tailrace is approximately 1.5 feet. The daily fluctuations decrease in a downstream direction. Near the mouth of the lower Niagara River in Lake Ontario, the average daily fluctuation during the tourist season was 0.6 feet.

Water level fluctuation in the Lewiston Reservoir, which ranges between 3 – 18 feet per day and as much as 36 feet per week during tourist season, is due to Niagara Power Project operations (the reservoir is drawn down gradually over the course of a week and refilled on the weekend) and Niagara River flow.

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Weekly drawdowns are typically greater during the tourist season (21-36 feet) than the non-tourist season (11-30 feet). Weekly drawdowns are also greater during low-flow periods than high-flow periods, as more water is rescheduled to generate electricity during peak demand periods.

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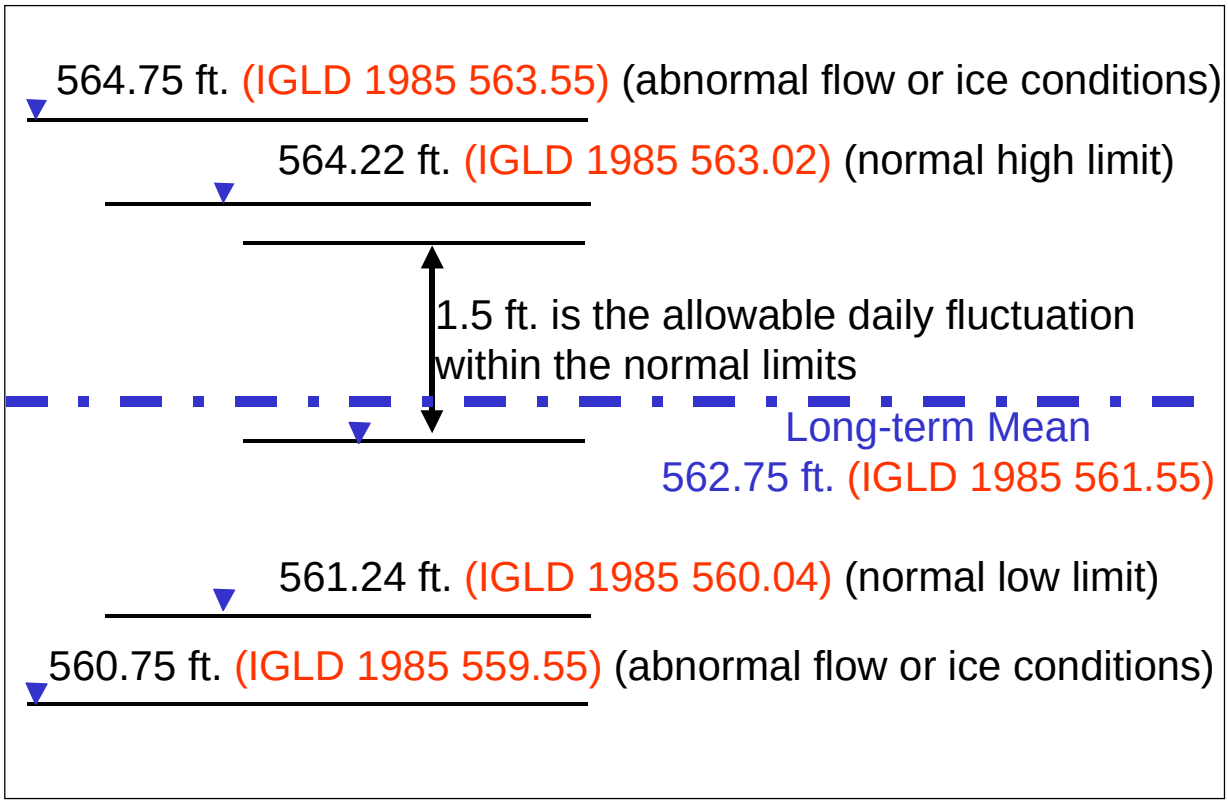
FIGURE EX-1

REGULATION OF THE CHIPPAWA-GRASS ISLAND POOL WATER LEVELS AS SPECIFIED BY THE INBC 1993 DIRECTIVE



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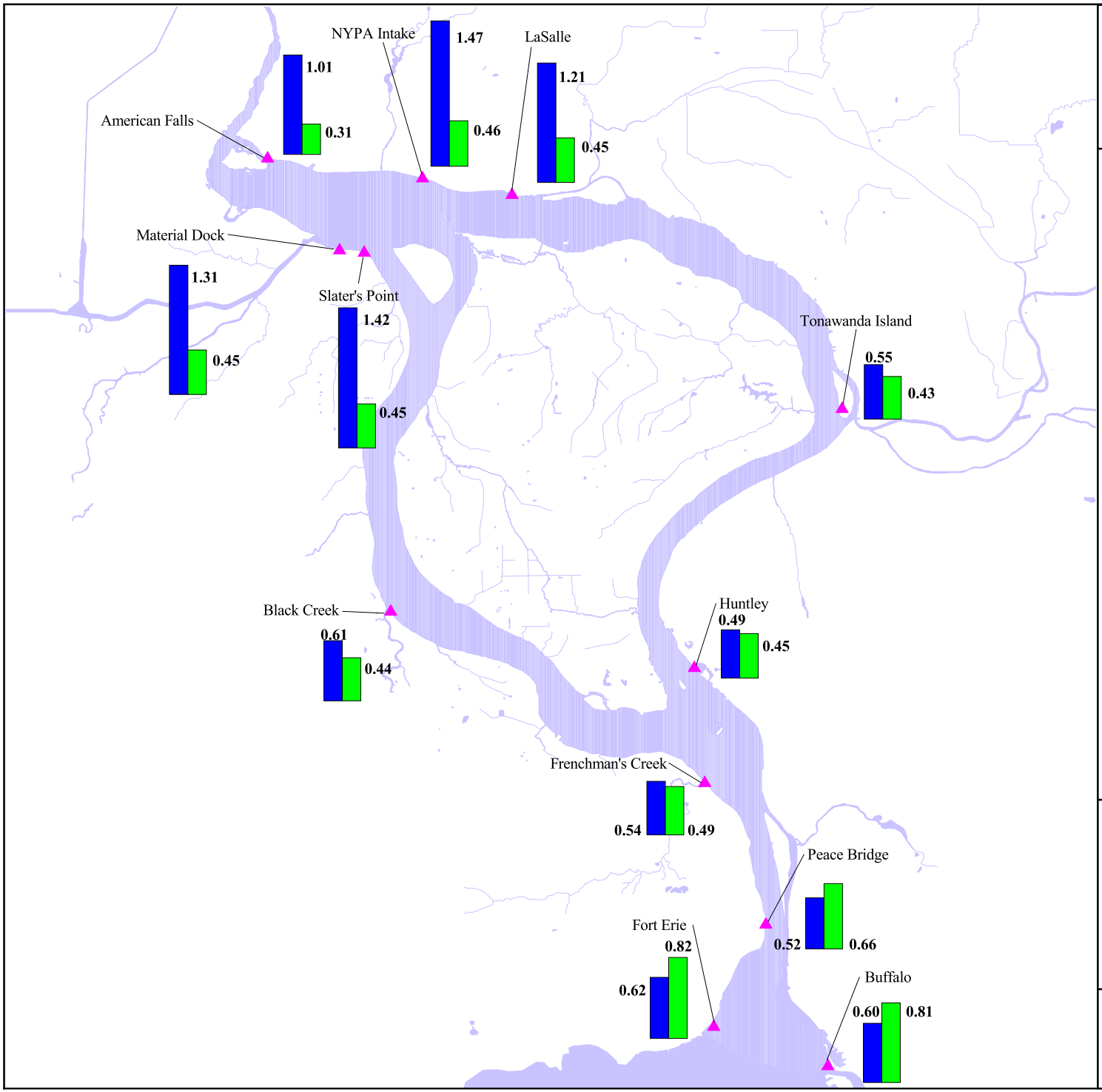

NIAGARA POWER PROJECT (FERC NO. 2216)
DESCRIBE WATER LEVEL AND FLOW FLUCTUATIONS IN THE NIAGARA RIVER AND TRIBUTARIES

Comparison of Daily Median Water Level Fluctuations for the Period 1991 - 2002

LEGEND

- Permanent Water Level Gauges
- Water Bodies
- Streams

Tourist Season (feet) — Non-Tourist Season (feet)

0 — 11500 — 23000 Feet

1" = 11,500'

EX-2

N

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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 in Lewiston, Niagara County, New York. The present operating license of the plant expires in August 2007. In preparation for the relicensing of the Niagara Power Project, NYPA is assembling information related to the ecological, engineering, recreational, cultural, and socioeconomic aspects of the Project. As part of this effort, Gomez and Sullivan conducted an engineering analysis of surface water and flow fluctuations in the Niagara River. The investigation area for this work includes the Niagara River from its head at Lake Erie to its mouth at Lake Ontario and Lewiston Reservoir.

All elevations in this report are referenced to U.S. Lake Survey Datum 1935 (USLSD). Values for other pertinent datums are listed in parentheses.

1.1 Background

The 1,880-MW (firm power output) Niagara Power Project 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, shown in Figure 1.1-1. Twin intakes are located approximately 2.6 miles above Niagara Falls. Water entering these intakes is routed around the Falls via two large underground conduits to a 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, 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. Under non-peak-usage conditions (i.e., at night and on weekends), water is pumped from the forebay via the plant's 12 pumps/generators into the Lewiston Reservoir, which lies east of the plant. During peak usage

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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 Robert Moses plant and tailwater for the Lewiston Plant. South of the forebay is a switchyard, which serves as the electrical interface between the Project and the interface between the Project and the interstate transmission grid operated by the New York Independent System Operator.

There are two regulatory constraints on flow and water level fluctuations - the Niagara River Water Diversion Treaty of 1950 and the 1993 Directive of the International Niagara Board of Control (INBC). For purposes of generating electricity from the Niagara River, two seasons are recognized: tourist season and non-tourist season. The tourist season (April – October) coincides with the months in which tourist hours are in effect. By international treaty, at least 100,000 cfs must be allowed to flow over Niagara Falls during tourist hours (April 1 - September 15, 8:00 a.m. – 10:00 p.m. E.D.S.T. and September 16 – October 31, 8:00 a.m. – 8:00 p.m.), and at least 50,000 cfs at all other times. Canada and the United States are entitled by treaty to produce hydroelectric power with the remainder.

Pursuant to the requirements of the 1993 Directive of the INBC, water level fluctuations in the Chippawa-Grass Island Pool (in the upper Niagara River, i.e., above Niagara Falls) are limited to 1.5 feet per day. The daily fluctuation is allowed within a 3-foot range for normal conditions (Figure 1.1-2). For extreme conditions (i.e., high flow, low flow, ice, etc.), the allowable range of Chippawa-Grass Island Pool water levels is extended to 4 feet and the 1.5 foot daily fluctuation tolerance can be waived.

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[1] from Lake Ontario. Water level fluctuations in the upper Niagara River from all causes are normally less than 1.5 feet per day.

[1] Backwater effect occurs when downstream water levels affect upstream water levels.

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Daily water level fluctuations in the lower Niagara River from all causes are typically around 10-12 feet per day during tourist season at the Ashland Avenue gauge, downstream of Niagara Falls. Fluctuations decrease to the 1.2-2.0 foot range at temporary gauge SG-01A (in place during 2002), 1.4 miles downstream of the tailrace.

Operation of the Niagara Power Project can result in water level fluctuations in the Lewiston Reservoir that range between 3 to 18 feet per day, and approximately 11-36 feet per week depending on the season and river flows. Weekly drawdowns are typically greater (21-36 feet per week) during the tourist season. Storage in the Lewiston Reservoir is used to generate power to meet daily peak energy demands.

1.2 Objectives

This investigation had two objectives: 1) to determine the magnitude, frequency, and spatial extent of water level and flow fluctuations in the Niagara River associated with power generation at the Project and Canadian hydroelectric projects and 2) to determine the magnitude and frequency of water level fluctuations in Lewiston Reservoir associated with power generation at the Project.

To determine the effect of power operations on water level and flow, natural conditions such as the changing levels of Lakes Erie and Ontario, variable flows from Lake Erie, and the effects of wind and ice must be considered.

1.3 Physical Description

The Niagara River, which flows from Lake Erie to Lake Ontario, forms a portion of the boundary between the State of New York and the Province of Ontario. The river drains four of the five Great Lakes, a drainage area of approximately 263,700 square miles. The difference in surface elevations between the two lakes is about 326 feet, half of this occurring at Niagara Falls.

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The Niagara River, as described in the following paragraphs, consists of two major reaches: the upper Niagara River and the lower Niagara River. A plan view of the river showing water level gauges and natural features is shown in Figure 1.3-1[2]. The two reaches are separated by the Cascades Rapids, just above Niagara Falls, and the Falls itself.

The upper Niagara River extends about 22 miles from Lake Erie to the Cascades Rapids, which begin 0.6 miles upstream of the Horseshoe Falls. From Lake Erie to Strawberry Island, a distance of approximately 5 miles, the channel width is greatest at the river's head (9,000 feet) and least at Squaw Island, just downstream of the Peace Bridge (1,500 feet). Between Squaw and Strawberry Islands, the river width is approximately 2,000 feet.

At Grand Island, just downstream of Strawberry Island, the river divides into the west channel, known as the Canadian or Chippawa Channel, and the east channel, known as the American or Tonawanda Channel. The Chippawa Channel, approximately 11 miles long, varies in width from 2,000 to 4,000 feet. The Chippawa Channel carries approximately 58% of total river flow. The 15-mile-long Tonawanda Channel, upstream of Tonawanda Island, varies in width from 1,500 to 2,000 feet. Downstream of this island it varies in width from 1,500 to 4,000 feet. At the downstream end of Grand Island (i.e., the north end), the channels unite to form the 3-mile-long Chippawa-Grass Island Pool, at the lower end of which is the International Niagara Control Structure. This linear structure, with 18 sluice gates for control of flow

[2] The profile view in Figure 1.3-1 shows the thalweg (bottom) elevation and water surface elevations for two different backwater conditions. For the upper Niagara River, the two water elevation profiles correspond to times when the Chippawa-Grass Island Pool is near its maximum (El. 564.22 feet) and its minimum (El. 561.24 feet) within the 3-foot normal range of regulation. Several profiles were studied. The intent of plotting the profiles was to show the upstream extent of the backwater effect from the Chippawa-Grass Island Pool for stable river conditions (i.e., no extreme event). The high pool level of El. 564.16 feet shown in Figure 1.3-1 occurred on May 2, 1991, at 3 p.m. and corresponded to a flow of 232,300 cfs at Fort Erie. Southwesterly winds prevailed with a peak speed of 21 mph. The low pool level of El. 561.73 feet occurred on April 25, 2000, at 9 p.m. and corresponded to a flow of 187,839 cfs at Fort Erie. Northeasterly winds prevailed with a maximum wind speed of 23 mph. Although the low pool level in Figure 1.3-1 is about half a foot higher than the allowable low level in the normal operating range, this profile was selected because it was very difficult to find any other profiles for lower elevations with normal conditions. Figure 1.3-1 shows two water surface profiles for the gauges in the lower Niagara River—one when the water level of Lake Ontario is low and one when it is high. Figure 1.3-2 shows cross-sections near each water level gauge with two water levels corresponding to the high and low water surface elevation profiles in Figure 1.3-1. The bathymetry used to develop these cross-sections is based on several sources. The location of the different data sources is shown in Figure 1.3-3.

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over Niagara Falls, extends perpendicularly from the Canadian shoreline to the approximate midpoint of the river. The Falls is located about 4,500 feet downstream of the International Niagara Control Structure.

The water level in the Chippawa-Grass Island Pool is regulated in accordance with a 1993 Directive of INBC. The Directive requires that, to ameliorate high or low water levels in the pool, Ontario Power Generation (OPG) and NYPA operate the International Niagara Control Structure to ensure the maintenance of an operational long-term average pool elevation of El. 562.75 (IGLD 1985 561.55). The fall from Lake Erie to the Chippawa-Grass Island Pool is approximately 9 feet. Below the International Niagara Control Structure, the river falls 50 feet through the Cascade Rapids before being divided into two channels by Goat Island. These channels convey the flow to the brink of the Canadian Falls on one side and the American Falls on the other. At this point the river drops approximately 167 feet, on the American side falling on a sizable volume of talus, or rock debris, that has accumulated at the foot of the precipice. (The Canadian Falls, because of its horseshoe-shaped crest, is also known as the Horseshoe Falls.) The treaty-mandated minimum flow over the American and Horseshoe Falls combined during tourist hours from April 1 through October 31 is 100,000 cfs. During non-tourist hours, the minimum treaty-mandated flow is 50,000 cfs.

Below Niagara Falls (i.e., in the lower Niagara River), the river runs through the narrow Niagara Gorge seven miles from the Falls to the foot of the Niagara escarpment at Lewiston, New York. The upper portion of this reach, which is navigable, extends from the base of the Falls to the Whirlpool Rapids, which are not navigable. The fall through this upper reach, known as the Maid of the Mist Pool, is approximately 5 feet. In the Whirlpool Rapids, the water surface elevation drops approximately 50 feet over the course of a mile. At the Whirlpool—a 1,700-foot long, 1,200-foot wide, 125-foot deep basin downstream of the rapids—the river bends nearly 90 degrees to the right. Below this point the river drops another 40 feet through the Devil's Hole Rapids. It emerges from the gorge at Lewiston, New York, subsequently dropping another 5 feet to Lake Ontario, and widening to 2,000 feet. The lower Niagara River is navigable from Lewiston to its mouth at Lake Ontario.

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This material is contained in:
Volume 2
Section: Niagara River Water Level and Flow Fluctuation Study Final Report

FIGURE 1.1-1

NIAGARA POWER PROJECT FEATURES

[NIP – General Location Maps]

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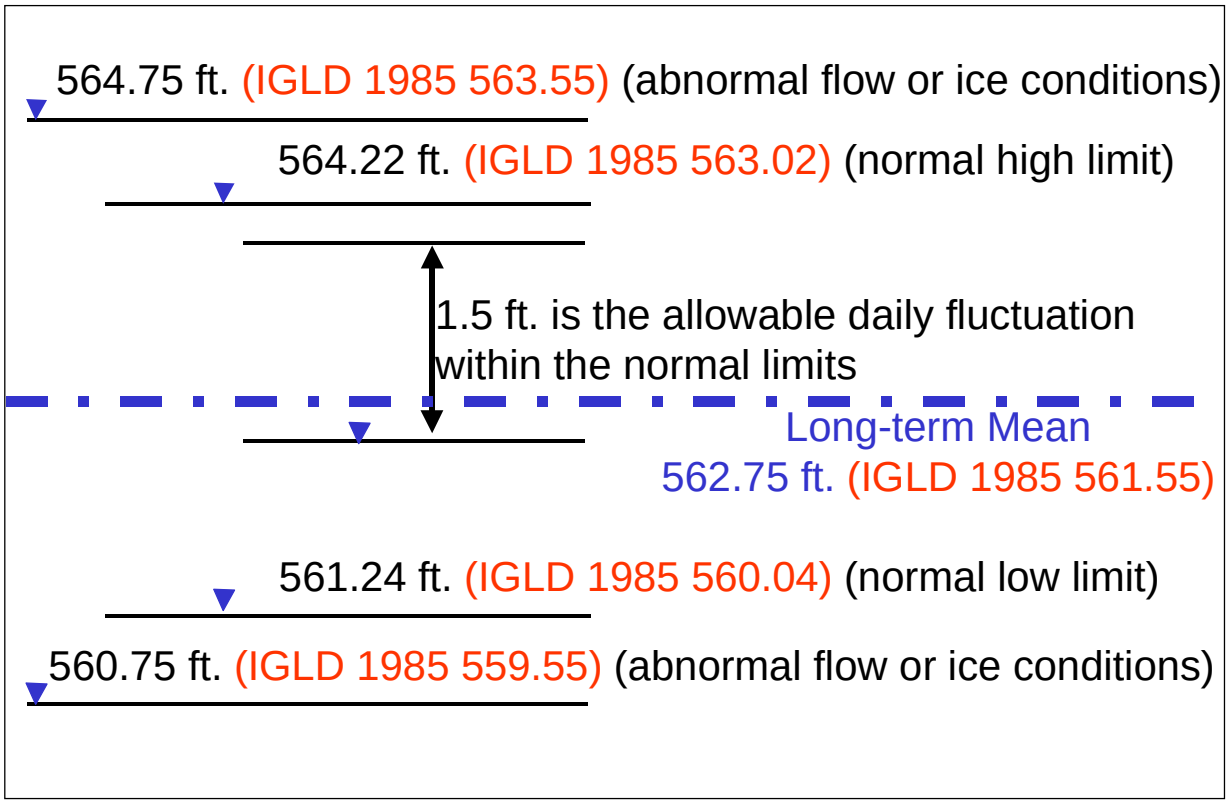
FIGURE 1.1-2

REGULATION OF CHIPPAWA-GRASS ISLAND POOL WATER LEVELS AS SPECIFIED BY THE INBC 1993 DIRECTIVE



Note: Elevation Datum: USLSD 1935. To convert water levels in the upper Niagara River from USLSD 1935 to IGLD 1985 subtract 1.2 feet

Abnormal flow conditions are considered to exist when any four consecutive hourly mean Niagara River flows, as determined from levels at the Fort Erie gauge, are greater than 270,000 cfs or less than 150,000 cfs.

Text of the 1993 Directive is located in Appendix G.

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FIGURE 1.3-1

NIAGARA RIVER PLAN AND PROFILE

[NIP – General Location Maps]

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FIGURE 1.3-2

NIAGARA RIVER CROSS-SECTIONS

[NIP – General Location Maps]

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FIGURE 1.3-3

SOURCES OF BATHYMETRIC DATA

[NIP – General Location Maps]

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2.0 FACTORS AFFECTING WATER LEVEL FLUCTUATION

The water level in the Niagara River at any location at any time is a complex function of manmade and natural factors. Water levels in the Niagara River are a function of treaty-stipulated flows, regulation of the Chippawa-Grass Island Pool, power generation flows, water level of Lake Erie, outflow of Lake Erie, water level of Lake Ontario, wind, and ice.

2.1 Niagara River Water Diversion Treaty of 1950

In 1950, the United States and Canada signed the Niagara River Water Diversion Treaty, the purpose of which was to increase the amount of water available for power generation while still preserving the scenic beauty of Niagara Falls (Treaty Between Canada and the United States of America Concerning the Diversion of the Niagara River, Oct. 10 1950, 1 U.S.T. 694). Article IV of the treaty states:

> In order to reserve sufficient amounts of water in the Niagara River for scenic purposes, no diversions of the water . . . shall be made for power purposes which will reduce the flow over Niagara Falls to less than one hundred thousand cubic feet per second each day between the hours of eight a.m. E.S.T., and ten p.m. E.S.T., during the period of each year beginning April 1 and ending September 15, both dates inclusive, or to less than one hundred thousand cubic feet per second each day between the hours of eight a.m. E.S.T., and eight p.m. E.S.T., during the period of each year beginning September 16 and ending October 31, both dates inclusive, or to less than fifty thousand cubic feet per second at any other time; the minimum rate of fifty thousand cubic feet per second to be increased when additional water is required for flushing ice above the Falls or through the rapids below the Falls.

By exchange of diplomatic notes in 1973, E.S.T. was changed to E.D.S.T. in the 1950 Treaty.

The operation of the International Niagara Control Structure ensures sufficient flow over the Falls to meet the requirements of the Niagara River Water Diversion Treaty of 1950.

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Changes in Falls flows between 50,000 and 100,000 cfs contribute to fluctuating water levels in the lower Niagara River directly downstream of the Falls as well as downstream of the Robert Moses and Sir Adam Beck tailraces. (See Figure 2.1-1 for gauge locations in the lower Niagara River.) At the Ashland Avenue gauge, due to changes in the Falls scenic flow, water levels fluctuate 10-12 feet daily (Figure 2.1-2). Figure 2.1-2 shows water levels for the period March 18 through April 14, 2001. The March dates occur during the non-tourist season, when Falls flow is a constant 50,000 cfs, and the April dates occur during tourist season, when Falls flow is 100,000 cfs during the day and 50,000 cfs at night.

2.2 Regulation of Water Levels in the Chippawa-Grass Island Pool

The water level in the Chippawa-Grass Island Pool is regulated in accordance with INBC's 1993 Directive. This Directive requires that, in order to ameliorate high or low water levels in the pool, the International Niagara Control Structure be operated so as to ensure the maintenance of an operational long-term average pool level of El. 562.75 (El. 561.55 IGLD 1985) (Figure 1.1-2). Water level fluctuations in the Chippawa-Grass Island Pool (in the upper Niagara River) caused by operation of the Canadian and NYPA hydroelectric plants are limited to 1.5 feet per day within a 3-foot normal range. The normal range for water levels is El. 561.24 (IGLD 1985 El. 560.04) to El. 564.22 (IGLD 1985 El. 563.02). The Directive also establishes adverse low pool levels as El. 560.75 (IGLD 1985 El. 559.55) and high levels as El. 564.75 (IGLD 1985 El. 563.55) in the pool. Regulations for water levels in the Chippawa-Grass Island Pool within the normal 3-foot range may be suspended for unusual conditions such as low flows, high flows, ice management (e.g., maximum level may exceed normal high level of El. 564.22 temporarily to assist in flushing ice over the Falls), or during emergency operations, flooding, and flow measurements. In practice, during any suspension of normal water level regulations, operators at the International Niagara Control Structure notify the local INBC representatives of such a suspension. Normal operating rules are to be resumed within 12 hours following the last abnormal flow period or event.

OPG personnel operate the International Niagara Control Structure, which ensures a dependable and ample flow of water over both the American and Horseshoe Falls and regulates the water level in the Chippawa-Grass Island Pool for power diversions.

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2.3 NYPA Hydroelectric Generation

NYPA operates the Niagara Power Project for the benefit of the state of New York by retiming its entitlement of Niagara River flow in order to generate more energy during periods of peak demand, through judicious use of storage in the Lewiston Reservoir (see Section 2.5).

It is important to note that NYPA's water intakes on the upper Niagara have no control mechanisms for the diversion of water from the Chippawa-Grass Island Pool into the twin conduits that carry water to the Project forebay. The volume of water diverted through the conduits by NYPA is a direct function of the difference in elevation between the pool and forebay. The forebay water level is controlled by NYPA due to pumping and generation at the Lewiston Pump Generating Plant and generation at the Robert Moses Niagara Power Plant. When Chippawa-Grass Island Pool levels are normal, the conduit diversion capacity is 102,000 cfs. When Chippawa-Grass Island Pool levels are abnormally high, the conduit capacity is 110,000 cfs.

2.3.1 Robert Moses Niagara Power Plant

If the flow that NYPA draws from the river is sufficient to generate the exact amount of power required using the Robert Moses units, the water system is in balance, and Lewiston Reservoir water is not utilized. If additional power output is required, however, as is usually the case during the daytime peak period, it is furnished by additional generation from reservoir water that flows first through the Lewiston Pump Generating Plant, becoming available afterwards for flow through the Robert Moses Niagara Power Plant. Conversely, if the conduit flow exceeds the flow required to produce the power demanded of the Project, as is usually the case at night or on weekends, part of the excess water is pumped into the reservoir for future use and part is sent through the Robert Moses Niagara Power Plant to generate the required energy for pumping. The change in flows available for power generation between peak and non-peak demand periods contributes to fluctuations in flow and water level in the lower Niagara River. In the lower Niagara River downstream of the Robert Moses tailrace, daily water level fluctuations are typically no more than 2 feet during the tourist season. Figure 2.3.1-1 shows water level fluctuations for the randomly selected week of July 15-21, 2002, when flow from the Robert Moses tailrace ranged

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between 30,560 and 97,630 cfs. Total flow in the Niagara River downstream of the Robert Moses and Sir Adam Beck tailraces for the week of July 15-21, 2002 varied between 133,025 and 255,794 cfs.

The design of the plant makes possible a weekly cycle of response to demand for electricity. On weekdays, when demand for power is highest, both the Robert Moses and Lewiston Pump Generating Plants are used for power generation. At night and on weekends, when demand is lower, only the Robert Moses Niagara Power Plant is used for generation, and excess water is pumped into the reservoir to be stored for use during the week.

2.3.2 Regulation of Pumped Storage in the Lewiston Reservoir

The Lewiston Pump Generating Plant and Reservoir allow NYPA to maximize the value of production from the United States' entitlement flows. As previously mentioned, during the tourist season, the treaty allows more water to be diverted from the river for power production at night. Nighttime, however, is a period of relatively low electrical demand. So as not to lose the benefit of water not required for immediate power production, the Lewiston Reservoir is used to store water at night (and on weekends) for use as "fuel" during high-demand periods. At night and on weekends, therefore, the units at the Lewiston Pump Generating Plant are used as pumps, to transport water from the forebay up to the reservoir behind the facility. The water remains stored in the reservoir until needed for power production.

In the daytime hours (during the week), when electricity demand rises and less water can be diverted from the river for power production, the Lewiston pumps are reversed to become turbine-generators. Stored water is released from the reservoir to create electricity. The water then flows back into the Niagara Power Project's forebay, where it is available for reuse in the form of generation at the Robert Moses Power Plant.

As shown in Figure 2.3.2-1, the Project operates on a weekly cycle. On Monday morning, the reservoir is at its highest water level and typically at its lowest on Thursday, as shown in Figure 2.3.2-1, or Friday evening. Each weekday, water is taken from storage during the daytime peak energy demand periods for power generation. Consequently, the reservoir water level decreases. Then each weekday night (during

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non-peak energy demand), the reservoir is partially refilled. On the weekend, the reservoir is completely refilled. Daily drawdown is normally 3-18 feet and weekly drawdown 11-36 feet, depending on the season and river flow. Since the storage in the Lewiston Reservoir is used to reallocate streamflow for power generation during peak demand periods, weekly drawdowns are typically greater during the tourist season (21-36 feet) than the non-tourist season (11-30 feet). Weekly drawdowns are also greater during low-flow periods than high-flow periods, as more water is rescheduled to generate electricity during peak demand periods.

Operation of the pumped storage facility contributes to observed daily water fluctuations in the lower Niagara River.

2.4 Canadian Hydroelectric Generation

Like NYPA, the Canadian hydroelectric plants are operated in compliance with the requirements of the 1950 Niagara Treaty and the INBC 1993 Directive, and in accordance with the Ontario energy market. In recent history, there have been 3 hydroelectric plants on the Canadian side of the Niagara River that generate power. They are the Sir Adam Beck Generating Stations, the Cascades plant, and the Rankin plant.

OPG, owned by the Government of Ontario, operates the Sir Adam Beck Generating Stations 1 and 2, across the river from the Robert Moses Niagara Power Plant. Like NYPA, OPG withdraws water from the Chippawa-Grass Island Pool and discharges it to the lower Niagara River (at Queenston, Ontario). Until November 26, 1999, when the plant was retired from service, OPG also operated the Ontario Power Generating Station at Niagara Falls, drawing water from the Cascades (just upstream of the Horseshoe Falls), and discharging it into the Maid of the Mist Pool. The capacity of this plant was 10,700 cfs. Canadian Niagara Power's Rankin Plant, still in operation, also diverts flow from the Cascades and discharges it to the Maid of the Mist Pool. The capacity of the Rankin Plant is 10,000 cfs. Since the operating efficiency and the available head of both these older plants has been much lower than that of the Sir Adam Beck plants, available water has normally been dispatched on a priority basis to the Sir Adam Beck plants, with the excess being directed to the low-head plants. OPG's diversion capacity for the Sir Adam Beck plants is 65,000 cfs. During the tourist season OPG, like NYPA, uses storage in the

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Chippawa-Grass Island Pool during the day and stores water at night for future use, not only to maximize generation during peak demand periods but also because OPG's diversion share often exceeds its nighttime diversion capacity. For example, at the average annual Niagara River daily flow of 212,300 cfs, OPG's diversion share during the nighttime hours, when the Falls flow is 50,000 cfs, is 81,150 cfs. Because this exceeds its 65,000 cfs diversion capacity, OPG stores water at night in the Chippawa-Grass Island Pool to use during the daytime hours (tourist season), when its diversion share decreases to 56,150 cfs.

OPG also uses its pumped-storage reservoir as NYPA uses Lewiston Reservoir, but OPG's reservoir has less storage capacity. The current total plant flow capacity from the two Sir Adam Beck plants is approximately 88,500 cfs. It should be noted that the capacity will increase as additional units are upgraded and if a third Sir Adam Beck plant is constructed.

2.5 Effect of the New York Independent System Operator on Project Operations

Prior to November 1999, NYPA and New York State's investor-owned utilities were coordinated and dispatched at the direction of the New York Power Pool. Since November 1999, New York has gone to a deregulated market, and the New York Independent System Operator (NYISO) has replaced the Power Pool. When New York made the change to an open-market system, where demand and supply sets the cost of services, operation of the Niagara Power Project was forced to change. Under the NYISO, the Niagara Power Project provides a significant portion of New York's regulation requirement. When regulating, minute to minute Niagara Power Project generation can vary substantially, and the resulting flow changes translate into water level changes in the Lewiston Reservoir and the Chippawa-Grass Island Pool.

2.6 Lake Erie Water Level and Discharge

The Niagara River is the main outlet channel of Lake Erie, with its head at the funnel-shaped eastern end of the lake. The rate of flow (and corresponding water levels) in the Niagara River depends on the

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elevation of Lake Erie, which fluctuates on a seasonal and daily or hourly basis. Wind-caused variations can occur over the course of just a few hours.

2.7 Wind Effects

Lake Erie is a long, narrow, and relatively shallow lake whose major axis is aligned with the prevailing southwesterly winds. The head of the Niagara River lies at the downwind end of the lake near Buffalo, New York. Strong southwest winds can increase the water level at Buffalo (wind setup) by 8 feet or more, increasing river flow at the same time.

An example of the rapidity with which wind-caused water level changes can occur, was seen on December 11-12, 2000, during a major winter storm. Sustained southwest winds of approximately 70 mph pushed Lake Erie water to the eastern end of the lake, causing lake levels to rise above pre-storm levels by about 9.2 feet at Buffalo. As levels rose at the eastern end of the lake, a corresponding drop occurred at the western end. At Toledo, Ohio, water levels fell about 4.3 feet below pre-storm level. At one point during the storm, the difference between water levels recorded at opposite ends of the lake was greater than 12.8 feet (INBC 2001). At Fort Erie, the Canadian municipality at the head of the Niagara River, it was observed that the water level on December 12 fluctuated 10.2 feet over the course of the day. The presence of this strong wind was correlated with a maximum average hourly Niagara River flow of 377,161 cfs, in an event that lasted seven hours. Importantly, this greatly increased Niagara River streamflow resulted from extreme atmospheric conditions (sustained wind), not from normal runoff such as snowmelt or extreme rainfall.

2.8 Ice Effects

In the winter, southwest winds are especially effective in driving ice floes into the narrowing at the eastern end of Lake Erie. The narrowing of the lake at its outlet restricts the volume of ice that can enter the river, causing an ice “arch” to form across the outlet. The ice boom aids in the formation of the ice arch. Under normal (i.e., low-wind) conditions, the Niagara River is therefore left relatively ice-free. Storms, however, can cause destabilization of this natural formation, permitting masses of lake ice to

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enter the river when the ice boom becomes submerged, and causing large-scale ice blockages that can reduce hydroelectric generation, flood shoreline property, and do serious damage to docks and other shoreline structures. The ice boom, first installed in 1964, promotes the formation of an ice arch and limits the duration and frequency of lake ice runs.

Besides ice coming from Lake Erie, various forms of river ice can form in the Niagara River itself. The long range consequences of river ice jams are less severe than lake ice jams.

Changes in water level can occur due to ice cover formation, accumulation of heavy snow or ice, ice jams, and flow changes related to ice operations. Water level fluctuations caused by ice conditions are a complex function of flow and meteorological conditions. They take on a special importance as causes of flow and water level fluctuation between December and April.

2.9 Lake Ontario Water Levels

Water levels in Lake Ontario influence water levels in the lower Niagara River downstream of the Robert Moses tailrace by creating a backwater effect. Lake Ontario water levels can vary up to almost 5 feet seasonally. For the 12-year period of record used for this investigation (1991-2002), the minimum hourly water level recorded at the Port Weller gauge (on Lake Ontario approximately 8 miles west of the mouth, see Figure 2.1-1) was El. 244.4 and the maximum hourly water level was El. 249.6.

2.10 Boat Wakes

Short-term water level fluctuations (less than a few minutes) caused by boat wakes have been observed in both the upper and lower Niagara River. The effect of this factor on water levels cannot be determined from the hourly data used for this study.

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Volume 2
Section: Niagara River Water Level and Flow Fluctuation Study Final Report

FIGURE 2.1-1

NIAGARA RIVER GAUGE LOCATIONS

[NIP – General Location Maps]

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FIGURE 2.1-2

ASHLAND AVENUE GAUGE – HOURLY WATER LEVEL GRAPH FOR MARCH 18 TO APRIL 14, 2001

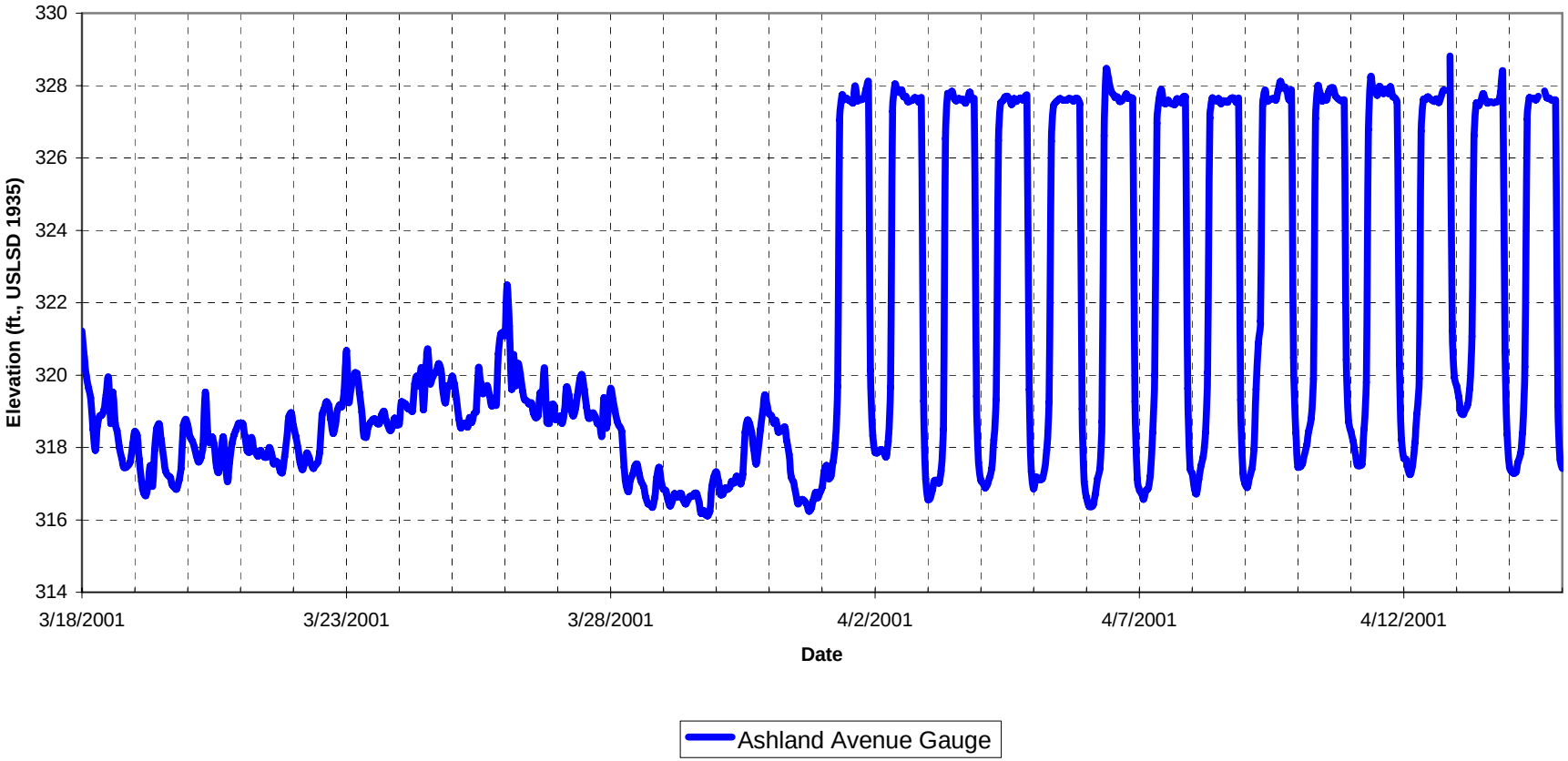

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FIGURE 2.3.1-1

LOWER NIAGARA RIVER – HOURLY WATER LEVEL GRAPH FOR JULY 15-21, 2002

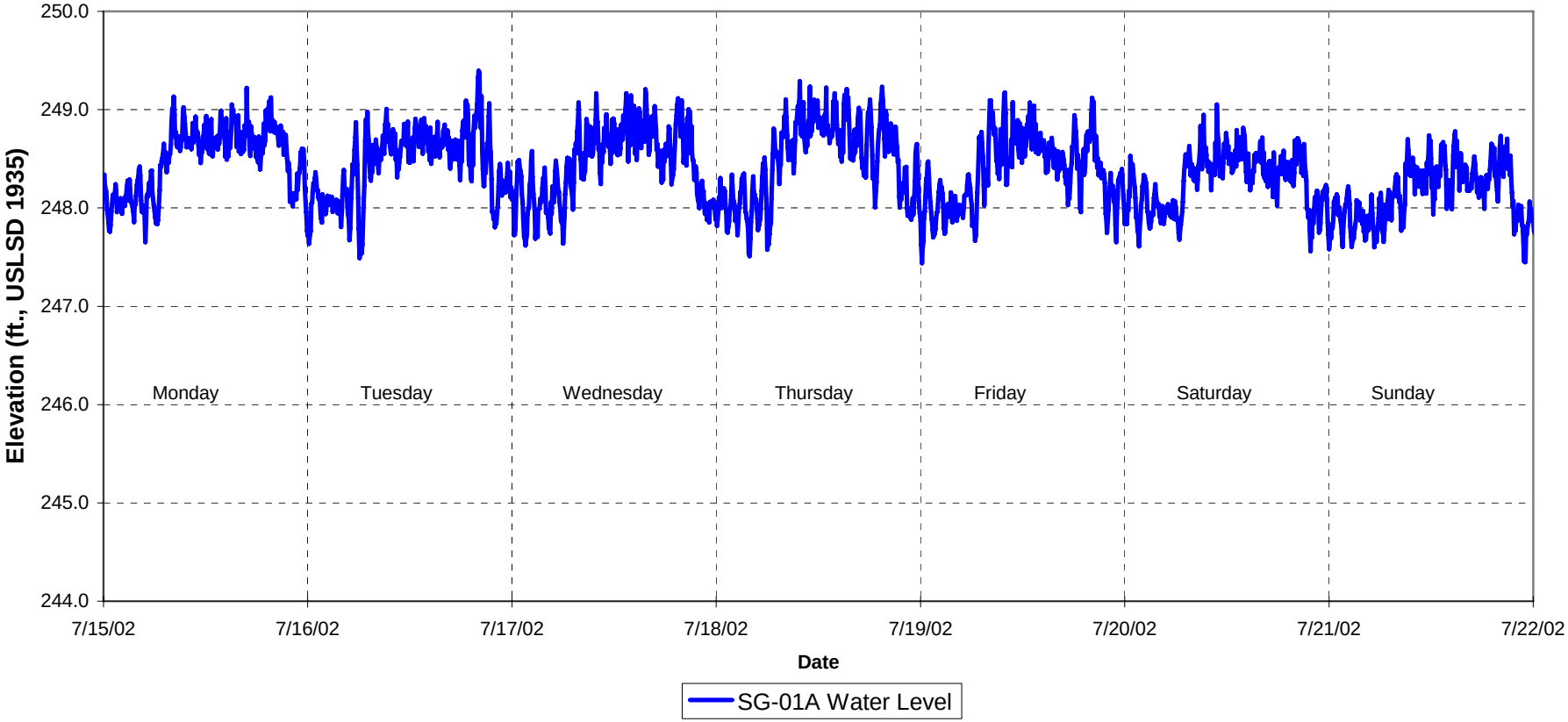

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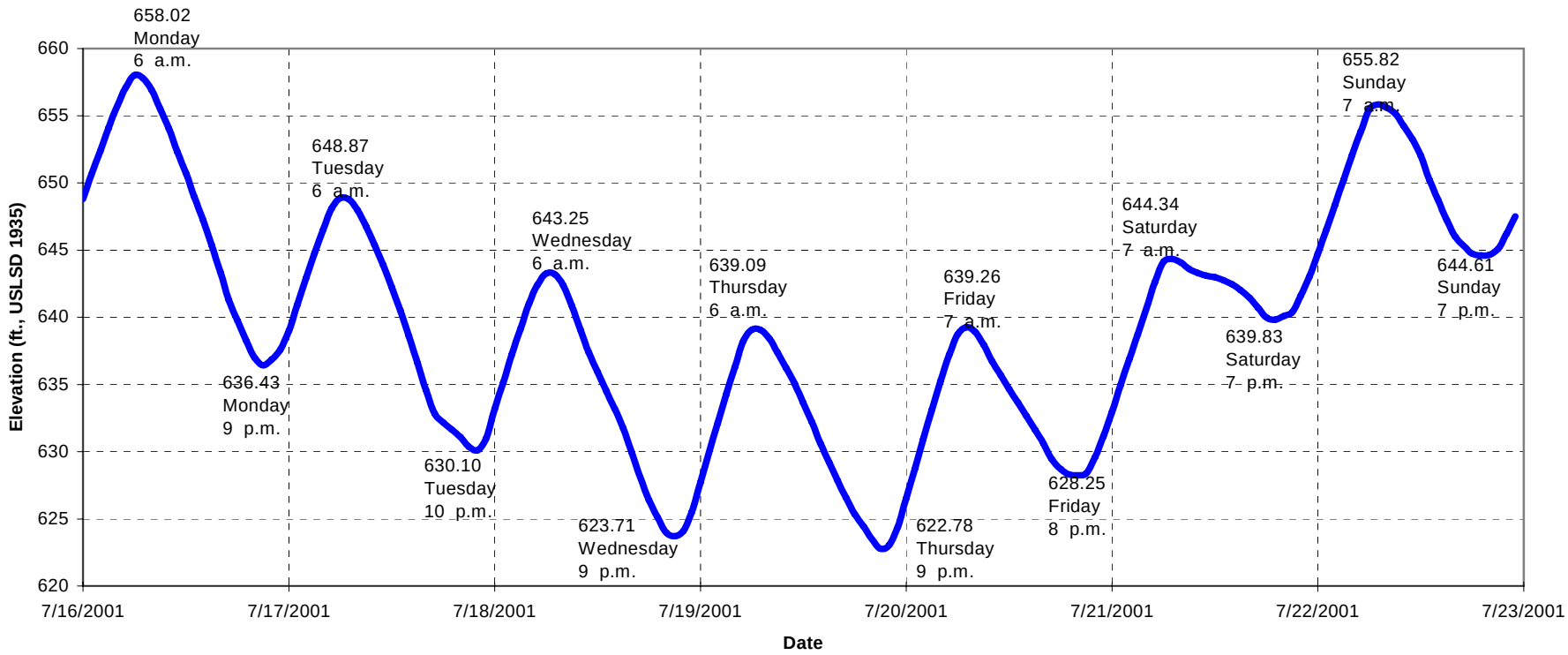
FIGURE 2.3.2-1

LEWISTON RESERVOIR – HOURLY WATER LEVEL GRAPH FOR JULY 16-22, 2001



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3.0 METHODOLOGY

Several different methodologies were used to investigate the amount and extent of water level and flow fluctuations in the Niagara River. Treaty flows and Canadian and U.S. hydroelectric generation as well as natural factors affect water levels and flows in the Niagara River. Parameters were defined and the data were sorted in an attempt to isolate the effect of manmade and natural causes of fluctuations. However, this approach had limitations because it is difficult to isolate the effects of manmade factors from natural factors such as flow surges (i.e., the outflow to the Niagara River from Lake Erie is unregulated) and wind events, which are independent of flow and season. Despite these limitations, the following analyses indicated the general zone and magnitude of influence of different factors. And in cases where factors could not be isolated such as wind events and ice conditions, additional analyses such as direct calculations of wind effects and the analysis of the 50 highest daily water fluctuations were conducted.

3.1 Database Preparation

A database was created containing both numerical data and documentation of events. Over 5 million records of water elevation and flow data from Niagara River and Lake Ontario gauges were compiled for the period January 1, 1991, to December 31, 2002. Water level and flow data in the database from all the gauges were adjusted to report time in Eastern Standard Time (E.S.T.) as opposed to Eastern Daylight Savings Time (E.D.S.T.). Data from the following permanent gauges were compiled: Buffalo, Fort Erie, Peace Bridge, Frenchman's Creek, Huntley Station, Black Creek, Tonawanda Island, Slater's Point, Material Dock, LaSalle, NYPA Intake, American Falls, Ashland Avenue, Lewiston Reservoir, and Port Weller which is located in Lake Ontario. Operators of these gauges include the Niagara River Control Center (NRCC), NYPA, OPG, the National Oceanic and Atmospheric Administration (NOAA), Environment Canada (EC), and the Canadian Hydrographic Service (CHS). Figure 2.1-1 shows the location of each gauge in the Niagara River, and Table 3.1-1 lists each gauge, the operating entity, and the period of record. In addition to the data collected from the permanent water level gauges, data from the temporary gauges collected in 2001 and 2002 were added to the database.

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The data from these gauges were reviewed for errors and gauge malfunctions, as well as for unusual natural events (e.g., flow surges or ice) or manmade changes (e.g., reduction in flow for emergency rescue). Gauge data were also screened to identify erroneous readings.

In order to help explain unusual or erroneous readings, several documents were reviewed. They were:

- Annual Reports to INBC on Annual Operation of the Lake Erie – Niagara River Ice Boom by the International Niagara Working Committee from 1990-1991 to 2001-2002
- INBC's Semi-Annual Progress Reports to IJC from 1991 to 2002
- NRCC Daily Incidence Reports for 1999-20023
- NRCC Daily Ice Reports for 1999-2002
- Preventive (Routine) Gauge Maintenance Reports from 1996-2002
- Corrective Gauge Maintenance Reports from 1996-2002

Suspicious data that could not be explained by these reports were sent to NRCC for additional information. Any findings were noted in the database. Water level readings determined to be in error were eliminated from the data set.

Water level regulations for the Chippawa-Grass Island Pool were suspended for 242 days out of the 12-year period of record (i.e., 6% of the time). The 1993 Directive allows for the regulations to be suspended for unusually high flows, unusually low flows, ice management, flow measurements, and emergency operations. The records for these dates were labeled in the database. A suspension of the water level regulations for the Chippawa-Grass Island Pool does not necessarily mean there is a violation of treaty Falls flows requirements. In fact, for the 12-year period of record, it was unusual for there to be

[3]Previous years (1991-1998) of daily incidence report and daily ice reports were unavailable electronically. Paper records were obtained for specific days of interest for extreme event analysis. Preventive and corrective gauge maintenance reports were unavailable for years 1991-1995.

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Falls flow violations (28 days or 0.6%) and when violations did occur, they were usually for one to several hours as opposed to the entire day. The violations occurred for emergency rescues, flow measurements, operations error, and once in 1997 by ice jam flooding of the Maid of the Mist Pool. The times when water level regulations of the Chippawa-Grass Island Pool were suspended and/or when scenic Falls flow requirements were violated were included in the analyses for this study.

3.2 Parameter Selection

Two parameters were selected to determine the effect of regulation on water levels in the Niagara River. One was the hourly water level, and the other was the difference between maximum and minimum hourly water levels within a 24-hour period. These parameters were selected because daily peaking flow fluctuations affect the water level fluctuation within a one-day cycle about the daily mean level. This peaking cycle is repeated the next day. Additionally, weekly fluctuations were evaluated for the Lewiston Reservoir since the storage in the reservoir is utilized on a weekly cycle for generation. Other short-term, natural factors, such as wind effects, changing ice cover conditions, and flow surges also affect water level on an hourly basis. See Section 3.4.5 for further details on the analysis of water level fluctuations due to natural conditions.

3.3 Sorting

Water level and flow data were sorted according to tourist season (April 1-October 31) and non-tourist season (November 1-March 31). The distinction between the two seasons is important. During tourist season, regulation of the Chippawa-Grass Island Pool water levels and differences in daytime and nighttime scenic Falls flows were observed to have a larger influence on water levels in the Niagara River upstream of the intakes. During non-tourist season, natural conditions also have a significant influence on water levels. Analyses were generated for each sorted data set.

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3.4 Analyses

The analyses based on hourly data focused on the daily water levels and flows and daily fluctuations sorted for the tourist and non-tourist seasons. Niagara River water levels were analyzed by graphs of the hourly data, duration distribution analysis of water levels, analysis of the timing of daily fluctuations on particular days with steady state conditions, duration distribution analysis on the water level fluctuation within one day, analysis of the days when the largest water level fluctuations occurred, and the effect of wind on water levels. In addition to these analyses, stream velocities were studied.

3.4.1 Water Level Analysis

Hourly water level data were analyzed in several ways. Graphs of hourly water levels for gauges in the same locale were plotted and reviewed to identify trends caused by natural conditions (e.g., flow surges at Fort Erie) and by manmade regulation (e.g., Chippawa-Grass Island Pool regulation). Straight lines indicate that water levels are steady. Lines that increase show rising water levels and those that decrease show declining water levels. Water levels in the river can naturally rise or fall with increases or decreases in flow or by wind, or with regulation of water levels in the Chippawa-Grass Island Pool. From the observation of several gauges located along the river, one can identify rises and falls in water level and determine if the cause is due to changes in flow at Fort Erie or by regulation of the Chippawa-Grass Island Pool.

Data from several gauges in the same geographic area and their corresponding streamflow are shown on these graphs. Graphs of the upper Niagara River show water levels at the Material Dock, NYPA Intake, LaSalle, Tonawanda Island, Huntley, Frenchman's Creek, Peace Bridge, and Fort Erie gauges, and streamflow at Fort Erie.

Graphs of the lower Niagara River show water levels measured at the temporary gauges, and the Port Weller gauge, as well as the lower Niagara River flow. Port Weller is located on Lake Ontario, 8 miles west of the mouth of the Niagara River. The water levels for Lake Ontario at the Port Weller gauge are shown because the backwater from Lake Ontario influences water levels in the lower Niagara River.

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Graphs of the hourly water level data are presented in Appendix A. These graphs are available on a CD (as PDF files) upon request.

In addition to graphs of the hourly data, a table was prepared for each permanent gauge comparing the average, minimum, and maximum water levels on an annual basis, and for the tourist and non-tourist seasons for each year. These tables also show the differences between the average, minimum, and maximum water levels between the tourist and non-tourist seasons. Tables presenting the average, minimum, and maximum water levels each month from January 1991 through December 2002 are located in Appendix B.

3.4.2 Temporary Staff Gauges in the Upper and Lower Niagara River

Since no permanent gauges exist between the Robert Moses plant tailrace and Lake Ontario, temporary staff gauges were installed at four stations within this reach from October 29 to November 16, 2001 and mid June to mid November 2002. The four locations were:

- the Artpark Gorge Trail (SG-URS-01)
- the public dock at Lewiston Landing (SG-URS-02)
- Joseph Davis State Park (SG-URS-03)
- the Youngstown Yacht Club (SG-URS-04)

Figure 3.4.2-1 shows the lower Niagara River gauge locations. The distinction between the 2001 and 2002 locations is the letter A after the gauge title for the 2002 location. The purpose of placing staff gauges at these lower-river locations was to document the magnitude and frequency of water level fluctuations in the lower Niagara River. Water level fluctuations in the lower Niagara River are influenced by the scenic flows over Niagara Falls, by generation flows at the Robert Moses and Sir Adam Beck tailraces, and by the backwater from Lake Ontario.

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Temporary staff gauges were also installed in the upper Niagara River area in 2002. A total of six gauges were installed in the Buckhorn Island Marsh State Park area around Grand Island. See Figure 3.4.2-2 for gauge locations. The six locations were:

- Burnt Ship Creek, below the west weir in Buckhorn Island Marsh (SD-01)
- Buckhorn Island Marsh above the west weir (SD-02)
- Buckhorn Island Marsh above the east weir (SD-03)
- Woods Creek, below the east weir in Buckhorn Island Marsh (SD-04)
- Mouth of Burnt Ship Creek (SD-05)
- Niagara River near Grass Island (SD-06)

3.4.3 Duration Distribution Analysis of Water Levels and Flows

Duration distribution analyses of hourly water levels were also performed at each gauge. Similarly, duration distribution analyses were performed for flow gauges at Fort Erie and the lower Niagara River. Duration curves were computed for the tourist, and non-tourist periods for the 12 years of data (1991-2002). Monthly water level duration curves are located in Appendix C.

Duration curves show the percentage of time in the period of record that a value of any given magnitude has been equaled or exceeded. The median value represents the 50th percentile point. The extreme ends of the distribution curves (high and low percentiles) represent infrequent large or small fluctuations due to all factors represented in the data set.

3.4.4 Analysis of the Timing of Daily Fluctuation for Upper Niagara River

To determine the upstream limits of fluctuation induced by daily drawdowns for power operations during the tourist season, a more rigorous evaluation of hourly water level data was performed at several gauge locations along the Niagara River between the NYPA Intake gauges and the Fort Erie and Buffalo Harbor gauges at the river headwaters. Due to a backwater effect, water levels in the Niagara River upstream of

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the Chippawa-Grass Island Pool are affected by water levels in the pool. Dynamic river conditions make it difficult to determine the length of river affected by Chippawa-Grass Island Pool levels. For this reason, a more detailed study of hourly data was conducted for days when conditions approached steady state[4]. The timing of the maximum and minimum hourly water levels at different gauges was compared to those at Fort Erie and the NYPA Intake.

The following gauges were evaluated:

- NYPA Intake
- LaSalle
- Tonawanda Island
- Huntley
- Frenchman's Creek
- Peace Bridge
- Fort Erie
- Buffalo Harbor

Hourly water level data were reviewed using plots for the gauges noted above, in addition to flow data at the Fort Erie gauge and wind velocity and direction data for Buffalo (Buffalo Niagara International Airport). The tourist season (April 1 through October 31) was studied because daily drawdowns are more significant than those during the non-tourist season (see Section 4.1.1). The days identified for a more detailed analysis occurred in 2001. An analysis of 2001 data versus other years was desirable for several reasons: (1) 2001 was a particularly dry year, characterized by low flows (the Power Entities utilize the storage in the Chippawa-Grass Island Pool more in a dry year than in a wet year because the Power Entities (particularly the Canadians) have unused plant capability with which to cycle the storage in the Chippawa-Grass Island Pool); (2) fewer gauge malfunctions occurred during that year, allowing for a

[4] Under steady state conditions, flow and water level do not change with time.

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more complete record; (3) 2001 was one of three calendar years for which data from the Peace Bridge were available (as discussed in Section 4.1.1, the location of the Peace Bridge gauge was instrumental in determining the upstream extent of influence of water level regulation at the Chippawa-Grass Island Pool); and (4) 2001 is one of three calendar years during the period of record when NYISO was in existence.

Review of the data also focused on selecting days when all gauges were functioning and water level fluctuations at the Fort Erie and Buffalo Harbor gauges were small (to minimize the effect of natural causes, namely, Lake Erie conditions, on water levels in the upper Niagara River).

Based upon the above-listed criteria, the days in 2001 selected for analysis were April 30, May 1, June 6, August 12, September 9, and October 2.

3.4.5 Duration Distribution Analysis of Water Level Fluctuations

In order to characterize the water level fluctuation caused by daily peaking operations, the difference between maximum and minimum hourly water levels over a 24-hour period at every gauge was calculated for each day during the period of record. From the database, the daily maximum and minimum recorded water elevations for the period 1991-2002 were obtained for each gauge. These data were used for duration analysis and extreme-event analysis.

Duration distribution analyses were performed at each gauge on the daily water level fluctuation (difference in hourly maximum and minimum values). Duration distribution analyses were also performed for flow gauges at Fort Erie and the lower Niagara River on the daily flow fluctuation (difference in hourly maximum and minimum values). Duration curves were computed for the tourist, and non-tourist periods for the 12 years of data (1991-2002). Daily fluctuation duration curves for each month are located in Appendix D.

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3.4.6 Extreme-Events Analysis

Duration distribution curves show the variation with time of water levels and flows and how they fluctuate daily. Duration curves also show the relatively infrequent occurrence of small and large magnitude values. To determine the cause of the largest daily fluctuations, the 50 days with the largest water level fluctuations within one day were studied in greater detail to determine the cause of water level fluctuation. These events were scrutinized for secondary factors, such as flow surges due to high winds, or ice conditions that may have contributed to large water level fluctuations.

The daily fluctuations for 1991-2002 were then sorted and ranked from the highest to the lowest value. If a special circumstance (e.g., wind, ice, or emergency operation) was found to exist on the dates showing the highest fluctuations, these circumstances were noted.

3.4.7 Channel Velocity Analysis

Estimates of average river channel velocities were made for the upper Niagara River between Fort Erie and the NYPA intakes and for the lower Niagara River between NYPA/OPG's Project tailraces and Lake Ontario. Since both stream reaches are subject to backwater effects (see Section 1.3), the stage-discharge relationship at any given location varies for different downstream water levels. A range of average channel velocities was, therefore, calculated for a low and high downstream water level condition. The average stream velocity was determined at each cross-section for a range of flows corresponding to the 10% and 90% exceedance intervals for a high and low water level.

3.4.8 Point Velocities from Discharge Measurements

Discharge measurements have been made in the Niagara River as part of a regular program by the U.S. Army Corps of Engineers (USACE) for the INBC to verify stage-discharge relationships. Flow measurements have been made in the vicinity of the International Railway Bridge to develop a stage-discharge relationship for the Fort Erie gauge, and at the cableway just upstream of the Sir Adam Beck

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and Robert Moses tailraces to develop a stage-discharge relationship for the Ashland Avenue gauge. The USACE has collected velocity data by two methods – standard current meter and Acoustic Doppler Current Profiler (ADCP) measurements.

For the standard current meter measurements, each data set consists of measurements for 20 "verticals" across the Niagara River in which flow, depth, area, average vertical velocity, and discharge are listed. From this information tables listing the percentage of flow area with various depths and velocities were derived.

In addition to the standard current meter measurements, the USACE collected 4 sets of ADCP data from the Robert Moses cableway location on the lower Niagara River. ADCP data consists of high resolution, remotely sensed velocity magnitude and direction data. It should be noted that the ADCP data are subject to several caveats:

- The data represent the measurements obtained from an instrument on a boat moving across the river. These data have not been adjusted for irregularities in the path that the boat actually took as it attempted to approximately linearly traverse the river. Therefore, the river width and measured flow area are a few percent larger than the actual flow area and width.
- The ADCP instrument is not capable of measuring the velocities for every part of the flow area. The flow closest to the river banks is not measured because the boat cannot navigate there. Any data reported for the left and right sections of the flow cannot be regarded as accurate. Likewise, the top 2.5 to 3 feet of flow is not measured because the instrument is submerged on the hull of the boat, unable to measure flow above the level of the hull. The bottom approximately 6% of flow depth is also not measured due to the limitations of the instrument's ability to accurately detect the abrupt change in density from water to river bed material.
- The measured flow area is referred to as the "middle flow area" in the ADCP data set. Other flow areas (e.g., top area) are estimated. The left and right

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side flow areas were estimated by the USACE to be either zero or small (i.e., much less than 100 sq. ft). The top flow area was approximately 1,125 to 1,350 sq. ft. There is no estimate for the bottom flow area, but in general, it should be somewhat larger than the top flow area.

- Tables of percentage of total flow area with various velocities and depths were derived from the ADCP data from the Robert Moses cableway on the Niagara River.

3.4.9 Wind Analysis

Wind effects can contribute to water level fluctuations in the Niagara River and Lakes Erie and Ontario with wind setup and surface waves. Wind setup is a tilting of the water surface toward the leeward shore under the action of the wind. Surface waves occur when wind blows across a smooth water surface such as a river or lake. The wave height is a function of the wind speed and duration at that speed and the reach of water over which the wind blows.

Wind effects are therefore a complex function of wind direction, speed and duration, and basin geometry. Wind effects are independent of regulation. Theoretical wind setup and wave height were calculated for various wind speeds (see Section 4.9).

3.4.10 Effect of NYISO Operation on Water Levels and Water Level Fluctuation

Since November 1999, New York State has had a deregulated energy market as explained in Section 2.5. To see if this change affected water level fluctuation, a comparison of daily water level fluctuations was made prior to NYISO operation (January 1991 to October 1999) and during NYISO operation (November 1999 to December 2002). That analysis included comparisons of average daily water level fluctuations for locations throughout the Niagara River and Niagara Power Project for the periods before and after the switch to NYISO.

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A more detailed analysis of the potential effect of ISO operation on water levels was conducted for the Fort Erie, Frenchman's Creek, Material Dock, and Lewiston Reservoir gauges. For these four gauges, duration distribution analyses on water levels were determined for three periods – pre-NYISO, post-NYISO, and for the entire period of record (see Section 4.10).

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TABLE 3.1-1

SUMMARY OF LAKE ERIE, NIAGARA RIVER, AND LAKE ONTARIO GAUGE INFORMATION

Gauge	Operating Entity	Type	Period of Record
Buffalo	NOAA	water level	1/1/91-12/31/02
Fort Erie	NRCC	water level and flow	1/1/91-12/31/02
Peace Bridge	EC	water level	6/30/99-12/31/02
Frenchman's Creek	NRCC	water level	1/1/91-12/31/02
Huntley Station	NRCC	water level	1/1/91-12/31/02
Black Creek	NRCC	water level	1/1/91-12/31/02
Tonawanda Island	NRCC	water level	1/1/91-12/31/02
Slater's Point	NRCC	water level	1/1/91-12/31/02
LaSalle	NRCC	water level	1/1/91-12/31/02
NYPA Intake	NRCC, NOAA	water level	1/1/91-12/31/02
Material Dock	NRCC	water level	1/1/91-12/31/02
American Falls	NOAA	water level	1/1/91-12/31/02
Ashland Avenue	NRCC, NOAA	water level and flow	1/1/91-12/31/02
Lewiston Reservoir	NYPA	water level	6/1/91-12/31/02
Port Weller	CHS	water level	1/1/91-12/31/02
Lower Niagara River	calculated	flow	6/1/91-12/31/02

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FIGURE 3.4.2-1

TEMPORARY GAUGES - LOWER NIAGARA RIVER (2002)

[NIP – General Location Maps]

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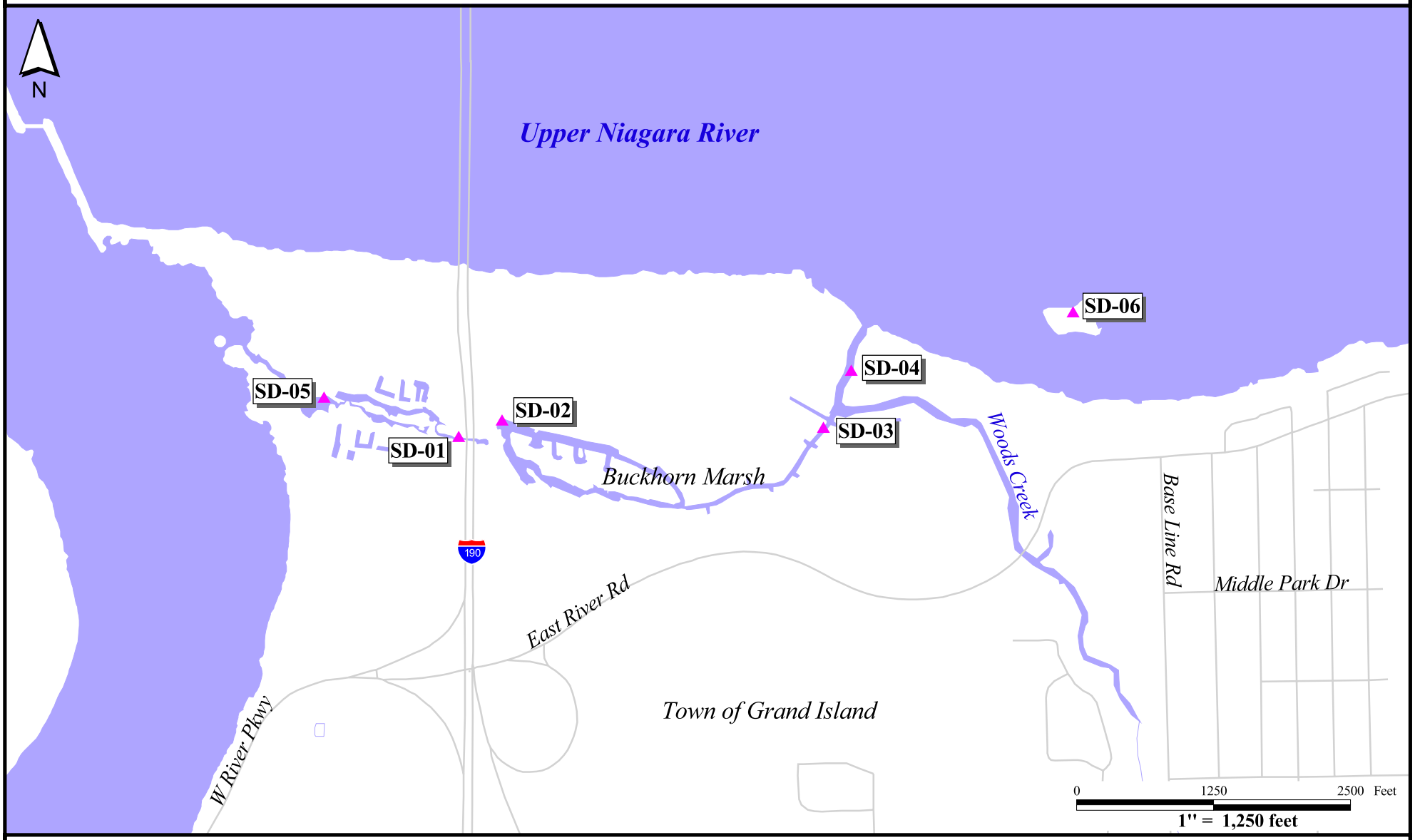

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TEMPORARY GAUGES - UPPER NIAGARA RIVER

NIAGARA POWER PROJECT

FIGURE 3.4.2-2

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4.0 RESULTS

Water level and flow fluctuations in the Niagara River result from natural conditions as well as manmade regulation of flow. Distinguishing the amount of fluctuation due to each factor is difficult because river conditions are dynamic. The dynamism of conditions refers to the changes in flow, water level, and water velocity that typically occur over time. Dynamic conditions are differentiated from steady-state conditions. Under steady-state conditions, flow, water level and velocity would not change with time. Water levels in the river would reach equilibrium, with an unchanging flow. Steady-state conditions rarely, if ever, exist in nature.

4.1 Analysis of Permanent Gauge Water Level Data

The period from 1991 to 2002 was selected for use in this study because this is the period for which electronic hourly water level data is available. This period of record is representative of both wet and dry periods based on a review of daily flow records for the Niagara River at the USGS Buffalo gauge.[5] Flow records at the Buffalo gauge are available for years 1926 to 2002. The mean annual flow for years 1991 to 2002 is 212,000 cfs, which is about 3% higher than the long-term average flow of 205,000 cfs for years 1926 to 2002. Figure 4.1-1 shows a plot of the annual mean flows for the full period of record. Years 1997-1998 were among the wettest on record, with 1997 being the third wettest year in 77 years of record. The years 1999 to 2001 are the driest since the mid-1960's, with 2001 being the driest of these three years. However, the 1930's and 1960's each contained drier periods than the 1991 to 2002 period contains.

Figure 4.1-2 shows duration curves for years 1926 to 2002 and for years 1991-2002. A review of the two duration curves indicates that the 1991-2002 period generally captures the range of behavior that is found

[5] The USGS gauging station on the Niagara River at Buffalo (No. 04216000) does not collect real flow data. The reported daily flow is the sum of Canadian and U.S. power plant flows and Niagara Falls flow, without Welland Canal diversion flow.

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in the full period of record, with the exception of the driest years of the 1930's and 1960's. The median flow for the full period of record is about 209,000 cfs. Flows similar to the median were recorded for years 1992, 1995, and 1996 in the period from 1991 to 2002.

Water levels particularly in the upper Niagara River have a natural seasonal cycle related to flow. Flows are highest in late spring and early summer with the peak usually in May and June and lowest in the winter months. Figure 4.1-3 compares the average monthly flows for years 1926 to 2002 and for years 1991 to 2002. Although the 1991-2002 period of record has higher average monthly flows (because it is lacking the very low flow years of the 1930's and 1960's), the seasonal relationship seems the same as the 1926-2002 period.

4.1.1 Upper Niagara River

Hourly water levels in the upper Niagara River and flow at Fort Erie were analyzed for each month for a typical year (1995), a wet year (1997) and a dry year (2001). From these graphs, daily water levels may be observed at each gauge. These figures also show the effect that wind or high flow events on Lake Erie may have on downstream water levels in the upper Niagara River, as well as the influence of Chippawa-Grass Island Pool water level regulation on upstream water levels, particularly during the tourist season.

Of the 12 years (1991 – 2002) of data that were analyzed, the average river flow at Fort Erie was 212,723 cfs. In 1995, the average hourly flow in the Niagara River at Fort Erie was approximately 212,668 cfs, which is close to the average flow. In 1997, the average hourly flow was approximately 243,000 cfs, and for 2001 the value was approximately 186,000 cfs. Figure 4.1.1-1 compares flow duration curves at Fort Erie for the period of record 1991-2002, 1995, 1997 and 2001. The flow duration curve for 1997 is always higher than that of 1995 because it was a wet year, while 2001 is always lower because it was a dry year. The curve for 1995 has a similar median flow compared to the period of record. There are higher and lower flows observed in 1995 as compared to the period of record, however the area that separates the two curves is nearly equivalent, which means the average flow for those two periods is about the same.

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In order to determine the effect of combined Canadian and NYPA hydroelectric operations on Niagara River water levels, significant wind events were identified and sorted from the data. Storm events were selected by analyzing wind data at Buffalo International Airport for 1995, 1997 and 2001 and corroborating those data with flow conditions observed at the Fort Erie gauge. Identification of the "significant" storm events to exclude was based on engineering judgment of the wind's impact on water level and streamflow. Some of the water level fluctuations observed during non-storm events may have a wind component but it is smaller. Significant wind events were defined as those that caused changes in flow on the order of 25,000 to 50,000 cfs per day or a change in water level at Fort Erie greater than 2 feet per day. The water level data was then analyzed without the significant storm events to determine the effect of Canadian and NYPA hydroelectric operations. This approach to determine the effects of hydroelectric operations on water levels in the upper Niagara River was considered conservative. Note that it is not possible to completely isolate the effects of power operations on water levels in the upper Niagara River, as there is usually some wind activity on Lake Erie. There are other factors that influence the water surface elevations and fluctuations in the river such as localized environmental conditions on Lake Erie that lead to flow changes; smaller wind events that were included in this analysis; local runoff and ice.

The figures for a typical year (1995) and for a dry year (2001) are presented in this section and those for 1997 are in Appendix F. Graphs of hourly water level data without the wind for other years (1991-2002) may be found in Appendix A.

Figures 4.1.1-2 through 4.1.1-13 show the hourly water level and flow values at the permanent gauges on the upper Niagara River for each month in 1995. During January through March 1995, large daily flow fluctuations at Fort Erie corresponded to sustained southwesterly winds of at least 27 mph at Buffalo Airport. Generally, the faster the observed wind speed is in a southwesterly or westerly direction, the greater the rise in flow at Fort Erie. The increase in flow had varying effects on water levels throughout the upper Niagara River. During these three non-tourist season months, flow increases had a smaller effect on water levels in the Chippawa-Grass Island Pool than those further upstream due to the regulation of water levels.

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In addition to the influence of streamflow on water levels, daily fluctuations due to power generation can be observed at the gauges in the Chippawa-Grass Island Pool. From a review of Figures 4.1.1-2 through 4.1.1-13, a distinction can be made regarding the characteristics of water level fluctuations during the tourist and non-tourist months. In general, these fluctuations are less during the non-tourist season. During the period March 9-18 (Figure 4.1.1-4) when water levels at Fort Erie were relatively stable (less than 0.5 foot fluctuation), daily water level fluctuations observed at the Material Dock and NYPA Intake gauges in the Chippawa-Grass Island Pool were 0.75 feet or less.

During the tourist season of 1995 (Figure 4.1.1-5 to 4.1.1-10), on the other hand, water levels at the gauges in the Chippawa-Grass Island Pool (LaSalle, Material Dock, and the NYPA Intake) display a daily rise and fall pattern due to regulation as the Power Entities reschedule flows for hydroelectric generation since they are required to pass more water over Niagara Falls for scenic purposes, making less of the natural flow in the river available. For the gauges closest to the Chippawa-Grass Island Pool, daily water level fluctuations during tourist season were typically less than 1.5 feet per day. The magnitude of daily water level fluctuations decreases as one proceeds upstream to the Tonawanda, Huntley, and Frenchman's Creek. At Frenchman's Creek, the influence of the 1.5-foot fluctuation at the Chippawa-Grass Island Pool is reduced to the point that daily water level fluctuations there are 0-0.5 feet. At the Peace Bridge gauge, the influence is observed at some times. (See Section 4.4 for a more detailed analysis of the hourly data, highlighting the timing of maximum and minimum water levels at different gauges). For Fort Erie, the furthest-upstream gauge on the Niagara River, water levels are influenced only by conditions occurring on Lake Erie.

Water levels at Fort Erie during the spring and summer of 1995 were fairly stable with no major fluctuations observed from April through September 1995 with the exception of a decrease in water levels observed on April 10, 1995 (Figure 4.1.1-5). This decrease can be attributed to winds from the north and east that were blowing for the previous three days.

Large water level and flow fluctuations were observed from October through December 1995 as shown in Figures 4.1.1-11 through 4.1.1-13. A shift in wind direction from 17 mph east-northeast to 29 mph southwest on October 5-6, 1995 was the cause of a large flow fluctuation at Fort Erie. The flow on these

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two days varied by nearly a factor of two - between 129,100 and 251,200 cfs. Corresponding water levels at the Fort Erie gauge varied nearly 6 feet from 568.67 feet at 9 p.m. on October 5th to 574.51 feet at 5 a.m. on October 6th. In comparison, this event appeared to have a smaller effect on the water levels of the Chippawa-Grass Island Pool gauges although water level tolerances for the Chippawa-Grass Island Pool were suspended for these two days due to low flows. Water levels at the Material Dock gauge varied 2 feet between 561.61 feet at 7 p.m. on October 5th to 563.58 feet at 7 a.m. on October 6th.

Flow surges at Fort Erie have a more pronounced effect on water levels in the Chippawa-Grass Island Pool during non-tourist months compared to tourist months as shown on Figures 4.1.1-12 and 4.1.1-13 for November and December 1995. Flow surges caused by wind storms on Lake Erie resulted in a rise of water levels for the November 11-12th storm of 4.66 feet and a fall in water levels for the November 28th storm of 6.58 feet. These changes in water level corresponded to changes in water levels at Material Dock of 2.23 feet and 1.40 feet respectively. For both storms, water level tolerance limits for the Chippawa-Grass Island Pool (i.e., the 1.5 feet maximum allowable daily water level fluctuation) were suspended due to the unusually high flows.

Table 4.1.1-1 illustrates the maximum and minimum monthly elevation at each gauge between the NYPA Intake and Frenchman's Creek during non-storm events (i.e., wind is short in duration and typically less than 20 mph as measured at the Buffalo International Airport) for the typical year. The purpose of excluding significant storm events was to determine the range of water levels and water level fluctuations that may be attributable to water level regulation of the Chippawa-Grass Island Pool for combined Canadian and NYPA power generation.

As can be seen from Table 4.1.1-1 for the non-tourist months of January through March and November through December the range of maximum and minimum elevations is 563.64 to 561.60 feet at Material Dock and 567.79 and 565.35 feet at Frenchman's Creek. Within this range, water levels during non-storm events may fluctuate as much as 1.8 feet per week and 1.4 feet per day at Material Dock. Comparable fluctuations during the non-tourist season excluding wind storm events at Frenchman's Creek are 1.8 feet per week and 1.3 feet per day. These fluctuations are due to a combination of smaller

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natural events in the river and Lake Erie as well as due to Canadian and NYPA power generation. The reader is referred to Figures 4.1.1-2 through 4.1.1-13 for data on individual gauges and/or months.

During tourist season, water level fluctuations at Material Dock in 1995 excluding storm events were up to 2.3 feet per week, and at Frenchman's Creek, were up to 1.7 feet per week. Excluding significant wind events, daily water levels fluctuated at Material Dock up to 1.9 feet and at Frenchman's Creek up to 1.6 feet during the 1995 tourist season. For both locations, the maximum daily fluctuation excluding significant storm events occurred on April 4th when winds switched from a southwest to southeast direction. This day was not excluded for wind because the change in water level at Fort Erie was less than 2 feet and there was no tolerance suspension of Chippawa-Grass Island Pool water level regulations issued for that day.

Figures 4.1.1-14 to Figure 4.1.1-25 are graphs of hourly water level and flow data for each month in 2001 for the upper Niagara River. Compared to 1995 there was, (on average) approximately 13% less flow entering the Niagara River at Fort Erie during 2001 (average daily flow of 213,000 vs. 186,000 cfs). Graphs from 2001 were selected to illustrate water level elevations for several reasons. One reason is that it was a particularly dry year. The year 2001 was also one of three years during the period of record when the Peace Bridge gauge was operating. This gauge's location was instrumental in determining the upstream influence of water level regulation of the Chippawa-Grass Island Pool. Finally, records from 2001 were chosen because that year was one of three years during the period of record when NYISO was in existence. During the winter months (January through March) there were only a few major wind storms that caused flow and water level increases as shown in Figures 4.1.1-14 through 4.1.1-16. These increases were observed during high south – southwesterly winds for sustained periods, just as in the other years examined. Flows were comparatively much lower as were water levels during these three months.

During April through September, flows at Fort Erie were relatively stable, ranging from a monthly average of 196,794 cfs in June to 179,660 cfs in September. As shown in Figures 4.1.1-17 through 4.1.1-22, the water levels during this time also remain fairly consistent. While the water levels at Fort Erie are stable, the daily pattern of water level fluctuation is observed at the gauges in the Chippawa-Grass Island

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Pool. The median daily water level fluctuation during the tourist season in 2001 at the NYPA Intake gauge was 1.26 feet compared to 1.66 feet in 1995, and at the Material Dock gauge the median daily water level fluctuation during the tourist season in 2001 was 1.11 feet compared to 1.45 feet in 1995.

As shown in Figure 4.1.1-23, flow and water level increased in the upper Niagara River again due to wind storms in October 2001. Each increase appears to be proportionate with the duration of hourly peak wind speeds over 30 mph. In contrast, the analysis revealed several examples that typify the effects of sustained northerly winds on water levels and flow. On November 10 – 11, 2001 (Figure 4.1.1-24) winds shift from westerly to northerly and remain from the north for much of the day. The result is a decrease in flow at Fort Erie of approximately 50,000 cfs. A similar occurrence is observed on November 28 - 29. These particular events occurred during non-tourist season. The resulting water level decreases were observed from Fort Erie to the NYPA Intake on each occasion. Strong northeasterly winds on December 14, 2001 resulted in a similar decrease in flow and water levels in the upper Niagara River as shown in Figure 4.1.1-25.

Table 4.1.1-2 illustrates the maximum and minimum elevation at each gauge between the NYPA Intake and Fort Erie during non-storm events for the low flow year 2001. As can be seen from Table 4.1.1-2 for non-tourist months the range of maximum and minimum elevations is 563.46 to 561.82 feet at Material Dock and 566.93 and 564.84 feet at Frenchman's Creek. Within this range, water levels during non-storm events may fluctuate as much as 1.4 feet per week and 0.8 feet per day at Material Dock. Comparable fluctuations at Frenchman's Creek are 1.3 feet per week and 0.9 feet per day.

During tourist season months in 2001 with major wind storms excluded, the maximum weekly fluctuation observed at Material Dock was 1.9 feet and at Frenchman's Creek, the maximum weekly fluctuation was approximately 1 foot. The maximum daily water level fluctuations at Material Dock were less than 1.4 feet except on April 25th when water level fluctuations were 1.7 feet at Material Dock due to regulation of water levels for streamflow measurements. For comparison, the daily water level fluctuation at Frenchman's Creek on that day was 0.65 feet.

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In addition to graphs of the hourly data, a table was prepared for each gauge comparing the average, minimum, and maximum water levels on an annual basis and for the tourist and non-tourist seasons. Tables 4.1.1-3 through 4.1.1-14 are for the gauges in the upper Niagara River. Tables displaying the average, minimum and maximum water level each month for permanent gauges in the Niagara River are located in Appendix B.

As Tables 4.1.1-3 and 4.1.1-4 indicate, water levels in the Niagara River near Lake Erie are higher during the tourist season than the non-tourist season because water levels reflect the naturally higher spring and summer flows. Further downstream in the middle upper Niagara River (Frenchman's Creek, Huntley, Black Creek, and Tonawanda Island), average water levels during the tourist season are still higher than those during non-tourist but less so at Frenchman's Creek, from April to September, the monthly average water level exceeds the yearly average water level. Average monthly water levels are even more constant at Tonawanda Island.

Climatic conditions seem to have less of an effect on the water levels in the Chippawa-Grass Island Pool. At the NYPA Intake gauge, the greatest difference in the average water level each year was only 0.35 feet. A similar characteristic is observed at Material Dock gauge, where said difference was only 0.19 feet. Monthly water levels are fairly constant.

4.1.2 Lower Niagara River

The water level elevation of the lower Niagara River is a complex function of Lake Ontario level, discharge from the Robert Moses and Canadian plants, and flow rate over Niagara Falls. Because there are no permanent water level elevation gauges in the lower Niagara River downstream of the Robert Moses tailrace, water levels in this area were analyzed using temporary gauges. Water levels in 2002 at the temporary gauges in the lower Niagara River were plotted for each month with water levels in Lake Ontario at Port Weller. Water levels in Lake Ontario increased steadily in 2002 through the month of June. Then, in July, water levels decreased through the remainder of the period of record (November

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2002). The 2002 data followed historic patterns as the water levels and outflow from Lake Ontario are regulated by the St. Lawrence River Board of Control according to the Plan of Regulation.

The average monthly water level in Lake Ontario at the Port Weller gauge is plotted in relation to the yearly average water level for the period 1991-2002 in Figure 4.1.2-1. The average water levels at the temporary gauges show a similar trend since water levels are influenced by a backwater effect from Lake Ontario. See Section 4.2.2 for a discussion of the temporary gauge data collected in the lower Niagara River.

Tables 4.1.2-1 and 4.1.2-2 summarize hourly water levels recorded for the gauges in the lower Niagara River and Lake Ontario. For the period 1991 through 2002 at the Ashland Avenue gauge, the average water level elevation was always higher during tourist season compared to non-tourist season. This can be attributed to increased flow over Niagara Falls during the daytime hours of tourist season. In contrast, the maximum water level elevation at the Ashland Avenue gauge is usually higher each year during non-tourist season due to natural phenomena (e.g., ice jams or spillage) and to a small extent to infrequent generation at Ontario Power's and Canadian Niagara's plants that discharge at the base of the falls. Table 4.1.2-1 shows the greatest difference in maximum elevations between tourist and non-tourist season was over 11 feet in 1992. At the Port Weller gauge (Table 4.1.2-2), the average, minimum and maximum water level elevation each year is always higher during tourist season than non-tourist season.

4.1.3 Lewiston Reservoir

Niagara Power Project operations determine the water level of Lewiston Reservoir. Project operations react to the demand for energy and the Niagara River flow. Lewiston Reservoir water levels are higher during the non-tourist season, when storage in the lowest part of the reservoir is held in reserve in case it is needed to compensate for reduced diversion caused by ice problems. As a direct result, water level fluctuations are less during the non-tourist season. Table 4.1.3-1 presents a summary of water levels observed in the Lewiston Reservoir. Maximum water levels in Lewiston Reservoir (Table 4.1.3-1) are very consistent between the tourist and non-tourist seasons each year. The yearly average and minimum

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water level elevations are usually lower in the reservoir during tourist season as storage in the reservoir is utilized for generation during peak daytime weekday energy demand periods.

Operation of the Niagara Power Project can result in water level fluctuations in the Lewiston Reservoir of 3-18 feet per day, and approximately 11-36 feet per week depending on the season and river flows. Figure 2.3.2-1 displays the daily fluctuation of water levels in Lewiston Reservoir. Water levels are lowest in the evenings, and highest in the morning after the reservoir is filled overnight. Weekly drawdowns are typically greater (21-36 feet) during the tourist season than the non-tourist season (11-30 feet), when NYPA's allocated share of water for power generation is reduced during daytime hours to provide higher Falls flow for scenic purposes.

4.2 Analysis of Temporary Gauge Water Level Data

Temporary water level data loggers were placed in both the upper and lower Niagara River in 2002. A limited amount of data was collected from similar locations in the lower Niagara River in 2001.

4.2.1 Upper Niagara River

Six temporary gauges were placed in tributaries to the upper Niagara River on Grand Island and in the Niagara River at Grass Island to record water levels in the Buckhorn Marsh area, which is just upstream of the Chippawa-Grass Island Pool. The NYSDEC has installed two weirs in the Buckhorn Marsh to maintain water levels so that there is open water present in the marsh. The weirs prevent daily water level fluctuations in the portion of the marsh located between the weirs due to Project operations. The west weir (top of stoplog elevation=564.86 feet) and the east weir (top of stoplog elevation=564.23 feet) are located on Burnt Ship Creek. Three gauges were placed in Burnt Ship Creek (SD-01, SD-02 and SD-05) on Grand Island around the Buckhorn Marsh west weir. Two gauges were placed around the Buckhorn Marsh east weir – one was placed in the dredged out portion of Buckhorn Marsh upstream of the east weir (SD-03) and the other was placed in Woods Creek (SD-04). The remaining gauge, SD-06, was placed in the Niagara River near Grass Island. The location of these gauges is shown in Figure 3.4.2-2. All of the

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gauges were in place from late March through mid-November 2002. Water levels were recorded every five minutes.

Water levels at SD-01, SD-02 and SD-05 as well as at the Slater's Point gauge are shown in Figures 4.2.1-1 through 4.2.1-8. Water level fluctuations at SD-01, downstream of the west weir, were usually around 0.2-0.3 feet per day during the tourist season of 2002. This fluctuation can be attributed to the daily water level fluctuations in the Chippawa-Grass Island Pool. The daily fluctuations were not evident (either at the temporary gauges nor in the Niagara River – see Figure 4.1.1-11) during the first three weeks of November 2002, which corresponds to non-tourist season.

Water levels at SD-02 display a pattern largely independent of the water levels observed at SD-01, as this gauge is upstream of the west weir. From March 28 – April 16, 2002, the water level at SD-02 did fluctuate above the west weir, however after April 16, the water level appears to have stabilized. The cause of the fluctuations at SD-02 prior to April 16, 2002 is unknown, and these patterns were not observed at SD-03, which was located in the marsh above the east weir. These observations seem to indicate that there was gauge malfunction at the SD-02 location from March 28 to April 16, 2002. On occasion, SD-02 level rises similar to the rise observed at SD-01 perhaps indicative of a groundwater connection. SD-05 water levels exhibit near identical patterns as those at SD-01 except that the water levels at SD-05 are slightly higher by about 0.2-0.3 feet. The water level stabilizes after November 1, 2002 when operations switch back to non-tourist season.

Water levels in Burnt Ship Creek at SD-01 and SD-05 display very similar fluctuation patterns throughout 2002. Note that the water level at SD-05 is reported to be higher than that at SD-01, on average of about 0.3 feet. This is unusual due to the downstream positioning of SD-05 in relation to SD-01. Possible explanations for this include wind and wave action (SD-05 is due west of SD-01), surveying margins of error, or shifting of the water level logger due to the soft marshy soils. Therefore, the data from these two gauges are useful in categorizing water level fluctuations, however the data should not be relied upon when analyzing actual water level elevations.

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Figures 4.2.1-9 through 4.2.1-16 show water levels at SD-03 (in the marsh just west of the east weir) and SD-04 (in Woods Creek downstream of the weir). For reference, water levels at the LaSalle gauge are shown on these figures. Compared to SD-04, water levels at SD-03 either do not show a pronounced daily fluctuation pattern or a small one because of its location just west of the east weir. Some of the small daily fluctuations observed at SD-03 that coincide with fluctuations in the Chippawa-Grass Island Pool from July through October may be indicative of a groundwater connection. Water levels in Woods Creek downstream of the east weir at SD-04 follow a nearly identical pattern as those in the upper Niagara River at the LaSalle gauge.

Figures comparing the water levels at SD-04 and SD-06 are presented in Appendix E. Water level fluctuations observed in Woods Creek at SD-04 gauge are very similar to the fluctuations observed at SD-06. The SD-06 gauge is located on the northern end of Grass Island just north of Grand Island. Water levels at these two gauges from April through October display a daily fluctuation pattern. In November, when operations switch to non-tourist season, water level fluctuations at SD-04 and SD-06 do not display the daily pattern as observed during tourist season.

Water levels in the Buckhorn Island Marsh (inside the west and east weirs) are influenced by precipitation, flow surges from Lake Erie, and to a lesser extent daily water level fluctuations caused by hydroelectric power operations. Examples of each factor affecting the water levels in the marsh can be seen in the figures displaying the water levels at the temporary gauges SD-02 above the west weir in the marsh, and SD-03, which was above the east weir. In Figures 4.2.1-2 and 4.2.1-10, water levels at SD-02 and SD-03 rise by approximately 0.5 feet in response to over an inch of rain that was recorded at Buffalo on May 13, 2002. Similar patterns are evident on September 27, 2002 as shown in Figures 4.2.1-6 and 4.2.1-14. Almost 1.5 inches of rain were recorded at Buffalo on this day and water levels subsequently increased in the marsh after this event. On each occasion, the water levels in the upper Niagara River and tributaries on Grand Island did not rise in relation to the observed elevation changes in the marsh due to precipitation.

Examples of how water use by the Power Entities affects the water levels in the marsh can be seen in Figures 4.2.1-5 and 4.2.1-13. These figures show the water levels in the marsh at the west weir and the

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east weir, respectively during August 2002. This was a tourist season month when little or no daily precipitation occurred (the total rainfall at Buffalo for the month was 1.77 inches, 2.1 inches below normal). The average daily water level fluctuations during August 2002 for SD-02 and SD-03 were 0.07 and 0.06 feet respectively. In contrast, the corresponding gauges downstream of the weirs (SD-01 and SD-04) had average daily fluctuations of 0.2 and 0.7, respectively. The gauge in Woods Creek (SD-04) had a higher daily fluctuation during this time period due to its closer proximity to the Chippawa-Grass Island Pool. For comparison, the hourly water level and flow during August 2002 at the Slater's Point and LaSalle gauges are shown on Figures 4.2.1-5 and 4.2.1-13 respectively. It appears that any influence of project operations on water levels in the marsh occurs at the east weir, due to this weir being 0.63 feet lower than the elevation of the west weir.

An example of how flow surges from Lake Erie have the potential of affecting water levels in the marsh (indirectly through water level increases in the upper Niagara River) can be seen during October, 2002. Water levels at Fort Erie were relatively high on October 5, 7 and 19. Figures 4.2.1-7 and 4.2.1-15 display corresponding water level increases in the upper Niagara River and the Buckhorn Island Marsh above the east and west weir. The higher water levels in the upper Niagara River cause the water levels to increase in the marsh.

4.2.2 Lower Niagara River

Figures 4.2.2-1 through 4.2.2-3 show water level data collected from temporary staff gauges as well as the water levels for the Lake Ontario gauge at Port Weller for the period October 29 to November 16, 2001. From these graphs, it can be observed that water level fluctuations are attenuated within a short distance downstream of the tailrace. Temporary staff gauge SG-URS-01 is located only 1.4 miles downstream of the tailrace yet the observed water level fluctuations for the 3-week period of record ranged between 1.0 and 1.7 feet. Water level fluctuations at SG-URS-02, further downstream, were even lower. Due to a gauge malfunction, no data from SG-URS-03 are available for 2001. As expected, because of its proximity to Lake Ontario, water levels at SG-URS-04 (Youngstown Marina) show a pattern similar to the gauges at Port Weller on Lake Ontario.

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From the information collected from the temporary water level gauges in 2001, it appears that water level fluctuations at the Robert Moses tailrace are dampened within a relatively short distance downstream. Data limitations with respect to these gauges include the facts that: (1) the data were collected primarily during the non-tourist season, when water level fluctuations are less, (2) they were collected for an unusually dry period, characterized by low Niagara River flows and low Lake Ontario water levels, and (3) the period of record was short. Given this, gauges were placed in similar locations to collect water level data in 2002.

Four temporary gauges were placed in the lower Niagara River in mid-June 2002 to collect water level data every five minutes. The gauges were located on the American side of the river and their locations can be seen in Figure 2.1-1. SG-01A recorded data from the lower Niagara River near Artpark. The period of record for SG-01A was June 12 through August 5, 2002; data from August 6 through September 19, 2002 was not used due to gauge dewatering during times of low water levels. SG-01B was placed near the location of SG-01A on September 19, 2002. SG-01B was in place until October 10, 2002 when it was moved again due to dewatering concerns. SG-01C was located approximately 100 feet upstream of SG-01B and was in place from October 10, 2002 until November 19, 2002, the end of the period of record. SG-02A collected data at the Lewiston Landing boat launch area from June 11 through November 19, 2002. SG-03A was placed in the river near Joseph Davis State Park and collected data from June 26 through November 12, 2002. The data collected from October 6 through October 30, 2002 was not useable due to datalogger malfunction. The most downstream gauge was placed in Youngstown in the lower Niagara River near the Yacht Club. The period of record was June 12 through September 20, 2002. Data was lost from September 10 through September 19, 2002 due to a storm damaging the gauge.

The water levels at each temporary gauge are shown in relation to the total discharge in the lower Niagara River in Figures 4.2.2-4 through 4.2.2-9. The average water levels at the temporary gauges decline from June to November because the water level of Lake Ontario, which has a backwater effect on lower Niagara River water levels, declines as well. (See Section 4.1.2 for a discussion of Lake Ontario levels.) In general, the water level fluctuations in the lower Niagara River follow the pattern of flow fluctuations due to changes in the Treaty flow and Canadian and U.S. hydroelectric generation. This effect is lessened as the flow travels downstream of the hydroelectric project tailraces. Gauges SG-01A through SG-01C

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(those closest to the Robert Moses tailrace) display the greatest diurnal water level fluctuations. The average daily water level fluctuation during the 2002 tourist season (based on available data) at this location is approximately 1.5 feet, with a range of 1.1 to 2.1 feet. The daily fluctuations decrease progressively at the temporary gauges located further downstream. The average daily fluctuation during the 2002 tourist season at SG-02A was 1.3 feet, while at SG-03A and SG-04A the average daily fluctuations during this time were 0.8 and 0.6 feet, respectively. For comparison, the average daily water level fluctuation observed at the Port Weller gauge in Lake Ontario for the tourist season period of record (1991-2002) was 0.16 feet. From the limited data collected, it appears that manmade regulation for Treaty flows and Canadian and U.S. hydroelectric generation have an effect on water levels and flows in the lower Niagara River to its mouth with Lake Ontario.

4.3 Hourly Water Level and Flow Duration Analysis

At each permanent water level and flow gauge, a series of duration analyses were completed to determine the range of water levels observed at different locations along the river. The period of record for most gauges is January 1991 through December 2002 (except for the Peace Bridge gauge, from which data is available starting on June 30, 1999). For each gauge, water level duration analyses were developed for the tourist and non-tourist season during the period of record. Monthly and annual duration curves were also developed and are located in Appendix C. Duration analyses of water levels during tourist and non-tourist season are discussed below.

4.3.1 Upper Niagara River Water Level

Figures 4.3.1-1 through 4.3.1-12 show the water level elevation duration distribution curves for the tourist and non-tourist season for gauges on the upper Niagara River. Water level elevations were higher during the tourist season at Buffalo, Fort Erie and the Peace Bridge gauges, as seen in Figures 4.3.1-1 through 4.3.1-3. Comparing tourist season to non-tourist season, the median water level at Buffalo was 0.54 feet higher, at Fort Erie the water level was 0.63 feet higher during tourist season and at the Peace Bridge, the median water level was 0.64 feet higher in tourist season. This is due to the fact that there is more flow

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entering the river from Lake Erie during tourist season due to the natural seasonal water cycle (described in Section 4.1).

The next group of gauges downstream exhibits less of a difference between median water level elevations during the tourist season versus the non-tourist season. Figures 4.3.1-4 through 4.3.1-7 show the water level elevation duration analyses for the gauges located at Frenchmen's Creek, Huntley, Black Creek and Tonawanda Island. The differences between tourist season and non-tourist season median elevation are as follows: Frenchmen's Creek: 0.42 feet, Huntley: 0.35 feet, Black Creek: 0.31 feet, and Tonawanda Island: 0.49 feet. These four gauges display a pattern in which the duration curves for tourist and non-tourist season are closer together during the percent of time when elevations are the highest. Highest water levels are observed during non-tourist season, although they occur very rarely. The high water levels are attributed to storms coming off of Lake Erie in the winter. These storms create a flow surge that travels down the river and the influence of such is observed at these four gauges.

The water level elevation duration analyses of the four gauges in the vicinity of the Chippawa-Grass Island Pool- LaSalle, Slater's Point, NYPA Intake and Material Dock- are shown in Figures 4.3.1-8 through 4.3.1-11. The differences between the median water level elevations during tourist season and non-tourist season are relatively small, with the median elevation being higher during the tourist season. These differences range from 0.24 feet at LaSalle to 0.09 feet at Material Dock. The water level regulations keep the water surface elevation relatively stable throughout the year. There are effects from storms on Lake Erie that are still evident in this location. As depicted in Figures 4.3.1-8 through 4.3.1-11, the highest water level elevations occur more often in the non-tourist season.

Stable water levels are also observed at the American Falls water level gauge. Figure 4.3.1-12 shows that the median water level at the American Falls is only 0.08 feet higher during tourist season than during non-tourist season. This is most likely due to the increased flow mandated during daylight hours over the Falls during tourist season.

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4.3.2 Lower Niagara River Water Level

Figure 4.3.2-1 shows the water level elevation duration during non-tourist season and tourist season for the Ashland Avenue gauge.

Water level elevation duration distribution curves were also developed for the Port Weller gauge in Lake Ontario. Figure 4.3.2-2 shows the median water level elevation during tourist season is 1.8 feet higher than during non-tourist season. As shown previously in the data from the temporary gauges placed in the lower Niagara River during 2002, the water level in Lake Ontario peaks in June and gradually decreases through December. Figure 4.1.2-1 shows the monthly average water levels in Lake Ontario at Port Weller for the period 1991-2002. 2002 was a comparatively dry year.

4.3.3 Lewiston Reservoir

The water levels in Lewiston Reservoir are constantly in a state of flux due to Project operations and Niagara River flow. Over the 12-year period of record, the maximum water surface elevation is very consistent, regardless of season, being around 658.5 feet. The duration analysis in Figure 4.3.3-1 shows that the water levels in the Lewiston Reservoir are higher during non-tourist season than during tourist season. The difference in the tourist season median water level compared with that for the non-tourist season is about 4 feet. The water levels are higher in the reservoir during the non-tourist season, because storage in the lowest part of the reservoir is held in reserve in case it is needed to compensate for reduced diversion caused by ice problems.

4.3.4 Flow Duration Analysis

Flow duration analysis were developed for the Fort Erie gauges as well as for the flow calculated in the lower Niagara River. Figure 4.3.4-1 shows the Fort Erie flow duration analysis for tourist and non-tourist season. As with water levels, flows are usually higher during the tourist season, with the exception of severe winter storms causing high flow events during the non-tourist season. Figure 4.3.4-2 shows flows

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in the lower Niagara River during the tourist and non-tourist seasons. Unlike the flow duration curves for Fort Erie where the flow duration curve for the tourist season is parallel and higher than the flow duration curve for the non-tourist season, the tourist and non-tourist season curves intersect at around the 60% exceedance level. This shows the effect of Falls flow regulation and power demand on the lower Niagara River flows. Figure 4.3.4-2 for the lower Niagara River indicates a larger range of flows than those shown in Figure 4.3.4-1 at Fort Erie. Flows are higher during the daytime tourist hours when the Project and the Canadian hydroelectric stations are producing more power and the Falls flow is higher. At night, lower Niagara River flows are low as there is a minimal amount of generation flow from the Niagara Power Project and the Canadian hydroelectric stations as water is pumped into the storage reservoirs and less water is going over the Falls.

4.4 Analysis of the Timing of Daily Fluctuation for Upper Niagara River

A discussion of the review of hourly data to assess water level trends between gauges and between the NYPA Intake and Fort Erie was presented in Section 4.1.1. Water levels in the Niagara River upstream of the Chippawa-Grass Island Pool are subject to a backwater effect from the pool. Determining the amount of fluctuation at each gauge, and the upstream extent of influence by regulation of the Chippawa-Grass Island Pool is difficult because river conditions are dynamic. A more detailed study of the hourly data was therefore undertaken for periods when conditions on Lake Erie and in the headwaters of the Niagara River were relatively stable. The timing of the maximum and minimum hourly water levels at different gauges was compared to those at Fort Erie, Buffalo, and the NYPA Intake to determine the length of river upstream of the Chippawa-Grass Island Pool subject to the backwater from the pool.

Tables 4.4-1 to 4.4-6 indicate that maximum daily water level fluctuations recorded at the Fort Erie and Buffalo Harbor gauges were on the order of 0.2 to 0.5 feet for the six selected dates between April and October 2001 (Section 3.4.2). The readings taken at the Fort Erie and Buffalo Harbor gauges are always within 0.02 feet of each other. For the same dates, fluctuations at the NYPA Intake gauge were on the order of 1.1 to 1.5 feet. As would be expected, the LaSalle gauge, located nearest to the NYPA Intake gauge, followed the same trend as the NYPA Intake gauge but with a smaller maximum daily fluctuation (range of 0.9 to 1.3 feet).

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The river reach between the NYPA Intake and the Fort Erie and Buffalo Harbor gauges is about 21 miles long. The river reach between the Tonawanda Island and Frenchman's Creek gauges (located about midway between the NYPA Intake and the Fort Erie and Buffalo Harbor gauges) is approximately 8 miles long. Based on the data provided in Tables 4.4-1 through 4.4-6, the rate of change for the daily maximum fluctuation in this reach diminishes significantly upstream. This trend would indicate that daily fluctuations at the NYPA intakes are attenuated in this stretch of the river. For the same dates, the maximum daily fluctuations continue to decrease with distance upstream.

On June 6, 2001 (Table 4.4-3), August 12, 2001 (Table 4.4-4) and September 9, 2001 (Table 4.4-5) the maximum daily fluctuations at Fort Erie and Buffalo were greater than at the Peace Bridge, Frenchman's Creek, and Huntley gauges. This indicates that influences beyond daily fluctuations in the Chippawa-Grass Island Pool affect the water levels at Fort Erie and Buffalo.

Additional data regarding each gauge are provided on Tables 4.4-1 through 4.4-6. This includes the hour when the daily minimum and maximum water levels occur. The data provided in these tables show a significant time shift when maximum and minimum levels occur at the gauges. The timing of the maximum and minimum water levels at the gauges between the NYPA Intake and Frenchman's Creek are the same or lag by a short time those of the NYPA Intake. This is indicative of the backwater influence. The timing of the maximum and minimum water levels at the gauges at Fort Erie and Buffalo Harbor are consistent with each other but do not follow the same trend as the downstream Niagara River gauges. The gauge at the Peace Bridge can follow the upstream lake trend or the downstream river trend but always with a significant time lag. For instance, on August 12, 2001 (Table 4.4-4), the backwater appears to extend to the Peace Bridge (based on the timing of the maximum and minimum water levels at the gauges). However, on September 9, 2001 (Table 4.4-5), it appears that the backwater effect extends only to Frenchman's Creek. This would indicate that the upstream influence of the daily fluctuations at the NYPA intakes does not extend beyond the Peace Bridge. The timing of the fluctuations in Lake Erie appears to be independent of water level fluctuations in the Niagara River.

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4.5 Water Level and Flow Fluctuation Duration Distribution Analysis

Duration distribution curves of daily water level fluctuations were also used to differentiate the effects of manmade regulation (regulation of Chippawa-Grass Island Pool levels for scenic Falls flows and hydroelectric power generation) and natural conditions on Niagara River water levels. The duration curves, presented in Figures 4.5.1-1 through 4.5.3-2, show the daily difference in water level for the tourist and non-tourist seasons for the period 1991-2002.

4.5.1 Upper Niagara River

For the gauges near Lake Erie (Buffalo and Fort Erie, Figures 4.5.1-1 and 4.5.1-2), the duration curve for the non-tourist season is always higher than the curve for the tourist season (i.e., the curves never intersect) because water levels at these locations are influenced by conditions on Lake Erie and not by regulation of the Chippawa-Grass Island Pool. The non-tourist season coincides with the times during the year when the majority of extreme wind conditions (which cause flow surges and larger water level fluctuations) occur on Lake Erie. The graphs for the gauges in the Chippawa-Grass Island Pool (LaSalle, Slater's Point, NYPA Intake, Material Dock) show the opposite pattern (Figures 4.5.1-8 through 4.5.1-11). The duration curve for the tourist season is always higher, indicating that the regulation of Chippawa-Grass Island Pool levels is the primary influence on water levels at these gauges. Table 4.5.1-1 compares the difference in daily median water level fluctuations for the tourist and non-tourist seasons at various gauges in the upper Niagara River. This difference indicates that the impact of manmade regulation on water levels is more significant during the tourist season than the non-tourist season. The daily median water level fluctuation at the Material Dock gauge is 1.31 feet during the tourist season and 0.45 feet during the non-tourist season.

Figure 4.5.1-12, for the American Falls, shows that water level fluctuations are always higher during the tourist season (i.e., curves do not intersect). The daily median water level fluctuation at the American Falls is 1.0 foot during the tourist season and 0.3 feet during the non-tourist season. This is attributable to the change in water levels caused by the different daytime and nighttime flow over the Falls.

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Gauges in the middle reaches of the upper Niagara River (Frenchman's Creek, Huntley, Black Creek, and Tonawanda Island) as well as the Peace Bridge gauge (see Figures 4.5.1-3 through 4.5.1-7) are influenced both by the conditions on Lake Erie and by regulation of the Chippawa-Grass Island Pool water levels as indicated by the fact that the curves in these figures do intersect. For the lower exceedance intervals (large daily fluctuations that happen infrequently), water level fluctuations are higher in the non-tourist than in the tourist season. These large daily fluctuations, caused by storms on Lake Erie, are unrelated to regulation. For the higher exceedance intervals (small daily fluctuations that happen frequently), water level fluctuations are higher in the tourist season than the non-tourist season. These small daily fluctuations are due to regulation. At the Peace Bridge (Figure 4.5.1-3), the daily median water level fluctuation is 0.52 feet for the tourist season and 0.66 feet for the non-tourist seasons, indicating that the effects of regulation of the Chippawa-Grass Island Pool have dissipated. Further downstream of Peace Bridge, the effect is still minimal until the LaSalle gauge. The difference in daily median water level fluctuations between tourist and non-tourist seasons is 0.05 feet at Frenchman's Creek, 0.04 feet at Huntley, 0.17 feet at Black Creek, and 0.12 feet at Tonawanda Island (see Table 4.5.1-1).

4.5.2 Lewiston Reservoir

Water levels in the Lewiston Reservoir fluctuate in response to daily demand for energy and Niagara River flow. Water level fluctuations are less during the non-tourist season, when more storage in the lowest part of the reservoir is held in reserve in case it is needed to compensate for reduced diversion caused by ice problems. The duration curve for daily water level fluctuation in the Lewiston Reservoir is therefore always higher during the tourist season than during the non-tourist season, as shown in Figure 4.5.2-1.

Comparing tourist-season to non-tourist season, weekly water level fluctuations are greater in Lewiston Reservoir during tourist season. Duration analyses of weekly water level fluctuations in Lewiston Reservoir for tourist-season and non-tourist season are displayed in Figure 4.5.2-2. Weekly water level fluctuations are greater by 6-10 feet during the tourist season.

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4.5.3 Lower Niagara River

Figures 4.5.3-1 and 4.5.3-2 show the duration distribution for the Ashland Avenue and Port Weller gauges. The figure for Ashland Avenue indicates that manmade regulation of flow has the most influence on downstream water level fluctuation. The daily median water level fluctuation at Ashland Avenue is 11 feet during the tourist season and 3 feet during the non-tourist season (Figure 4.5.3-1). Each day in the tourist season, water levels at the Ashland Avenue gauge typically fluctuate 10 to 12 feet due to the change between the mandated minimum Falls flow of 50,000 cfs for nighttime hours and 100,000 cfs for daytime hours.

Figure 4.5.3-2, the duration distribution curve for daily water level fluctuations at the Port Weller gauge on Lake Ontario, shows little difference between the tourist and non-tourist seasons. The daily median water level fluctuation at the Port Weller gauge is 0.2 feet during the tourist season and 0.14 feet during the non-tourist season.

4.5.4 Flow Fluctuation Duration Distribution Analysis

Figures 4.5.4-1 and 4.5.4-2 are the duration distribution curves for flow gauges at Fort Erie and the lower Niagara River. Like the water level gauges at Fort Erie and Buffalo, the daily flow fluctuation duration curve for Fort Erie (Figure 4.5.4-1) during the non-tourist season shows higher daily flow fluctuations than the curve for the tourist season. These flow fluctuations are related to natural conditions on Lake Erie. Storms on Lake Erie are prevalent during the winter months, which corresponds to the non-tourist period.

As Figure 4.5.4-2 indicates, daily flow fluctuations in the lower Niagara River downstream of the Robert Moses and Sir Adam Beck tailraces are greater during the tourist season than the non-tourist season. This is due to the daily change in the scenic Falls flow from 50,000 cfs to 100,000 cfs as well as to differences in generation flows from peak and non-peak demand periods for OPG's and NYPA's hydroelectric projects.

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4.6 Extreme-Event Analysis

Eleven gauges were used to investigate large daily water level fluctuations along the Niagara River. A summary of the 50 highest daily fluctuation values is provided on Tables 4.6-1 through 4.6-11. If historical records provided an explanation for a large daily water level fluctuation, this explanation is offered as part of the table.

4.6.1 Upper Niagara River

For surface water levels in the Chippawa-Grass Island Pool, as measured at the official Material Dock gauge, a maximum daily fluctuation range of 1.5 feet and an absolute operating range of 4.0 feet are allowed. As shown on Tables 4.6-1 through 4.6-9, the magnitude of the daily fluctuation for extreme events increases with distance upstream of the NYPA intakes. This increase may be attributed to large changes in river flow at the head of the Niagara River and to the contribution of regulation in dampening water level fluctuation in the river as the surge moves downstream.

Wind storms and atmospheric pressure changes can cause large fluctuations in Lake Erie water levels throughout the day. These fluctuations send surges of water down through the Niagara River. NRCC operators monitoring the water level gauges note this rise in water level and make the appropriate changes in allocating entitlement flows of Niagara River water between the two Power Entities. As the flow surge progresses downstream to the Chippawa-Grass Island Pool, much of the potential for change in water level can be reduced by increasing the amount of water passing through the U.S. and Canadian power plants. As the storm surge progresses downstream, storage in the river further contributes to this dampening effect.

Figure 4.6.1-1 and Figure 4.6.1-2 are profiles of river water levels during storm surges on Lake Erie. The effect of storm surges on water levels varies with the duration of the storm and river conditions. Figure 4.6.1-1 shows how a storm surge is dissipated between Fort Erie and the Chippawa-Grass Island Pool. On November 2, 1992, a 10.22-foot water level increase at the Fort Erie gauge was followed by a rise to

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only 1.59 feet at Frenchman's Creek and 1.05 feet at the NYPA Intake gauges. The storm on Lake Erie did not impact water levels downstream of Peace Bridge because the wind duration was only for a few hours. However, another storm on March 9-10, 2002 (shown in Figure 4.6.1-2) with a longer duration caused a 7.68 foot water level rise at Fort Erie followed by a rise of 6.3 feet at the Peace Bridge, 4.63 feet at Frenchman's Creek, and 2.45 feet at the NYPA Intake gauges.

Of the ten highest recorded fluctuations at 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), 76 of the 90 values (84%) were attributed to rapid flow surges at Fort Erie. The remaining 14 large fluctuation values (16%), all at gauges downstream of Fort Erie, which could not be explained by historical records, were conservatively attributed to regulation but may also be partially caused by localized environmental conditions such as wind and local runoff.

For the 50 highest water level fluctuations at each of the four Chippawa-Grass Island Pool gauges (Material Dock, Slater's Point, NYPA Intake, LaSalle):

- 1 out of 200 values were related to ice flow into the Niagara River;
- 8 out of 200 values were related to a combination of regulation and a rapid flow change at Fort Erie;
- 59 out of 200 values were related to rapid flow changes at Fort Erie;
- 132 out of 200 values were related to regulation.

Out of 12 years of data, the ten highest daily water level fluctuations recorded ranged from 1.9 to 2.8 feet at the four gauges located in the Chippawa-Grass Island Pool. The next 40 highest daily water level fluctuations varied between 1.65 and 1.95 feet at LaSalle, 1.92 and 2.07 feet at the NYPA intakes, 1.84 and 2.03 feet at Slater's Point, and 1.70 and 1.89 feet at Material Dock. The remaining daily fluctuations in the 12 years of record are less than 1.65 feet at LaSalle, less than 1.92 feet at the NYPA intakes, less than 1.84 feet at Slater's Point, and less than 1.70 feet at Material Dock. These values are remarkably

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low, considering that the water level regulations for the Chippawa-Grass Island Pool were suspended on 6% of the days in the period of record.

For the 50 highest water level fluctuations at each of the four mid-upper Niagara River gauges (Black Creek, Tonawanda Island, Huntley, Frenchman's Creek):

- 1 out of 200 values were related to a rapid flow change at Fort Erie and ice in the Niagara River;
- 6 out of 200 values were related to a combination of regulation and a rapid flow change at Fort Erie;
- 189 out of 200 values were related to rapid flow changes at Fort Erie;
- 4 out of 200 values were related to regulation.

The range of extreme daily water level fluctuations at the four mid-upper Niagara River gauges is considerably greater than those for gauges in the Chippawa-Grass Island Pool. For instance, the ten highest daily water level fluctuations at Frenchman's Creek range between 3.1 and 5.4 feet as compared with those at the NYPA intakes, which range between 2.1 and 2.7 feet. These statistics illustrate that the extreme upper Niagara River fluctuations are attributable to natural events, namely large flow surges formed from rapid surface water elevation changes at Lake Erie. At least for the period of record studied, based on the dates when extreme events occurred and historic water temperature and daily ice logs, ice was not a significant factor in the largest daily water level fluctuations in the upper Niagara River.

The extreme daily water level fluctuations at the American Falls are shown in Table 4.6-10. The largest ten daily water fluctuations range from 1.8 to 2.3 feet. Causes of these fluctuations can include manmade regulation, flow surges, flow measurement, and ice.

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4.6.2 Lower Niagara River

As mentioned in Section 4.5.3, typical daily water level fluctuations during the tourist season (April 1-October 31) at the Ashland Avenue gauge are 10 to 12 feet. This is attributed to the change in Falls flow between 50,000 cfs at night, and 100,000 cfs during the day. The highest fluctuations typically occur with high flow surges from Lake Erie and/or river ice jams. The fifty highest daily fluctuations at the Ashland Avenue gauge in the lower Niagara River, listed on Table 4.6-11, range from 13.12 to 22.66 feet. Nine of the ten largest daily fluctuations, which were between 17.02 and 22.66 feet, probably resulted from unusually high flows (greater than 270,000 cfs) at Fort Erie. These flows exceed the capacities of the Canadian and NYPA hydroelectric plants and so water was spilled over the Falls. Since the Ashland Avenue gauge is located in a gorge, even small changes in flow can cause large changes in water elevations. For instance, the daily water level fluctuation of 22.66 feet on October 10, 1996 can be attributed to a peak flow in the gorge of 181,000 cfs.

4.7 Channel Velocity Analysis

Estimates of average river channel velocities for low and high water levels are shown in Table 4.7-1. In the upper Niagara River, the low elevation profile corresponds to when the Chippawa-Grass Island Pool water level was low on April 25, 2000, at 9 p.m. and the high elevation profile when the pool level was high on May 2, 1991, at 3 p.m. In the lower Niagara River, the low elevation profile corresponds to a low Lake Ontario water level on December 22, 1998, at 1 p.m. and the high elevation profile to a high lake level on May 12, 1993.

Velocities were calculated for both a high and low water level over a range of flows. The range of flows corresponds to the 10% and 90% exceedance interval. For the upper Niagara River, the flow range was 183,000 to 243,000 cfs and for the lower Niagara River, the flow range was 153,000 to 261,000 cfs. The flow duration curve for the upper Niagara River was based on the monthly basis-of-comparison flows for the Niagara Power Project for the period of record 1900-1999. The flow duration curve for the lower

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Niagara River was based on the hourly flows at the computed lower Niagara River gauge for the period of record 1991-2002.

For the upper Niagara River, the average stream velocities vary between 1.5 and 3.3 fps at all locations except the Peace Bridge. The velocities at the Peace Bridge are higher due to the smaller stream width and cross-sectional area and a drop in elevation. They range from 5 to 8.5 fps. For the lower Niagara River, average stream velocities are higher at SG-URS-01 than SG-URS-02 because the stream is more constricted, with a smaller cross-sectional area. Velocities downstream of SG-URS-02 are lower as the river widens towards its mouth.

4.8 Analysis of Point Velocities from Discharge Measurements

Discharge measurements have been made in the Niagara River as part of a regular program by USACE and EC for the INBC to verify stage-discharge relationships. Flow measurements have been made in the vicinity of the International Railway Bridge to develop the stage-discharge relationship for the Fort Erie gauge, and at the cableway just upstream of the Sir Adam Beck and Robert Moses tailraces to develop the stage-discharge relationship for the Ashland Avenue gauge. The USACE has collected velocity data by two methods - standard current meter and Acoustic Doppler Current Profiler (ADCP) measurements.

For the standard velocity measurements, each data set consists of measurements for 20 "verticals"[6] across the Niagara River in which flow, depth, area, average vertical velocity, and discharge are listed. At the International Railway Bridge location (see Figure 4.8-1 for a cross-sectional plot from USACE's upper Niagara River backwater model), data were collected for 23 different flows ranging between 207,936 cfs and 262,759 cfs. Tables 4.8-1 and 4.8-2 correspond the percentage of flow area for various velocities and depths for the lowest flow measured, 207,396 cfs, and for the highest flow measured, 262,759 cfs, respectively. The results indicate that about 9-10 percent of the flow area at the International Railway Bridge occurs in locations where the depth is 20 feet or less.

[6] The length of a cross-section is divided into "verticals." Width, depth, and velocity are measured for each vertical.

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At the Robert Moses cableway location (see Figure 4.8-2 for a cross-sectional plot from USACE's ADCP data), data were collected for 20 different flows ranging between 48,965 cfs and 112,171 cfs. Tables 4.8-3 and 4.8-4 show the percentage of flow area for various velocities and depths for the lowest flow measured, 48,965 cfs, and for the highest flow measured, 112,171 cfs. The results indicate that about 9-10% of the flow area at the Robert Moses cableway occurs in locations where the depth is 20 feet or less.

In addition to the standard current meter measurements, the USACE has collected 4 sets of ADCP data from the Robert Moses cableway location on the lower Niagara River. The data represent the measurements obtained from an instrument on a boat moving across the river. As was discussed in Section 3.4.8, the ADCP instrument is not capable of measuring the velocities in every part of the flow area. The flow closest to the river banks, the top 2.5 to 3 feet of flow, and the approximately 6% bottom of the flow depth is not measured. Velocity measurements were made for flows of 53,464 cfs, 56,121 cfs, 103,919 cfs, and 105,191 cfs. Table 4.8-5 summarizes for each measured flow, the amount of flow in the left and right bank areas, the top few feet, the bottom, and the middle. For a flow of 53,464 cfs, Table 4.8-6 shows the percentage of flow area corresponding to various depths and velocities and Figure 4.8-3 shows the velocity distribution by depth. Table 4.8-7 shows the percentage of flow area corresponding to various depths and velocities and Figure 4.8-4 shows the velocity distribution by depth for a flow of 105,191 cfs. For both flows which span the typical range of Treaty flows of 50,000 to 100,000 cfs, over 90% of the flow is in depths greater than 30 feet.

4.9 Wind Analysis

Water level fluctuations in the Niagara River are influenced by wind. Wind setup on Lake Erie can cause water levels to rise up to 10 feet, which causes a flow surge in the river. Wind blowing across the surface of the river can cause surface waves several feet high. Both these phenomena were investigated with theoretical calculations. Although the permanent and temporary water level gauges employed for this

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study can record the effect of seiches on Lake Erie on water level, they cannot measure fluctuations caused by surface waves[7].

In calculating the potential effect of wind setup and surface waves, wind speeds of 10, 20, 30, 40, 50, and 60 mph were used. To create a baseline for estimating the frequency of these winds over water, wind speeds measured hourly over land (at the Buffalo, New York, airport weather station) were factored to create a correlation with wind velocities over water. The period of record consulted was 1991-2001.

4.9.1 Wind Setup

Wind setup is a piling up of water at the leeward end of a basin and the lowering of the surface level at the windward end—all under the action of the wind. (It can result in water level fluctuations when the wind subsides, as the water body oscillates back to equilibrium around its nodal line.) This "tilting" of the water surface is a result of a shearing stress exerted by wind at the air-water interface, and its magnitude is dependent on the depth of water, the length of the water surface across which the wind blows (i.e., the fetch), and the wind speed. For this analysis, wind setup was estimated using the following equation for reservoirs (from Saville Jr. et al. 1962):

$$Z_s = (V^2 F)/(1400\ d)$$

Where:

Z_s = the water rise above still water (feet)

V = the wind speed (mph)

[7] Gauges are designed to filter out short term water level changes in order to give an averaged elevation as measured in the stilling well.

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F = fetch, or length of water surface over which the wind blows (miles)

d = average depth of water (feet)

It has been found that the setup from high winds on Lake Erie can cause a large change in Niagara River flow. That change will induce a rise in the water surface elevation in the reaches downstream of Lake Erie (with a fall upon wind subsidence). Theoretical calculations of wind setup in the Niagara River were made for wind speeds of 10, 20, 30, 40, 50, and 60 mph at Fort Erie, the Chippawa-Grass Island Pool, the lower Niagara River at Lewiston and Youngstown, and the river mouth at Lake Ontario. The wind setup calculations for Fort Erie shown on Table 4.9.1-1 indicate that surface water at Fort Erie can rise approximately 10 feet when sustained 60 mph winds blow along the long axis of Lake Erie, i.e., from the southwest, the predominant direction in the Niagara region. This calculation is consistent with the results of the extreme-events analysis for the Fort Erie gauge (see Table 4.6-1). The shorter fetch in the Chippawa-Grass Island Pool results in a wind setup effect of less than one foot at all locations (see Table 4.9.1-2). At the NYPA intakes, the wind setup effect is greatest when winds are from the west.

The wind setup analysis for the lower Niagara River included determining the locations where the longest fetch could occur since this is an important factor in determining the magnitude of wind setup. The critical locations were determined to be at Lewiston approximately 5.8 miles upstream of the mouth of the river on the U.S. side of the river and at Youngstown approximately 1500 feet upstream of the mouth on the U.S. side. As shown on Tables 4.9.1-3 and 4.9.1-4, the amount of wind setup is small (less than 0.33 feet) even for 60 mph winds.

Table 4.9.1-5 shows the wind setup at the mouth of Lake Ontario. The depth of Lake Ontario limits the wind setup. The maximum rise (1.3 feet) occurs when winds are from the northeast, which is uncommon. Prevailing winds over Lake Ontario are from the west and southwest.

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Table 4.9.1-6 shows the measured wind speed over land, calculated wind speeds over water of 10-60 mph, and the percentage of time that winds of that speed are equaled or exceeded on Lakes Erie and Ontario. Table 4.9.1-7 provides the same information for the Chippawa-Grass Island Pool.

It has been found that the setup from high winds on Lake Erie can cause a large change in Niagara River flow. That change will induce fluctuations in the water surface elevation in the reaches downstream of Lake Erie. For gauge locations between Fort Erie and LaSalle, nearly all of the ten highest recorded fluctuations were due to surge at Fort Erie (see Section 4.4). Nearly two-thirds of the ten highest recorded fluctuations at the NYPA Intake gauge were due to flow surges at Fort Erie. For those extreme fluctuation events not found to be related to surge at Fort Erie or other natural occurrences (such as ice-related events), fluctuations may be explained by a combination of power operations, localized wind effects, and other natural causes that were not listed in the historical records that were reviewed for this report.

4.9.2 Surface Waves

The formation of surface waves was also investigated, on the grounds that such waves could also cause water level fluctuations in the Niagara River. The height of a surface wave is a function of wind speed, duration of that wind speed, and fetch.

Wave height was estimated from the equation for reservoirs (from Saville Jr. et al. 1962)

$$Z_w = 0.034\ V_w^{1.06}\ F^{0.47}$$

Where:

Z_w = the average wave height of the highest one-third of the waves (feet)

V_w = the wind speed about 25 feet above the water surface (mph)

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F = fetch (miles)

The duration of the wind and an uninterrupted fetch line are important in the formation of a wave.

In the Chippawa-Grass Island Pool, surface waves are likely more significant than wind setup (see Table 4.9.2-1). At the NYPA intakes, for a 60-mph wind and a fetch of 3.5 miles, a theoretical wave height of 4.7 feet was calculated. This wind must be sustained for approximately 40 minutes for such a wave to occur. Note that wind setup near the intakes was calculated to be approximately 0.6 feet for the same wind speed and direction (westerly).

Like the Chippawa-Grass Island Pool, surface waves in the lower Niagara River are larger than wind setup. Table 4.9.2-2 shows the surface wave height at Lewiston and Youngstown for different wind speeds. At Lewiston, a 60 mph wind theoretically could cause a wave height of 4.6 feet and at Youngstown a wave height of 5 feet. These wave heights would require that the wind was sustained for approximately 40 and 45 minutes, respectively.

Because of the long fetch and relatively deep waters, no wave calculations were performed for Lakes Erie or Ontario. Also, the equation by Saville to calculate significant wave height applies primarily to reservoirs. Wave calculations for large lakes like Lakes Erie and Ontario would require a different analysis of the hydrodynamics (wind speed, duration, fetch, depth of water, etc.). Winds must be sustained on these water bodies for several hours for the significant wave height calculation to be valid, and a constant high wind speed (>40 mph) for more than 3 hours is rare. Note that a lower wind speed (10 mph) might create a 5-foot-high wave on Lake Erie.

4.10 Effect of NYISO Operation on Water Levels and Water Level Fluctuations

Since November 1999, New York State has had a deregulated energy market as explained in Section 2.5. To see if this change affected the magnitude of water level fluctuation, a comparison of daily water level fluctuations was made prior to NYISO operation (January 1991 to October 1999) and during NYISO

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operation (November 1999 to December 2002). It should be noted that since NYISO operation began, river flows, which affect water level, have been low. Table 4.10-1 shows the average daily water level fluctuations for locations throughout the Niagara River and Niagara Power Project for the periods before and after the switch to NYISO. It can be seen in this table that daily water level fluctuations declined after NYISO came on line by at least 10% for 4 of the 13 locations listed. Conversely, fluctuations increased in Lewiston Reservoir by 21.6% and at Huntley by 9.8%. Of the 13 locations, fluctuations declined for 7 locations and rose for the remaining 6 locations.

To determine if these differences are due to natural lower flows in the Great Lakes system, a more detailed analysis of the potential effect of NYISO operation on water levels was conducted for the Fort Erie, Frenchman's Creek, Material Dock, and Lewiston Reservoir gauges. For these four gauges, duration distribution analyses on water levels were determined for three periods – pre-NYISO, post-NYISO, and for the entire period of record.

Figure 4.10-1 shows that the water levels during pre-NYISO are higher than those for post-NYISO at the Fort Erie gauge. This is as expected since the post-NYISO period was characterized by low river flows and hence lower water levels. Figure 4.10-2 comparing the water levels for pre-NYISO and post-NYISO at Frenchman's Creek shows a similar pattern. Figure 4.10-3 shows that water levels at the Material Dock gauge are essentially the same pre- or post-ISO. The slight differences are only evident at very high exceedances or very low exceedances, which are indicative of the low flows that prevailed during the post-NYISO period.

An analysis of the water level duration curves for Lewiston Reservoir (Figure 4.10-4) indicates that average water levels since November 1999 are nearly two feet higher than prior to this date. The average water level for post-NYISO period is 644.8 feet, while the average for pre-NYISO period is 643.4 feet. Figure 4.10-4 shows that while the higher elevation water levels are similar for both periods, the low to middle elevation water levels are different.

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TABLE 4.1.1-1

UPPER NIAGARA RIVER MONTHLY NON-SIGNIFICANT STORM ELEVATIONS AND FLOW FOR 1995

Month		Material Dock (ft)	NYPA Intake (ft)	Slater's Point (ft)	LaSalle (ft)	Black Creek (ft)	Tonawanda Island (ft)	Huntley Station (ft)	Frenchman's Creek (ft)	Fort Erie Elevation (ft)	Fort Erie Flow (cfs)
Jan	High	563.46	563.73	563.46	564.17	566.33	567.16	567.30	567.79	574.63	254,000
	Low	561.76	561.95	562.25	562.63	564.48	564.88	565.64	565.62	571.67	188,500
	Diff.	1.70	1.78	1.21	1.54	1.85	2.28	1.76	2.17	2.96	65,500
Feb	High	563.48	563.87	563.90	564.36	566.32	566.83	567.45	567.60	574.26	245,500
	Low	561.60	561.88	561.97	562.37	564.24	564.77	565.63	565.72	571.67	188,500
	Diff.	1.88	1.99	1.93	1.99	2.08	2.06	1.92	1.88	2.59	57,000
Mar	High	563.64	563.81	563.85	564.17	565.80	566.12	566.75	566.92	573.46	227,300
	Low	561.61	561.86	561.94	562.38	564.29	564.71	565.54	565.46	571.49	184,700
	Diff.	2.03	1.95	1.91	1.79	1.51	1.41	1.21	1.46	1.97	42,600
Apr	High	563.96	564.09	564.20	564.99	566.33	567.85	567.55	567.74	574.18	243,600
	Low	561.59	561.77	561.82	562.42	564.63	565.19	565.90	566.03	571.84	192,100
	Diff.	2.37	2.32	2.38	2.57	1.70	2.66	1.65	1.71	2.34	51,500
May	High	563.79	564.07	564.06	564.39	565.98	566.47	No Data	567.36	574.16	243,200
	Low	561.59	561.73	561.96	562.37	564.80	565.19	No Data	566.03	572.34	202,700
	Diff.	2.20	2.34	2.10	2.02	1.18	1.28	No Data	1.33	1.82	40,500
Jun	High	563.46	563.86	563.88	564.18	565.78	566.17	No Data	567.09	573.77	234,300
	Low	561.46	561.79	561.89	562.42	564.60	565.07	No Data	565.91	572.52	206,600
	Diff.	2.00	2.07	1.99	1.76	1.18	1.10	No Data	1.18	1.25	27,700

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TABLE 4.1.1-1 (CONT.)

UPPER NIAGARA RIVER MONTHLY NON-SIGNIFICANT STORM ELEVATIONS AND FLOW FOR 1995

Month		Material Dock (ft)	NYPA Intake (ft)	Slater's Point (ft)	LaSalle (ft)	Black Creek (ft)	Tonawanda Island (ft)	Huntley Station (ft)	Frenchman's Creek (ft)	Fort Erie Elevation (ft)	Fort Erie Flow (cfs)
Jul	High	563.62	564.06	563.97	564.42	566.19	566.61	No Data	567.53	574.31	246,600
	Low	561.62	561.97	562.00	562.44	564.90	565.33	No Data	566.23	572.50	206,200
	Diff.	2.00	2.09	1.97	1.98	1.29	1.28	No Data	1.30	1.81	40,400
Aug	High	563.46	564.07	564.12	564.39	565.96	No Data	No Data	567.21	574.22	244,500
	Low	561.27	561.94	562.01	562.45	564.89	No Data	No Data	566.01	571.86	192,500
	Diff.	2.19	2.13	2.11	1.94	1.07	No Data	No Data	1.20	2.36	52,000
Sep	High	563.60	564.08	563.87	564.43	566.02	No Data	No Data	567.09	573.12	219,800
	Low	561.61	561.97	564.56	562.57	564.56	No Data	No Data	565.63	571.41	183,000
	Diff.	1.99	2.11	1.77	1.86	1.46	No Data	No Data	1.46	1.71	36,800
Oct	High	563.59	564.05	563.91	564.35	565.91	566.24	567.60	567.23	574.22	244,500
	Low	561.60	561.85	561.90	562.45	564.57	565.02	565.64	565.83	571.75	190,200
	Diff.	1.99	2.20	2.01	1.90	1.34	1.22	1.96	1.40	2.47	54,300
Nov	High	563.41	563.70	563.66	563.64	565.93	566.35	566.98	567.16	573.53	228,900
	Low	561.81	562.04	562.11	562.73	564.51	564.95	565.58	565.72	571.34	181,600
	Diff.	1.60	1.66	1.55	0.91	1.42	1.40	1.40	1.44	2.19	47,300
Dec	High	563.51	563.83	563.84	563.85	566.08	566.44	No Data	567.29	573.64	231,400
	Low	561.93	562.20	562.26	562.66	564.34	564.72	No Data	565.35	570.60	166,400
	Diff.	1.58	1.63	1.58	1.19	1.74	1.72	No Data	1.94	3.04	65,000

Note: High and low elevations for each gauge exclude the storm events. The monthly extremes at any given gauge may not occur on the same day. Elevations in USLS 1935 Datum. "No Data" can include data removed due to gauge malfunction or defective readings.

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TABLE 4.1.1-2

UPPER NIAGARA RIVER MONTHLY NON-SIGNIFICANT STORM ELEVATIONS AND FLOW FOR 2001

Month		Material Dock (ft)	NYPA Intake (ft)	Slater's Point (ft)	LaSalle (ft)	Black Creek (ft)	Tonawanda Island (ft)	Huntley Station (ft)	Frenchman's Creek (ft)	Peace Bridge (ft)	Fort Erie Elevation (ft)	Fort Erie Flow (cfs)
Jan	High	563.05	563.26	563.29	No Data	564.88	565.80	566.36	566.42	567.50	572.02	196,138
	Low	561.82	562.19	562.20	No Data	564.07	564.47	565.12	565.08	566.16	570.36	161,600
	Diff.	1.23	1.07	1.09	No Data	0.81	1.33	1.24	1.34	1.34	1.66	34,538
Feb	High	563.46	563.68	563.66	No Data	565.13	565.84	566.37	566.49	567.70	572.26	201,046
	Low	561.94	562.28	562.29	No Data	563.86	564.25	565.16	564.84	565.86	570.00	154,466
	Diff.	1.52	1.40	1.37	No Data	1.27	1.59	1.21	1.65	1.84	2.26	46,580
Mar	High	563.16	563.31	563.35	No Data	565.00	565.48	566.19	566.25	567.57	572.34	202,459
	Low	561.99	562.24	562.29	No Data	564.00	564.42	565.27	565.05	566.16	570.46	163,578
	Diff.	1.17	1.07	1.06	No Data	1.00	1.06	0.92	1.20	1.41	1.88	38,881
Apr	High	563.73	564.02	564.02	No Data	565.46	565.66	566.43	566.54	567.83	572.45	205,319
	Low	561.77	562.04	561.98	No Data	564.39	564.96	565.41	565.02	566.65	570.79	170,217
	Diff.	1.96	1.98	2.04	No Data	1.07	0.70	1.02	1.02	1.18	1.66	35,102
May	High	563.47	563.81	563.86	No Data	565.56	565.97	566.57	566.69	568.10	572.77	211,711
	Low	561.91	562.23	562.22	No Data	564.43	564.87	565.42	565.51	566.82	571.10	176,926
	Diff.	1.56	1.58	1.64	No Data	1.13	1.10	1.15	1.18	1.28	1.67	34,785
Jun	High	563.58	563.94	563.93	No Data	565.77	566.21	566.80	566.89	568.16	572.91	215,314
	Low	561.79	561.96	562.10	No Data	564.69	565.12	565.68	565.80	567.08	571.22	178,939
	Diff.	1.79	1.98	1.83	No Data	1.08	1.09	1.12	1.09	1.08	1.69	36,375

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TABLE 4.1.1-2 (CONT.)

UPPER NIAGARA RIVER MONTHLY NON-SIGNIFICANT STORM ELEVATIONS AND FLOW FOR 2001

Month		Material Dock (ft)	NYPA Intake (ft)	Slater's Point (ft)	LaSalle (ft)	Black Creek (ft)	Tonawanda Island (ft)	Huntley Station (ft)	Frenchman's Creek (ft)	Peace Bridge (ft)	Fort Erie Elevation (ft)	Fort Erie Flow (cfs)
Jul	High	563.55	563.99	563.98	No Data	565.70	No Data	566.60	566.85	568.19	572.78	212,453
	Low	561.80	561.95	562.02	No Data	564.29	No Data	565.42	565.89	566.82	570.86	171,523
	Diff.	1.75	2.04	1.96	No Data	1.41	No Data	1.18	0.96	1.38	1.92	40,930
Aug	High	563.64	564.08	563.98	No Data	565.50	566.04	566.52	566.68	568.00	572.55	207,438
	Low	561.88	562.14	562.11	No Data	564.32	564.97	565.71	565.83	566.78	570.85	171,523
	Diff.	1.76	1.94	1.87	No Data	1.18	1.07	0.81	0.85	1.21	1.70	35,915
Sep	High	563.46	563.90	563.94	564.24	565.36	565.91	No Data	566.56	567.83	572.39	203,872
	Low	561.70	562.10	562.04	562.70	564.32	564.91	No Data	565.52	566.59	570.57	165,555
	Diff.	1.76	1.80	1.90	1.54	1.04	1.00	No Data	1.04	1.25	1.82	38,317
Oct	High	563.48	563.87	563.87	564.29	565.52	566.10	No Data	566.71	567.87	572.18	198,963
	Low	561.80	562.10	562.07	562.32	564.40	564.60	No Data	565.23	566.32	570.39	162,271
	Diff.	1.68	1.77	1.80	1.97	1.12	1.50	No Data	1.48	1.54	1.79	36,692
Nov	High	563.09	563.46	563.36	563.75	564.92	565.59	566.15	566.41	567.77	572.29	201,753
	Low	561.89	562.21	562.17	562.23	564.30	564.54	565.28	565.20	566.32	570.52	164,884
	Diff.	1.20	1.25	1.19	1.52	0.62	1.05	0.87	1.21	1.44	1.77	36,869
Dec	High	563.38	563.73	563.60	563.79	565.52	566.07	566.89	566.93	568.59	573.66	232,123
	Low	562.14	562.55	562.40	562.33	564.14	564.48	565.22	565.11	566.16	570.17	157,680
	Diff.	1.24	1.18	1.20	1.46	1.38	1.59	1.67	1.82	2.43	3.49	74,443

Note: High and low elevations for each gauge exclude the storm events. The monthly extremes at any given gauge may not occur on the same day. Elevations in USLS 1935 Datum. "No Data" can include data removed due to gauge malfunction or defective readings.

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TABLE 4.1.1-3

FORT ERIE – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	570.59	577.1	572.99	569.05	578.19	572.84	569.05	578.19	572.93	1.54	-1.09	0.15
1992	571.48	576.84	573.19	570.49	581.79	572.74	570.49	581.79	573.0	0.99	-4.95	0.45
1993	571.48	577.12	573.64	571.12	577.01	573.3	571.12	577.12	573.5	0.36	0.11	0.34
1994	571.67	576.01	573.35	570.01	576.91	572.53	570.01	576.91	573.01	1.66	-0.9	0.82
1995	568.67	575.54	572.92	570.11	577.11	572.62	568.67	577.11	572.79	-1.44	-1.57	0.3
1996	570.77	578.89	573.32	568.91	576.73	572.54	568.91	578.89	572.99	1.86	2.16	0.78
1997	571.74	577.97	574.47	570.98	578.17	573.68	570.98	578.17	574.15	0.76	-0.2	0.79
1998	571.72	576.37	573.82	570.97	577.62	573.21	570.97	577.62	573.57	0.75	-1.25	0.61
1999	569.46	575.63	572.25	569.05	576.01	571.9	569.05	576.01	572.11	0.41	-0.38	0.35
2000	569.63	574.58	572.05	569.79	575.9	571.35	569.63	575.9	571.76	-0.16	-1.32	0.7
2001	569.53	575.4	571.67	568.97	574.25	571.37	568.97	575.4	571.55	0.56	1.15	0.3
2002	569.87	575.15	572.26	569.36	579.27	571.73	569.36	579.27	572.04	0.51	-4.12	0.53

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TABLE 4.1.1-4

BUFFALO – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	571.23	575.6	573.28	569.32	578.53	573.08	569.32	578.53	573.2	1.91	-2.93	0.2
1992	571.74	577.06	573.44	571.34	579.81	573.02	571.34	579.81	573.27	0.4	-2.75	0.42
1993	571.68	577.5	573.9	571.29	577.44	573.5	571.29	577.5	573.74	0.39	0.06	0.4
1994	571.96	575.55	573.62	570.2	575.58	572.76	570.2	575.58	573.28	1.76	-0.03	0.86
1995	569.1	575.62	573.2	570.58	577.69	572.92	569.1	577.69	573.09	-1.48	-2.07	0.28
1996	571.36	579.36	573.65	569.19	576.92	572.86	569.19	579.36	573.33	2.17	2.44	0.79
1997	572.03	578.44	574.77	571.26	578.62	574.02	571.26	578.62	574.45	0.77	-0.18	0.75
1998	572.03	576.11	574.14	571.25	578.07	573.51	571.25	578.07	573.88	0.78	-1.96	0.63
1999	571.2	574.92	572.61	568.77	576.38	572.26	568.77	576.38	572.47	2.43	-1.46	0.35
2000	571.22	574.92	572.4	569.57	580.14	571.81	569.57	580.14	572.23	1.65	-5.22	0.59
2001	571.2	575.96	572.1	569.97	574.55	571.86	569.97	575.96	572.02	1.23	1.41	0.24
2002	570.13	575.6	572.58	569.48	579.88	572.03	569.48	579.88	572.35	0.65	-4.28	0.55

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TABLE 4.1.1-5

PEACE BRIDGE – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1999	566.00	569.21	567.68	566.68	569.24	567.65	566.00	569.24	567.67	-0.69	-0.03	0.03
2000	565.63	569.64	567.63	565.83	573.34	567.07	565.63	573.34	567.44	-0.20	-3.71	0.56
2001	566.03	570.39	567.40	565.08	569.11	566.96	565.08	570.39	567.22	0.95	1.28	0.44
2002	566.06	569.95	567.85	565.18	573.61	567.2	565.18	573.61	567.57	0.88	-3.66	0.65

Note: Period of record begins on June 30, 1999 however gauge was malfunctioning for much of the remainder of 1999.

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TABLE 4.1.1-6

FRENCHMAN'S CREEK – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	565	568.28	566.58	564.32	569.45	566.63	564.32	569.45	566.6	0.68	-1.17	-0.05
1992	565.51	568.95	566.79	565.36	569.58	566.73	565.36	569.58	566.77	0.15	-0.63	0.06
1993	565.87	569.37	567.05	565.29	569.58	566.88	565.29	569.58	566.98	0.58	-0.21	0.17
1994	565.58	568.14	566.88	564.68	569.07	566.42	564.68	569.07	566.69	0.9	-0.93	0.46
1995	565.63	568.33	566.63	564.9	569.19	566.46	564.9	569.19	566.56	0.73	-0.86	0.17
1996	565.33	570.33	566.93	564.36	569	566.4	564.36	570.33	566.73	0.97	1.33	0.53
1997	566.06	569.54	567.62	565.64	570	567.29	565.64	570	567.48	0.42	-0.46	0.33
1998	566.09	568.61	567.34	565.52	569.5	566.83	565.52	569.5	567.13	0.57	-0.89	0.51
1999	564.91	567.59	566.4	563.92	567.99	566.02	563.92	567.99	566.24	0.99	-0.4	0.38
2000	564.63	567.82	566.39	564.65	570.05	565.73	564.63	570.05	566.11	-0.02	-2.23	0.66
2001	565.2	568.4	566.14	564.27	567.44	565.74	564.27	568.4	565.96	0.93	0.96	0.4
2002	565.11	568.1	566.48	564.23	570.33	565.87	564.23	570.33	566.22	0.88	-2.23	0.61

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TABLE 4.1.1-7

HUNTLEY – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	565.99	567.63	566.78	565.74	568.6	566.76	565.74	568.6	566.76	0.25	-0.97	0.02
1993	565.5	569.21	566.81	565.25	569.41	566.73	565.25	569.41	566.77	0.25	-0.2	0.08
1994	565.8	567.66	566.66	564.6	568.95	566.3	564.6	568.95	566.34	1.2	-1.29	0.36
1995	565.6	567.6	566.42	565.52	568.84	566.35	565.52	568.84	566.36	0.08	-1.24	0.07
1996	565.27	567.51	566.63	565.42	568.79	566.32	565.27	568.79	566.46	-0.15	-1.28	0.31
1997	567.05	569.47	567.56	565.54	569.51	567.07	565.54	569.51	567.24	1.51	-0.04	0.49
1998	566.05	568.32	567.14	565.45	569.35	566.7	565.45	569.35	566.95	0.6	-1.03	0.44
1999	565.21	567.57	566.27	564	567.75	565.92	564	567.75	566.07	1.21	-0.18	0.35
2000	565.22	567.74	566.33	564.63	569.96	565.69	564.63	569.96	565.99	0.59	-2.22	0.64
2001	565.41	568.23	566.05	564.22	567.29	565.7	564.22	568.23	565.86	1.19	0.94	0.35
2002	565.05	567.44	566.38	564.16	570.71	565.81	564.16	570.71	566.13	0.89	-3.27	0.57

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TABLE 4.1.1-8

BLACK CREEK – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	564.28	566.91	565.35	563.54	568.25	565.4	563.54	568.25	565.37	0.74	-1.34	-0.05
1992	564.48	567.44	565.57	564.38	568.76	565.59	564.38	568.76	565.58	0.1	-1.32	-0.02
1993	564.83	567.66	565.74	564.21	567.96	565.6	564.21	567.96	565.69	0.62	-0.3	0.14
1994	564.49	566.69	565.62	563.84	567.1	565.22	563.84	567.1	565.44	0.65	-0.41	0.4
1995	563.59	566.64	565.39	564.02	567.58	565.23	563.59	567.58	565.32	-0.43	-0.94	0.16
1996	564.29	568.56	565.66	563.53	567.26	565.28	563.53	568.56	565.49	0.76	1.3	0.38
1997	564.75	567.9	566.11	564.45	567.83	565.9	564.45	567.9	566.02	0.3	0.07	0.21
1998	564.87	566.93	565.9	564.53	567.8	565.61	564.53	567.8	565.78	0.34	-0.87	0.29
1999	563.91	566.39	565.27	563.17	566.56	564.95	563.17	566.56	565.15	0.74	-0.17	0.32
2000	563.79	566.25	565.2	563.8	567.09	564.7	563.79	567.09	564.96	-0.01	-0.84	0.5
2001	564.21	566.65	565.01	563.5	566.02	564.65	563.5	566.65	564.87	0.71	0.63	0.36
2002	564.06	566.42	565.22	563.27	568.58	564.72	563.27	568.58	565.01	0.79	-2.16	0.5

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TABLE 4.1.1-9

TONAWANDA ISLAND – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	564.36	567.41	565.7	563.98	568.78	565.78	563.98	568.78	565.73	0.38	-1.37	-0.08
1992	564.83	569.12	565.9	564.8	568.4	565.86	564.80	569.12	565.89	0.03	0.72	0.04
1993	565.1	567.57	566.12	564.42	568.79	565.9	564.42	568.79	566.03	0.68	-1.22	0.22
1994	564.92	567.83	566.01	564.06	567.27	565.58	564.06	567.83	565.84	0.86	0.56	0.43
1995	564.93	567.85	565.8	564.26	567.9	565.63	564.26	567.9	565.71	0.67	-0.05	0.17
1996	564.62	568.98	566.06	563.79	568.42	565.66	563.79	568.98	565.9	0.83	0.56	0.4
1997	565.73	568.36	566.58	565.14	568.69	566.38	565.14	568.69	566.52	0.59	-0.33	0.2
1998	565.24	567.47	566.39	564.89	568.16	565.88	564.89	568.16	566.2	0.35	-0.69	0.51
1999	564.23	566.87	565.71	563.37	567.13	565.29	563.37	567.13	565.51	0.86	-0.26	0.42
2000	564.05	567.21	565.7	563.99	568.35	565.08	563.99	568.35	565.44	0.06	-1.14	0.62
2001	564.6	566.53	565.45	563.79	566.57	565.07	563.79	566.57	565.26	0.81	-0.04	0.38
2002	564.55	567.39	565.78	563.67	569.23	565.18	563.67	569.23	565.53	0.88	-1.84	0.6

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TABLE 4.1.1-10

LASALLE – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	562.35	565.04	563.42	562.43	565.71	563.57	562.35	565.71	563.48	-0.08	-0.67	-0.15
1992	562.32	565.18	563.59	562.39	566.01	563.61	562.32	566.01	563.6	-0.07	-0.83	-0.02
1993	562.47	565.38	563.61	562.18	564.66	563.42	562.18	565.38	563.54	0.29	0.72	0.19
1994	561.96	564.9	563.62	562.41	564.87	563.31	561.96	564.9	563.5	-0.45	0.03	0.31
1995	562.3	564.99	563.53	562.37	564.47	563.3	562.3	564.99	563.45	-0.07	0.52	0.23
1996	562.44	565.9	563.83	562.3	565.55	563.42	562.3	565.9	563.66	0.14	0.35	0.41
1997	562.58	565.73	563.87	562.49	566	563.88	562.49	566	563.87	0.09	-0.27	-0.01
1998	562.54	565.04	563.73	562.6	565.21	563.65	562.54	565.21	563.7	-0.06	-0.17	0.08
1999	562.3	564.41	563.5	562.31	564.4	563.31	562.3	564.41	563.36	-0.01	0.01	0.19
2000	562.25	565.11	563.57	562.21	564.27	563.1	562.21	565.11	563.44	0.04	0.84	0.47
2001	562.23	564.58	563.46	562.16	564.18	563.12	562.16	564.58	563.28	0.07	0.4	0.34
2002	562.29	564.59	563.56	562.06	566	563.04	562.06	566	563.37	0.23	-1.41	0.52

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TABLE 4.1.1-11

NYPA INTAKE – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	561.83	564.66	563.02	562.08	565.11	563.2	561.83	565.11	563.09	-0.25	-0.45	-0.18
1992	561.83	564.68	563.22	561.79	565.02	563.21	561.79	565.02	563.21	0.04	-0.34	0.01
1993	561.91	564.92	563.24	562.07	564.78	563.05	561.91	564.92	563.17	-0.16	0.14	0.19
1994	561.77	564.29	563.17	561.81	564.23	562.89	561.77	564.29	563.05	-0.04	0.06	0.28
1995	561.73	564.16	563.11	561.86	564.56	562.88	561.73	564.56	563.02	-0.13	-0.4	0.23
1996	561.3	564.98	563.4	561.77	564.96	562.98	561.3	564.98	563.22	-0.47	0.02	0.42
1997	561.9	564.82	563.33	562.13	565.21	563.36	561.9	565.21	563.34	-0.23	-0.39	-0.03
1998	561.84	564.41	563.23	562.06	564.58	563.25	561.84	564.58	563.24	-0.22	-0.17	-0.02
1999	561.91	564.4	563.3	561.76	564.47	563.02	561.76	564.47	563.19	0.15	-0.07	0.28
2000	561.71	564.02	562.98	561.96	564.35	563.0	561.71	564.35	562.99	-0.25	-0.33	-0.02
2001	561.95	564.55	563.18	562.16	563.97	562.94	561.95	564.55	563.08	-0.21	0.58	0.24
2002	562.03	564.16	563.23	561.93	565.47	562.92	561.93	565.47	563.1	0.1	-1.31	0.31

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TABLE 4.1.1-12

SLATERS POINT – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	561.74	564.5	562.9	561.74	564.87	563.11	561.74	564.87	562.99	0.0	-0.37	-0.21
1992	561.74	564.56	563.06	561.87	564.78	563.12	561.74	564.78	563.09	-0.13	-0.22	-0.06
1993	561.91	563.93	563.12	561.74	565.64	563.10	561.74	565.64	563.1	0.17	-1.71	0.02
1994	561.87	564.39	563.15	562.18	564.81	562.91	561.87	564.81	563.08	-0.31	-0.42	0.24
1995	561.82	564.2	563.10	561.94	564.52	562.9	561.82	564.52	563.01	-0.12	-0.32	0.2
1996	561.93	564.75	563.3	561.83	564.77	562.98	561.83	564.77	563.17	0.1	-0.02	0.32
1997	561.86	564.88	563.25	562.09	564.98	563.31	561.86	564.98	563.27	-0.23	-0.1	-0.06
1998	561.99	564.69	563.17	562.14	564.35	563.16	561.99	564.69	563.17	-0.15	0.34	0.01
1999	561.83	564.23	563.16	561.67	564.31	562.94	561.67	564.31	563.07	0.16	-0.08	0.22
2000	561.83	564.14	563.14	561.92	564.25	562.9	561.83	564.25	563.04	-0.09	-0.11	0.24
2001	561.98	564.54	563.19	562.02	563.84	562.9	561.98	564.54	563.07	-0.04	0.7	0.29
2002	561.93	564.03	563.14	561.9	565.05	562.8	561.9	565.05	563.0	0.03	-1.02	0.34

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TABLE 4.1.1-13

MATERIAL DOCK – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	561.43	564.16	562.56	561.69	564.27	562.89	561.43	564.27	562.69	-0.26	-0.11	-0.33
1992	561.43	564.23	562.82	561.45	564.28	562.97	561.43	564.28	562.88	-0.02	-0.05	-0.15
1993	561.39	564.22	562.74	561.47	564	562.74	561.39	564.22	562.74	-0.08	0.22	0.0
1994	561.47	564.11	562.81	561.61	563.83	562.67	561.47	564.11	562.75	-0.14	0.28	0.14
1995	561.27	563.96	562.73	561.6	564.14	562.64	561.27	564.14	562.69	-0.33	-0.18	0.09
1996	561.55	564.09	562.92	561.34	564.17	562.66	561.34	564.17	562.81	0.21	-0.08	0.26
1997	561.27	564.49	562.72	561.76	564.22	562.88	561.27	564.49	562.79	-0.49	0.27	-0.16
1998	561.31	564.41	562.68	561.74	563.8	562.82	561.31	564.41	562.74	-0.43	0.61	-0.14
1999	561.36	563.83	562.79	561.35	563.98	562.66	561.35	563.98	562.74	0.01	-0.15	0.13
2000	561.49	563.96	562.78	561.63	563.79	562.64	561.49	563.96	562.72	-0.14	0.17	0.14
2001	561.7	564.14	562.86	561.75	563.6	562.63	561.7	564.14	562.76	-0.05	0.54	0.23
2002	561.63	563.53	562.77	561.56	564.33	562.55	561.56	564.33	562.68	0.07	-0.8	0.22

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TABLE 4.1.1-14

AMERICAN FALLS – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	559.2	561.16	560.23	559.18	561.53	560.35	559.18	561.53	560.29	0.02	-0.37	-0.12
1992	559.07	561.57	560.44	558.9	561.58	560.31	558.9	561.58	560.38	0.17	-0.01	0.13
1993	559.21	561.41	560.36	559.26	561.26	560.27	559.21	561.41	560.32	-0.05	0.15	0.09
1994	559.09	561.39	560.42	559.08	561.15	560.2	559.08	561.39	560.33	0.01	0.24	0.22
1995	557.96	561.17	560.38	559.14	561.4	560.26	557.96	561.4	560.33	-1.18	-0.23	0.12
1996	559.45	561.42	560.59	559.18	561.19	560.55	559.18	561.42	560.57	0.27	0.23	0.04
1997	558.96	561.59	560.37	559.1	561.21	560.39	558.96	561.59	560.38	-0.14	0.38	-0.02
1998	559.2	561.62	560.32	559.66	561.18	560.42	559.2	561.62	560.36	-0.46	0.44	-0.1
1999	559.55	561.2	560.48	558.74	561.1	560.27	558.74	561.2	560.39	0.81	0.1	0.21
2000	559.48	561.19	560.44	559.51	561.03	560.3	559.48	561.19	560.38	-0.03	0.16	0.14
2001	559.48	561.12	560.53	559.22	560.97	560.29	559.22	561.12	560.43	0.26	0.15	0.24
2002	559.21	560.99	560.39	559.61	560.78	560.24	559.21	560.99	560.33	-0.4	0.21	0.15

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TABLE 4.1.2-1

ASHLAND AVENUE – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	315.74	330.05	323.07	315.66	339.86	319.66	315.66	339.86	321.64	0.08	-9.81	3.41
1992	315.78	329.85	323.42	315.07	341.22	319.72	315.07	341.22	321.9	0.71	-11.37	3.7
1993	315.85	334.52	324.56	315.75	335.99	321.22	315.75	335.99	323.19	0.1	-1.47	3.34
1994	315.76	331.84	323.98	315.69	336.19	319.71	315.69	336.19	322.23	0.07	-4.35	4.27
1995	314.5	330.58	323.35	315.78	332.65	319.55	314.5	332.65	321.79	-1.28	-2.07	3.8
1996	315.83	339.42	323.89	315.87	336.43	320.25	315.83	339.42	322.37	-0.04	2.99	3.64
1997	316.29	340.11	327.57	315.93	341.22	323.97	315.93	341.22	326.08	0.36	-1.11	3.6
1998	315.78	335.58	325.64	315.84	336.24	321.91	315.78	336.24	324.09	-0.06	-0.66	3.73
1999	315.84	328.97	323.25	315.62	328.39	318.53	315.62	328.97	321.3	0.22	0.58	4.72
2000	315.84	330.4	323.52	315.67	337.7	317.91	315.67	337.7	321.19	0.17	-7.3	5.61
2001	315.76	332.24	323.26	315.63	328.33	318.09	315.63	332.24	321.11	0.13	3.91	5.17
2002	315.76	331.77	323.76	315.54	341.39	318.95	315.54	341.39	321.78	0.22	-9.62	4.81

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TABLE 4.1.2-2

RIVER MOUTH AT LAKE ONTARIO – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	245.26	249.19	247.07	244.44	247.82	246.38	244.44	249.19	246.78	0.82	1.37	0.69
1992	246.11	247.78	247.16	244.93	247.03	245.99	244.93	247.78	246.67	1.18	0.75	1.17
1993	245.45	249.59	247.72	245.32	248.21	246.83	245.32	249.59	247.35	0.13	1.38	0.89
1994	245.55	247.78	246.93	245.16	246.18	245.68	245.16	247.78	246.41	0.39	1.6	1.25
1995	245.78	247.23	246.55	245.03	246.54	246.11	245.03	247.23	246.37	0.75	0.69	0.44
1996	245.95	248.14	247.19	245.39	246.93	246.3	245.39	248.14	246.82	0.56	1.21	0.89
1997	245.75	248.57	247.51	245.45	247.78	246.53	245.45	248.57	247.11	0.3	0.79	0.98
1998	245.16	248.93	247.35	244.4	248.21	246.34	244.4	248.93	246.93	0.76	0.72	1.01
1999	245.22	246.8	246.13	244.5	245.95	245.35	244.5	246.8	245.81	0.72	0.85	0.78
2000	245.59	248.47	247.18	244.8	246.14	245.56	244.8	248.47	246.51	0.79	2.33	1.62
2001	245.16	247.39	246.63	244.96	246.37	245.71	244.96	247.39	246.25	0.2	1.02	0.92
2002	245.21	248.53	247.13	244.57	246.9	245.71	244.57	248.53	246.54	0.64	1.63	1.42

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TABLE 4.1.3-1

LEWISTON RESERVOIR – ANALYSIS OF WATER LEVEL

Year	Tourist Season Water Level (USLS 1935)			Non-Tourist Season Water Level (USLS 1935)			Yearly Water Level (USLS 1935)			Tourist/Non-Tourist Comparison (Diff. in Feet)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
1991	620.62	658.49	640.71	624.71	657.84	642.24	620.62	658.49	641.26	-4.09	0.65	-1.53
1992	621.27	658.46	641.23	629.05	658.23	648.65	621.27	658.46	644.27	-7.78	0.23	-7.42
1993	620.98	658.46	640.78	627.4	658.34	646.8	620.98	658.46	643.27	-6.42	0.12	-6.02
1994	620.16	658.56	640.47	620.3	658.17	644.24	620.16	658.56	642.07	-0.14	0.39	-3.77
1995	620.33	658.58	640.15	620.59	658.38	643.23	620.33	658.58	641.42	-0.26	0.2	-3.08
1996	625.98	658.47	643.1	627.21	658.38	645.84	625.98	658.47	644.24	-1.23	0.09	-2.74
1997	627.87	658.6	644.72	626.93	658.44	648.89	626.93	658.6	646.43	0.94	0.16	-4.17
1998	621.87	658.44	641.39	625.09	658.46	646.67	621.87	658.46	643.57	-3.22	-0.02	-5.28
1999	621.94	658.62	642.04	623.66	658.57	643.22	621.94	658.62	642.53	-1.72	0.05	-1.18
2000	624.35	658.63	645.36	624.43	658.61	645.01	624.35	658.63	645.22	-0.08	0.02	0.35
2001	621.44	658.82	642.52	623.95	658.56	647.84	621.44	658.82	644.72	-2.51	0.26	-5.32
2002	621.86	658.59	643.5	625.08	658.49	646.75	621.86	658.59	644.84	-3.22	0.1	-3.25

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TABLE 4.4-1

EVALUATION OF UPPER RIVER WATER LEVEL FLUCTUATION – APRIL 30, 2001

Gauge Location	Hour	Minimum Gauge El. (ft.)	Maximum Gauge El. (ft.)	Ft. Erie Gauge Flow (cfs)	Minimum-Maximum El. Difference (ft.)	Distance from Lake Erie (miles)	Buffalo Harbor Wind Conditions	
							from Direction	Speed (mph)
NYPA Intake	21	562.3						
NYPA Intake	7		563.73		1.43	20.65		
LaSalle	*	*						
LaSalle	*		*		*	18.99		
Tonawanda Island	22	565.05						
Tonawanda Island	8		565.49		0.44	12.16		
Huntley	22	565.64						
Huntley	9		566.11		0.47	6.36		
Frenchman's Creek	22	565.74						
Frenchman's Creek	9		566.23		0.49	4.63		
Peace Bridge	22	567.11						
Peace Bridge	9		567.47		0.36	1.89		
Fort Erie	1	571.71		189,216			Southeast	8.1
Fort Erie	6		571.92	194,054	0.21	0.00	South	6.9
Buffalo Harbor	1	571.98						
Buffalo Harbor	6		572.20		0.22	0.00		

Note: Minimum - Maximum Flow Difference at Fort Erie = 4,838 cfs. Elevations in USLSD 1935. * LaSalle gauge data excluded for the day due to defective readings.

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TABLE 4.4-2

EVALUATION OF UPPER RIVER WATER LEVEL FLUCTUATION – MAY 1, 2001

Gauge Location	Hour	Minimum Gauge El. (ft.)	Maximum Gauge El. (ft.)	Fort Erie Gauge Flow (cfs)	Minimum-Maximum El. Difference (ft.)	Distance from Lake Erie (miles)	Buffalo Harbor Wind Conditions	
							from Direction	Speed (mph)
NYPA Intake	21	562.46						
NYPA Intake	7		563.65		1.19	20.65		
LaSalle	*	*						
LaSalle	*		*		*	18.99		
Tonawanda Island	1	565.08						
Tonawanda Island	11		565.46		0.38	12.16		
Huntley	1	565.68						
Huntley	10		566.07		0.39	6.36		
Frenchman's Creek.	2	565.78						
Frenchman's Creek	10		566.17		0.39	4.63		
Peace Bridge	3	567.11						
Peace Bridge	9		567.47		0.36	1.89		
Fort Erie	4	571.68		188,510			South/SE	5.8
Fort Erie	9		571.90	193,348	0.22	0.00	West/SW	9.2
Buffalo Harbor	4	571.96						
Buffalo Harbor	9		572.17		0.21	0.00		

Note: Minimum - Maximum Flow Difference at Fort Erie = 4,838 cfs. Elevations in USLSD 1935. * LaSalle gauge data excluded for the day due to defective readings.

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TABLE 4.4-3

EVALUATION OF UPPER RIVER WATER LEVEL FLUCTUATION – JUNE 6, 2001

Gauge Location	Hour	Minimum Gauge El. (ft.)	Maximum Gauge El. (ft.)	Fort Erie Gauge Flow (cfs)	Minimum-Maximum El. Difference (ft.)	Distance from Lake Erie (miles)	Buffalo Harbor Wind Conditions	
							from Direction	Speed (mph)
NYPA Intake	21	562.48						
NYPA Intake	7		563.84		1.36	20.65		
LaSalle	21	562.89						
LaSalle	7		564.06		1.17	18.99		
Tonawanda Island	1	565.27						
Tonawanda Island	9		565.82		0.55	12.16		
Huntley	1	565.91						
Huntley	9		566.31		0.40	6.36		
Frenchman's Creek	1	565.97						
Frenchman's Creek	8		566.42		0.45	4.63		
Peace Bridge	1	567.28						
Peace Bridge	8		567.64		0.36	1.89		
Fort Erie	10	571.74		189,887			North/NE	9.2
Fort Erie	23		572.21	199,669	0.47	0.00	Southeast	3.5
Buffalo Harbor	10	572.03						
Buffalo Harbor	23		572.49		0.46	0.00		

Note: Minimum - Maximum Flow Difference at Fort Erie = 9,782 cfs. Elevations in USLSD 1935.

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TABLE 4.4-4

EVALUATION OF UPPER RIVER WATER LEVEL FLUCTUATION – AUGUST 12, 2001

Gauge Location	Hour	Minimum Gauge El. (ft.)	Maximum Gauge El. (ft.)	Fort Erie Gauge Flow (cfs)	Minimum-Maximum El. Difference (ft.)	Distance from Lake Erie (miles)	Buffalo Harbor Wind Conditions	
							from Direction	Speed (mph)
NYPA Intake	22	562.49						
NYPA Intake	7		563.60		1.11	20.65		
LaSalle	*	*						
LaSalle	*		*		*	18.99		
Tonawanda Island	24	565.30						
Tonawanda Island	11		565.52		0.22	12.16		
Huntley	23	565.91						
Huntley	12		566.07		0.16	6.36		
Frenchman's Creek	24	565.90						
Frenchman's Creek	10		566.15		0.25	4.63		
Peace Bridge	24	567.24						
Peace Bridge	10		567.47		0.23	1.89		
Fort Erie	8	571.31		180,988			0	0.0
Fort Erie	2		571.71	189,216	0.40	0.00	0	0.0
Buffalo Harbor	14	571.63						
Buffalo Harbor	2		572.05		0.42	0.00		

Note: Minimum - Maximum Flow Difference at Fort Erie = 8,228 cfs. Elevations in USLSD 1935. * LaSalle gauge data excluded for the day due to defective readings.

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TABLE 4.4-5

EVALUATION OF UPPER RIVER WATER LEVEL FLUCTUATION – SEPTEMBER 9, 2001

Gauge Location	Hour	Minimum Gauge El. (ft.)	Maximum Gauge El. (ft.)	Fort Erie Gauge Flow (cfs)	Minimum-Maximum El. Difference (ft.)	Distance from Lake Erie (miles)	Buffalo Harbor Wind Conditions	
							from Direction	Speed (mph)
NYPA Intake	2	562.73						
NYPA Intake	7		563.73		1.00	20.65		
LaSalle	21	563.20						
LaSalle	7		564.08		0.88	18.99		
Tonawanda Island	1	565.25						
Tonawanda Island	8		565.63		0.38	12.16		
Huntley	*	*						
Huntley	*		*		*	6.36		
Frenchman's Creek	1	565.92						
Frenchman's Creek	8		566.25		0.33	4.63		
Peace Bridge	24	567.07						
Peace Bridge	8		567.37		0.30	1.89		
Fort Erie	13	570.99		174,207			Southwest	13.8
Fort Erie	3		571.51	185,084	0.52	0.00	South	6.9
Buffalo Harbor	13	571.31						
Buffalo Harbor	3		571.82		0.51	0.00		

Note: Minimum - Maximum Flow Difference at Fort Erie = 10,877 cfs. Elevations in USLSD 1935. * Huntley gauge data excluded for the day due to defective readings.

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TABLE 4.4-6

EVALUATION OF UPPER RIVER WATER LEVEL FLUCTUATION – OCTOBER 2, 2001

Gauge Location	Hour	Minimum Gauge El. (ft.)	Maximum Gauge El. (ft.)	Fort Erie Gauge Flow (cfs)	Minimum-Maximum El. Difference (ft.)	Distance from Lake Erie (miles)	Buffalo Harbor Wind Conditions	
							from Direction	Speed (mph)
NYPA Intake	19	562.19						
NYPA Intake	7		563.73		1.54	20.65		
LaSalle	19	562.73						
LaSalle	7		564.06		1.33	18.99		
Tonawanda Island	20	565.12						
Tonawanda Island	12		565.64		0.52	12.16		
Huntley	*	*						
Huntley	*		*		*	6.36		
Frenchman's Creek	20	565.79						
Frenchman's Creek	11		566.29		0.50	4.63		
Peace Bridge	21	566.95						
Peace Bridge	11		567.37		0.43	1.89		
Fort Erie	1	571.00		174,207			South/SW	4.6
Fort Erie	24		571.31	180,988	0.31	0.00	South	6.9
Buffalo Harbor	1	571.31						
Buffalo Harbor	24		571.62		0.31	0.00		

Note: Minimum - Maximum Flow Difference at Ft. Erie =6,781 cfs. Elevations in USLSD 1935. * Huntley gauge data excluded for the day due to defective readings.

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TABLE 4.5.1-1

COMPARISON OF DAILY MEDIAN WATER LEVEL FLUCTUATIONS FOR THE PERIOD 1991-2002

Gauge	Tourist (ft.)	Non-Tourist (ft.)	Difference (ft.)
Buffalo	0.60	0.81	-0.21
Fort Erie	0.62	0.82	-0.20
Peace Bridge	0.52	0.66	-0.14
Frenchman's Creek	0.54	0.49	0.05
Huntley	0.49	0.45	0.04
Black Creek	0.61	0.44	0.17
Tonawanda Island	0.55	0.43	0.12
LaSalle	1.21	0.45	0.76
Slater's Point	1.42	0.45	0.97
NYPA Intake	1.47	0.46	1.01
Material Dock	1.31	0.45	0.86
American Falls	1.01	0.31	0.70

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TABLE 4.6-1

FORT ERIE – DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	10.22	11/02/92	High Flow (Wind Storm on Lake Erie)
2	9.18	11/12/92	High Flow (Wind Storm on Lake Erie)
3	7.18	03/09/02	High Flow (surge at Ft. Erie)
4	7.18	03/10/02	High to Low Flow (surge at Ft. Erie)
5	7.15	10/30/96	High Flow (Wind Storm on Lake Erie)
6	6.81	11/28/95	High Flow (Wind Storm on Lake Erie)
7	6.74	12/03/91	High Flow (Wind Storm on Lake Erie)
8	6.46	12/14/91	High Flow (Wind Storm on Lake Erie)
9	6.30	02/27/97	High Flow (Wind Storm on Lake Erie)
10	5.63	11/13/92	High Flow (Wind Storm on Lake Erie)
11 thru 20	5.17 - 4.57 feet		40 events were surges at Ft. Erie
21 thru 30	4.56 - 4.21 feet		
31 thru 40	4.20 - 3.90 feet		
41 thru 50	3.89 - 3.78 feet		

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TABLE 4.6-2

FRENCHMAN'S CREEK – DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	5.39	11/12/92	High Flow (surge at Ft. Erie)
2	4.83	12/12/00	High Flow (surge at Ft. Erie)
3	4.20	10/30/96	High Flow (surge at Ft. Erie)
4	4.00	03/09/02	High Flow (surge at Ft. Erie)
5	3.95	12/03/91	Low to High Flow (surge at Ft. Erie)
6	3.61	12/14/91	High Flow (surge at Ft. Erie)
7	3.48	11/28/95	High Flow (surge at Ft. Erie)
8	3.47	01/27/96	High Flow (surge at Ft. Erie)
9	3.13	12/17/00	High Flow (surge at Ft. Erie)
10	3.08	02/27/97	High Flow (surge at Ft. Erie)
11 thru 20	3.07 - 2.69 feet		39 events were surges at Ft. Erie 1 event was due to ice and high flows
21 thru 30	2.61 - 2.31 feet		
31 thru 40	2.31 - 2.17 feet		
41 thru 50	2.14 - 2.05 feet		

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TABLE 4.6-3

HUNTLEY – DAILY WATER SURFACE FLUCTUATIONS, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	4.78	12/12/00	High Flow (surge at Ft. Erie)
2	3.64	10/30/96	High Flow (surge at Ft. Erie)
3	3.41	03/10/02	High to Low Flow (surge at Ft. Erie)
4	3.28	01/27/96	High Flow (surge at Ft. Erie)
5	3.10	12/17/00	High Flow (surge at Ft. Erie)
6	3.05	01/19/96	High Flow (surge at Ft. Erie)
7	2.92	11/28/94	High Flow (surge at Ft. Erie)
8	2.82	11/11/95	High Flow (surge at Ft. Erie)
9	2.79	01/05/97	High Flow (surge at Ft. Erie)
10	2.76	10/25/01	High Flow (surge at Ft. Erie)
11 thru 20	2.74 - 2.35 feet		39 events were surges at Ft. Erie 1 event was due to rapid flow change and operations[8]
21 thru 30	2.33 - 2.05 feet		
31 thru 40	2.04 - 1.95 feet		
41 thru 50	1.94 - 1.74 feet		

[8] Large flow change at Fort Erie and large drawdown in elevation of the Chippawa-Grass Island Pool

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TABLE 4.6-4

BLACK CREEK – DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	3.36	02/01/02	High Flow (surge at Ft. Erie)
2	3.34	12/03/91	Low to High Flow (surge at Ft. Erie)
3	3.32	10/30/96	High Flow (surge at Ft. Erie)
4	3.08	12/14/91	High Flow (surge at Ft. Erie)
5	2.97	03/10/02	High to Low Flow (surge at Ft. Erie)
6	2.92	03/09/02	High Flow (surge at Ft. Erie)
7	2.88	11/28/95	High Flow (surge at Ft. Erie)
8	2.77	01/27/96	High Flow (surge at Ft. Erie)
9	2.69	10/27/97	High Flow (surge at Ft. Erie)
10	2.68	12/17/00	High Flow (surge at Ft. Erie)
11 thru 20	2.60 - 2.14 feet		38 events were surges at Ft. Erie 2 events were fluctuations related to operations
21 thru 30	2.13 - 1.93 feet		
31 thru 40	1.93 - 1.85 feet		
41 thru 50	1.84 - 1.73 feet		

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TABLE 4.6-5

TONAWANDA ISLAND – DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	3.72	12/12/00	High Flow (surge at Ft. Erie)
2	3.64	10/30/96	High Flow (surge at Ft. Erie)
3	3.59	12/03/91	Low to High Flow (surge at Ft. Erie)
4	3.14	10/17/92	High Flow (surge at Ft. Erie)
5	3.13	12/14/91	High Flow (surge at Ft. Erie)
6	3.10	03/09/02	High Flow (surge at Ft. Erie)
7	3.09	03/10/02	High to Low Flow (surge at Ft. Erie)
8	2.99	01/27/96	High Flow (surge at Ft. Erie)
9	2.84	11/28/95	High Flow (surge at Ft. Erie)
10	2.77	01/19/96	High Flow (surge at Ft. Erie)
11 thru 20	2.73 - 2.36 feet		33 events were surges at Ft. Erie 5 events were due to rapid flow changes and operations[9] 2 events were fluctuations related to operations
21 thru 30	2.36 – 2.03 feet		
31 thru 40	1.98 - 1.92 feet		
41 thru 50	1.90 - 1.79 feet		

[9] Large flow change at Fort Erie and large drawdown in elevation of the Chippawa-Grass Island Pool

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TABLE 4.6-6

LASALLE – DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	2.77	12/03/91	Low to High Flow (surge at Ft. Erie)
2	2.66	01/27/96	High Flow (surge at Ft. Erie)
3	2.65	03/10/02	High to Low Flow (surge at Ft. Erie)
4	2.50	10/30/96	High Flow (surge at Ft. Erie)
5	2.30	12/14/91	High Flow (surge at Ft. Erie)
6	2.30	04/18/94	
7	2.18	01/19/96	High Flow (surge at Ft. Erie)
8	2.17	10/17/92	High Flow (surge at Ft. Erie)
9	2.04	01/28/96	High Flow (surge at Ft. Erie)
10	2.01	04/04/95	High Flow (surge at Ft. Erie)
11 thru 20	1.95 - 1.86 feet		21 events were surges at Ft. Erie 2 events were due to rapid flow change and operations[10] 17 events were fluctuations related to operations
21 thru 30	1.83 - 1.77 feet		
31 thru 40	1.77 - 1.69 feet		
41 thru 50	1.69 - 1.65 feet		

[10] Large flow change at Fort Erie and large drawdown in elevation of the Chippawa-Grass Island Pool

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TABLE 4.6-7

NYPA INTAKE – DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	2.69	05/02/96	
2	2.51	12/03/91	High Flow (surge at Ft. Erie)
3	2.45	01/27/96	High Flow (surge at Ft. Erie)
4	2.42	11/11/95	High Flow (surge at Ft. Erie)
5	2.39	05/03/96	
6	2.29	10/17/92	High Flow (surge at Ft. Erie)
7	2.23	09/01/92	
8	2.17	04/07/97	High Flow (surge at Ft. Erie)
9	2.11	04/27/92	
10	2.09	09/27/93	High Flow (surge at Ft. Erie)
11 thru 20	2.07 - 1.97 feet		1 events was ice related 3 events were surges at Ft. Erie 5 events were due to rapid flow change and operations[11] 31 events were fluctuations related to operations
21 thru 30	1.97 - 1.96 feet		
31 thru 40	1.96 - 1.94 feet		
41 thru 50	1.94 - 1.92 feet		

[11] Large flow change at Fort Erie and large drawdown in elevation of the Chippawa-Grass Island Pool

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TABLE 4.6-8

SLATER'S POINT – DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	2.44	11/06/94	High Flow (surge at Ft. Erie)
2	2.36	12/03/91	High Flow (surge at Ft. Erie)
3	2.34	06/16/92	
4	2.30	11/11/95	High Flow (surge at Ft. Erie)
5	2.28	01/27/96	High Flow (surge at Ft. Erie)
6	2.23	11/02/91	High Flow (surge at Ft. Erie)
7	2.17	09/25/92	
8	2.14	09/23/94	
9	2.12	04/23/92	
10	2.12	04/28/92	
11 thru 20	2.03 - 1.95 feet		5 events were surges at Ft. Erie 35 events were fluctuations related to operations
21 thru 30	1.94 - 1.91 feet		
31 thru 40	1.90 - 1.86 feet		
41 thru 50	1.85 - 1.84 feet		

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TABLE 4.6-9

MATERIAL DOCK – DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	2.54	04/28/98	
2	2.23	11/11/95	High Flow (surge at Ft. Erie)
3	2.20	12/03/91	High Flow (surge at Ft. Erie)
4	2.09	05/05/00	
5	2.08	09/27/93	High Flow (surge at Ft. Erie)
6	2.06	10/17/92	High Flow (surge at Ft. Erie)
7	2.06	01/27/96	High Flow (surge at Ft. Erie)
8	2.03	08/31/99	
9	1.99	06/19/92	
10	1.92	04/29/98	High Flow (surge at Ft. Erie)
11 thru 20	1.89 to 1.78 feet		4 events were surges at Ft. Erie 1 event was due to rapid flow change and operations[12] 35 events were fluctuations related to operations
21 thru 30	1.77 to 1.74 feet		
31 thru 40	1.73 to 1.72 feet		
41 thru 50	1.72 to 1.70 feet		

[12] Large flow change at Fort Erie and large drawdown in elevation of the Chippawa-Grass Island Pool

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TABLE 4.6-10

AMERICAN FALLS – DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	2.32	04/08/97	High Flow (surge at Ft. Erie)
2	2.10	04/28/98	Flow Measurement
3	1.89	06/19/92	
4	1.86	04/26/94	Lake Erie Ice Run
5	1.83	07/30/92	
6	1.83	06/29/92	
7	1.82	10/17/92	High Flow (surge at Ft. Erie)
8	1.81	05/10/92	
9	1.80	07/01/92	
10	1.80	07/22/92	
11 thru 20	1.79 - 1.74 feet		
21 thru 30	1.73 - 1.70 feet		
31 thru 40	1.69 - 1.67 feet		
41 thru 50	1.67 - 1.65 feet		

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TABLE 4.6-11

ASHLAND AVENUE– DAILY WATER SURFACE FLUCTUATION, FIFTY HIGHEST DAILY FLUCTUATION VALUES

Rank	Difference (ft) between Daily Max. & Min. El.	Date of Event	Special Event (if applicable)
1	22.66	10/30/96	High Flow (surge at Ft. Erie)
2	20.90	12/12/00	High Flow (surge at Ft. Erie)
3	20.51	02/01/02	High Flow (surge at Ft. Erie)
4	19.95	11/28/94	High Flow (surge at Ft. Erie)
5	18.14	02/27/97	High Flow (surge at Ft. Erie)
6	17.75	10/21/93	High Flow (surge at Ft. Erie)
7	17.47	10/27/97	High Flow (surge at Ft. Erie)
8	17.37	12/14/91	
9	17.10	03/28/91	High Flow (surge at Ft. Erie)
10	17.02	11/13/92	High Flow (surge at Ft. Erie)
11 thru 20	16.31 - 14.50 feet		
21 thru 30	14.47 – 13.80 feet		
31 thru 40	13.79 – 13.44 feet		
41 thru 50	13.43 – 13.12 feet		

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TABLE 4.7-1

NIAGARA RIVER – AVERAGE RIVER VELOCITIES

Gauge	Low Elevation[1] (ft.)	Range of Velocities[2] (fps)	High Elevation[3] (ft.)	Range of Velocities[2] (fps)
Upper Niagara River				
Fort Erie	571.64	1.79 – 2.38	573.79	1.54 –2.05
Peace Bridge	567.01	6.40 – 8.50	571.334	4.99 – 6.62
Frenchman's Creek	565.61	1.94 - 2.57	567.76	1.72 – 2.28
Huntley	565.52	1.96 - 2.61	567.564	1.70 – 2.26
Tonawanda Island	564.91	2.47 – 3.28	566.87	2.19 – 2.91
LaSalle	562.34	1.88 – 2.50	564.85	1.46 – 1.95
River Intake	561.77	2.34 – 3.11	564.55	1.81 – 2.41
Lower Niagara River[4]				
SG-URS-01	251.49	4.02 –6.85	256.56	3.76 – 6.42
SG-URS-02	250.33	2.59 – 4.42	255.39	2.21 – 3.76

Notes:

1. Elevations for the upper Niagara River gauges are based on those on 4/25/00 at 9 p.m. when the Chippawa-Grass Island Pool water level was low and Fort Erie flow was 187,839 cfs. Elevations for the lower Niagara River gauges are based on those on 12/22/98 at 1 p.m. when Lake Ontario water level was low and lower Niagara flow was 240,507 cfs.

2. For upper Niagara River, 10% exceedance flow = 243,000 cfs and 90% exceedance flow = 183,000 cfs based on monthly basis of comparison flows at Fort Erie gauge for period 1900-1999. For lower Niagara River, 10% exceedance flow = 261,000 cfs and 90% exceedance flow = 153,000 cfs based on hourly flows at computed gauge for period 1991-2001.

3. Elevations for the upper Niagara River gauges are based on those on 5/2/91 at 3 p.m. when the Chippawa-Grass Island Pool water level was high and Fort Erie flow was 232,300 cfs. Elevations for the lower Niagara River gauges are based on those on May 12, 1993 at 9 p.m. when Lake Ontario water level was high and lower Niagara flow was 274,090 cfs.

4. Velocities were not calculated for locations SG-URS –03 and SG-URS-04 due to lack of available bathymetric data for the channel portion of this river section.

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TABLE 4.8-1

FLOW AREAS BY VELOCITY AND WATER COLUMN DEPTH RANGES AT INTERNATIONAL RAILWAY BRIDGE (% OF THE TOTAL FLOW AREA OF 47,067 SQ. FT.) FOR THE DISCHARGE OF 207,936 CFS

Velocity Range (feet/sec)	Depth Range (feet)					
	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	Total
0 to 1	0.0%	1.2%	0.0%	0.0%	0.0%	1.2%
1 to 2	0.0%	3.9%	0.0%	0.0%	0.0%	3.9%
2 to 3	1.2%	0.0%	4.5%	0.0%	0.0%	5.6%
3 to 4	0.0%	0.0%	0.0%	9.9%	11.2%	21.1%
4 to 5	0.0%	4.0%	11.7%	0.0%	17.6%	33.2%
5 to 6	0.0%	0.0%	5.4%	23.3%	6.2%	34.9%
Total	1.2%	9.1%	21.6%	33.2%	34.9%	47,067 sq. ft.

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TABLE 4.8-2

FLOW AREAS BY VELOCITY AND WATER COLUMN DEPTH RANGES AT INTERNATIONAL RAILWAY BRIDGE (% OF THE TOTAL FLOW AREA OF 48,427 SQ. FT.) FOR THE DISCHARGE OF 262,759 CFS

Velocity Range (feet/sec)	Depth Range (feet)					
	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	Total
0 to 1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1 to 2	0.0%	0.0%	1.5%	0.0%	0.0%	1.5%
2 to 3	0.0%	4.0%	4.6%	0.0%	0.0%	8.6%
3 to 4	1.3%	0.0%	0.0%	5.0%	0.0%	6.3%
4 to 5	0.0%	4.0%	0.0%	5.0%	0.0%	9.0%
5 to 6	0.0%	0.0%	17.0%	0.0%	16.8%	33.9%
6 to 7	0.0%	0.0%	0.0%	23.1%	17.8%	40.8%
Total	1.3%	8.0%	23.0%	33.0%	34.6%	48,427 sq. ft.

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TABLE 4.8-3

FLOW AREAS BY VELOCITY AND WATER COLUMN DEPTH RANGES AT ROBERT MOSES CABLEWAY (% OF THE TOTAL FLOW AREA OF 17,348 SQ. FT.) FOR THE DISCHARGE OF 48,965 CFS

Velocity Range (feet/sec)	Depth Range (feet)					
	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	Total
0 to 1	2.52%	4.71%	0.00%	0.00%	0.00%	7.23%
1 to 2	0.00%	3.22%	7.19%	6.53%	0.00%	16.93%
2 to 3	0.00%	0.00%	0.00%	15.15%	10.86%	26.01%
3 to 4	0.00%	0.00%	0.00%	0.00%	29.43%	29.43%
4 to 5	0.00%	0.00%	0.00%	10.43%	9.97%	20.40%
Total	2.52%	7.93%	7.19%	32.10%	50.26%	17,348 sq. ft.

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TABLE 4.8-4

FLOW AREAS BY VELOCITY AND WATER COLUMN DEPTH RANGES AT ROBERT MOSES CABLEWAY (% OF THE TOTAL FLOW AREA OF 21,362 SQ. FT.) FOR THE DISCHARGE OF 112,171 CFS

Velocity Range (feet/sec)	Depth Range (feet)						
	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	Total
0 to 1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1 to 2	0.00%	4.92%	0.00%	0.00%	0.00%	0.00%	4.92%
2 to 3	0.00%	0.00%	0.00%	6.43%	0.00%	0.00%	6.43%
3 to 4	0.00%	3.87%	0.00%	6.94%	0.00%	0.00%	10.81%
4 to 5	0.00%	0.00%	3.74%	0.00%	6.42%	0.00%	10.16%
5 to 6	0.00%	0.00%	0.00%	0.00%	13.99%	12.01%	26.00%
6 to 7	0.00%	0.00%	0.00%	0.00%	4.91%	26.70%	31.61%
7 to 8	0.00%	0.00%	0.00%	0.00%	4.99%	5.08%	10.07%
Total	0.00%	8.79%	3.74%	13.37%	30.32%	43.79%	21,362 sq. ft.

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TABLE 4.8-5

SUMMARY DATA FOR THE FOUR ADCP DATA SETS AT THE ROBERT MOSES CABLEWAY ON THE LOWER NIAGARA RIVER

Data set number	1	2	3	4
Date	Nov. 8, 2001	Nov. 8, 2001	June 6, 2002	June 6, 2002
Time	11:35 a.m.	11:40 a.m.	8:51 a.m.	8:55 a.m.
Transect length (ft)	481.70	469.72	497.85	478.88
Maximum depth (ft)	53.81	54.98	58.53	59.08
Left discharge (cfs)	-6.84	0.00	0.00	0.00
Right discharge (cfs)	0.00	34.21	0.00	0.00
Top discharge (cfs)	3,623.77	3,763.80	7,160.39	7,313.60
Measured discharge (cfs)	45,243.80	47,191.61	88,049.88	88,458.28
Bottom discharge (cfs)	4,603.24	5,131.65	8,709.10	9,419.53
Total Discharge (cfs)	53,463.98	56,121.27	103,919.37	105,191.41

Note: Left bank is the Canadian side and right bank is the U.S. side of the river.

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TABLE 4.8-6

FLOW AREAS BY VELOCITY AND WATER COLUMN DEPTH RANGES (% OF TOTAL FLOW AREA) ON NOVEMBER 8, 2001 FOR FLOW OF 53,464 CFS AT THE ROBERT MOSES CABLEWAY ON THE LOWER NIAGARA RIVER

Velocity Range (feet/sec)	Depth Range (feet)						
	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	All Depths
0 to 1	0.00	1.23	1.13	1.56	3.02	0.82	7.76
1 to 2	0.00	0.78	1.65	5.02	6.22	3.23	16.90
2 to 3	0.00	0.73	2.55	4.59	6.00	8.24	22.11
3 to 4	0.00	0.08	0.49	4.37	7.07	11.81	23.82
4 to 5	0.00	0.00	0.00	4.34	5.26	8.06	17.66
5 to 6	0.00	0.00	0.00	2.85	2.67	3.52	9.03
6 to 7	0.00	0.00	0.00	0.83	0.44	1.21	2.47
7 to 8	0.00	0.00	0.00	0.05	0.05	0.13	0.23
8 to 9	0.00	0.00	0.00	0.00	0.02	0.00	0.02
9 to 10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum Over All Velocities	0.00	2.81	5.83	23.60	30.75	37.02	100.00

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TABLE 4.8-7

FLOW AREAS BY VELOCITY AND WATER COLUMN DEPTH RANGES (% OF TOTAL FLOW AREA) ON JUNE 6, 2002 FOR A FLOW OF 105,191 CFS AT THE ROBERT MOSES CABLEWAY ON THE LOWER NIAGARA RIVER

Velocity Range (feet/sec)	Depth Range (feet)						
	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	All Depths
0 to 1	0.00	0.31	0.71	0.91	0.53	0.51	2.97
1 to 2	0.00	0.27	0.67	1.49	2.24	1.29	5.97
2 to 3	0.00	0.34	0.37	1.17	3.17	2.98	8.03
3 to 4	0.00	0.47	0.80	1.33	3.01	4.35	9.98
4 to 5	0.00	0.56	1.26	1.77	3.12	5.55	12.27
5 to 6	0.00	0.29	1.24	3.24	5.00	6.29	16.06
6 to 7	0.00	0.08	0.75	3.50	4.98	6.41	15.73
7 to 8	0.00	0.03	0.19	3.40	3.93	6.64	14.19
8 to 9	0.00	0.00	0.03	1.86	2.31	4.93	9.13
9 to 10	0.00	0.00	0.00	0.75	1.15	2.27	4.17
Sum Over All Velocities	0.00	2.36	6.03	19.51	29.96	42.15	100.00

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TABLE 4.9.1-1

ESTIMATED WIND SETUP AT FORT ERIE

Measured Wind Speed over Land at Buffalo, NY (mph)	Equivalent Wind Speed over Lake Erie (mph)	Maximum Wind Setup Height at Fort Erie (ft)
7.6	10	0.3
15.3	20	1.1
22.9	30	2.5
30.5	40	4.5
38.2	50	7.0
45.8	60	10.1

Note: Fetch length at Fort Erie is over 8 miles. Therefore, the ratio of Wind Over Land to Wind Over Water (V_{water}/V_{land}) is limited to 1.31.

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TABLE 4.9.1-2

ESTIMATED WIND SETUP AT NYPA INTAKE

Measured Wind Speed over Land at Buffalo, NY (mph)	Equivalent Wind Speed over Chippawa-Grass Island Pool (mph)	Maximum Wind Setup Height (ft)
7.7	10	0.02
15.4	20	0.07
23.2	30	0.16
30.9	40	0.28
38.6	50	0.44
46.3	60	0.63

Note: The maximum fetch length in the Chippawa-Grass Island Pool is approximately 5 miles. Therefore, the ratio of Wind Over Land to Wind Over Water (V_{water}/V_{land}) is 1.295.

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TABLE 4.9.1-3

ESTIMATED WIND SETUP AT LEWISTON

Measured Wind Speed over Land at Buffalo, NY (mph)	Equivalent Wind Speed over Lake Ontario (mph)	Maximum Wind Setup Height (ft)
7.9	10	0.01
15.9	20	0.03
23.8	30	0.07
31.7	40	0.12
39.7	50	0.19
47.6	60	0.27

Notes: Location is approximately 5.8 miles upstream of the mouth on the U.S. side of the river.

Fetch length at Lewiston is approximately 3.4 miles. Therefore, the ratio of Wind Over Land to Wind Over Water (V_{water}/V_{land}) is 1.26.

The potential effect of the gorge on wind speeds was not determined in this analysis.

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TABLE 4.9.1-4

ESTIMATED WIND SETUP AT YOUNGSTOWN

Measured Wind Speed over Land at Buffalo, NY (mph)	Equivalent Wind Speed over Lake Ontario (mph)	Maximum Wind Setup Height (ft)
7.8	10	0.01
15.6	20	0.04
23.4	30	0.08
31.3	40	0.15
39.1	50	0.23
46.9	60	0.37

Notes: Location is approximately 1500 feet upstream of the mouth on the U.S. side of the river.

Fetch length at Youngstown is approximately 4.05 miles. Therefore, the ratio of Wind Over Land to Wind Over Water (V_{water}/V_{land}) is 1.28.

The potential effect of the gorge on wind speeds was not determined in this analysis.

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TABLE 4.9.1-5

ESTIMATED WIND SETUP AT MOUTH OF NIAGARA RIVER

Measured Wind Speed over Land at Buffalo, NY (mph)	Equivalent Wind Speed over Lake Ontario (mph)	Maximum Wind Setup Height (ft)
7.6	10	0.04
15.3	20	0.14
22.9	30	0.32
30.5	40	0.57
38.2	50	0.90
45.8	60	1.30

Note: Fetch length at the mouth of the Niagara River is over 8 miles. Therefore, the ratio of Wind Over Land to Wind Over Water (V_{water}/V_{land}) is limited to 1.31.

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TABLE 4.9.1-6

PERCENT OF TIME WIND SPEED IS EQUALED OR EXCEEDED ON LAKES ERIE AND ONTARIO

Measured Wind Speed over Land at Buffalo, NY (mph)	Equivalent Wind Speed over Lakes Erie and Ontario (mph)	Percent of Time Wind Speed is Equaled or Exceeded
7.6	10	63.2%
15.3	20	16.9%
22.9	30	3.5%
30.5	40	0.37%
38.2	50	0.03%
45.8	60	<0.003%

Note: Wind at Buffalo was recorded on an hourly basis. Wind gusts were not taken into consideration.

Period of Wind Records: 1991 - 2001, inclusive.

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TABLE 4.9.1-7

PERCENT OF TIME WIND SPEED IS EQUALED OR EXCEEDED AT CHIPPAWA-GRASS ISLAND POOL

Measured Wind Speed on Land at Buffalo, NY (mph)	Equivalent Wind Speed over Chippawa-Grass Island Pool (mph)	Percent of Time Wind Speed is Equaled or Exceeded
7.7	10	63.2%
15.4	20	16.8%
23.2	30	2.6%
30.9	40	0.37%
38.6	50	0.03%
46.3	60	<0.001%

Note: Wind at Buffalo was recorded on an hourly basis. Wind gusts were not taken into consideration.

Period of Wind Records: 1991 - 2001, inclusive.

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TABLE 4.9.2-1

CHIPPAWA-GRASS ISLAND POOL WAVE HEIGHT CALCULATIONS

Location	Rise for Upstream Fetch (ft)						Rise for Downstream Fetch (ft)					
	10 mph	20 mph	30 mph	40 mph	50 mph	60 mph	10 mph	20 mph	30 mph	40 mph	50 mph	60 mph
Black Creek	0.67	1.40	2.15	2.91	3.69	4.47	0.68	1.42	2.18	2.95	3.74	4.54
Buckhorn Island	0.76	1.59	2.44	3.32	4.20	5.10	0.66	1.37	2.11	2.86	3.63	4.40
NYPA Intake	0.39	0.81	1.25	1.70	2.15	2.61	0.70	1.46	2.24	3.04	3.85	4.67
LaSalle	0.81	1.70	2.61	3.54	4.48	5.44	0.73	1.51	2.33	3.16	4.00	4.85
Tonawanda Island	0.52	1.08	1.66	2.25	2.86	3.46	0.63	1.31	2.01	2.73	3.45	4.19

Note: The upstream fetch is the length of water surface upstream of a location over which the water blows. The downstream fetch is the length of water surface downstream of a location over which the water blows.

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TABLE 4.9.2-2

LOWER NIAGARA RIVER WAVE HEIGHT CALCULATIONS

Location	Rise for Downstream Fetch (ft)					
	10 mph	20 mph	30 mph	40 mph	50 mph	60 mph
Lewiston	0.69	1.44	2.22	3.01	3.82	4.63
Youngstown	0.75	1.57	2.41	3.28	4.15	5.03

Notes: Fetch and other calculations do not consider the effect of the gorge on wind speeds, durations, etc.

The upstream fetch is the length of water surface upstream of a location over which the water blows. The downstream fetch is the length of water surface downstream of a location over which the water blows.

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TABLE 4.10-1

COMPARISON OF AVERAGE DAILY WATER LEVEL FLUCTUATIONS IN THE NIAGARA RIVER, LEWISTON RESERVOIR, AND LAKE ONTARIO FOR PRE- AND POST-ISO OPERATION (FEET)

Location	Pre-NYISO Data from 1991 to Oct. 31, 1999	Post-NYISO Data from Nov. 1, 1999 to 2002	Difference (feet)	Difference (%)
Fort Erie	0.906	0.939	0.033	3.7%
Frenchman's Creek	0.612	0.604	-0.009	-1.4%
Huntley	0.574	0.631	0.056	9.8%
Black Creek	0.596	0.590	-0.007	-1.2%
Tonawanda Island	0.575	0.586	0.011	2.0%
LaSalle	0.910	0.926	0.016	1.8%
Slater's Point	1.057	0.948	-0.109	-10.3%
Material Dock	0.972	0.872	-0.101	-10.3%
NYPA Intakes	1.088	0.954	-0.134	-12.3%
Ashland Avenue	7.723	7.590	-0.133	-1.7%
Lewiston Reservoir	10.633	12.927	2.295	21.6%
Port Weller	0.186	0.193	0.006	9.3%

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FIGURE 4.1-1

ANNUAL MEAN FLOWS OF THE NIAGARA RIVER AT BUFFALO, NY (1926-2002)

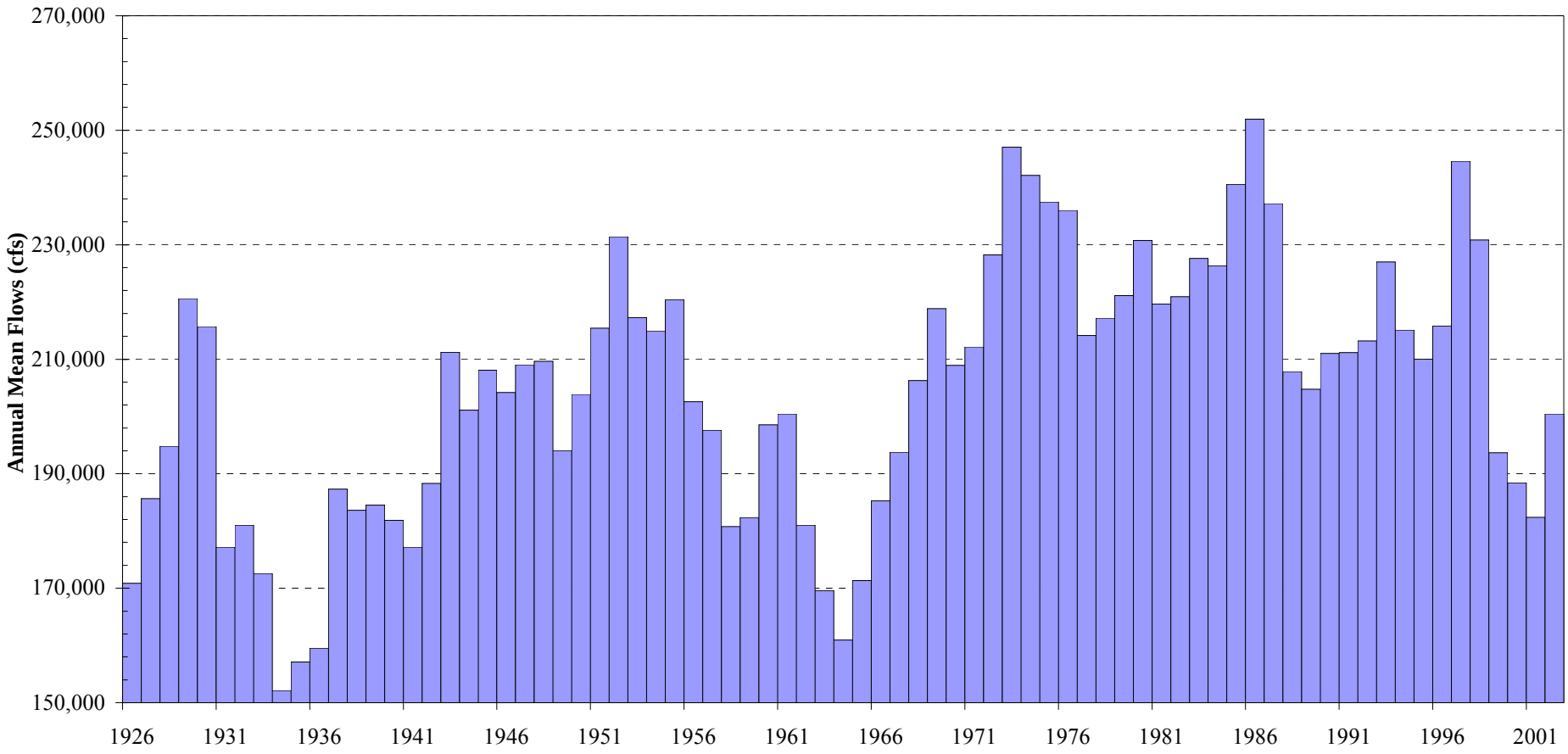

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FIGURE 4.1-2

DURATION CURVES FOR ANNUAL MEAN FLOWS OF THE NIAGARA RIVER AT BUFFALO, NY

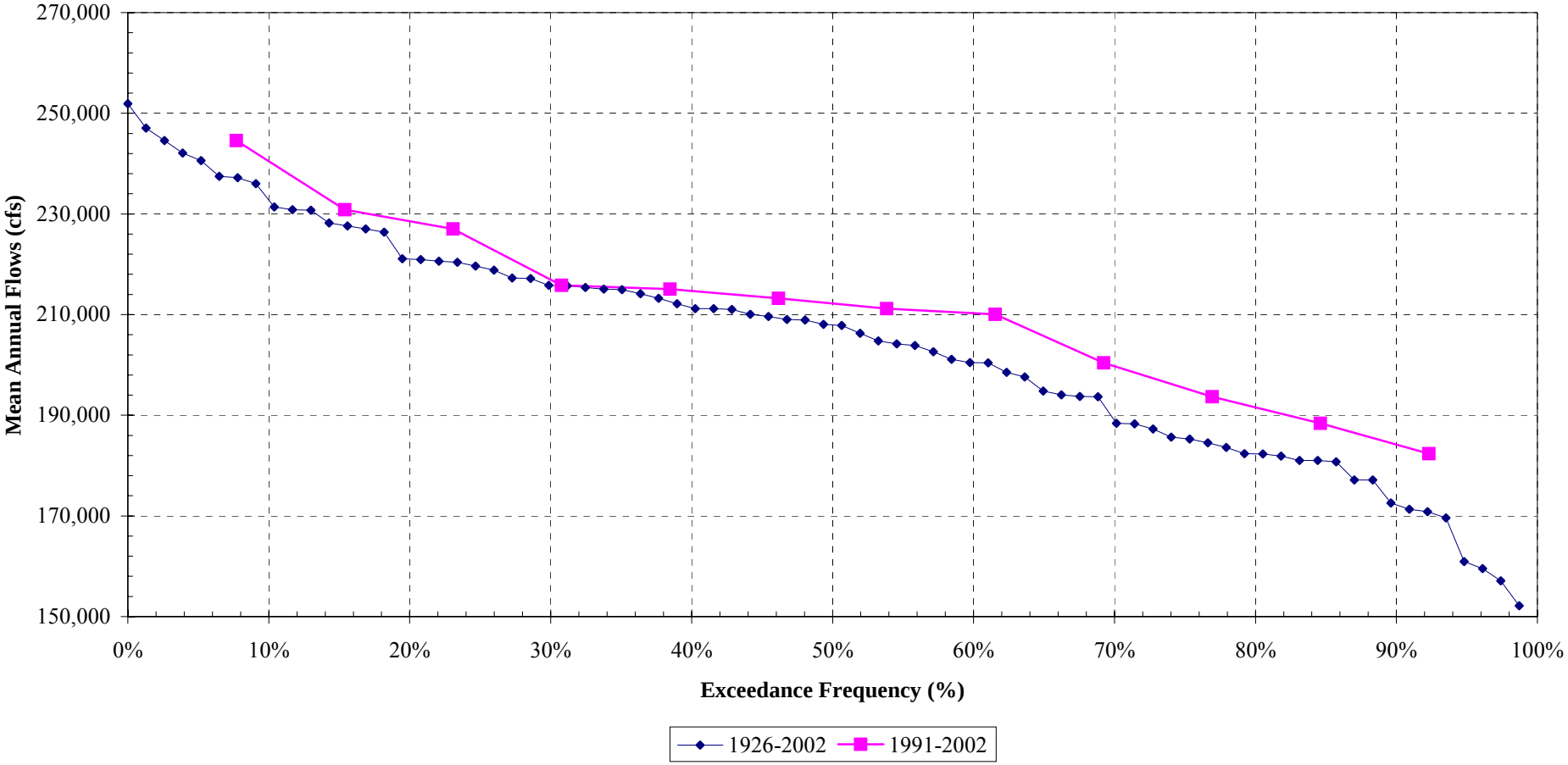

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FIGURE 4.1-3

MEAN MONTHLY FLOWS OF THE NIAGARA RIVER AT BUFFALO, NY (1926-2002)

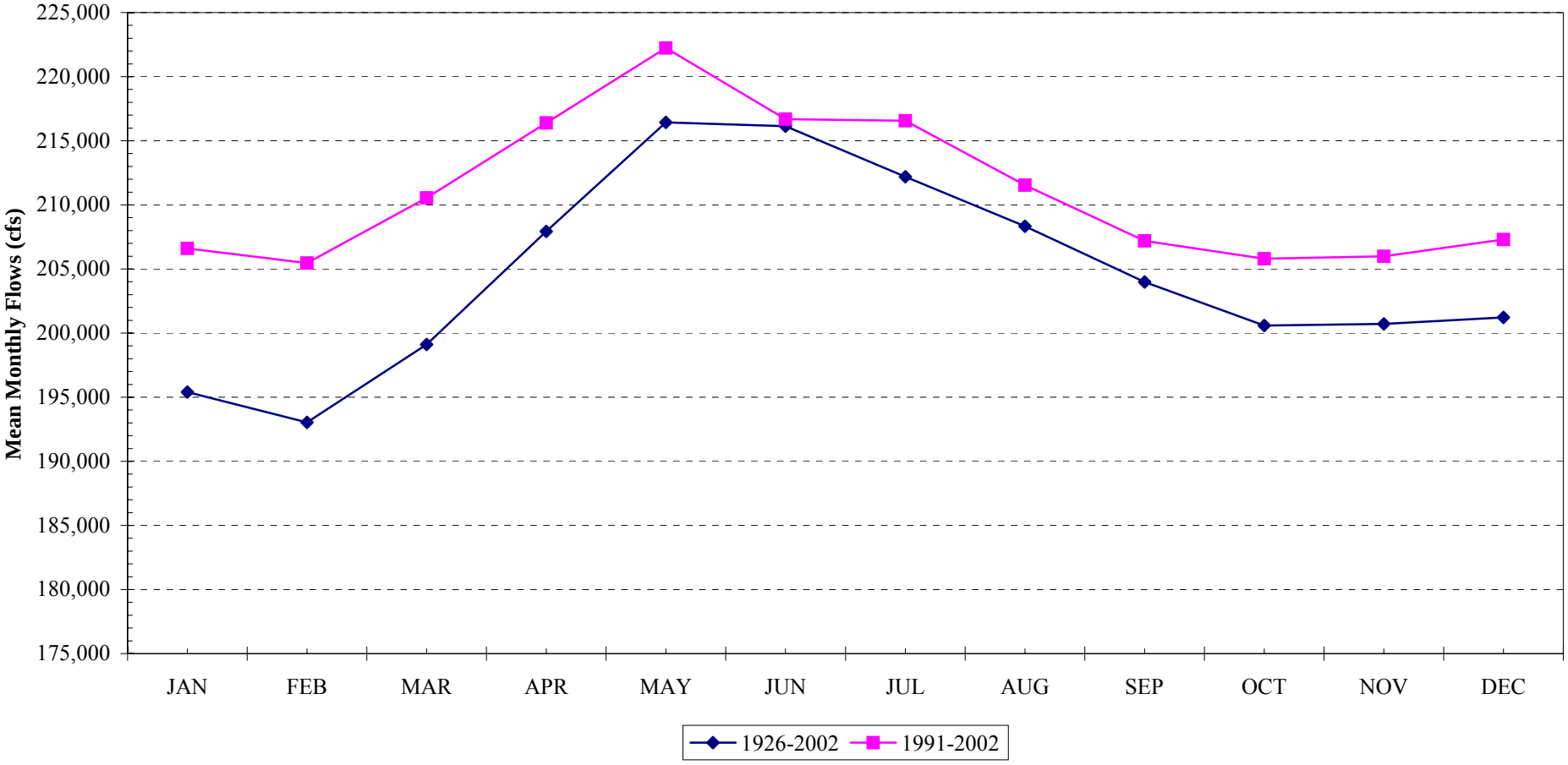

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FIGURE 4.1.1-1

FORT ERIE FLOW DURATION: 1995, 1997, 2001 AND PERIOD OF RECORD (1991-2002)

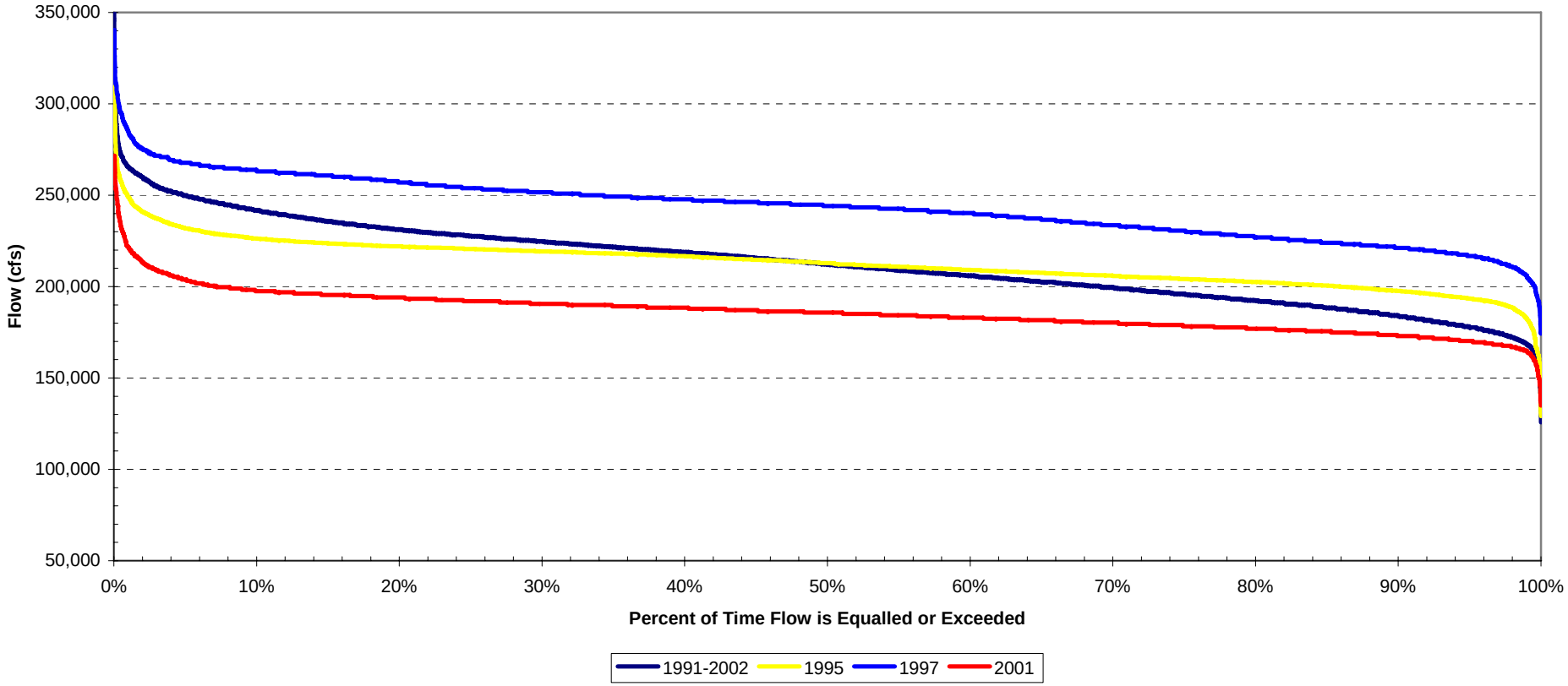

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FIGURE 4.1.1-2

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR JANUARY 1995

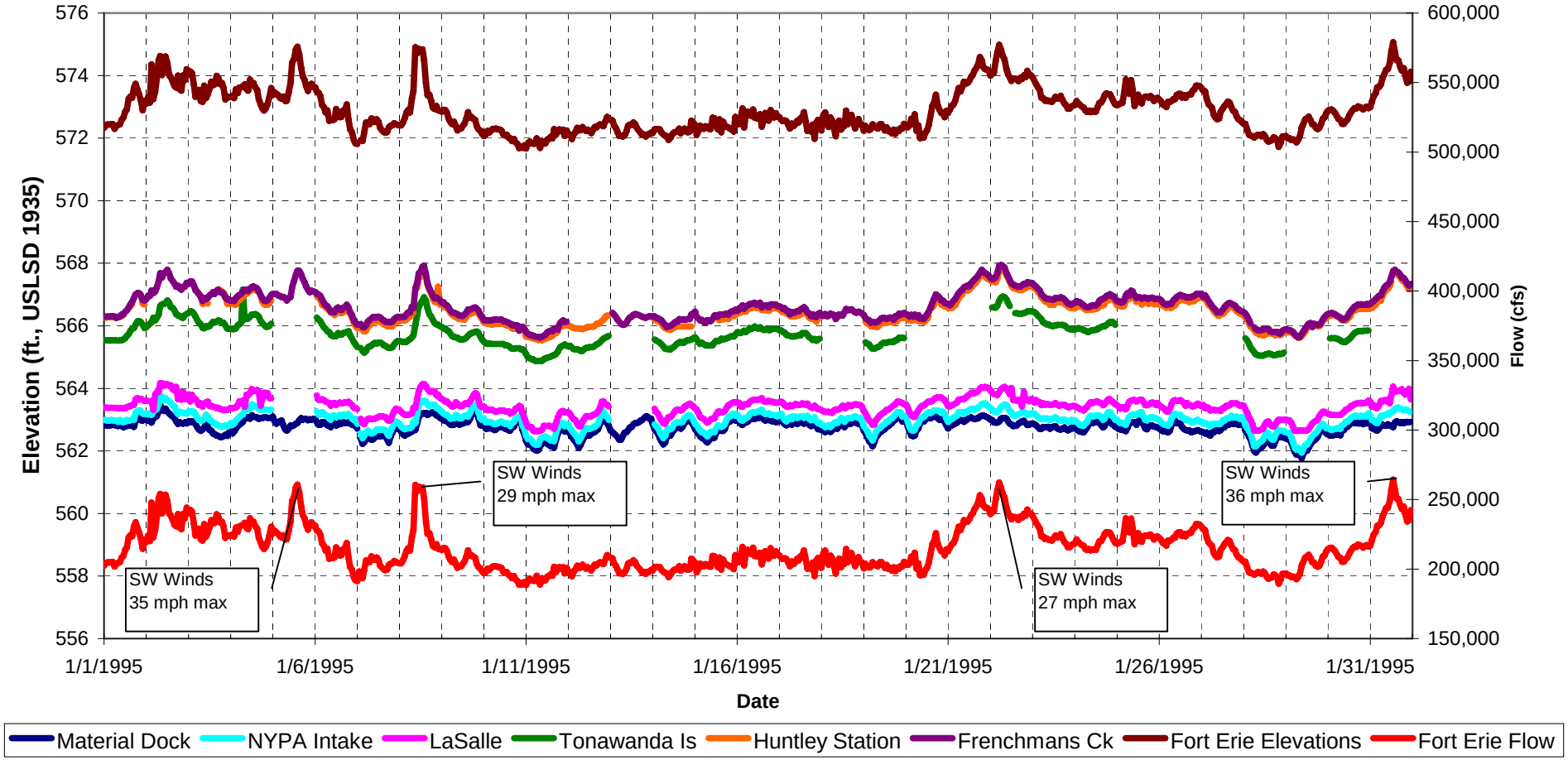

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FIGURE 4.1.1-3

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR FEBRUARY 1995

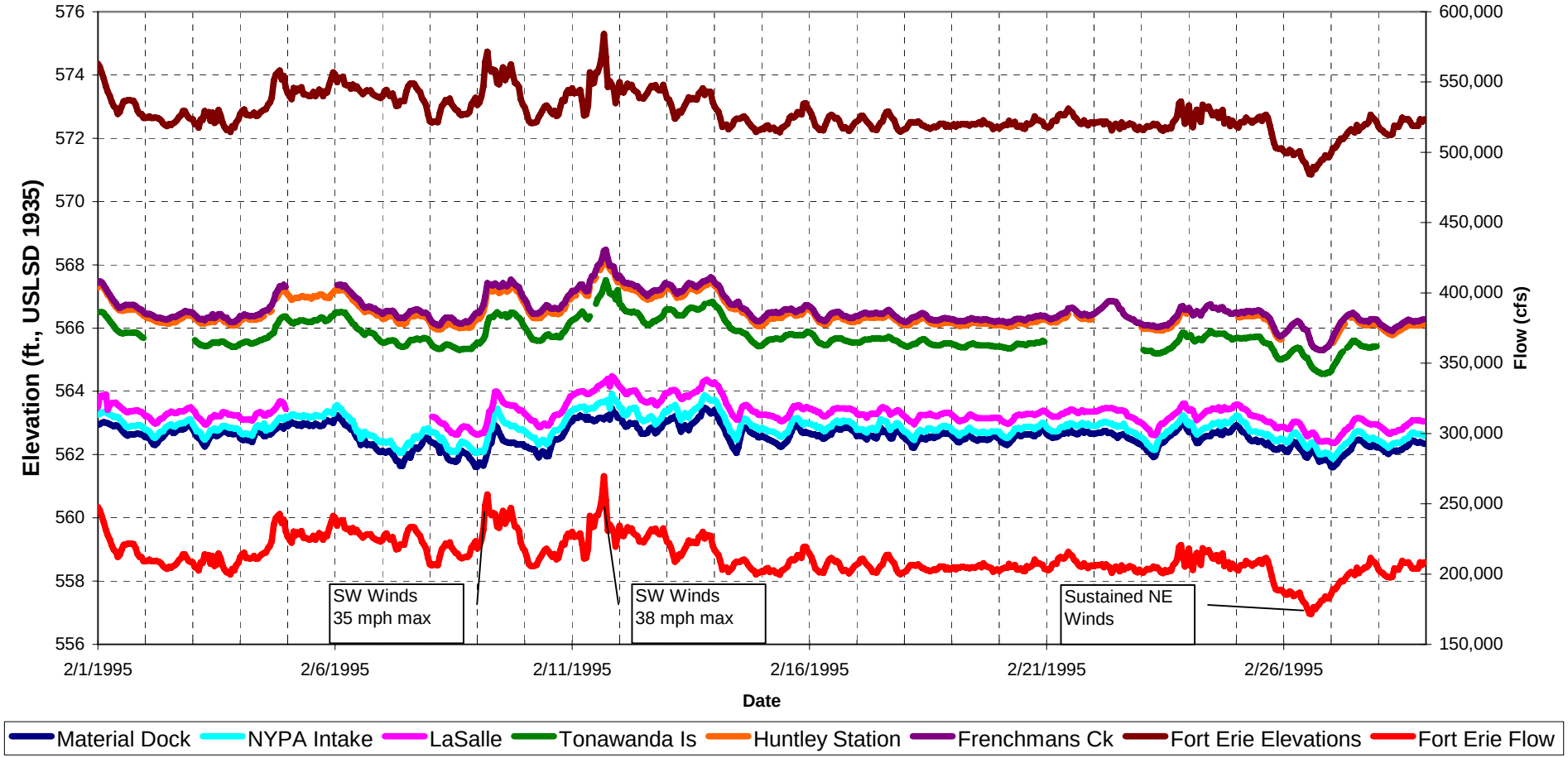

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FIGURE 4.1.1-4

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR MARCH 1995

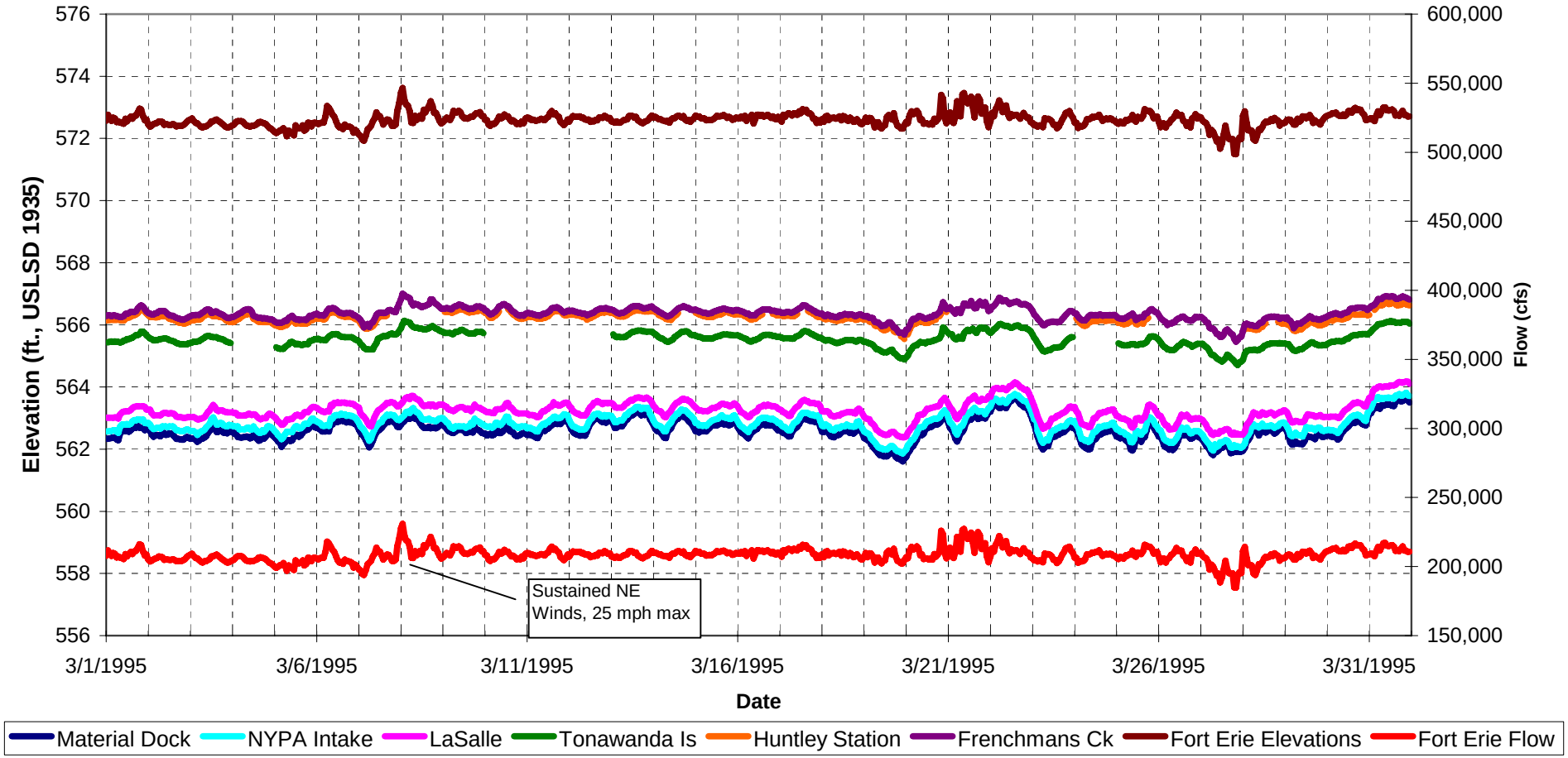

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FIGURE 4.1.1-5

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR APRIL 1995

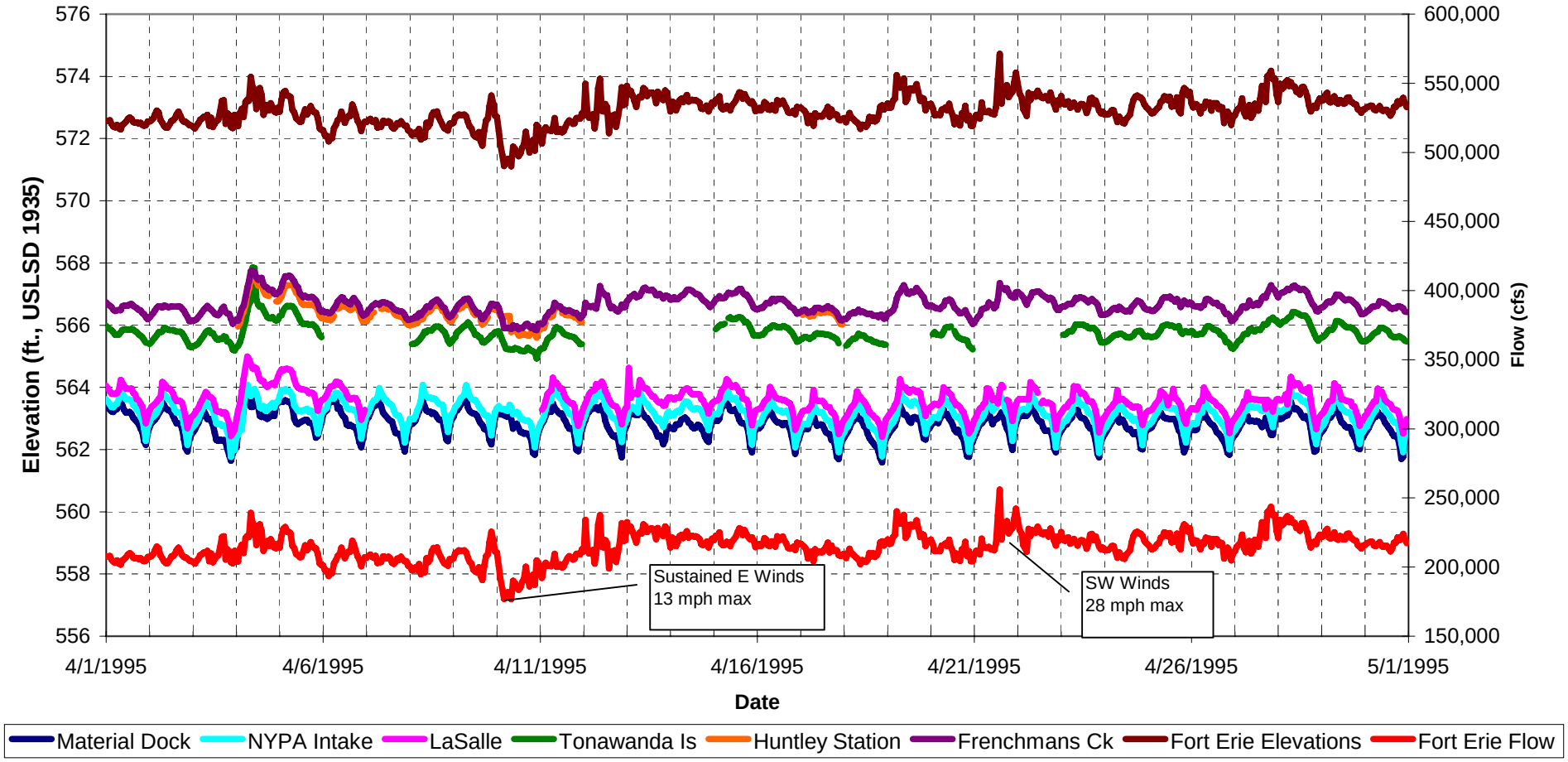

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FIGURE 4.1.1-6

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR MAY 1995

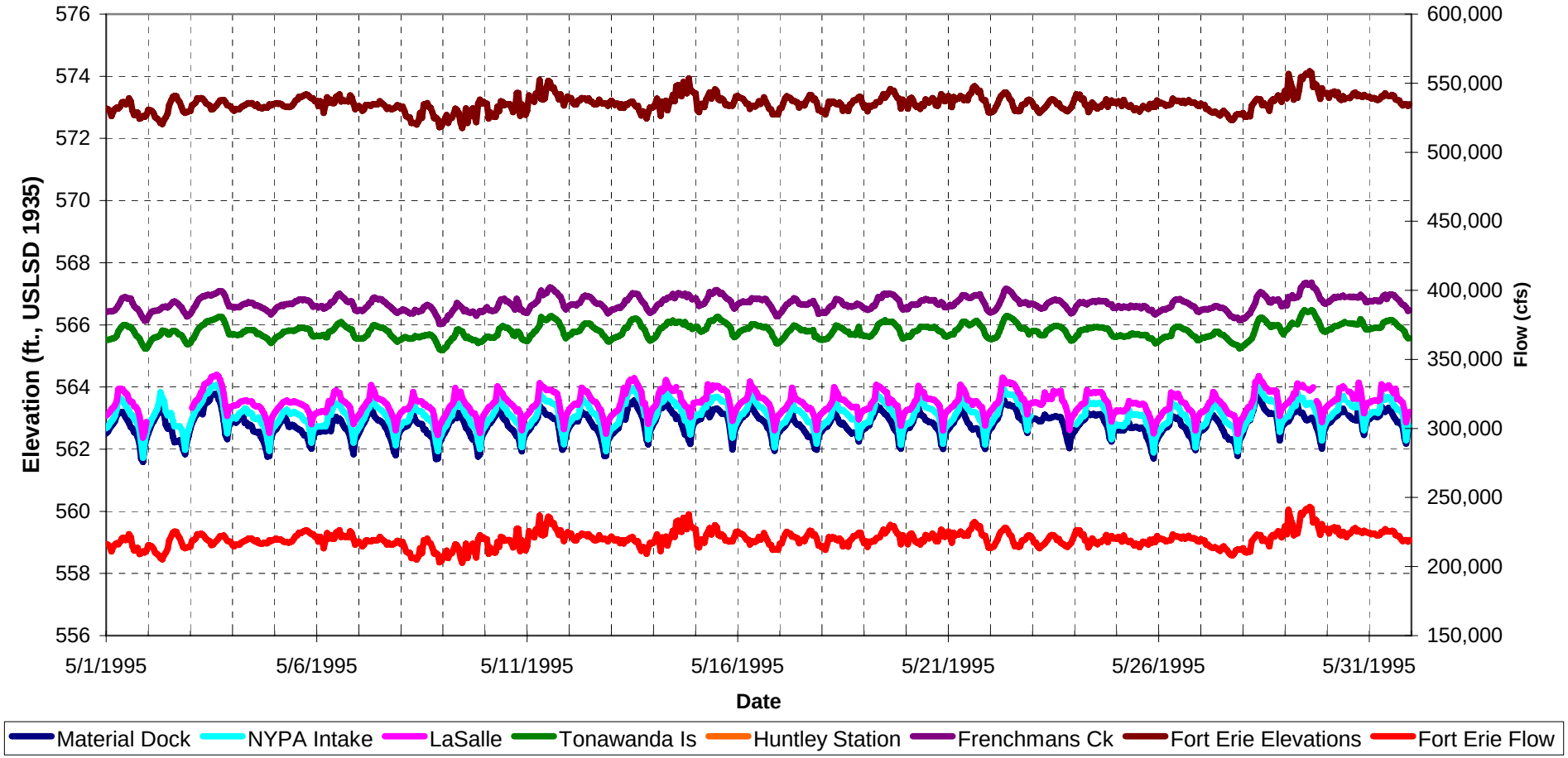

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FIGURE 4.1.1-7

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR JUNE 1995

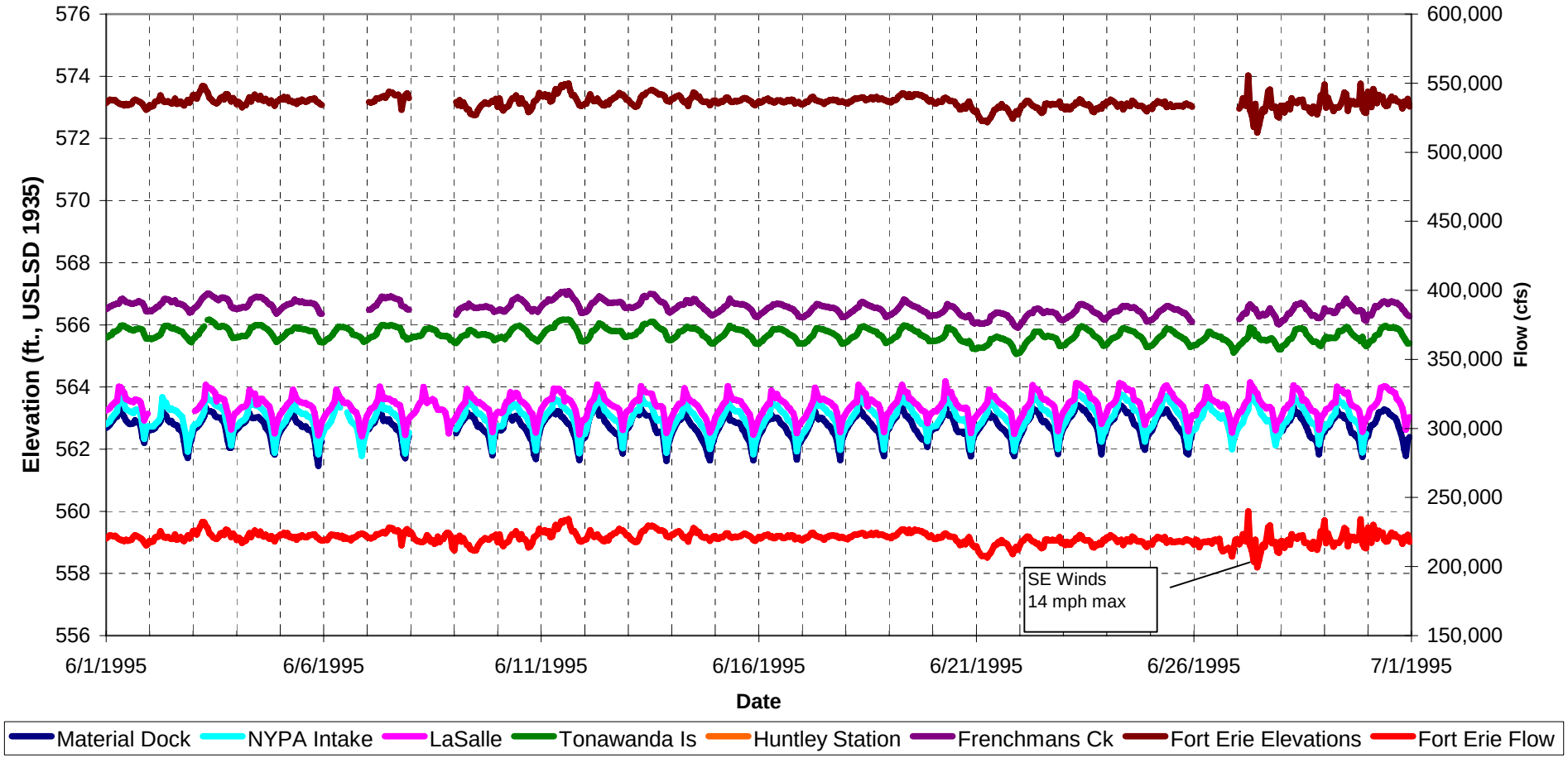

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FIGURE 4.1.1-8

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR JULY 1995

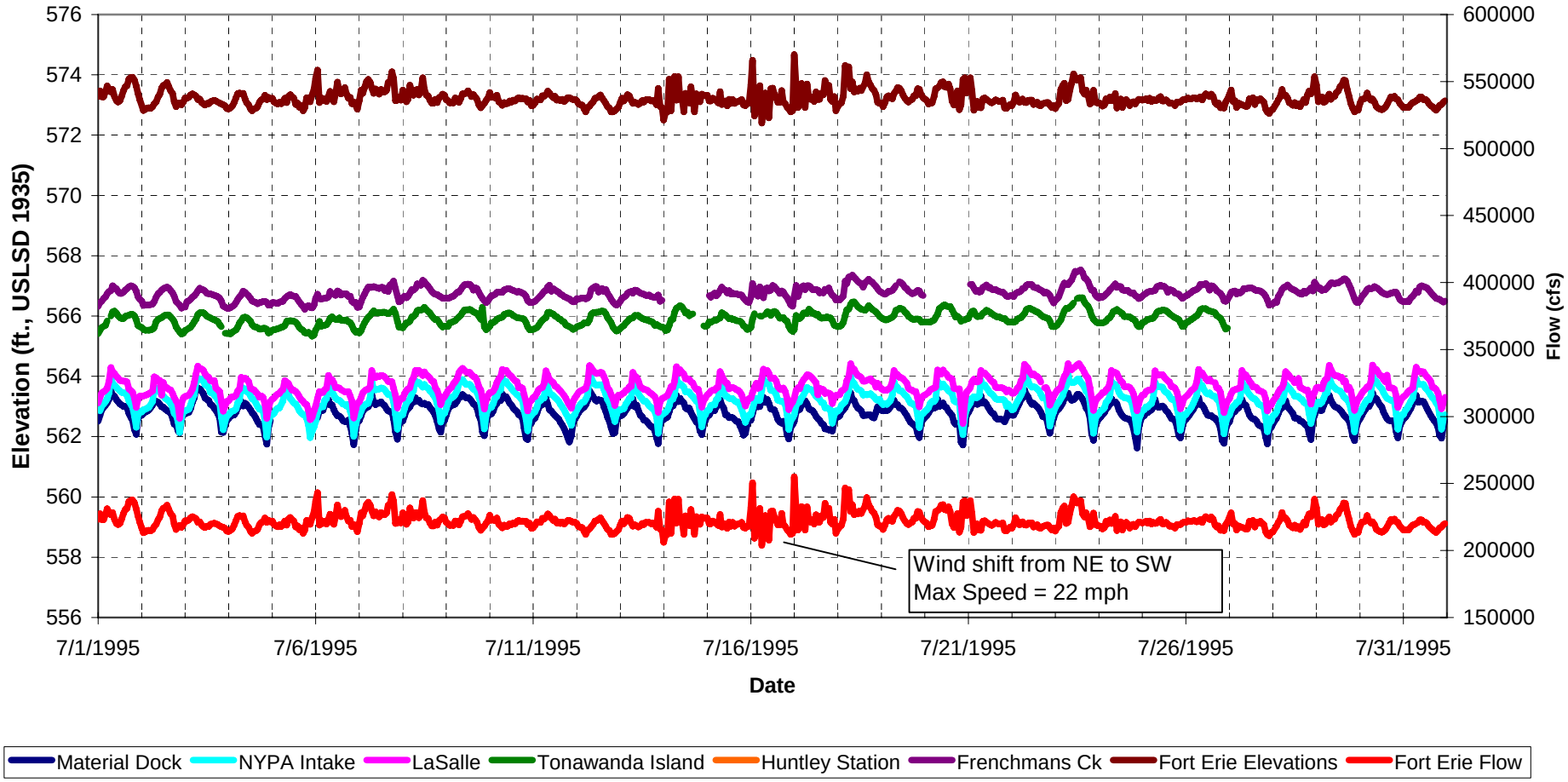

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FIGURE 4.1.1-9

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR AUGUST 1995

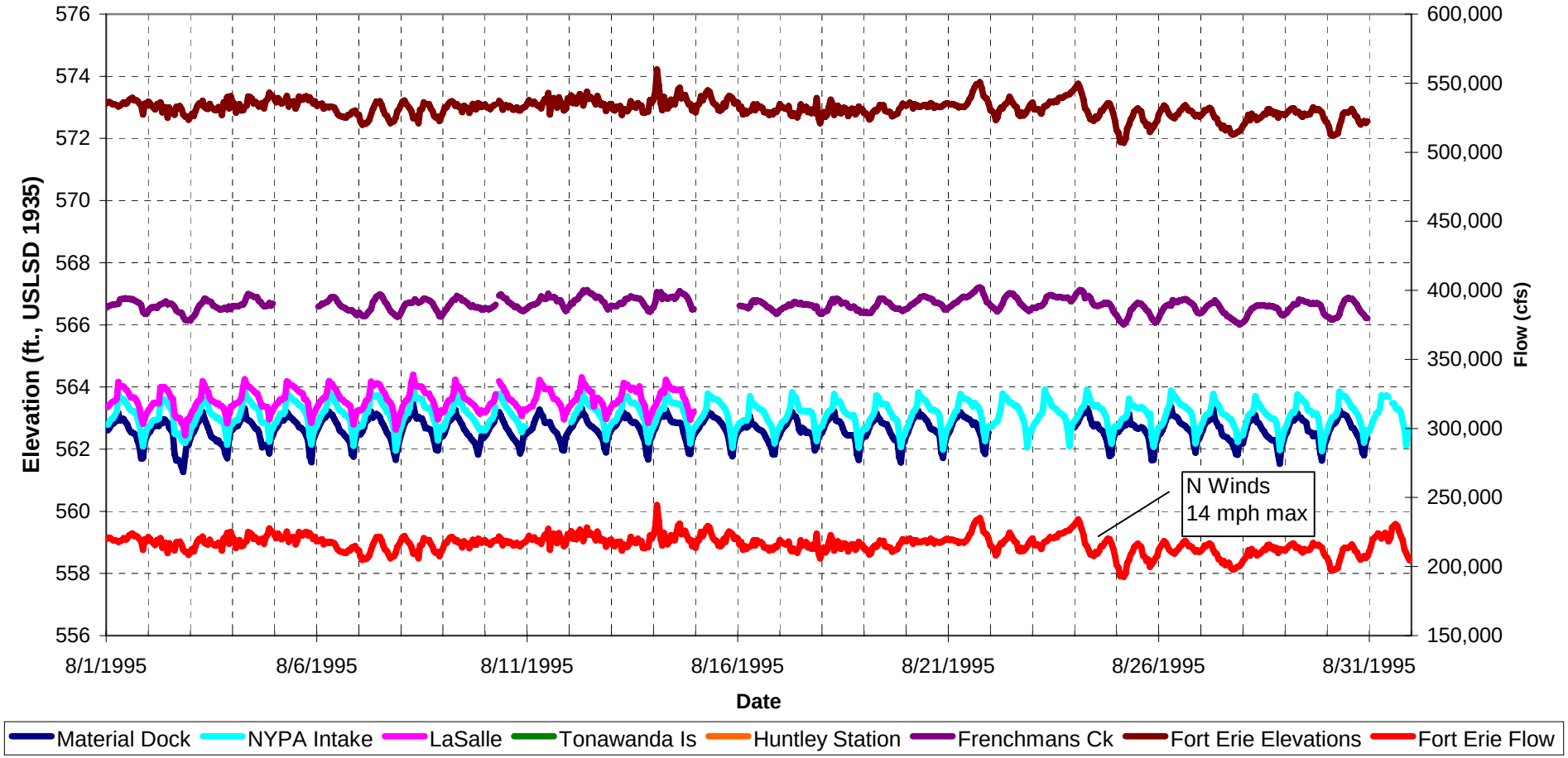

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FIGURE 4.1.1-10

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR SEPTEMBER 1995

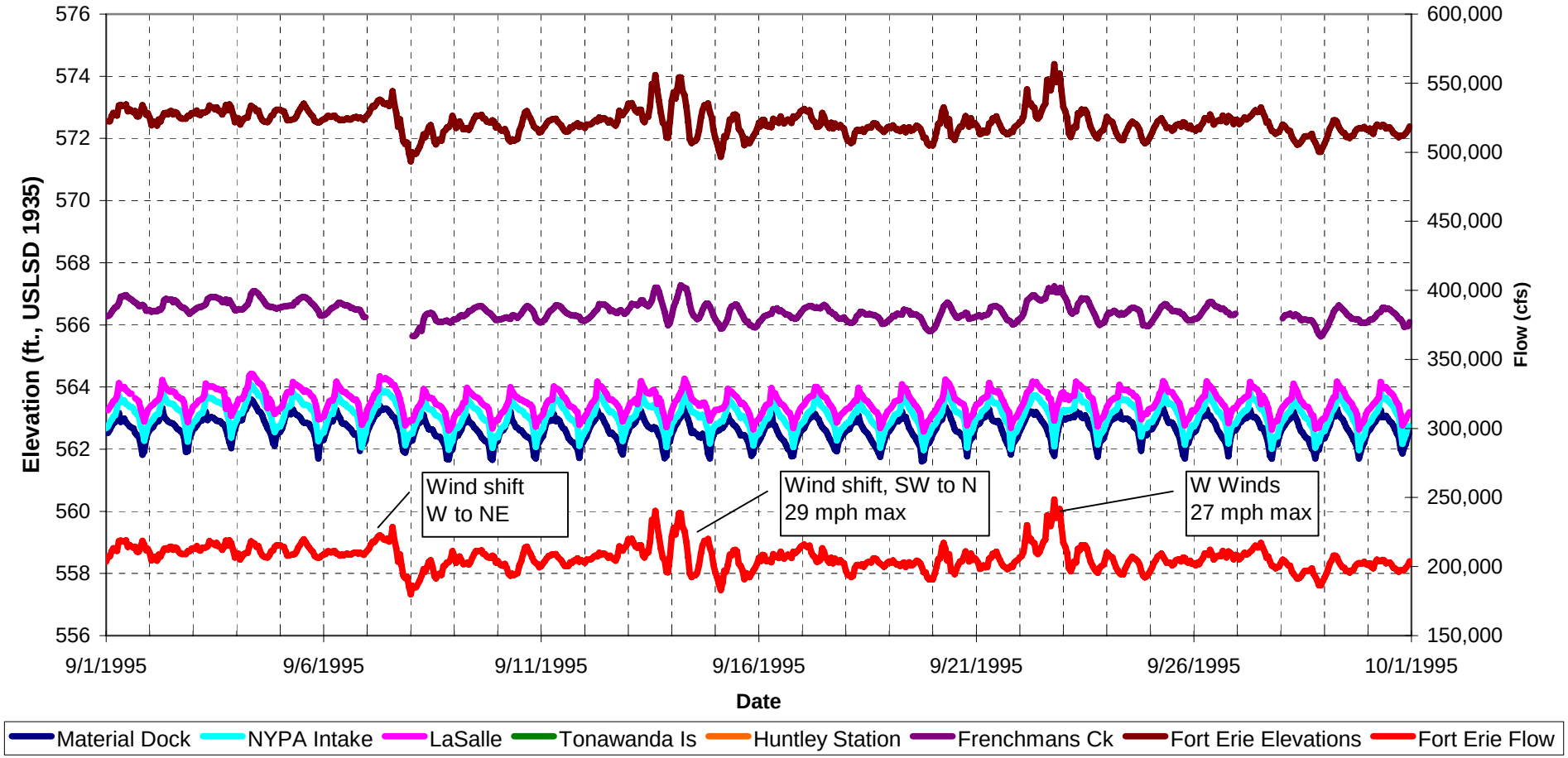

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FIGURE 4.1.1-11

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR OCTOBER 1995

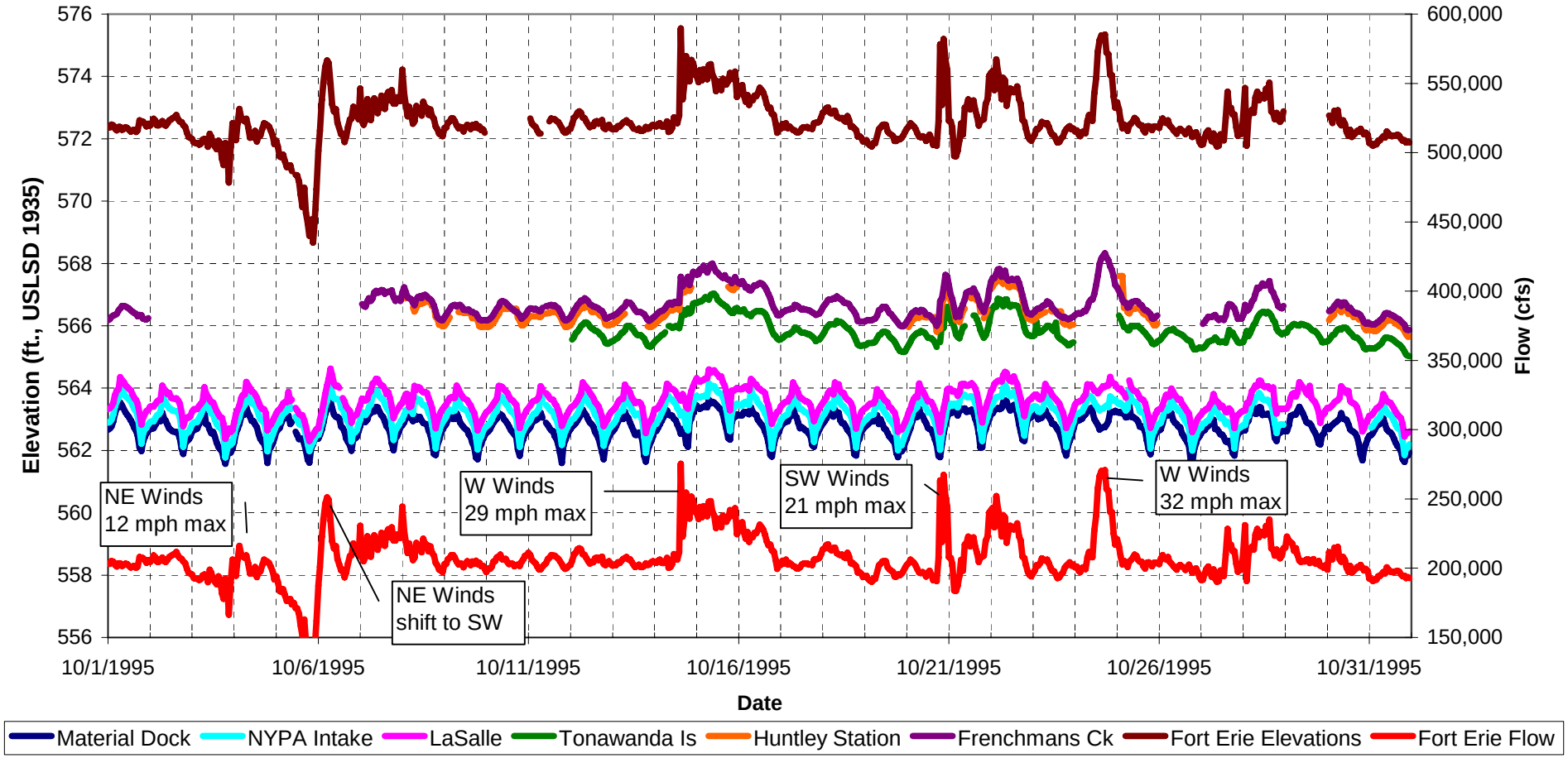

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FIGURE 4.1.1-12

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR NOVEMBER 1995

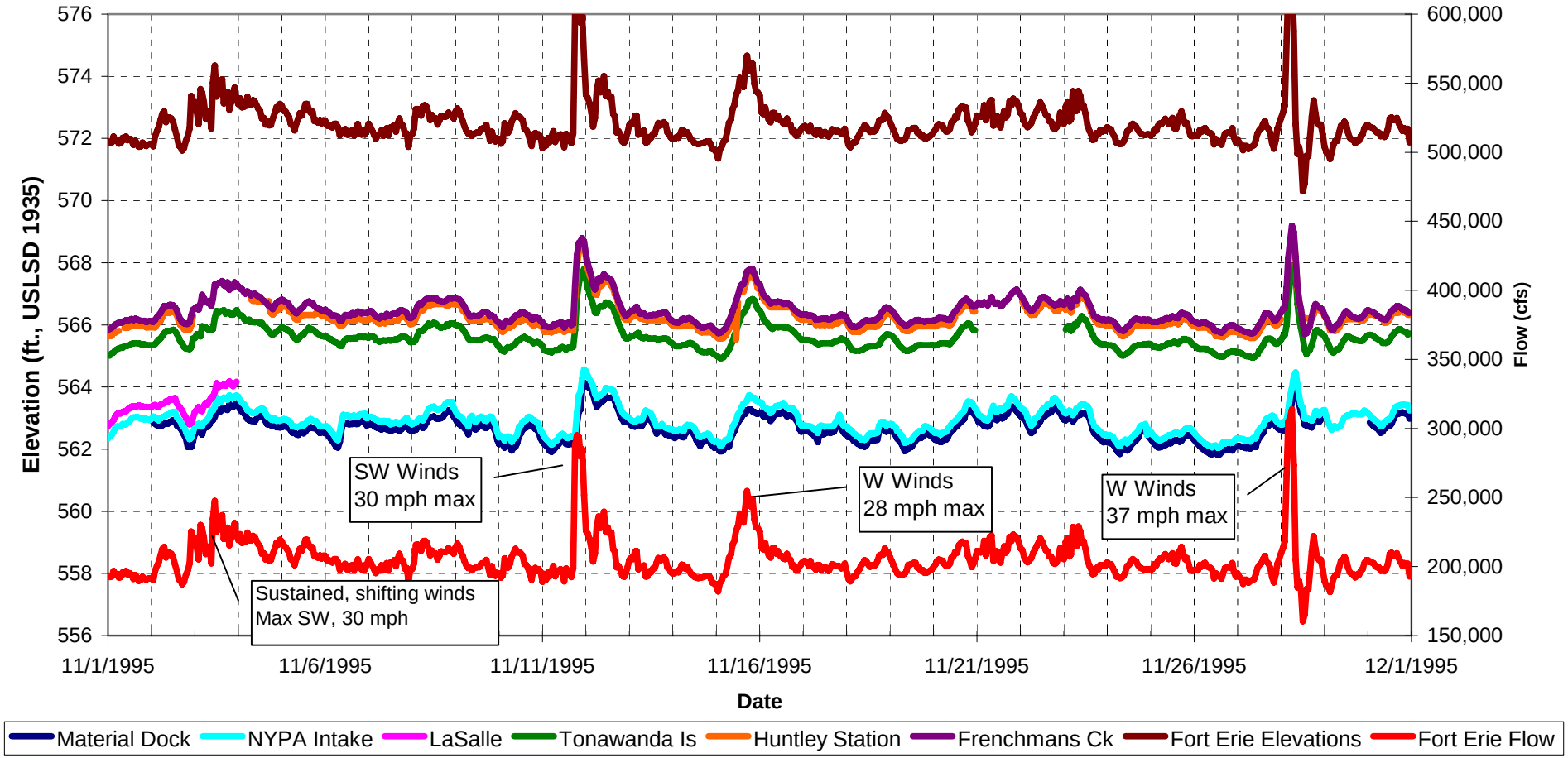

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FIGURE 4.1.1-13

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR DECEMBER 1995

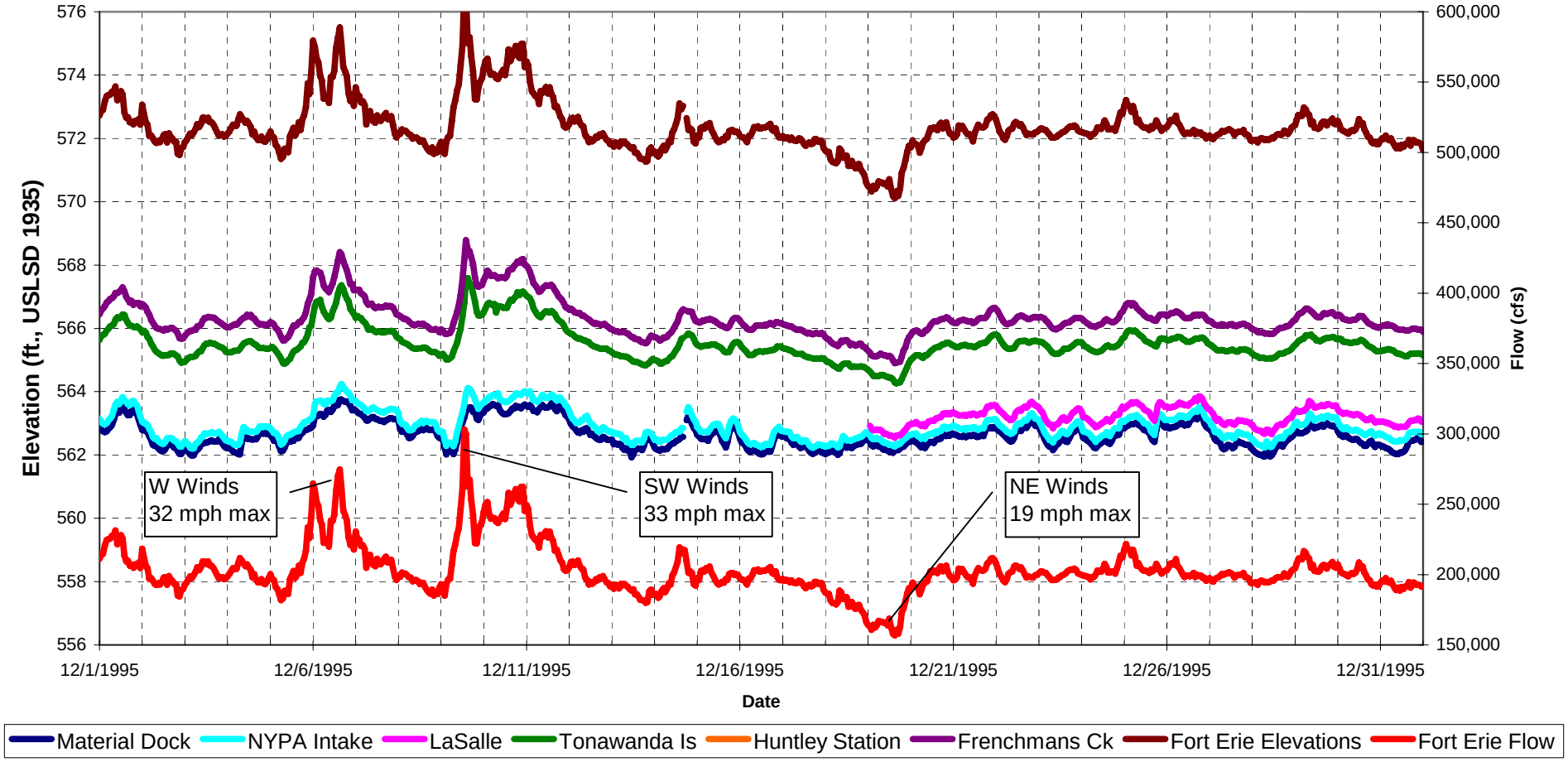

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FIGURE 4.1.1-14

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR JANUARY 2001

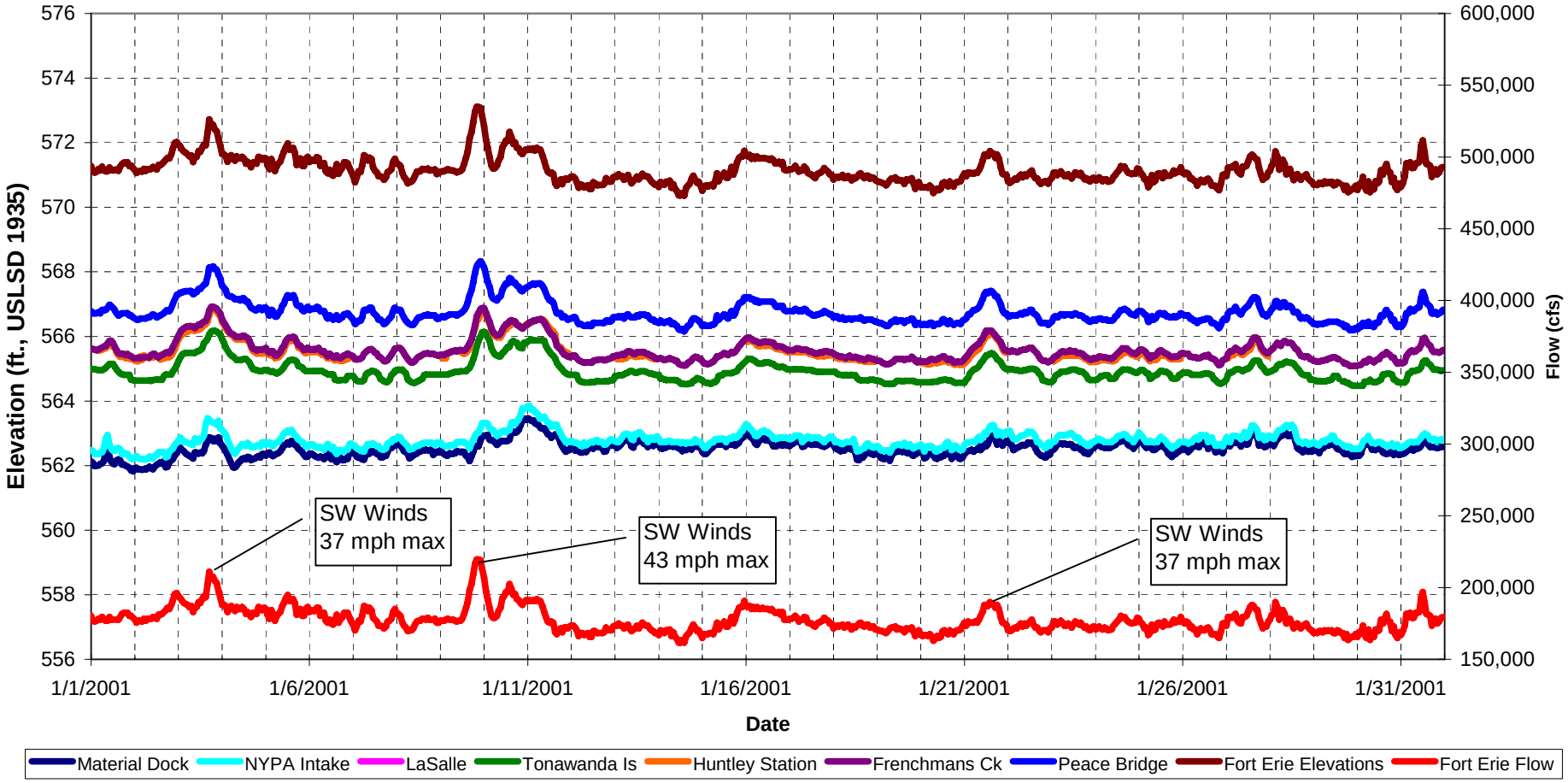

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FIGURE 4.1.1-15

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR FEBRUARY 2001

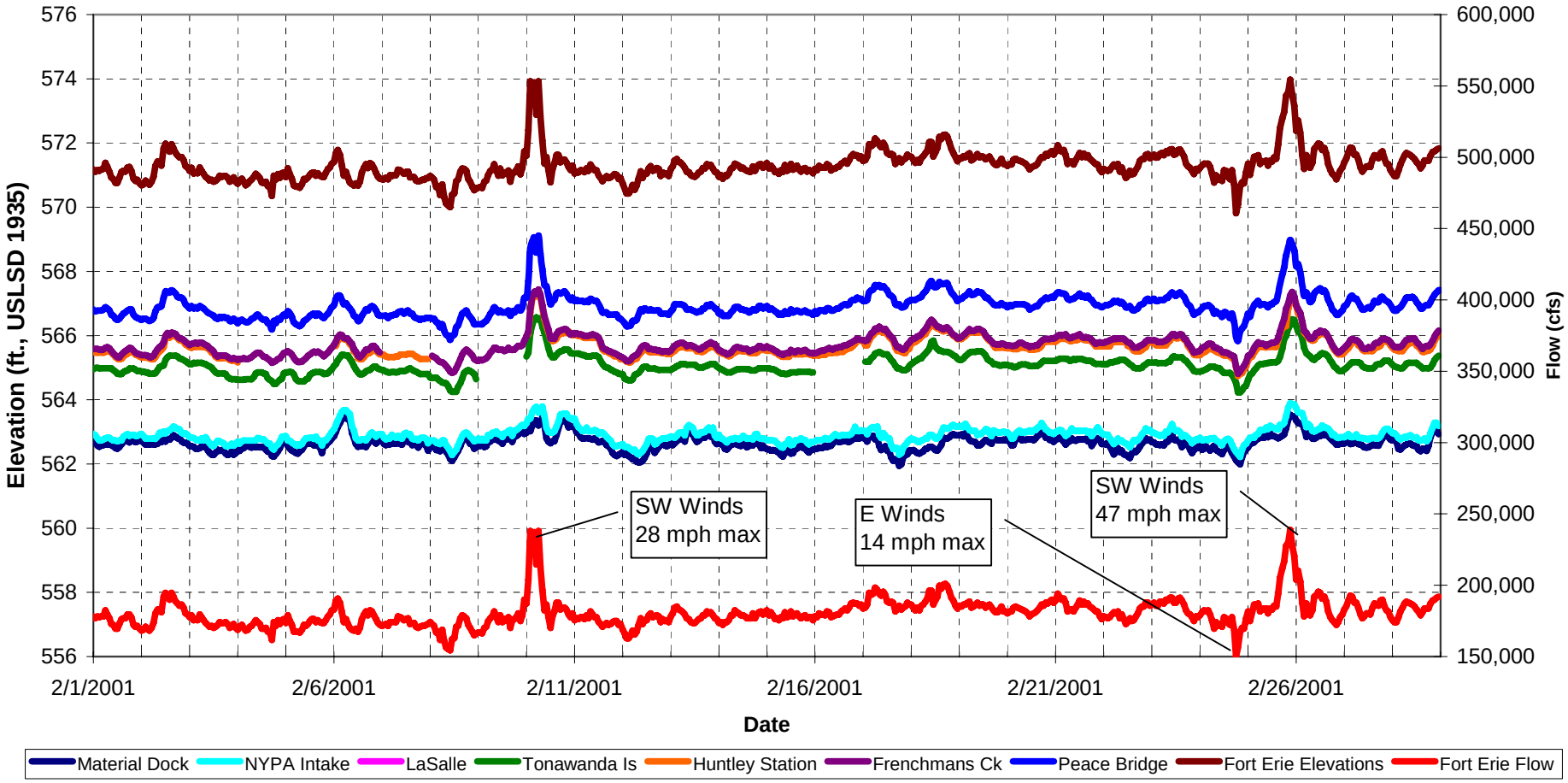

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FIGURE 4.1.1-16

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR MARCH 2001

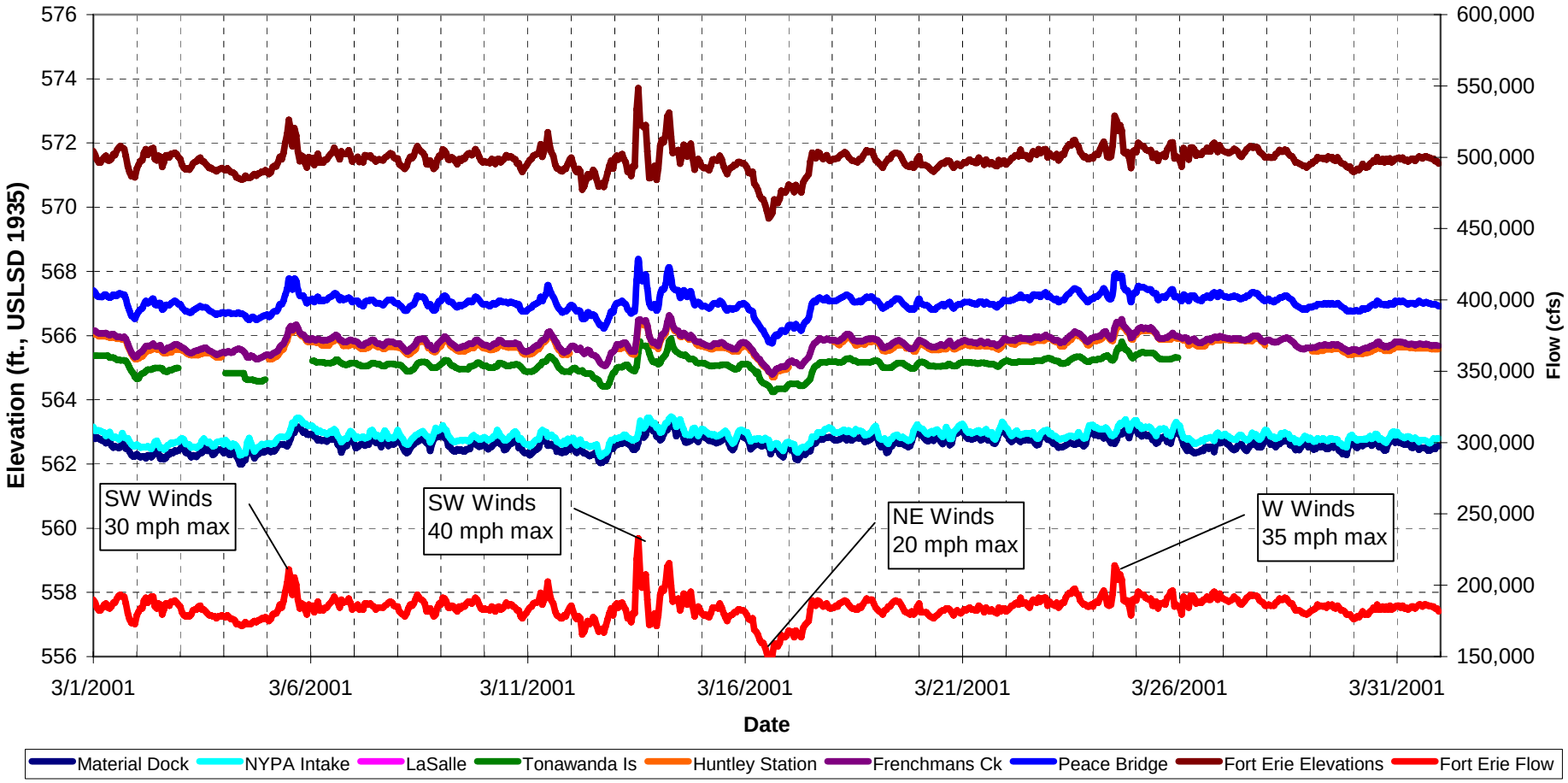

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FIGURE 4.1.1-17

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR APRIL 2001

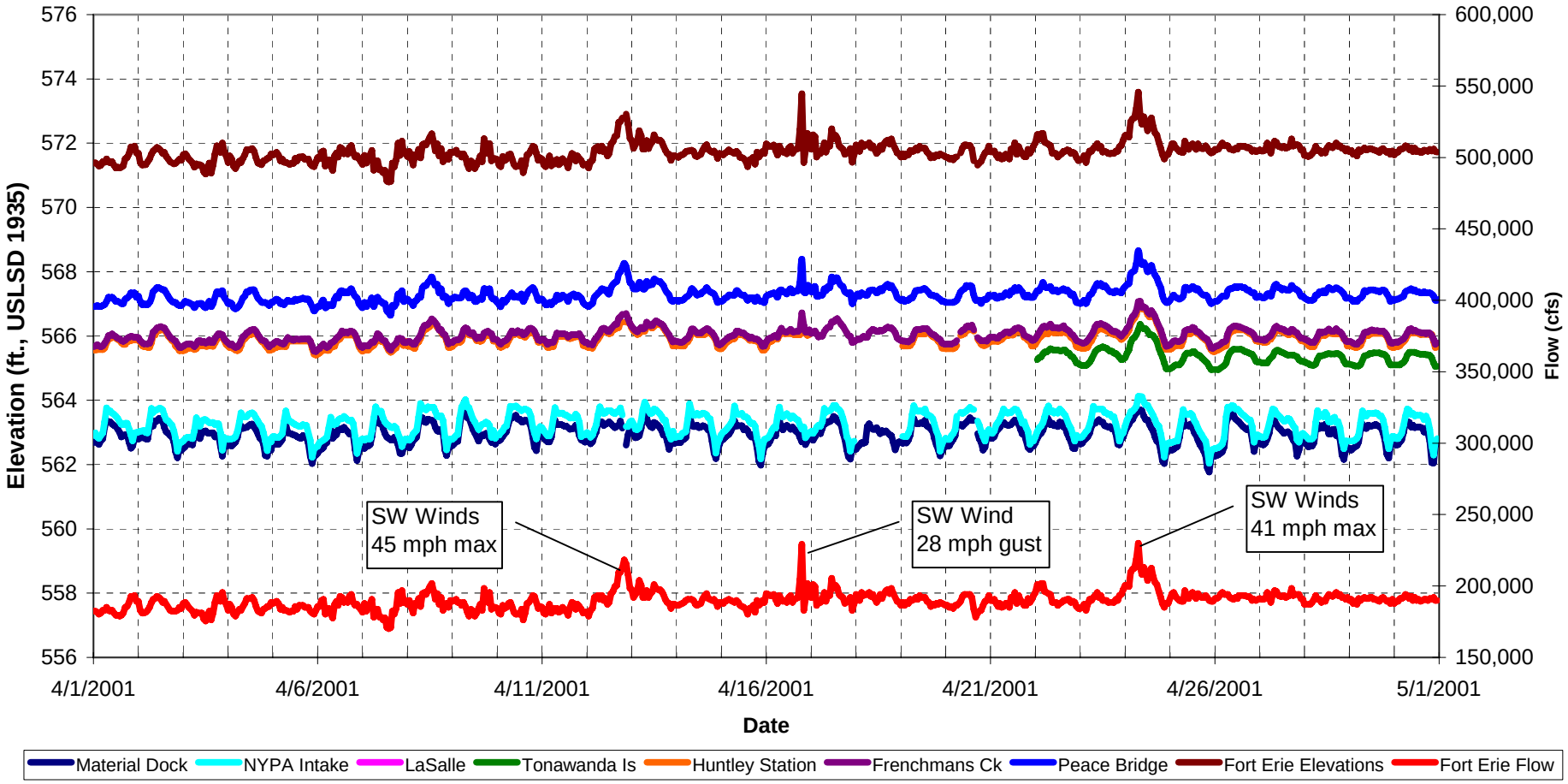

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FIGURE 4.1.1-18

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR MAY 2001

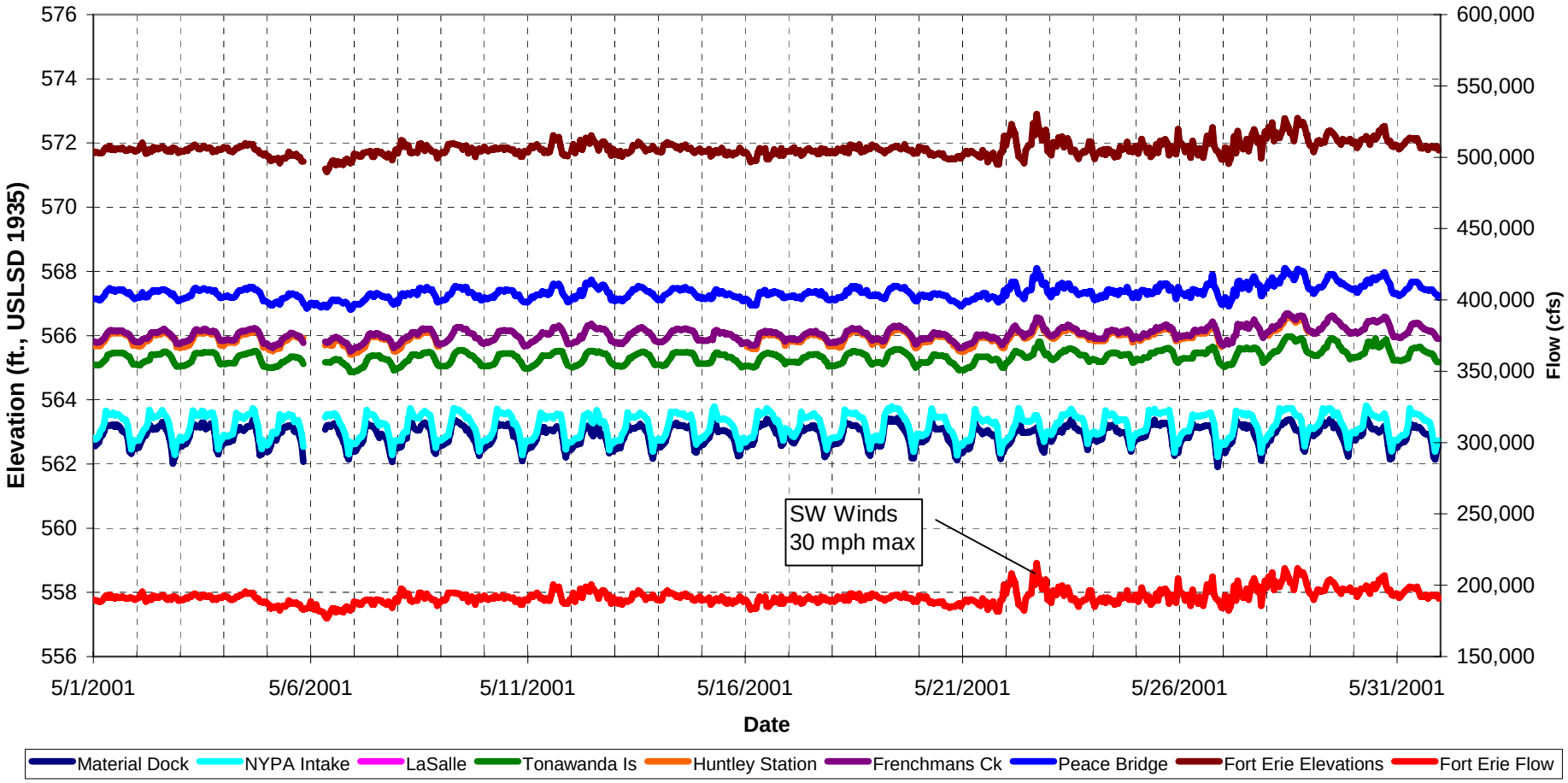

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FIGURE 4.1.1-19

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR JUNE 2001

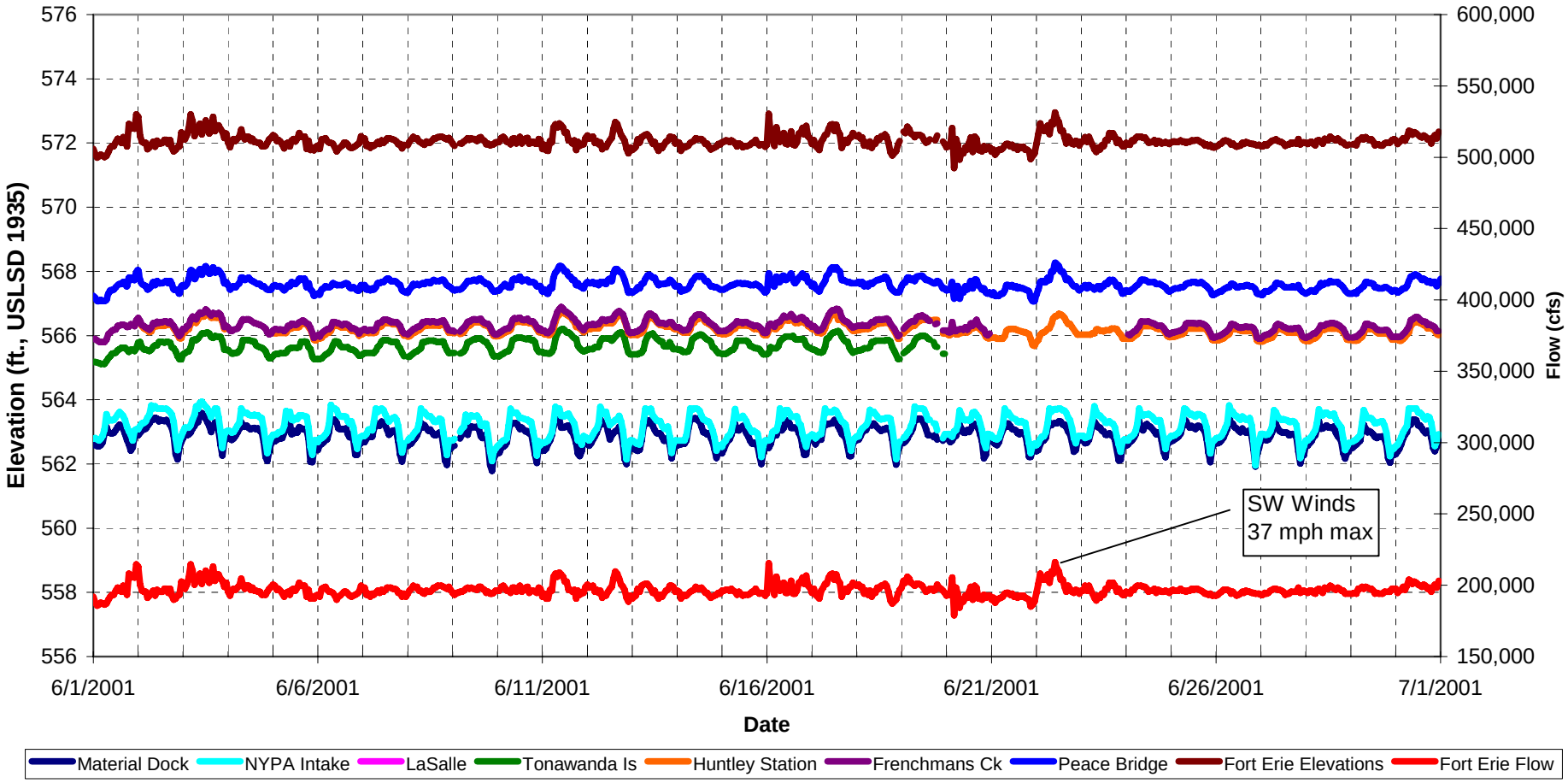

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FIGURE 4.1.1-20

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR JULY 2001

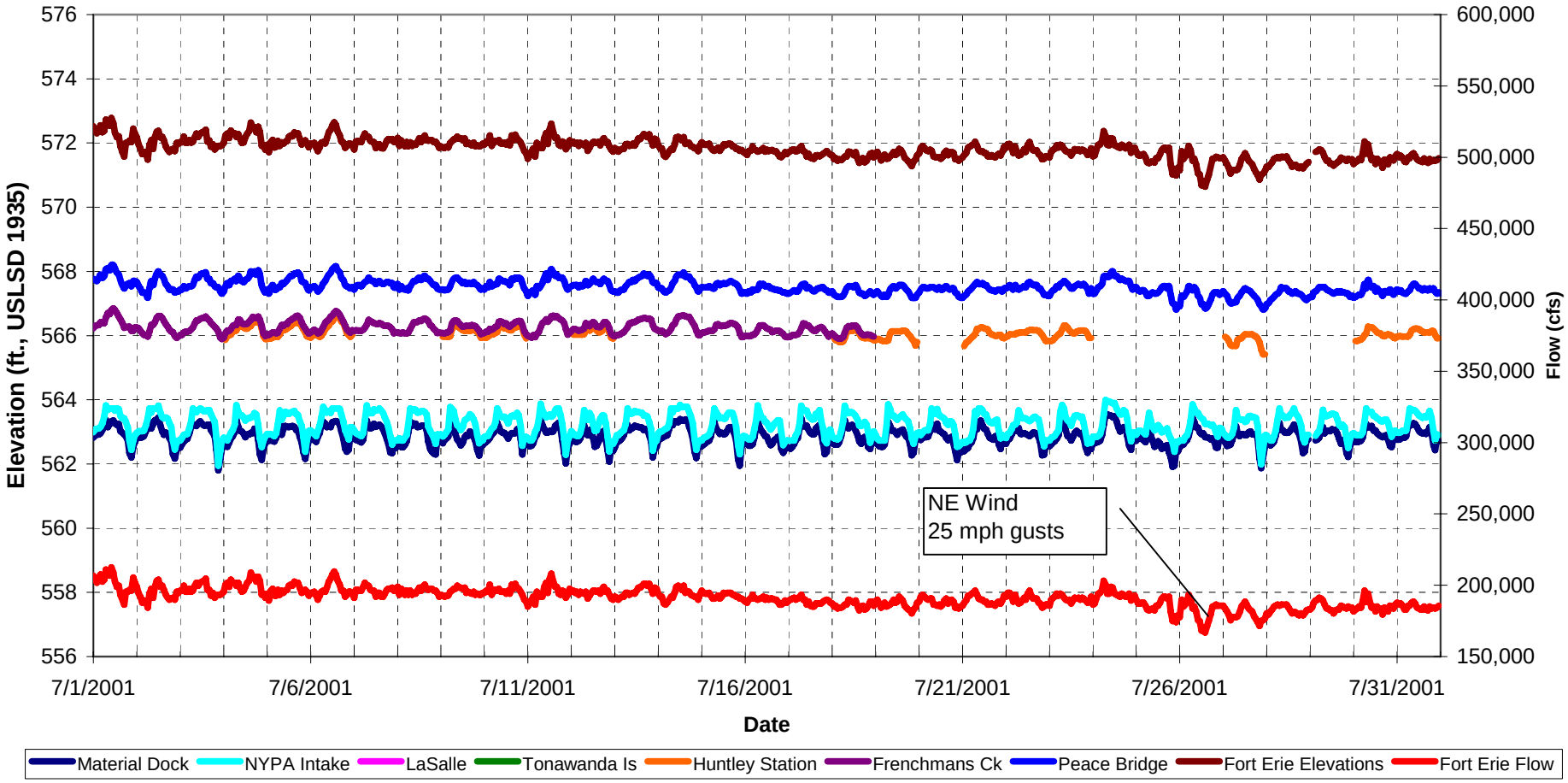

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FIGURE 4.1.1-21

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR AUGUST 2001

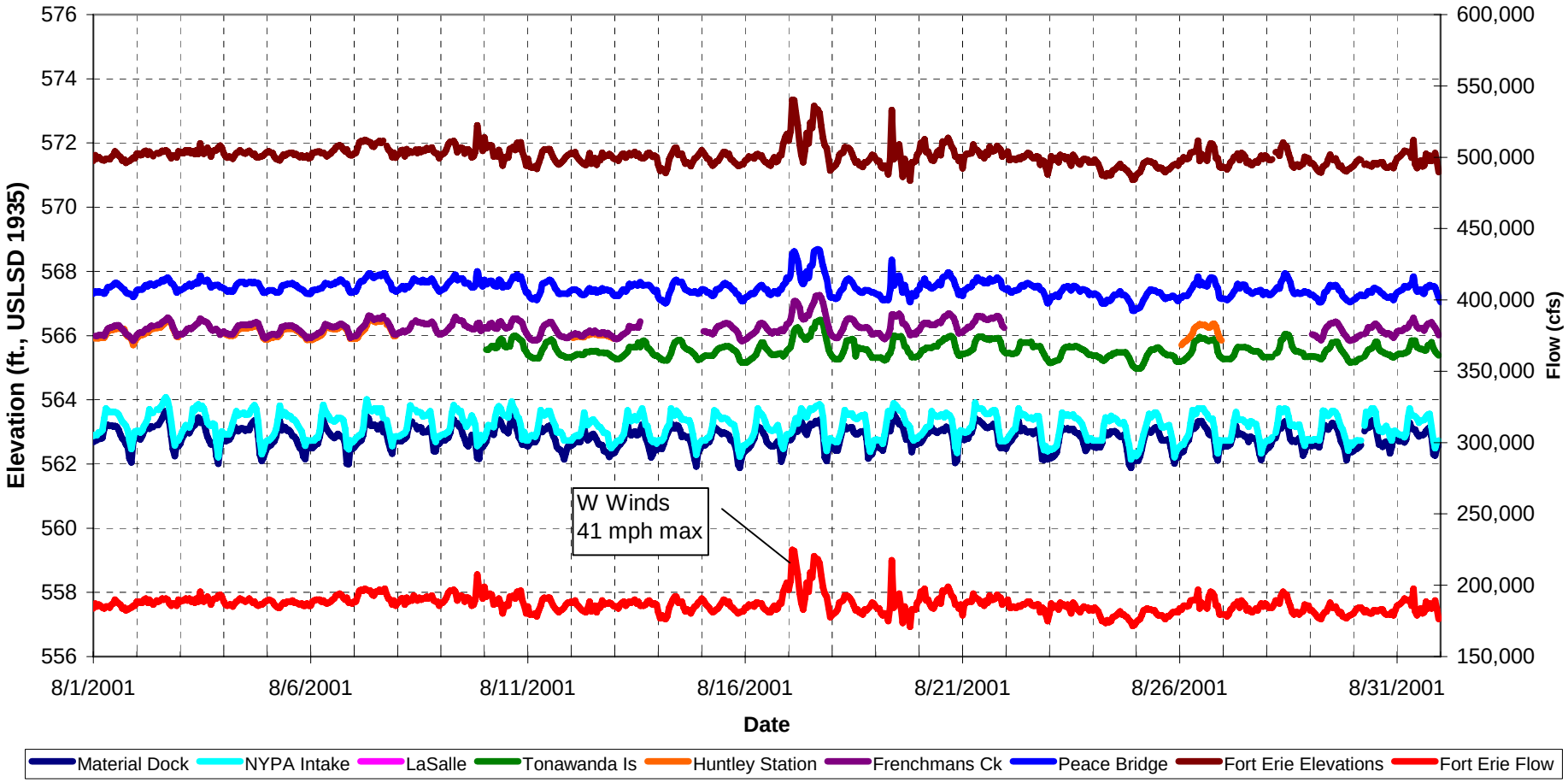

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FIGURE 4.1.1-22

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR SEPTEMBER 2001

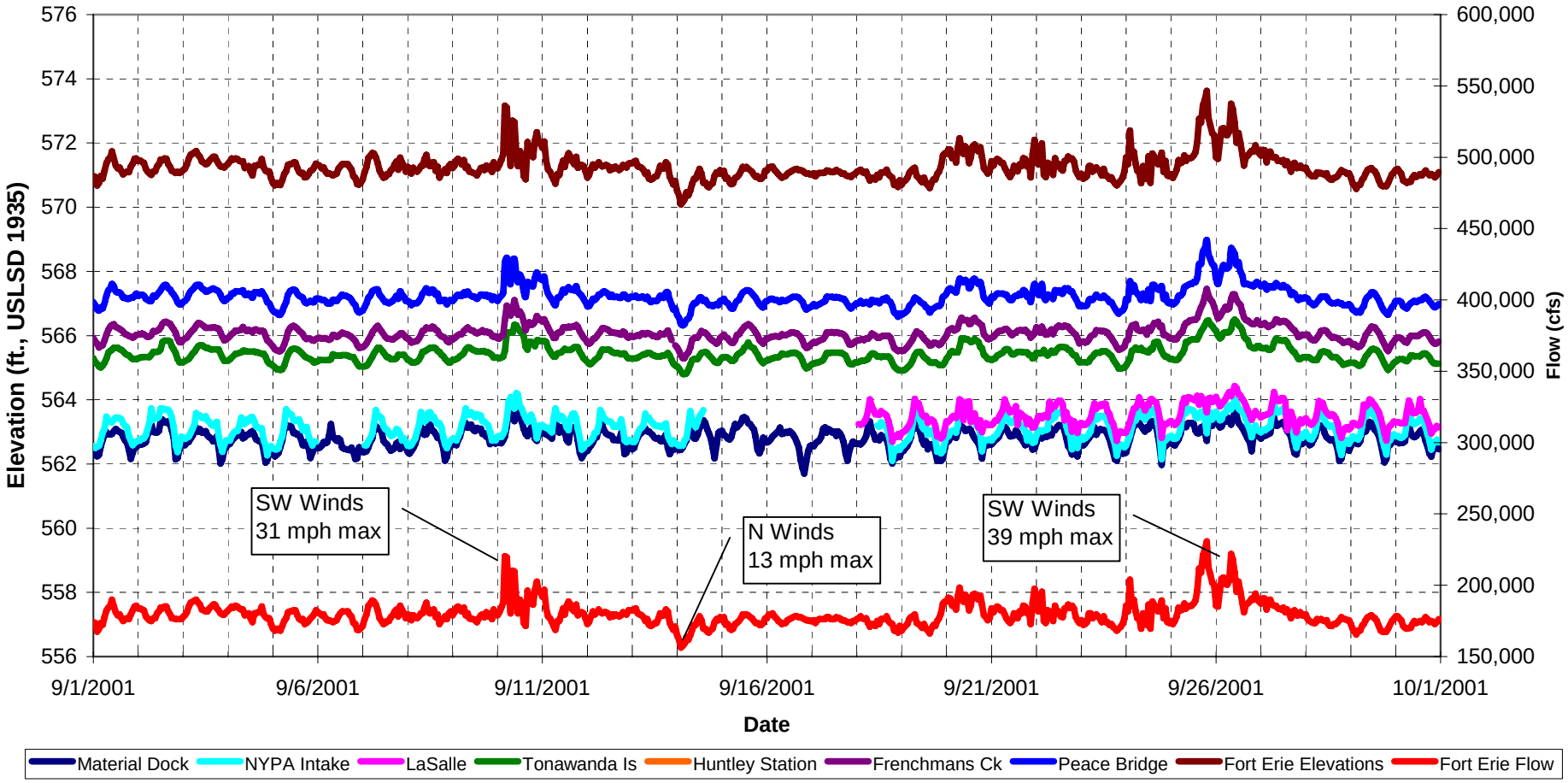

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FIGURE 4.1.1-23

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR OCTOBER 2001

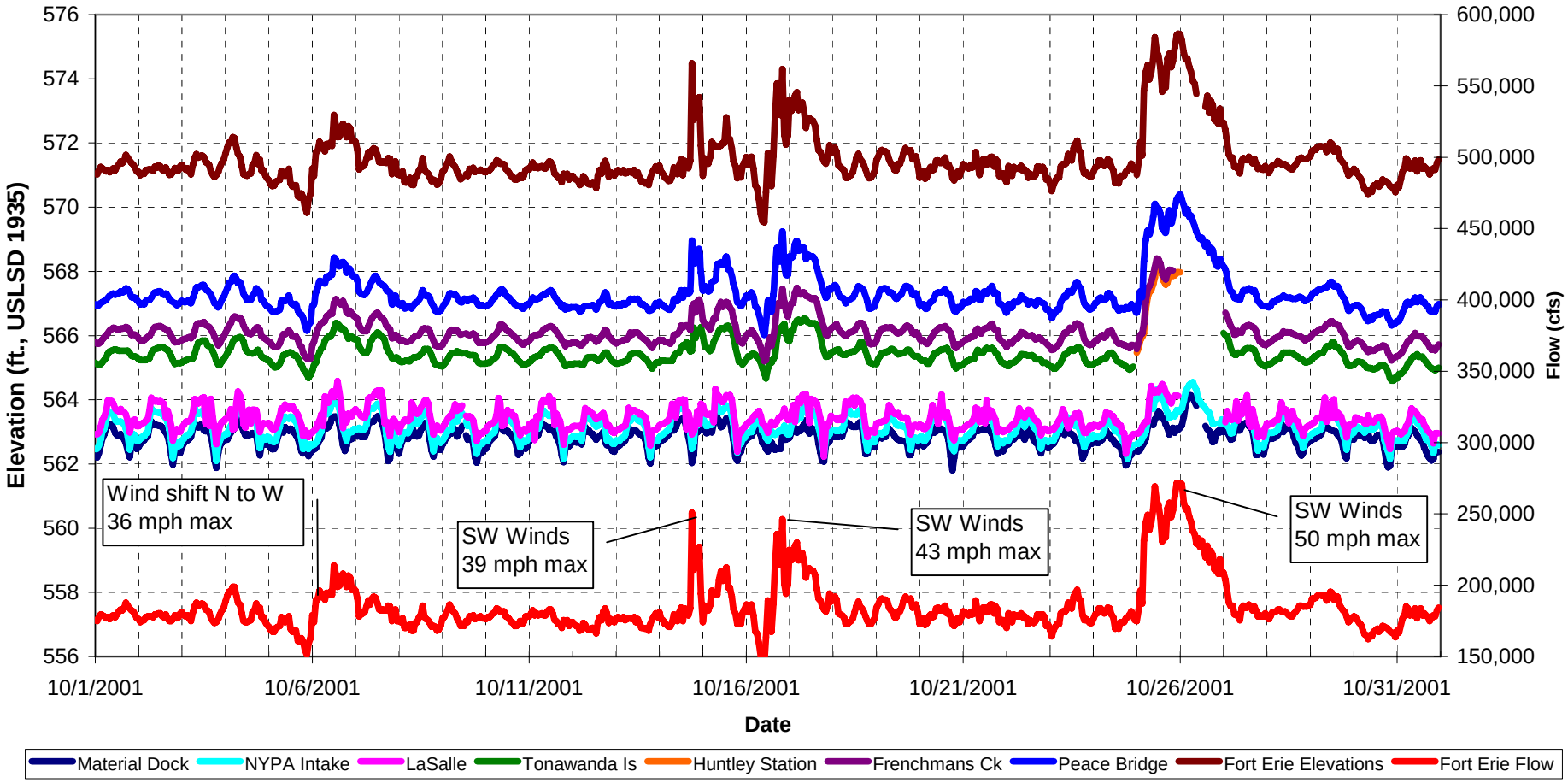

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FIGURE 4.1.1-24

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR NOVEMBER 2001

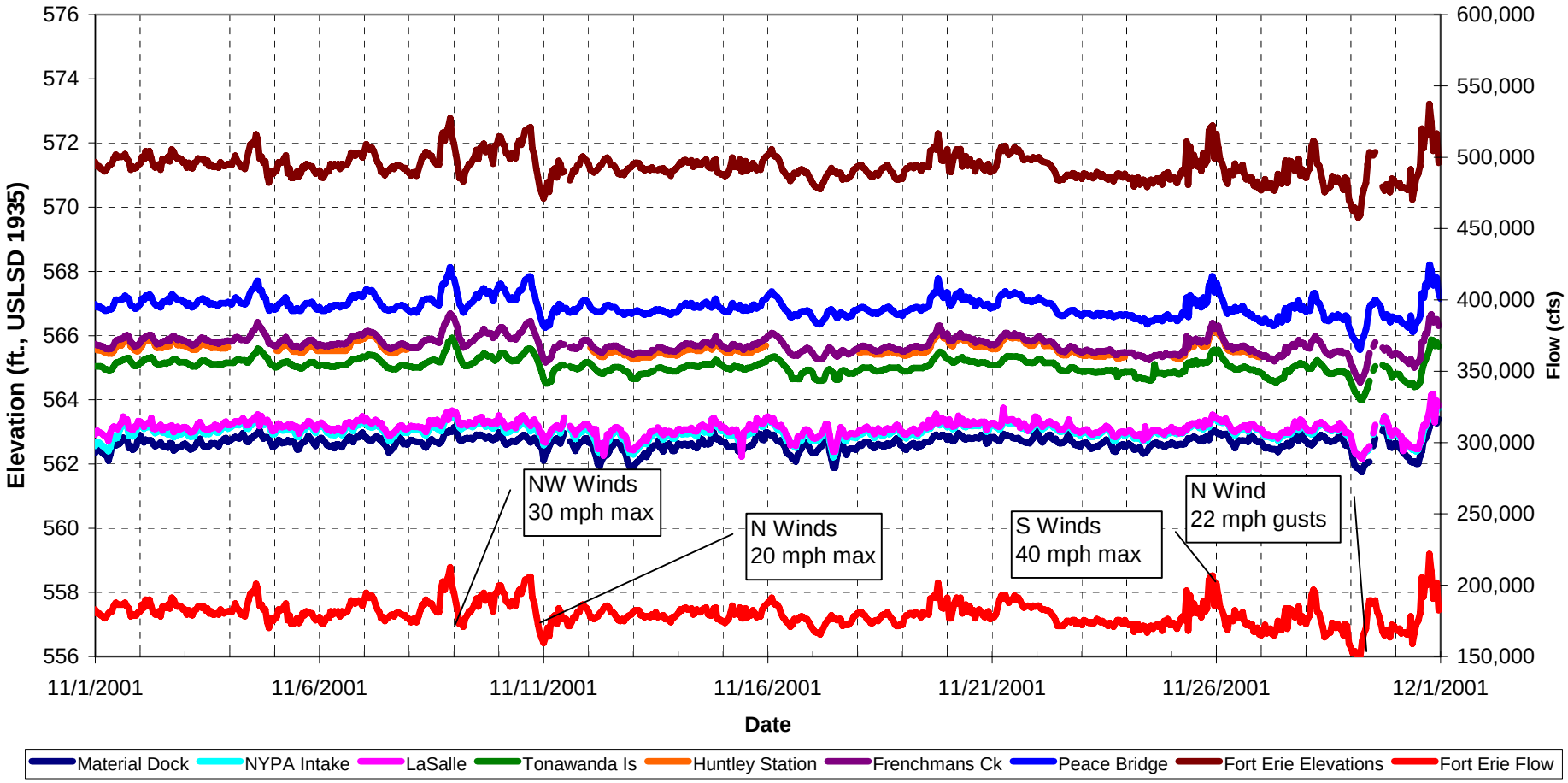

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FIGURE 4.1.1-25

UPPER NIAGARA RIVER – HOURLY WATER LEVEL AND FLOW GRAPH FOR DECEMBER 2001

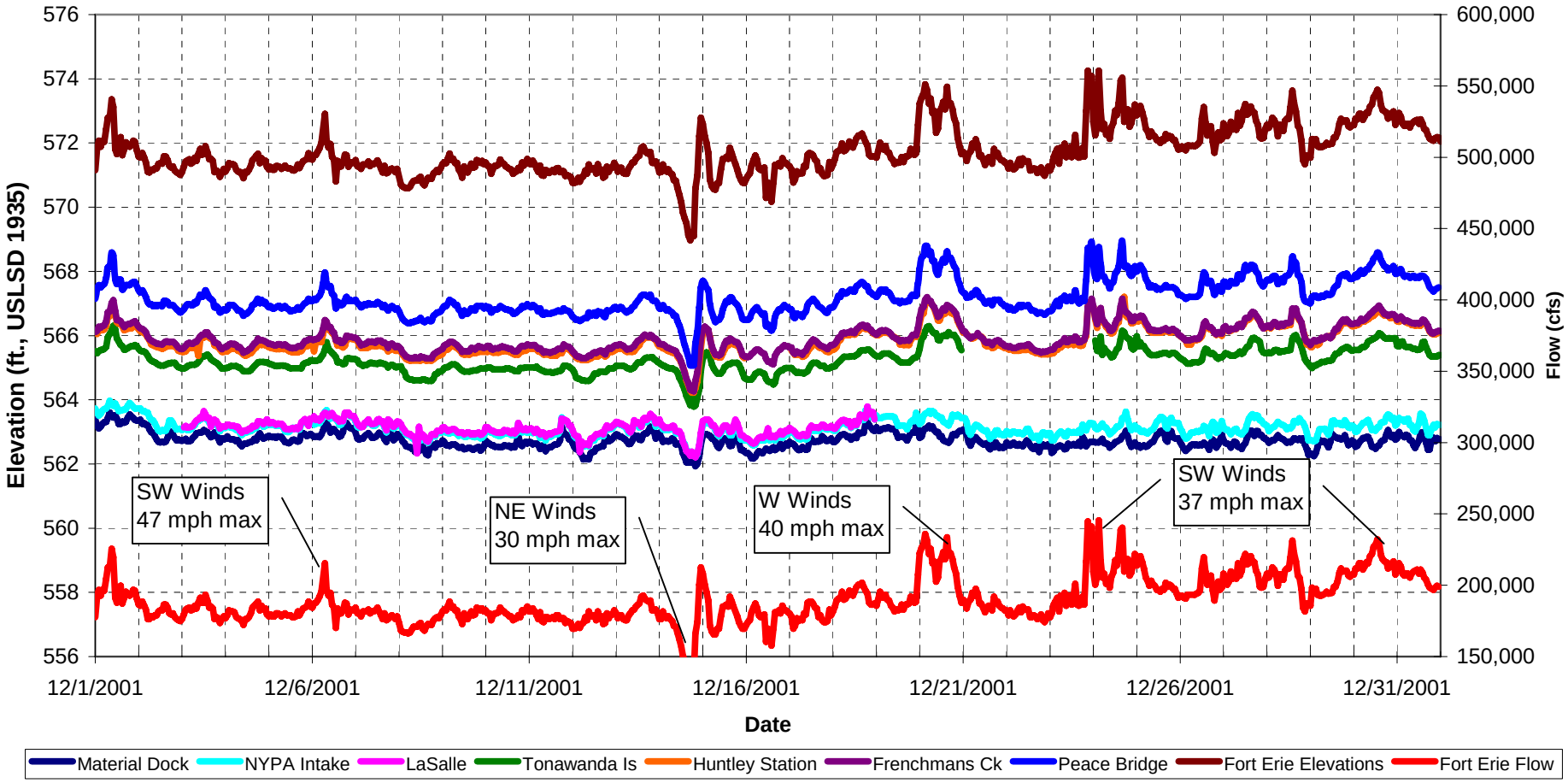

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FIGURE 4.1.2-1

PORT WELLER MONTHLY WATER LEVEL STATISTICS (PERIOD OF RECORD: 1991-2002)

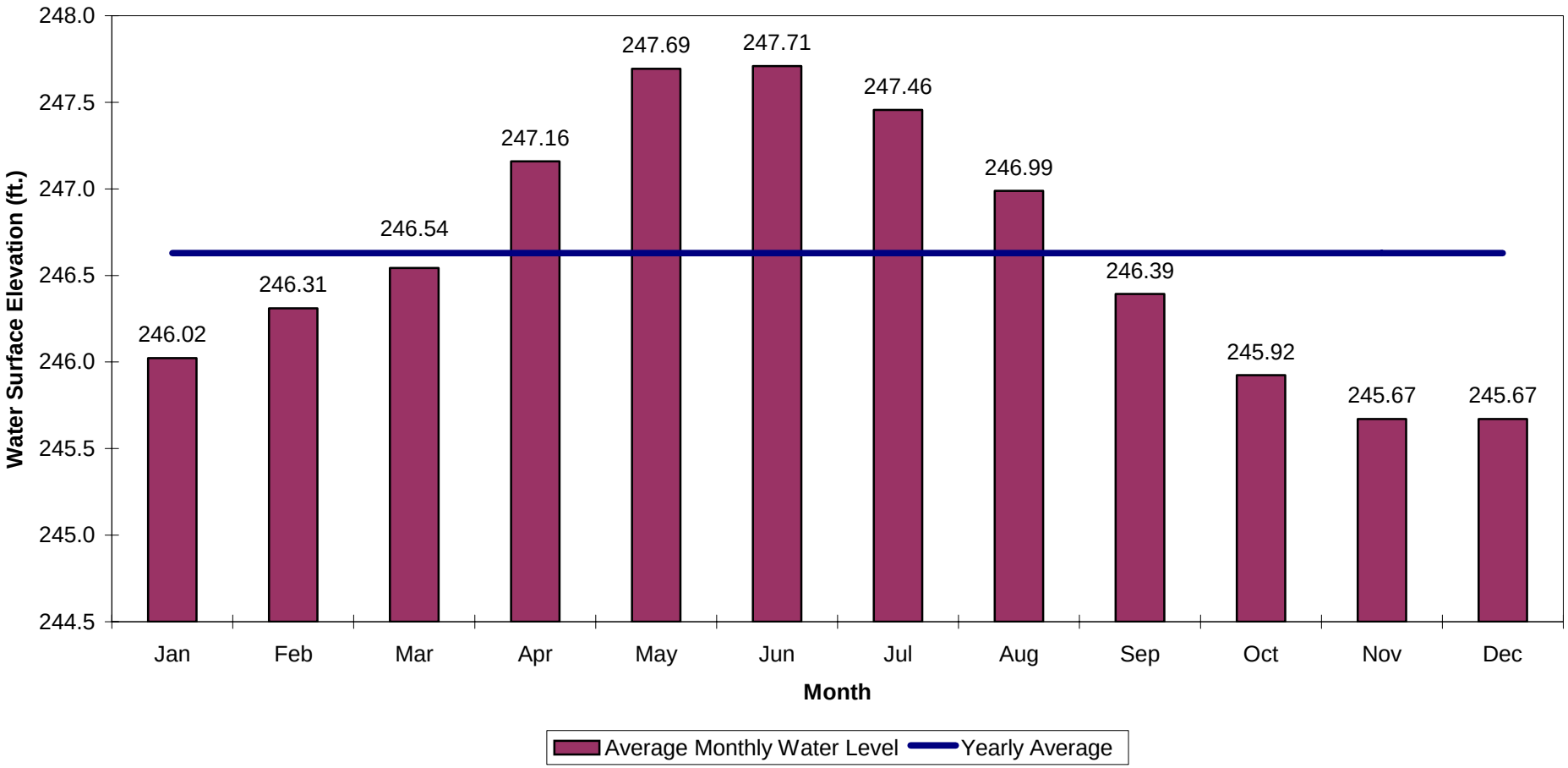

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FIGURE 4.2.1-1

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH WEST WEIR, APRIL 2002

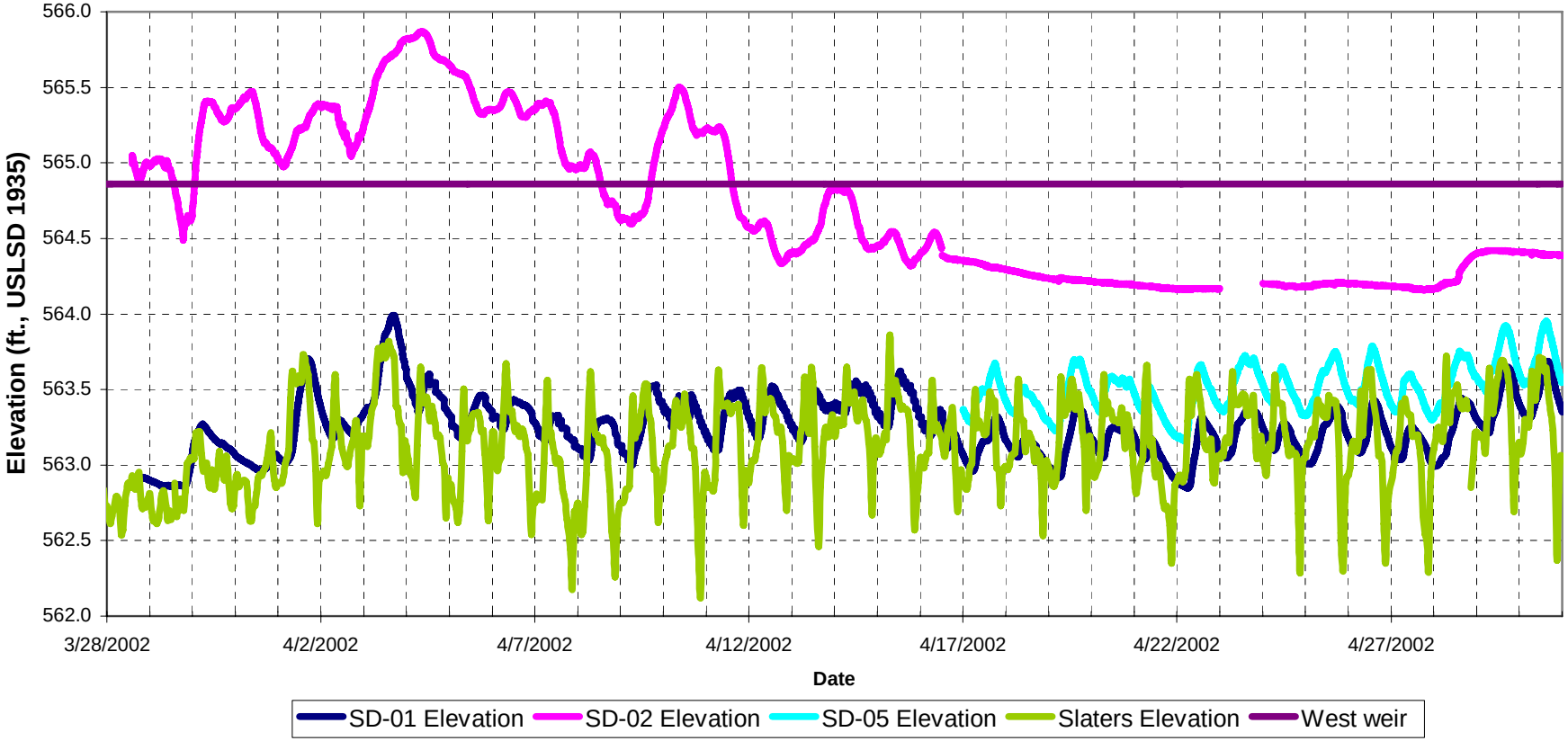

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FIGURE 4.2.1-2

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH WEST WEIR, MAY 2002

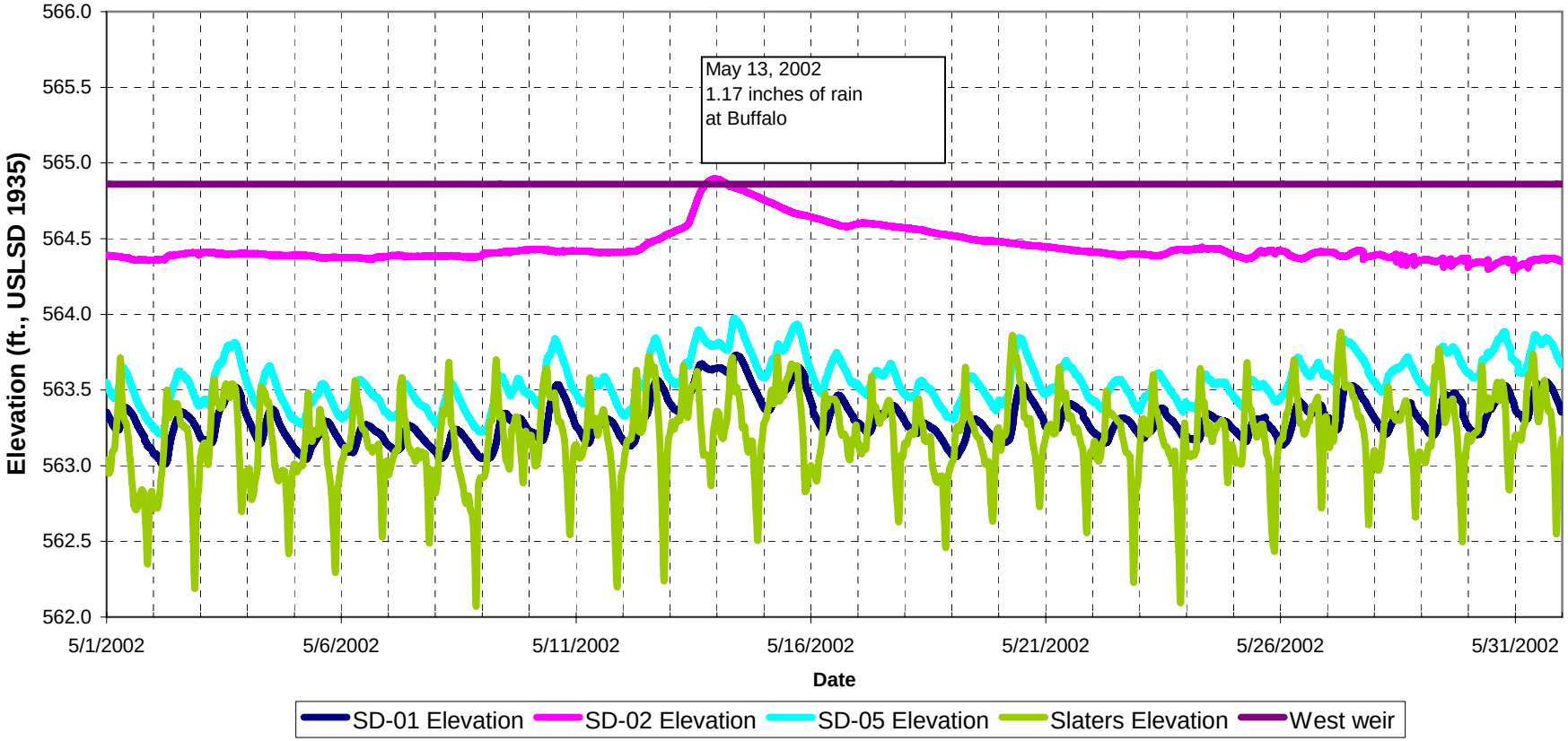

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FIGURE 4.2.1-3

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH WEST WEIR, JUNE 2002

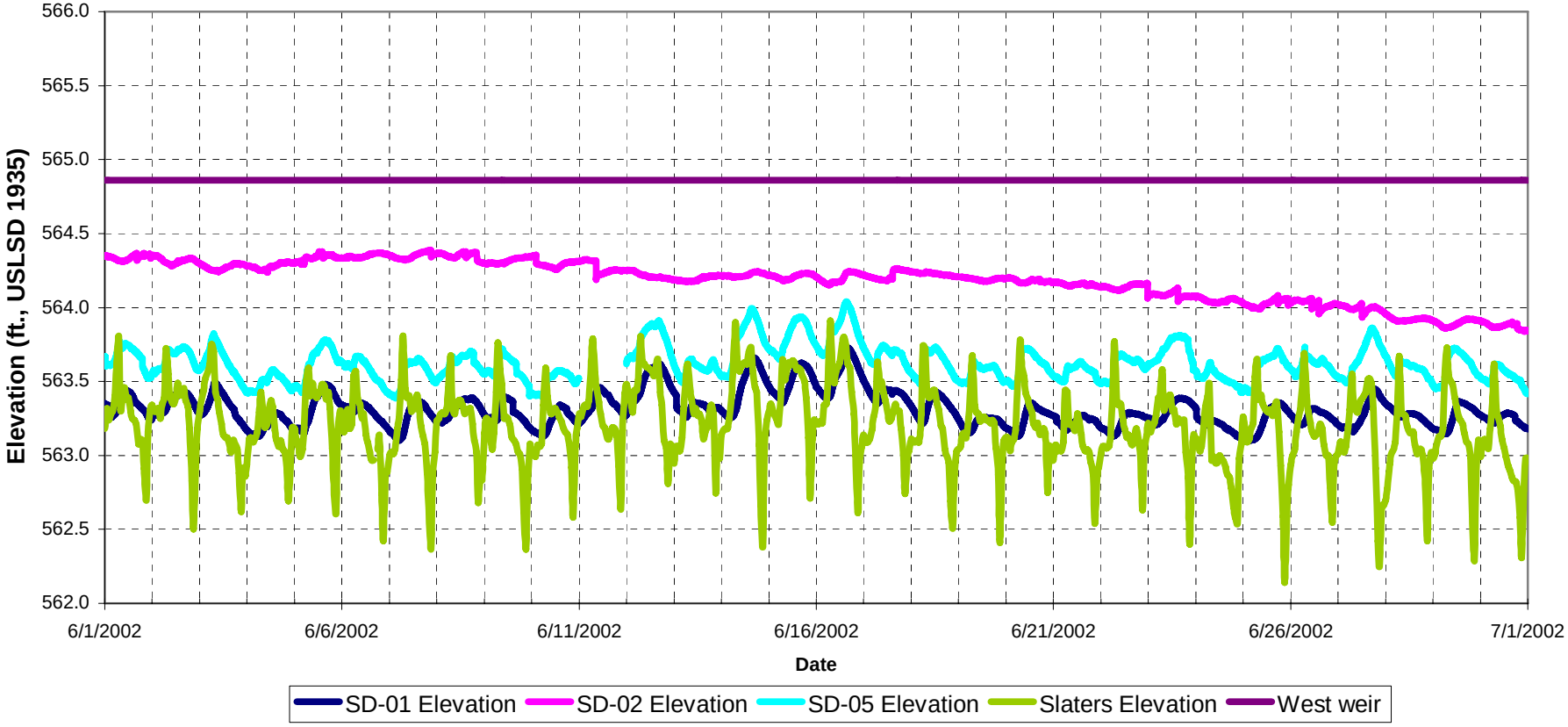

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FIGURE 4.2.1-4

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH WEST WEIR, JULY 2002

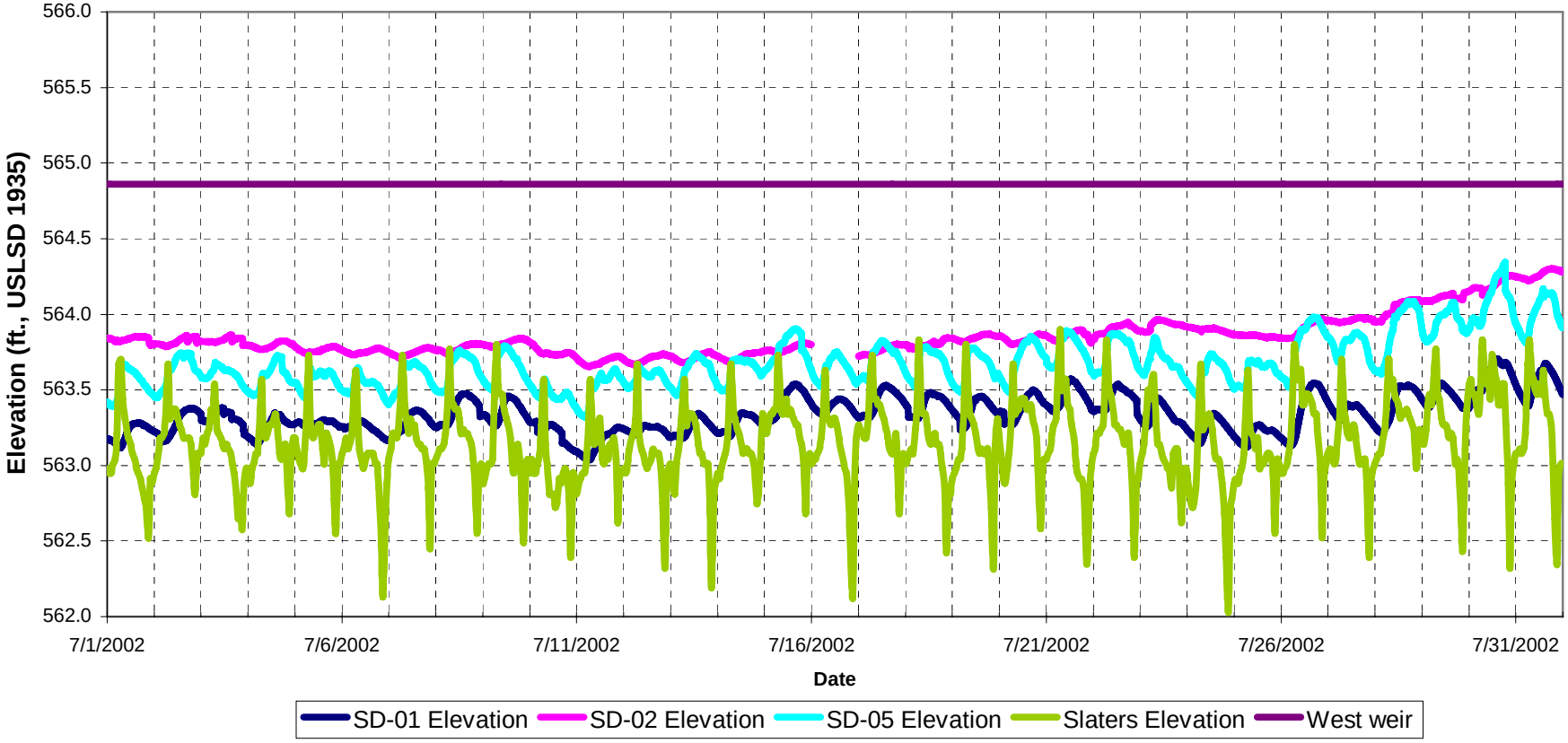

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FIGURE 4.2.1-5

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH WEST WEIR, AUGUST 2002

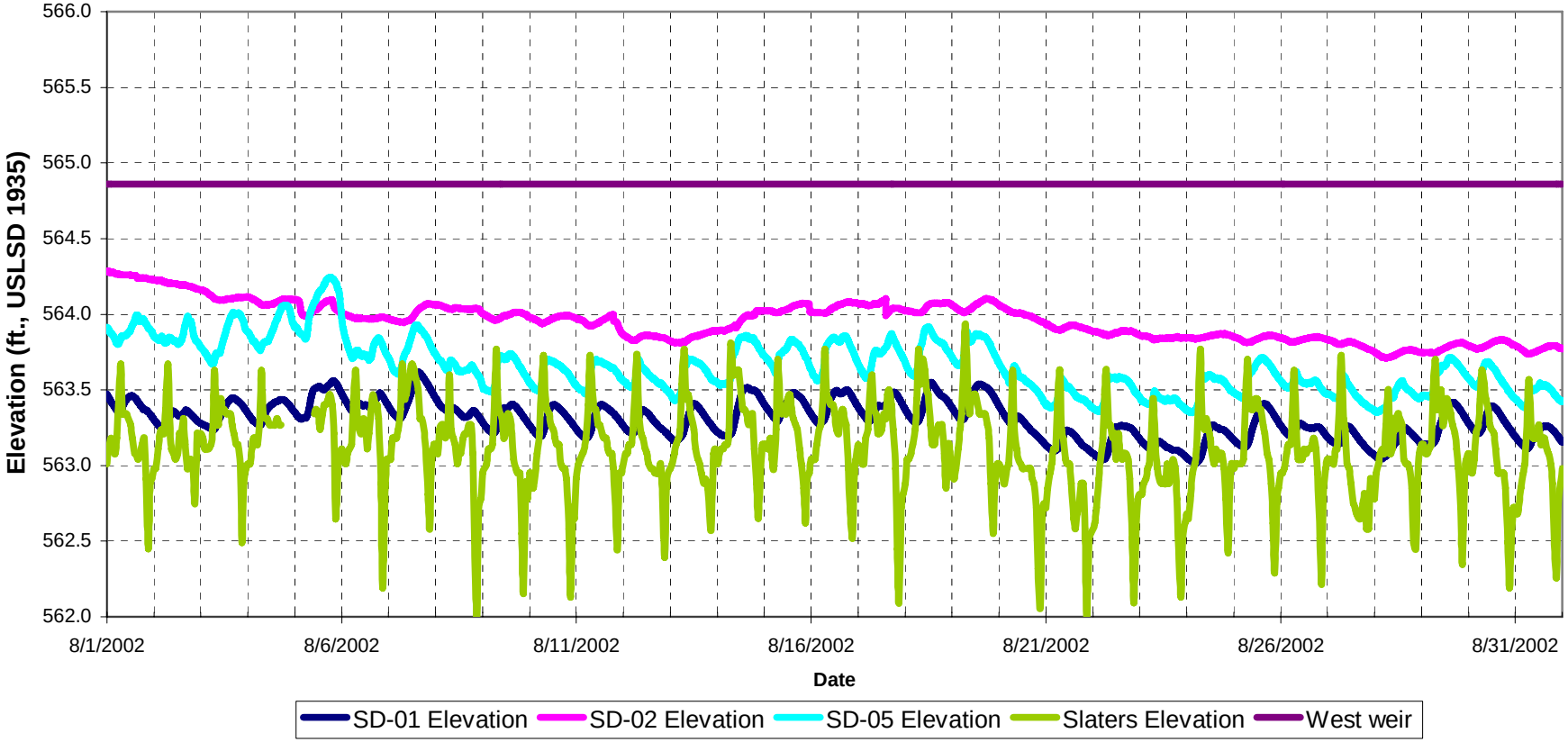

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FIGURE 4.2.1-6

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH WEST WEIR, SEPTEMBER 2002

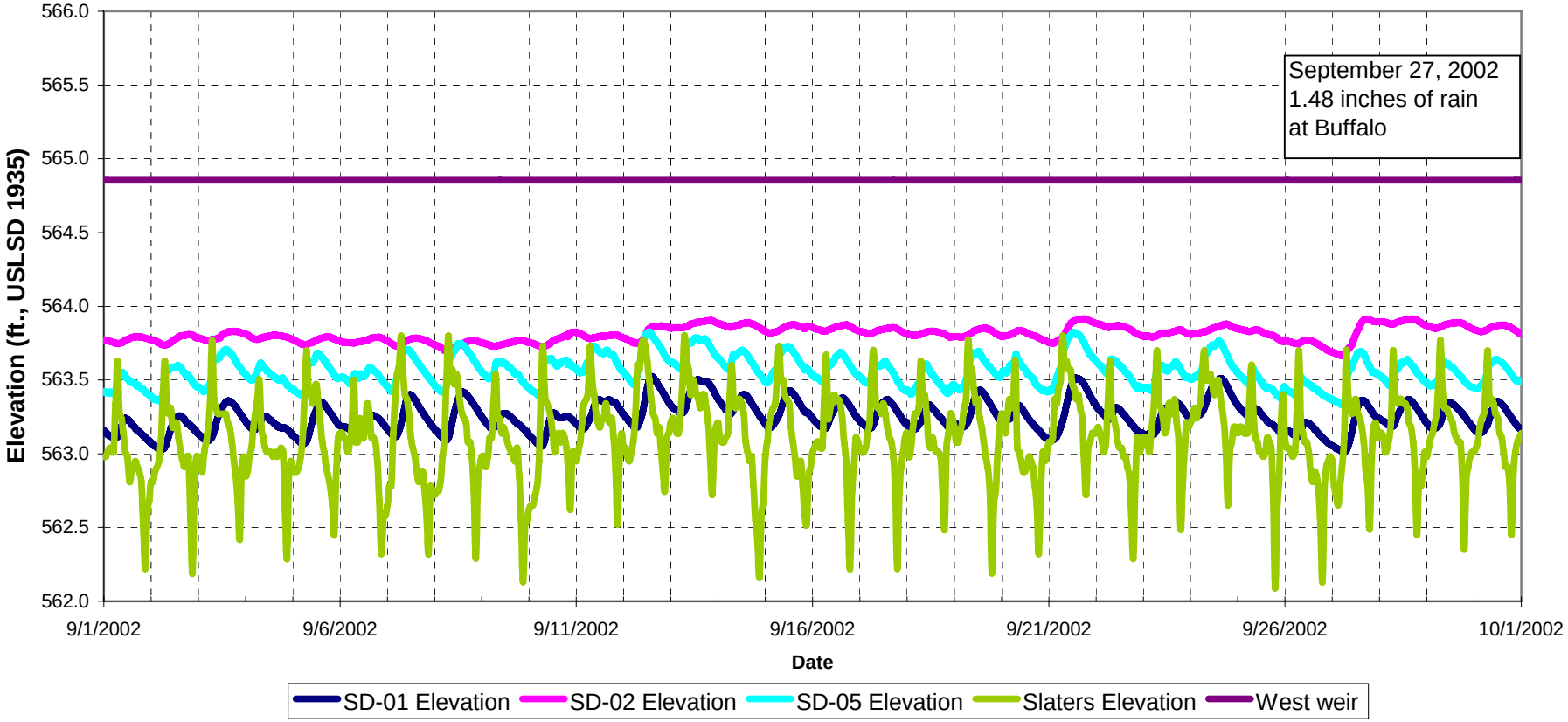

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FIGURE 4.2.1-7

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH WEST WEIR, OCTOBER 2002

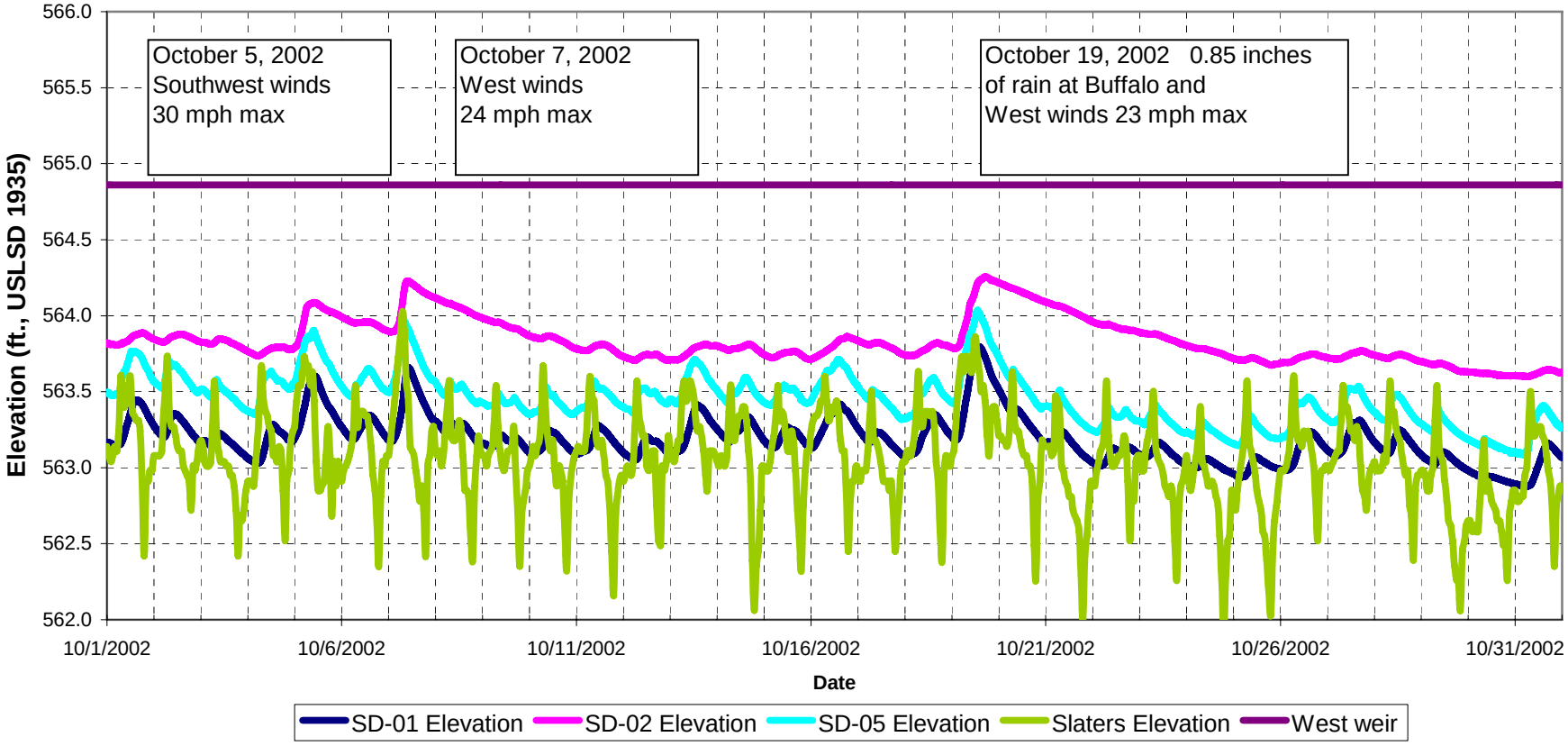

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FIGURE 4.2.1-8

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH WEST WEIR, NOVEMBER 2002

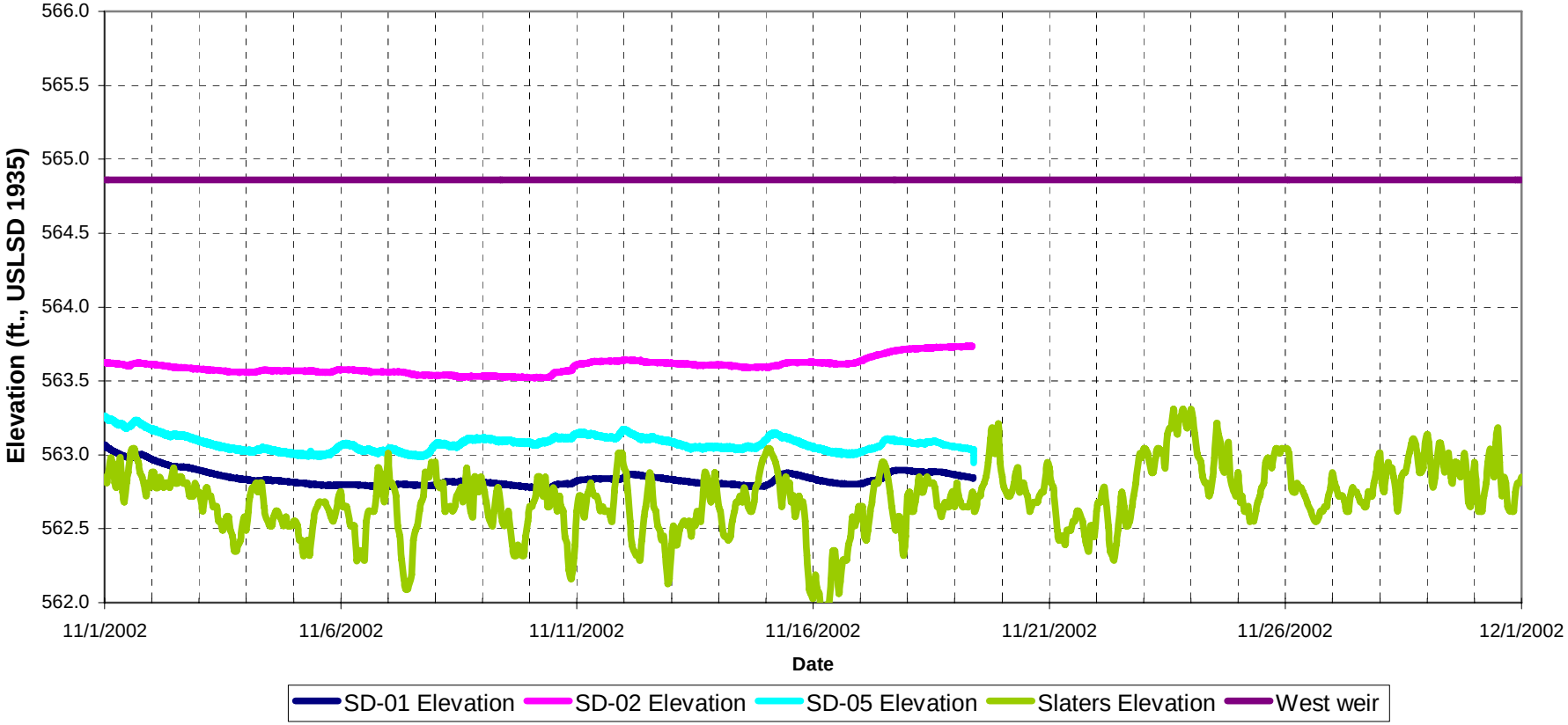

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FIGURE 4.2.1-9

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH EAST WEIR, APRIL 2002

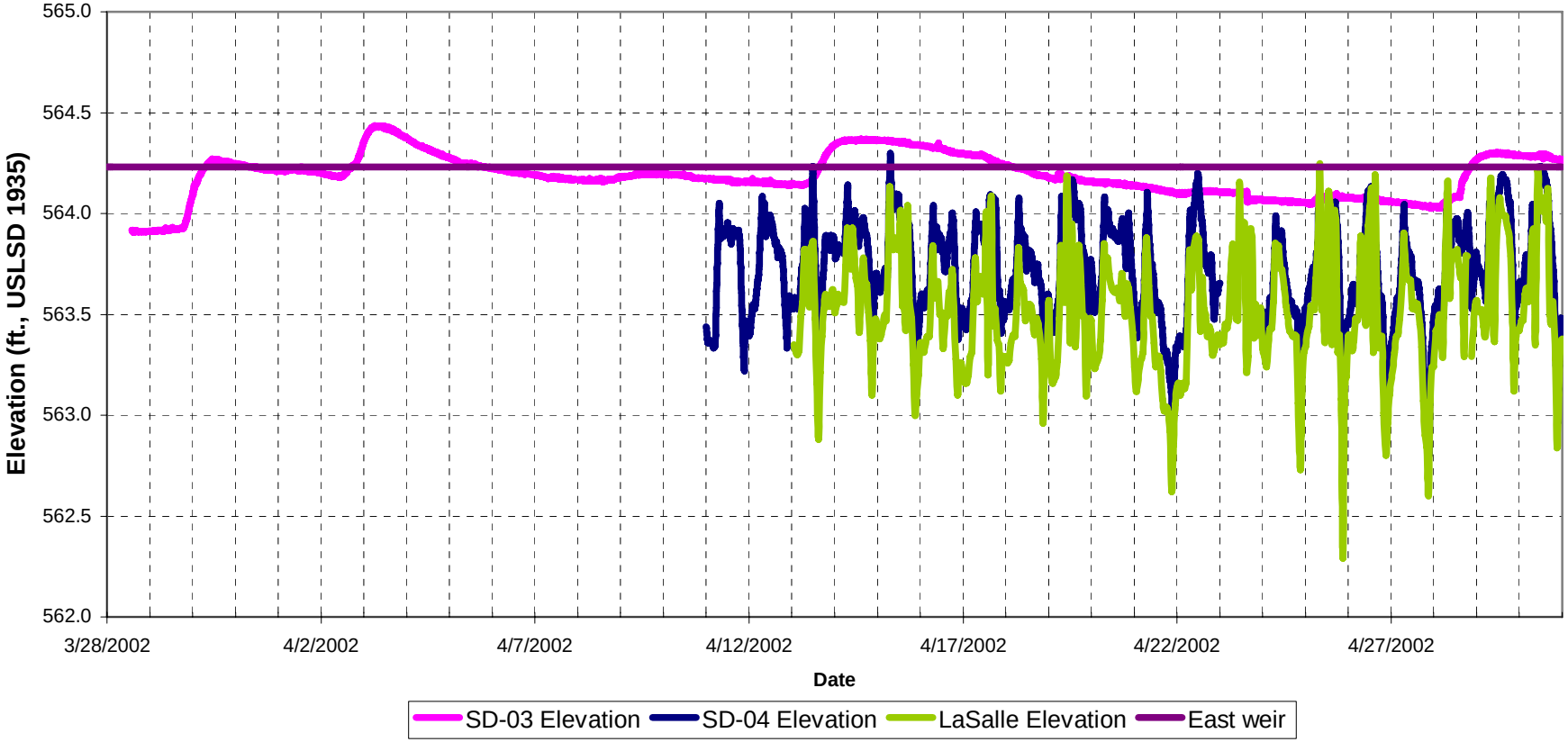

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FIGURE 4.2.1-10

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH EAST WEIR, MAY 2002

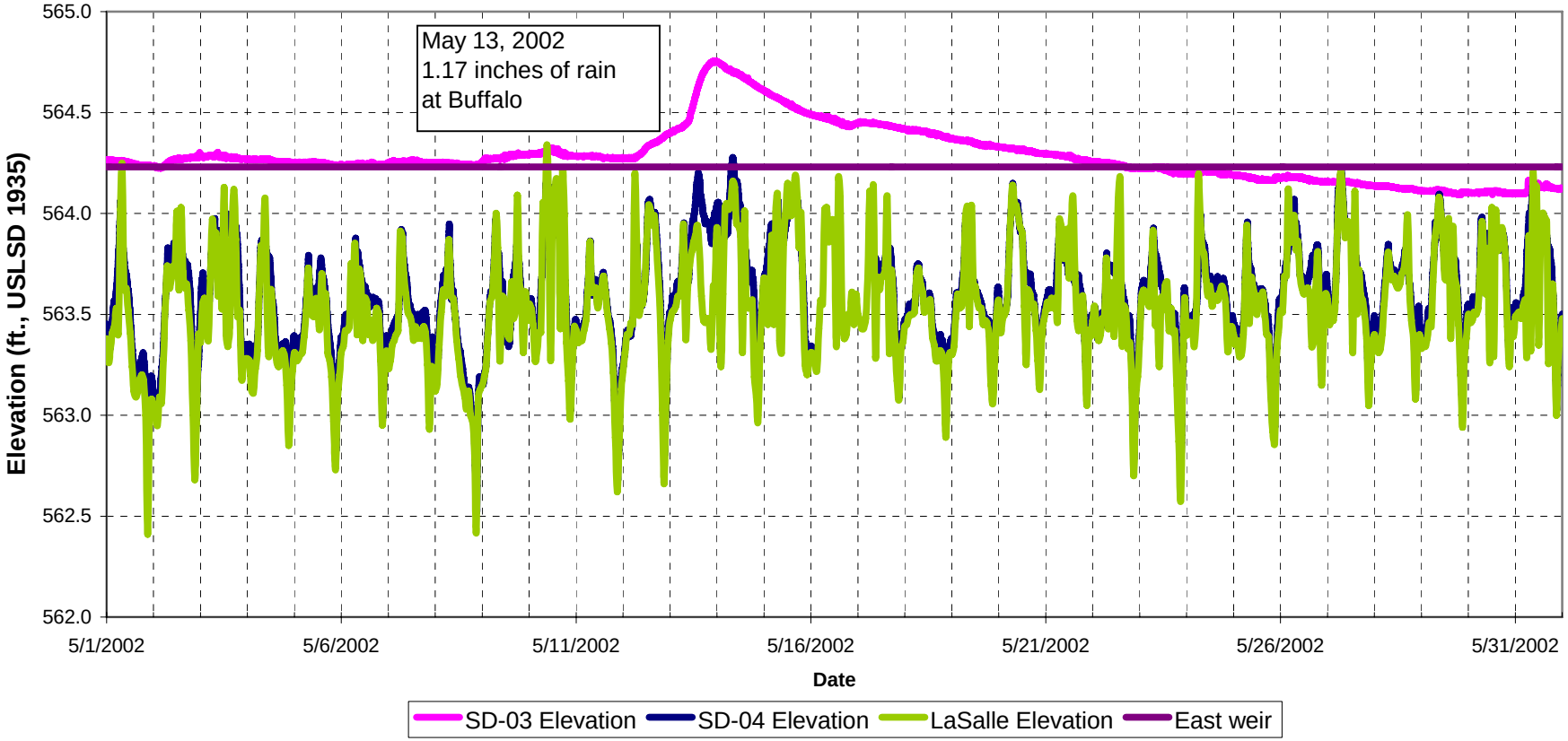

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FIGURE 4.2.1-11

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH EAST WEIR, JUNE 2002

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FIGURE 4.2.1-12

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH EAST WEIR, JULY 2002

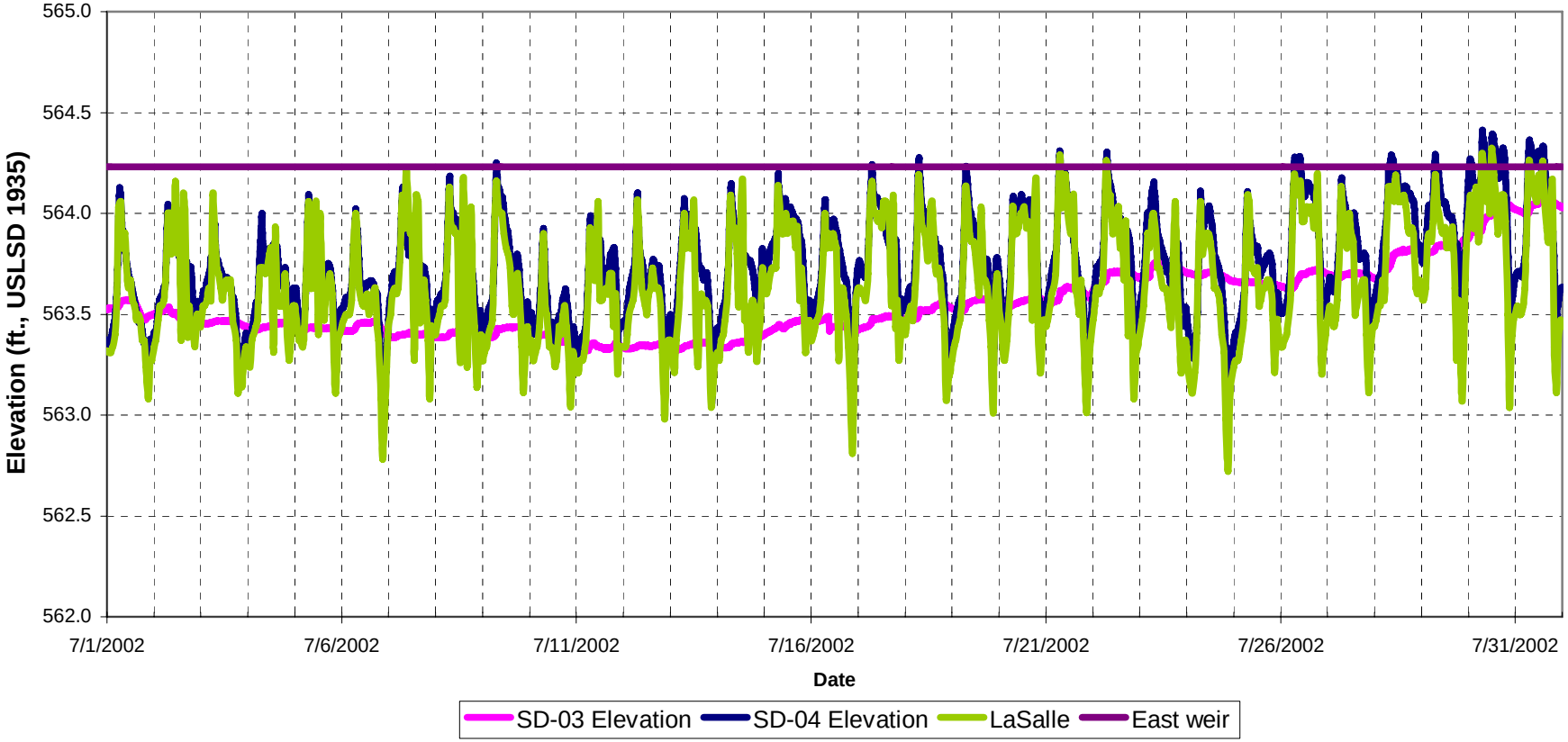

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FIGURE 4.2.1-13

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH EAST WEIR, AUGUST 2002

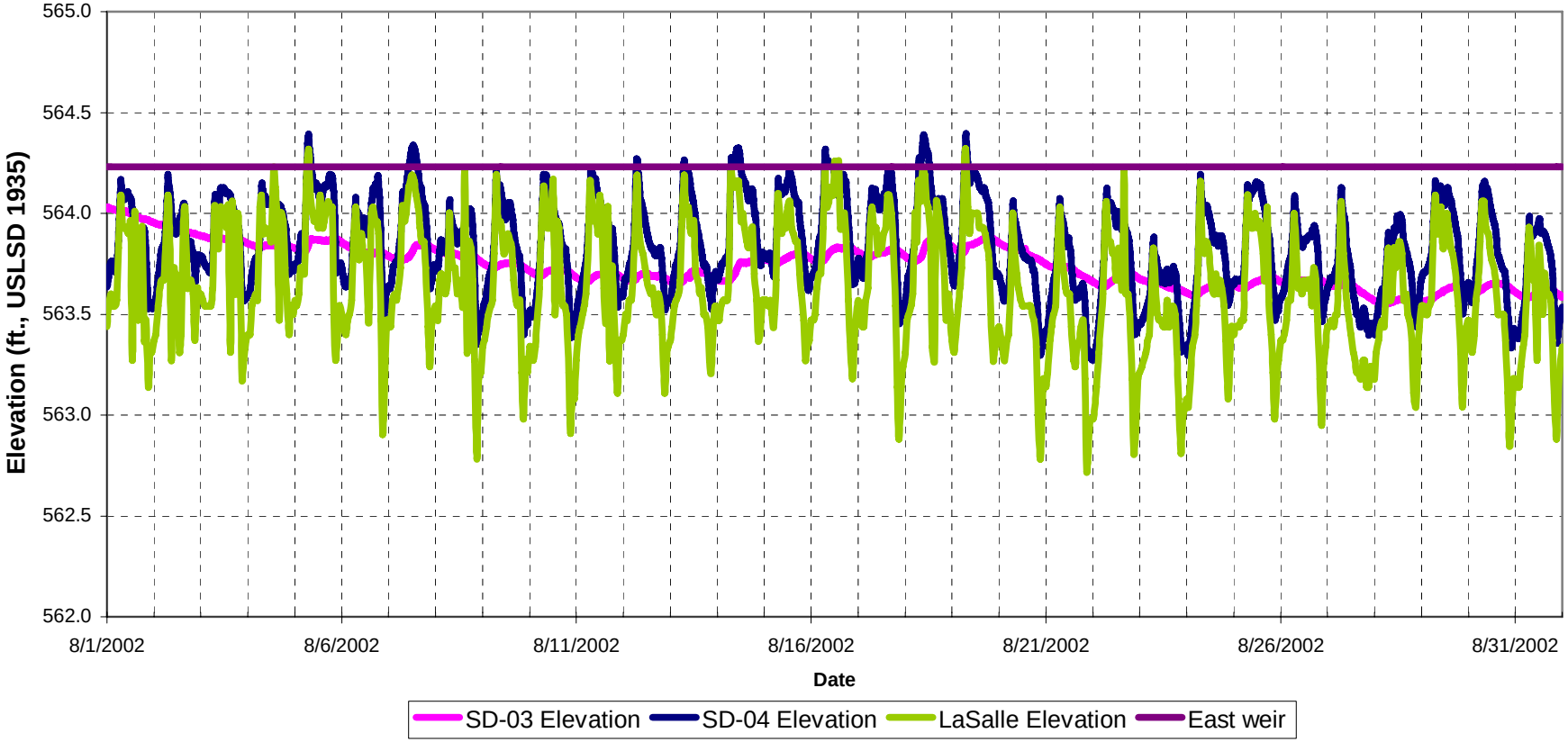

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FIGURE 4.2.1-14

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH EAST WEIR, SEPTEMBER 2002

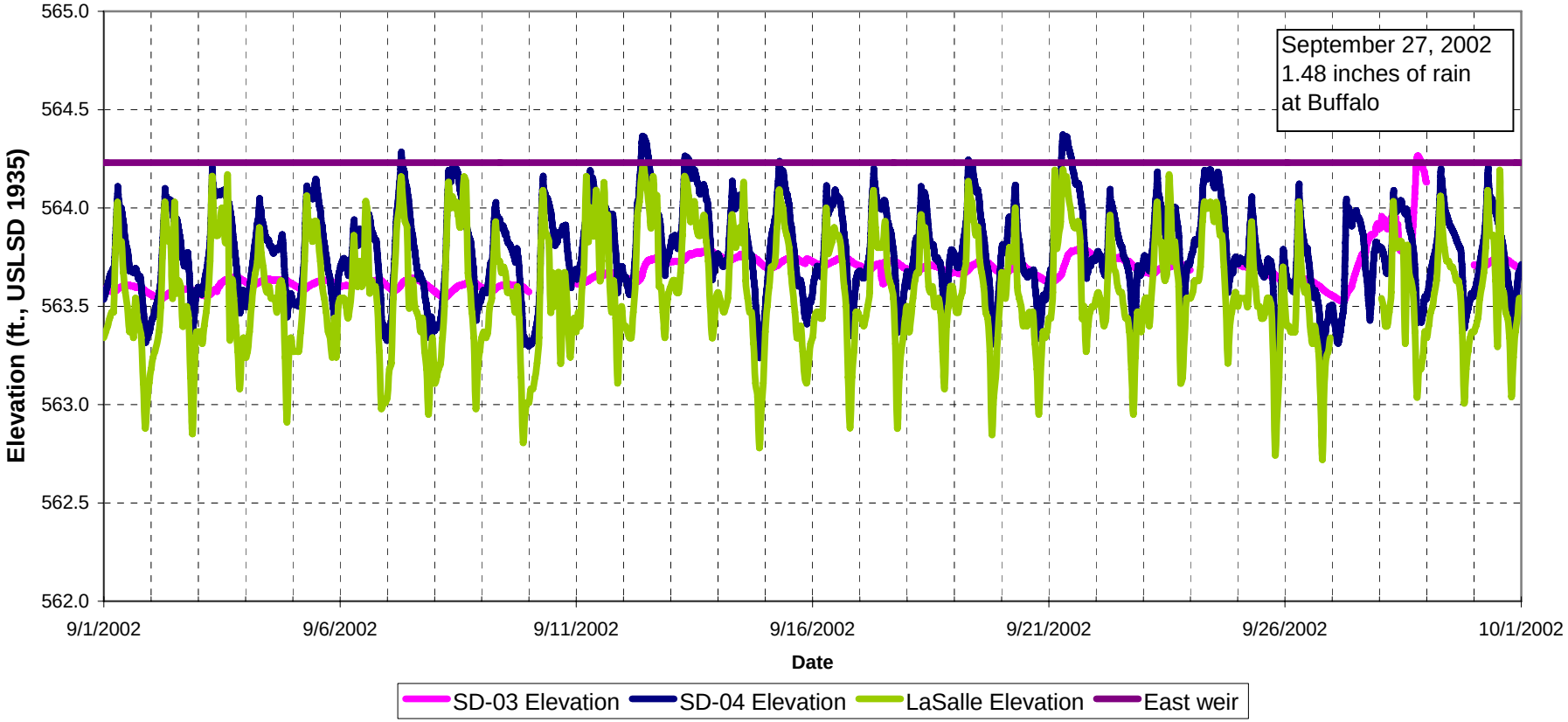

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FIGURE 4.2.1-15

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH EAST WEIR, OCTOBER 2002

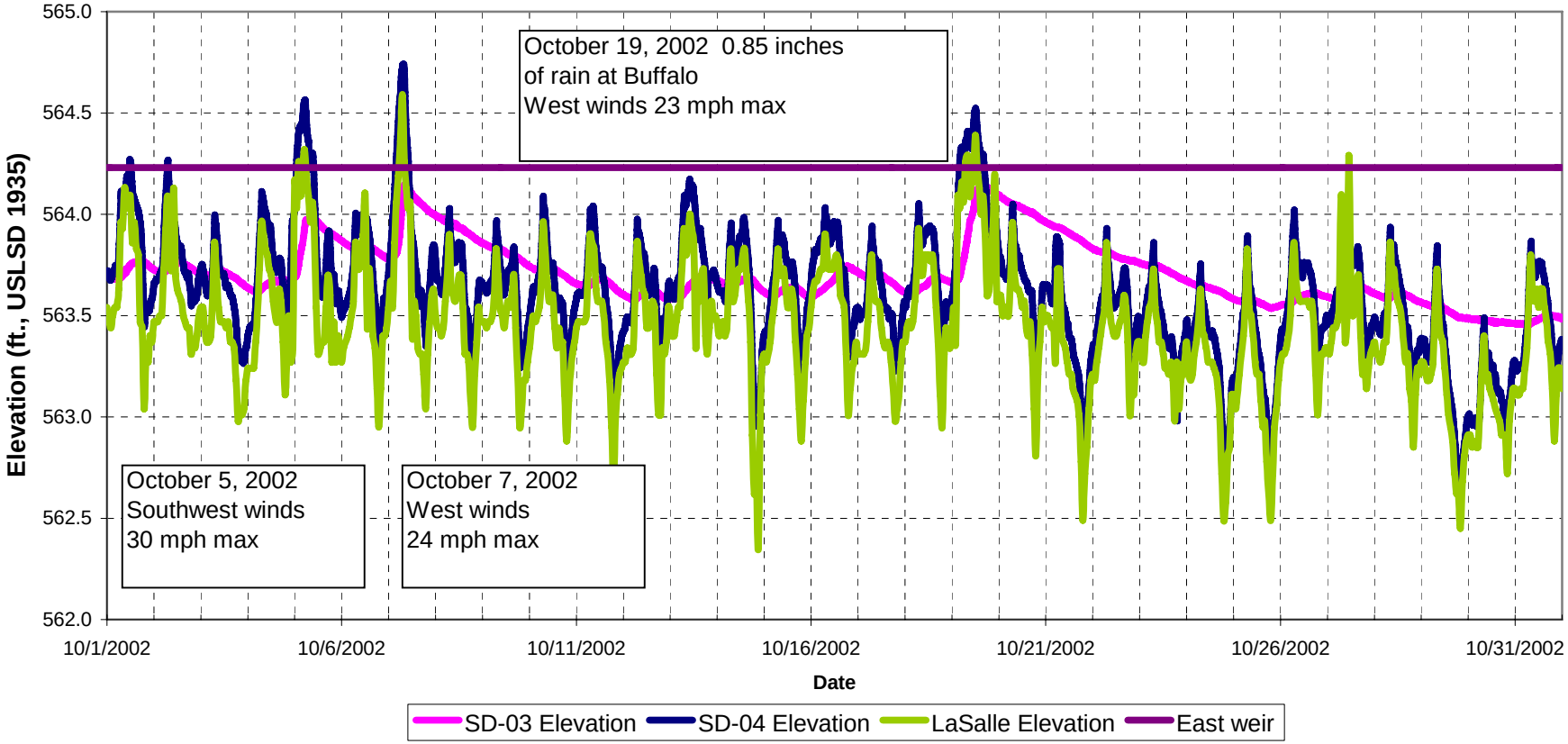

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FIGURE 4.2.1-16

UPPER RIVER TEMPORARY GAUGES – 5-MINUTE WATER LEVELS AT BUCKHORN ISLAND MARSH EAST WEIR, NOVEMBER 2002

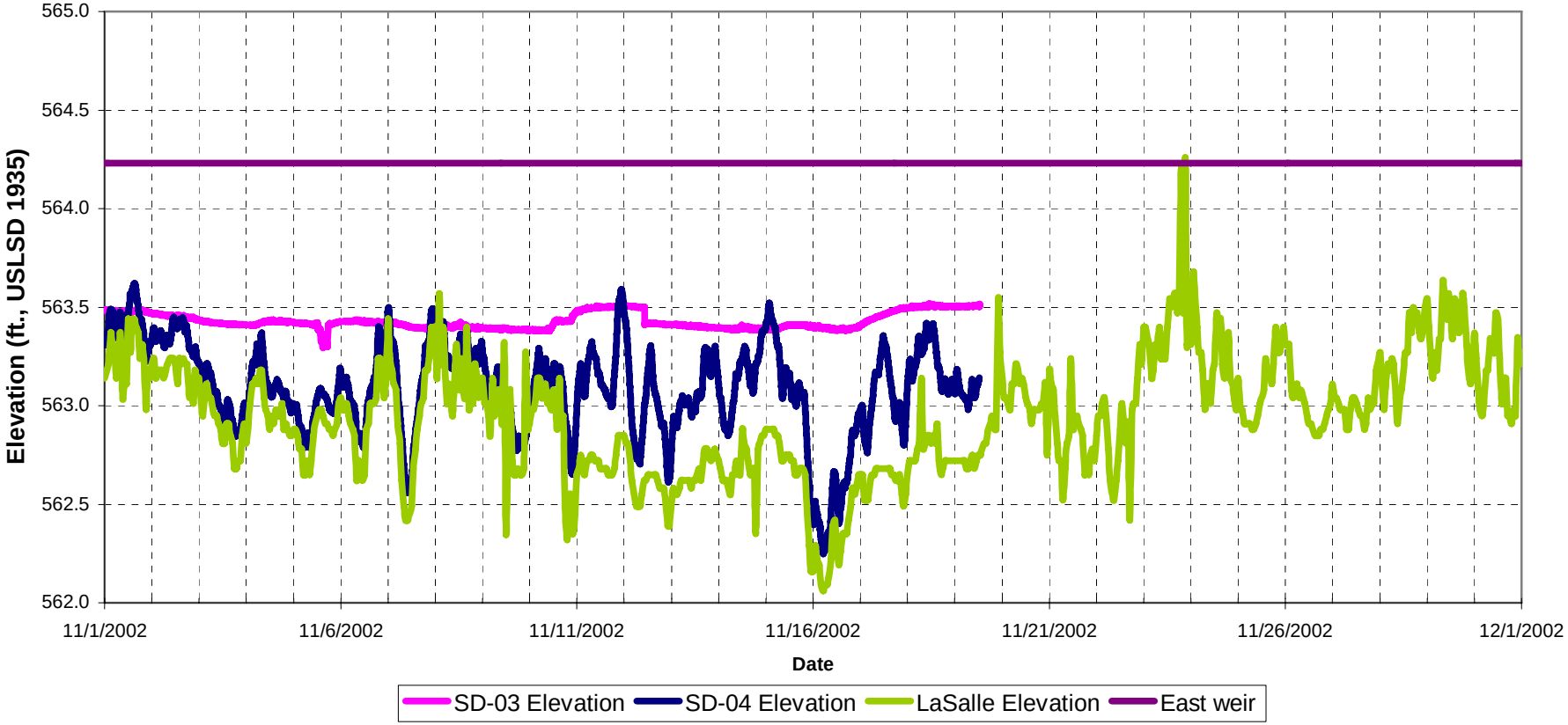

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FIGURE 4.2.2-1

LOWER RIVER TEMPORARY GAUGES – HOURLY WATER LEVEL AND FLOW GRAPH FOR OCTOBER 29 TO NOVEMBER 4, 2001

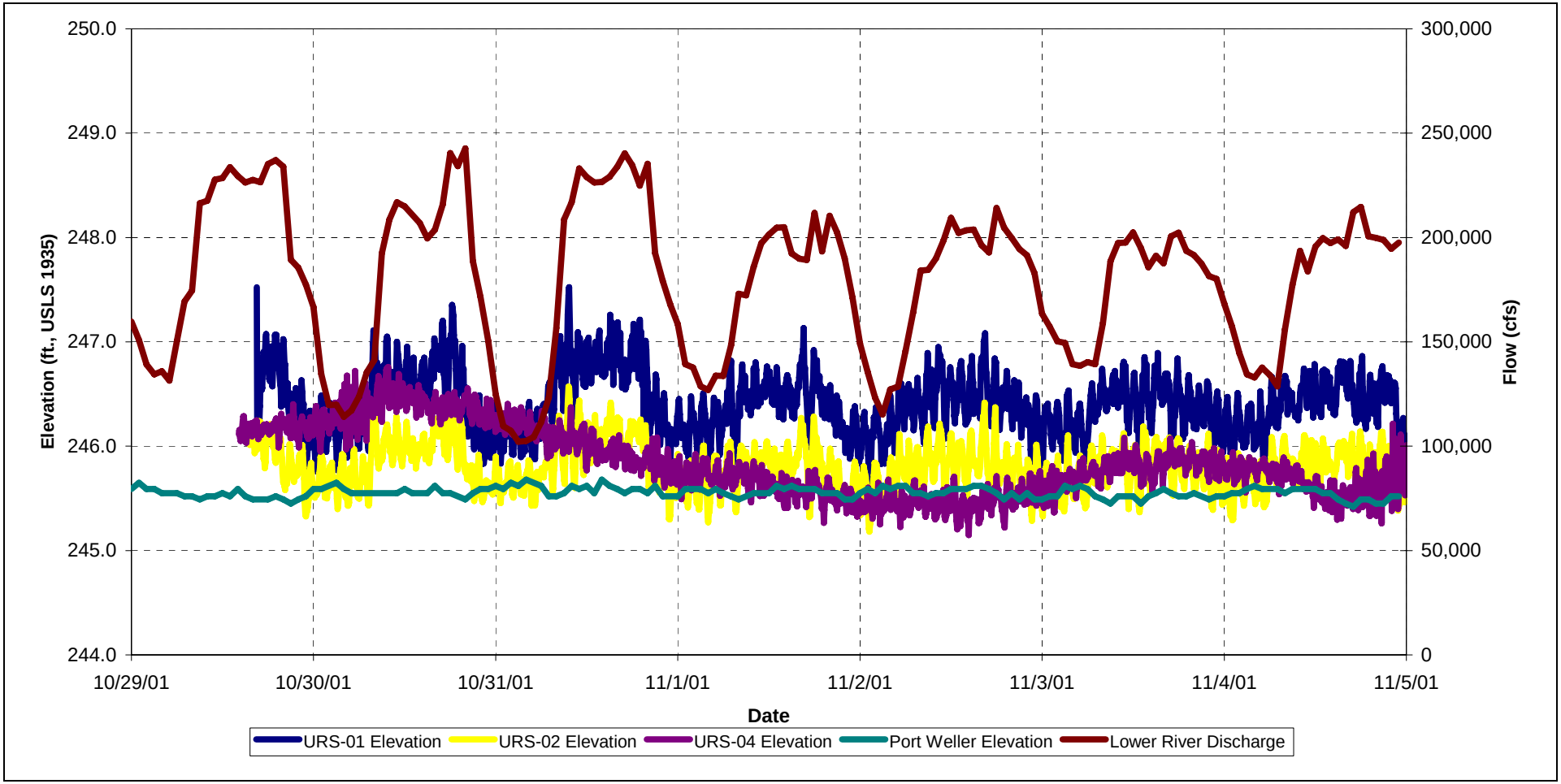

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FIGURE 4.2.2-2

LOWER RIVER TEMPORARY GAUGES – HOURLY WATER LEVEL AND FLOW GRAPH FOR NOVEMBER 6-11, 2001

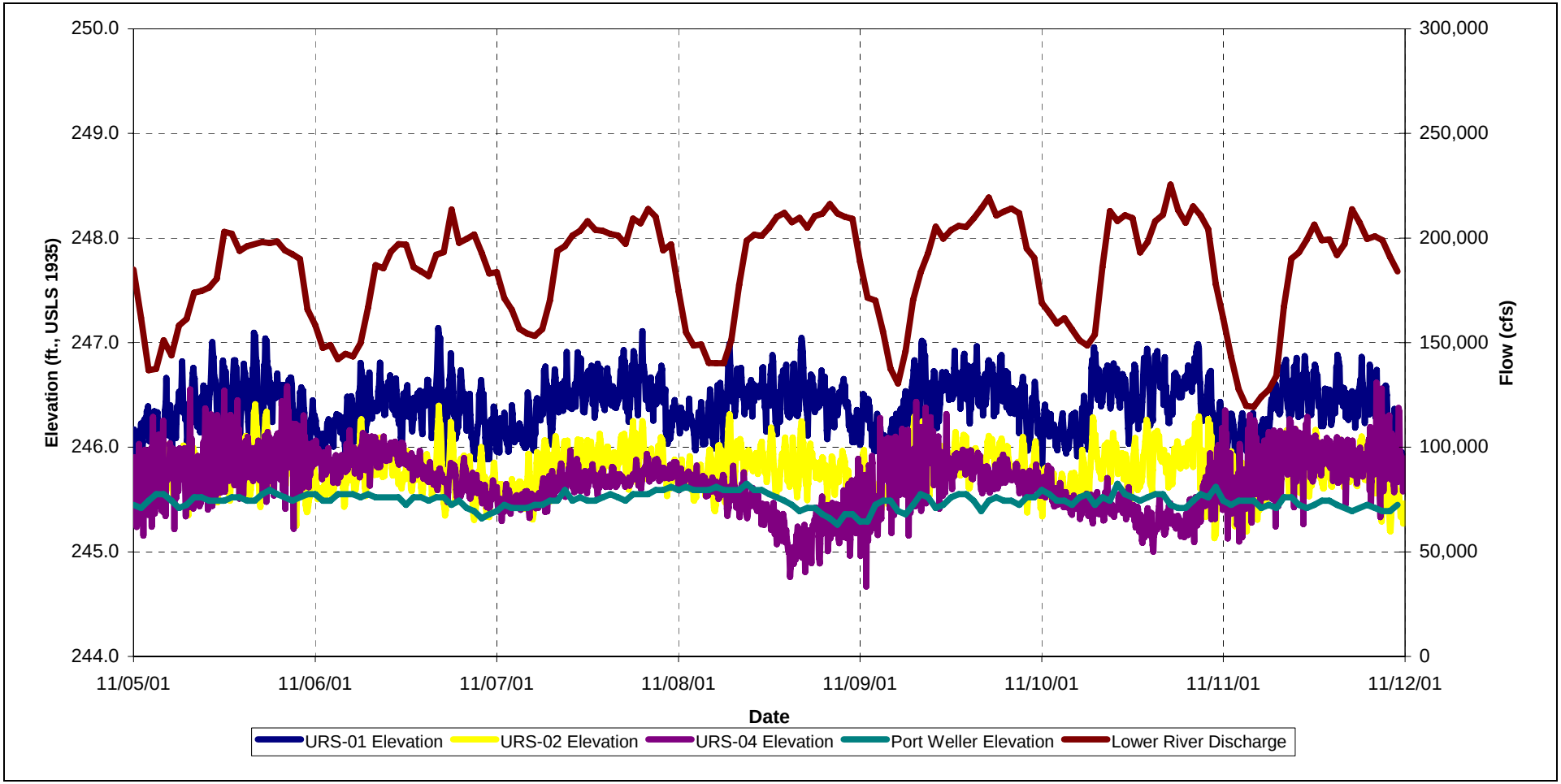

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FIGURE 4.2.2-3

LOWER RIVER TEMPORARY GAUGES – HOURLY WATER LEVEL AND FLOW GRAPH FOR NOVEMBER 12-16, 2001

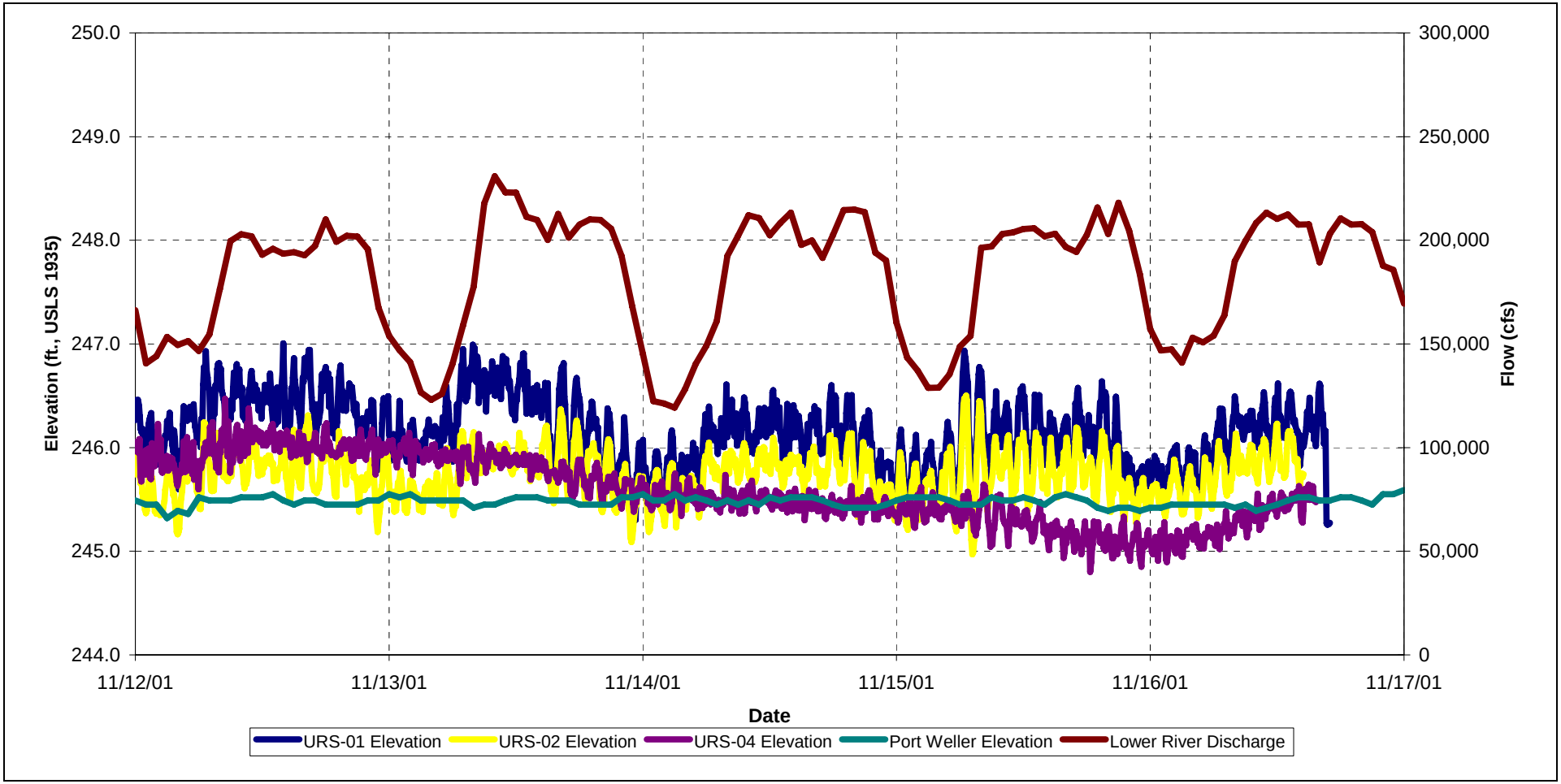

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FIGURE 4.2.2-4

LOWER RIVER TEMPORARY GAUGES – WATER LEVEL (5-MINUTE) AND HOURLY FLOW GRAPH FOR JUNE 2002

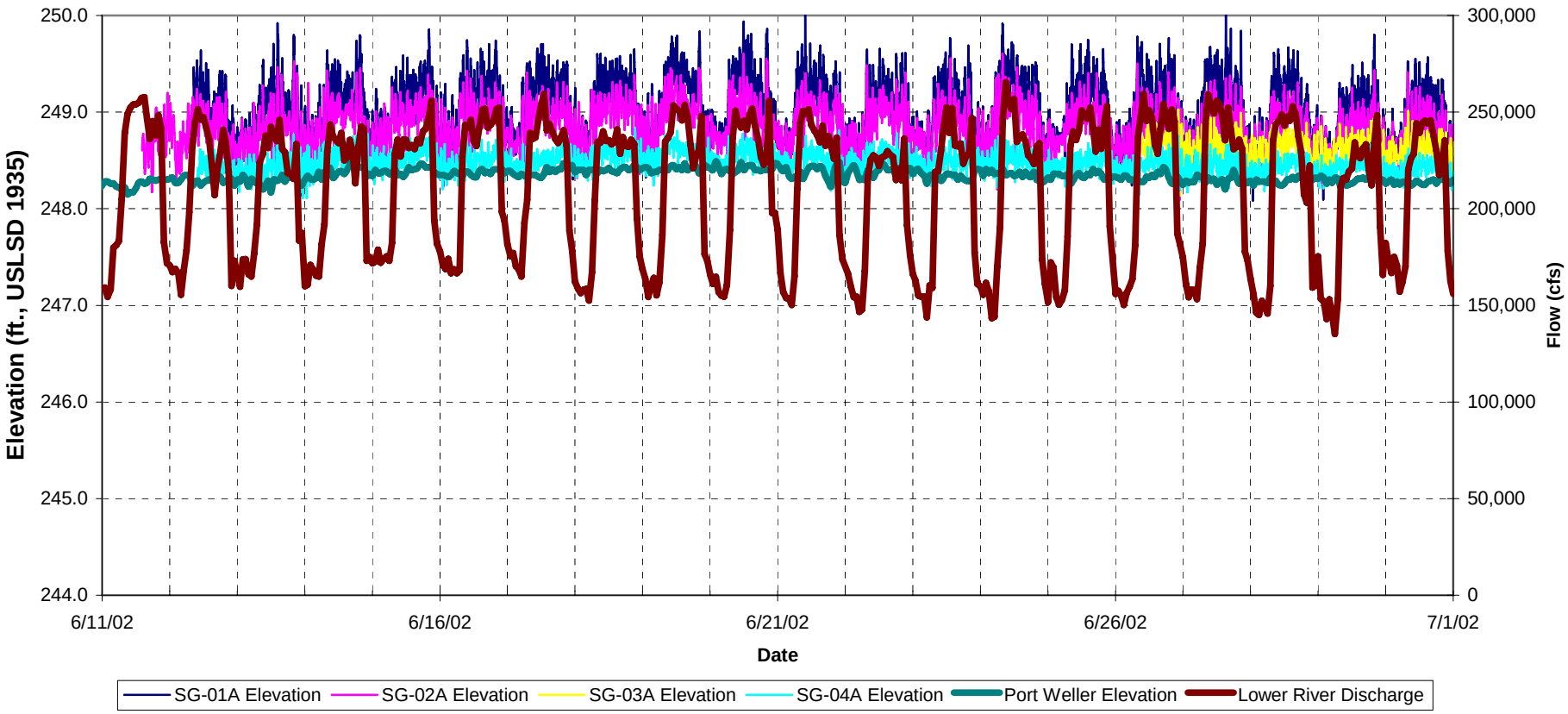

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FIGURE 4.2.2-5

LOWER RIVER TEMPORARY GAUGES – WATER LEVEL (5-MINUTE) AND HOURLY FLOW GRAPH FOR JULY 2002

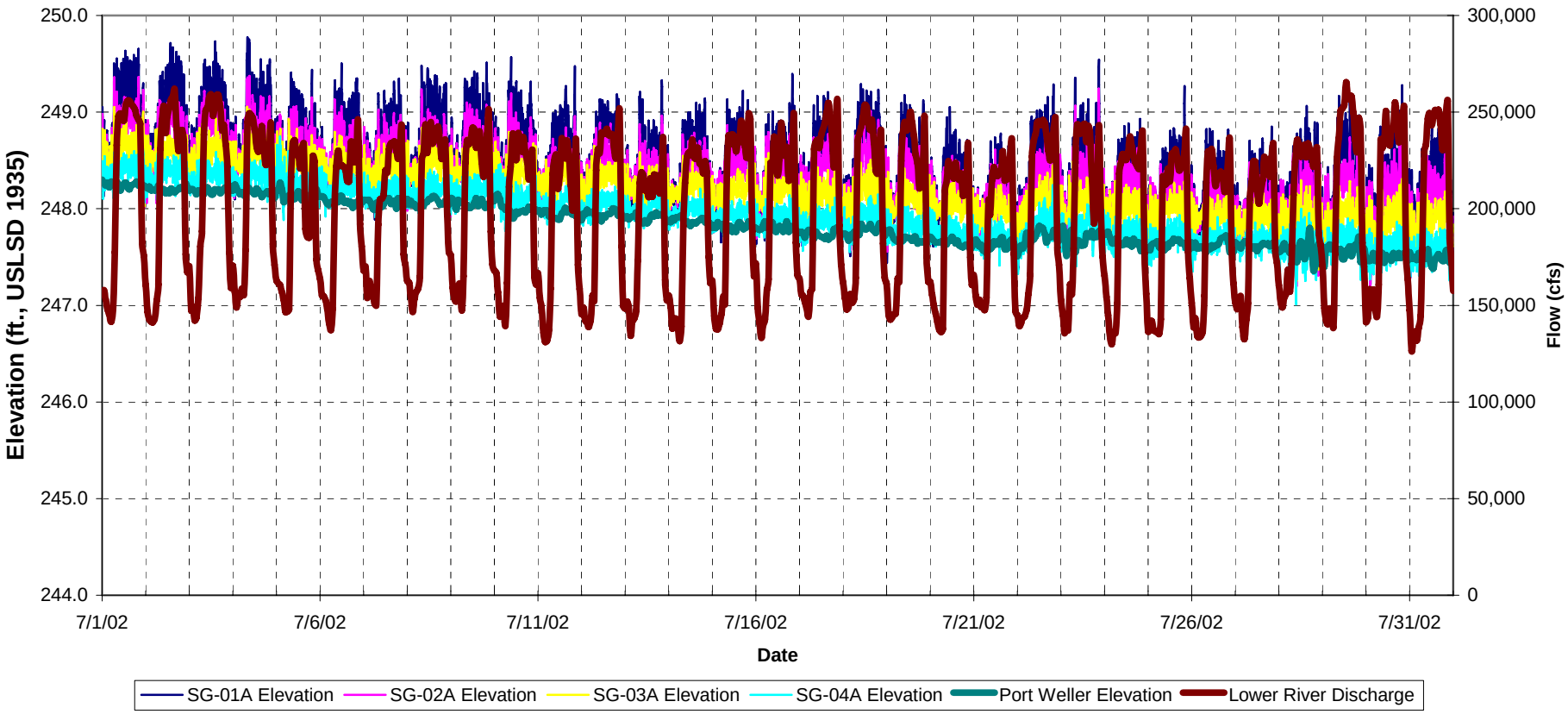

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FIGURE 4.2.2-6

LOWER RIVER TEMPORARY GAUGES – WATER LEVEL (5-MINUTE) AND HOURLY FLOW GRAPH FOR AUGUST 2002

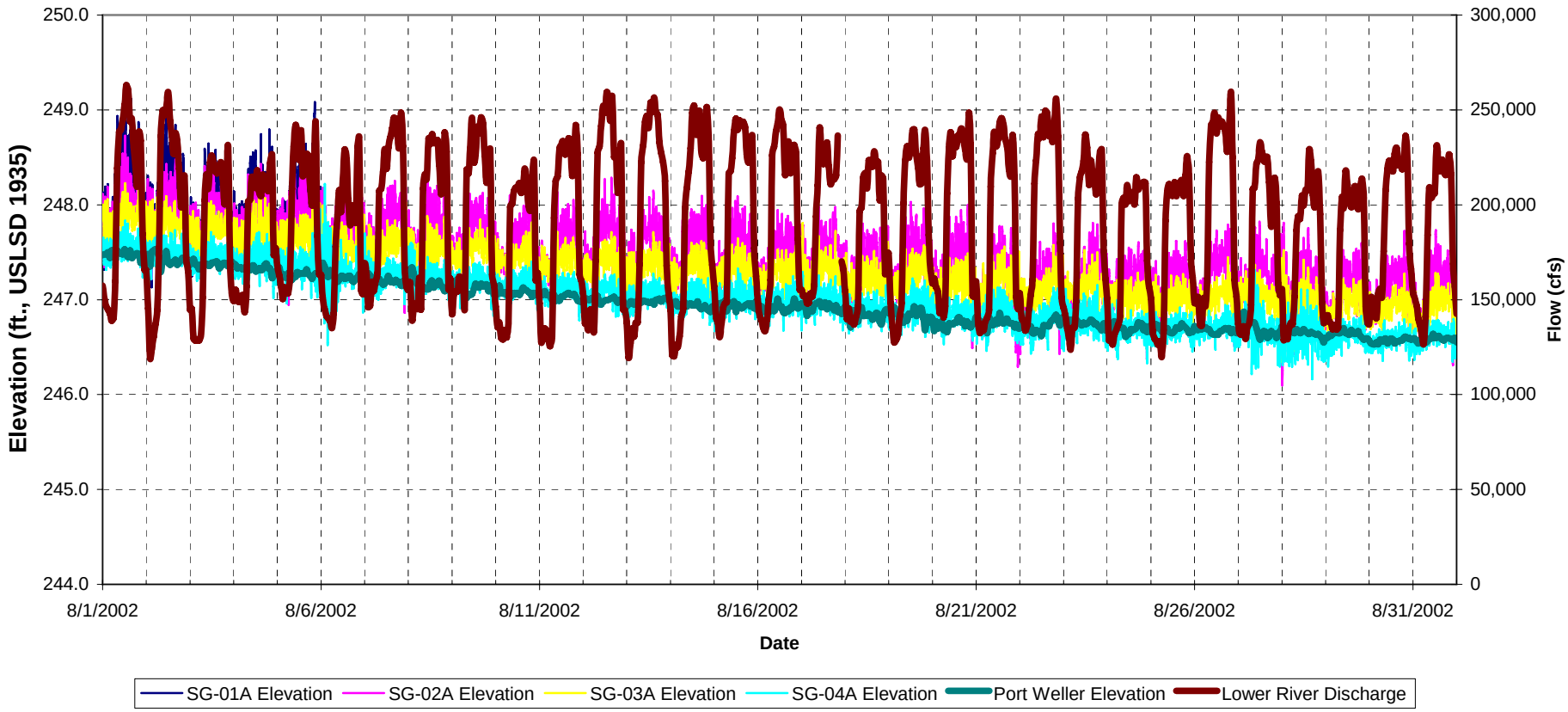

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FIGURE 4.2.2-7

LOWER RIVER TEMPORARY GAUGES – WATER LEVEL (5-MINUTE) AND HOURLY FLOW GRAPH FOR SEPTEMBER 2002

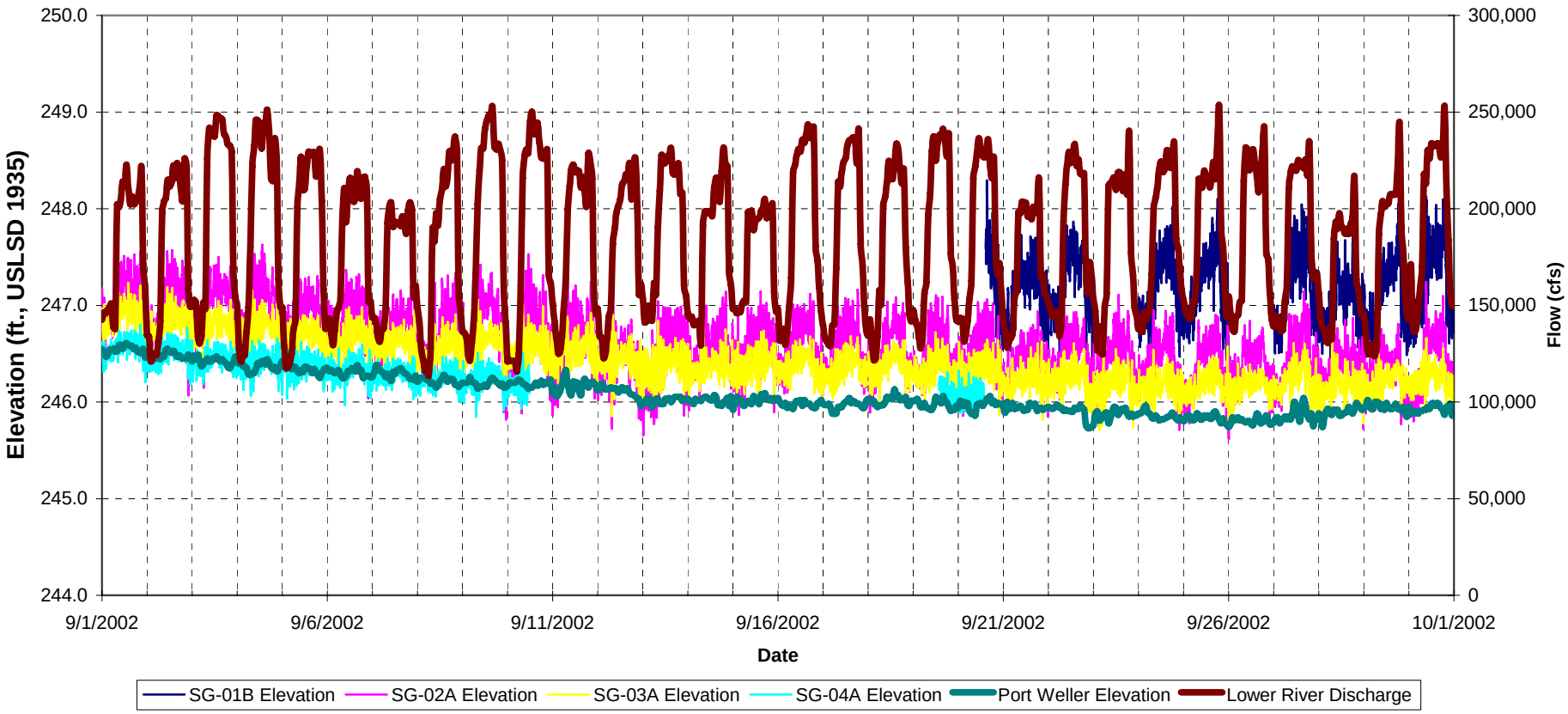

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FIGURE 4.2.2-8

LOWER RIVER TEMPORARY GAUGES – WATER LEVEL (5-MINUTE) AND HOURLY FLOW GRAPH FOR OCTOBER 2002

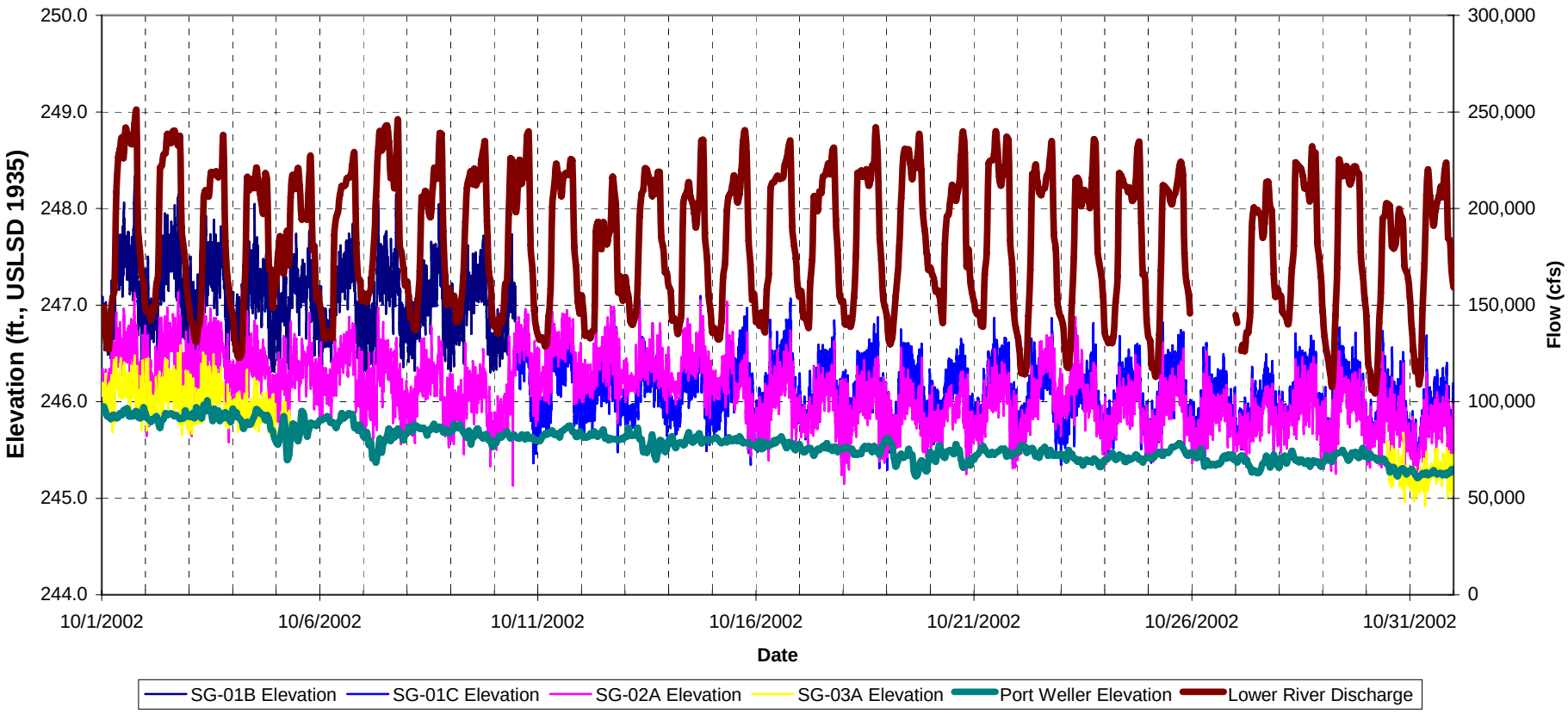

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FIGURE 4.2.2-9

LOWER RIVER TEMPORARY GAUGES – WATER LEVEL (5-MINUTE) AND HOURLY FLOW GRAPH FOR NOVEMBER 2002

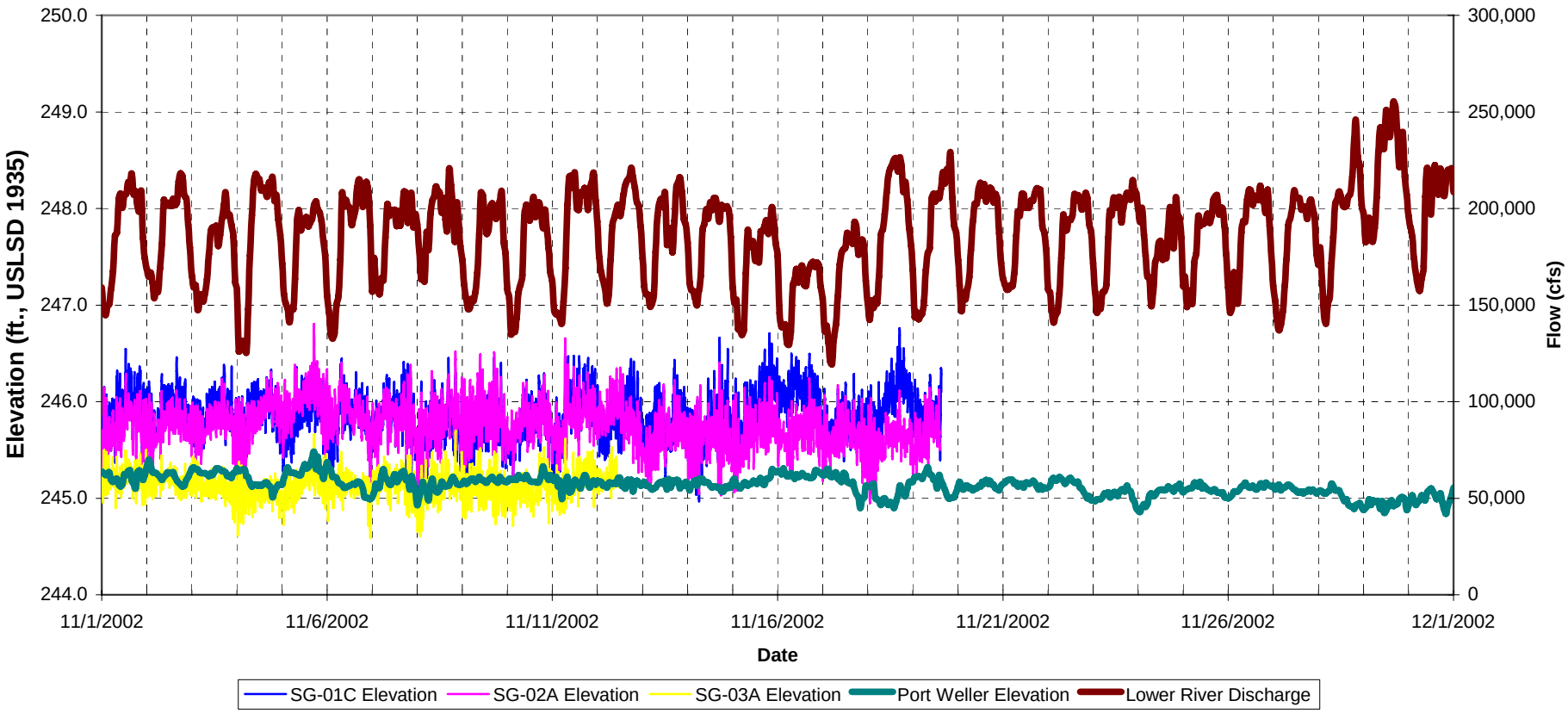

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FIGURE 4.3.1-1

BUFFALO – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

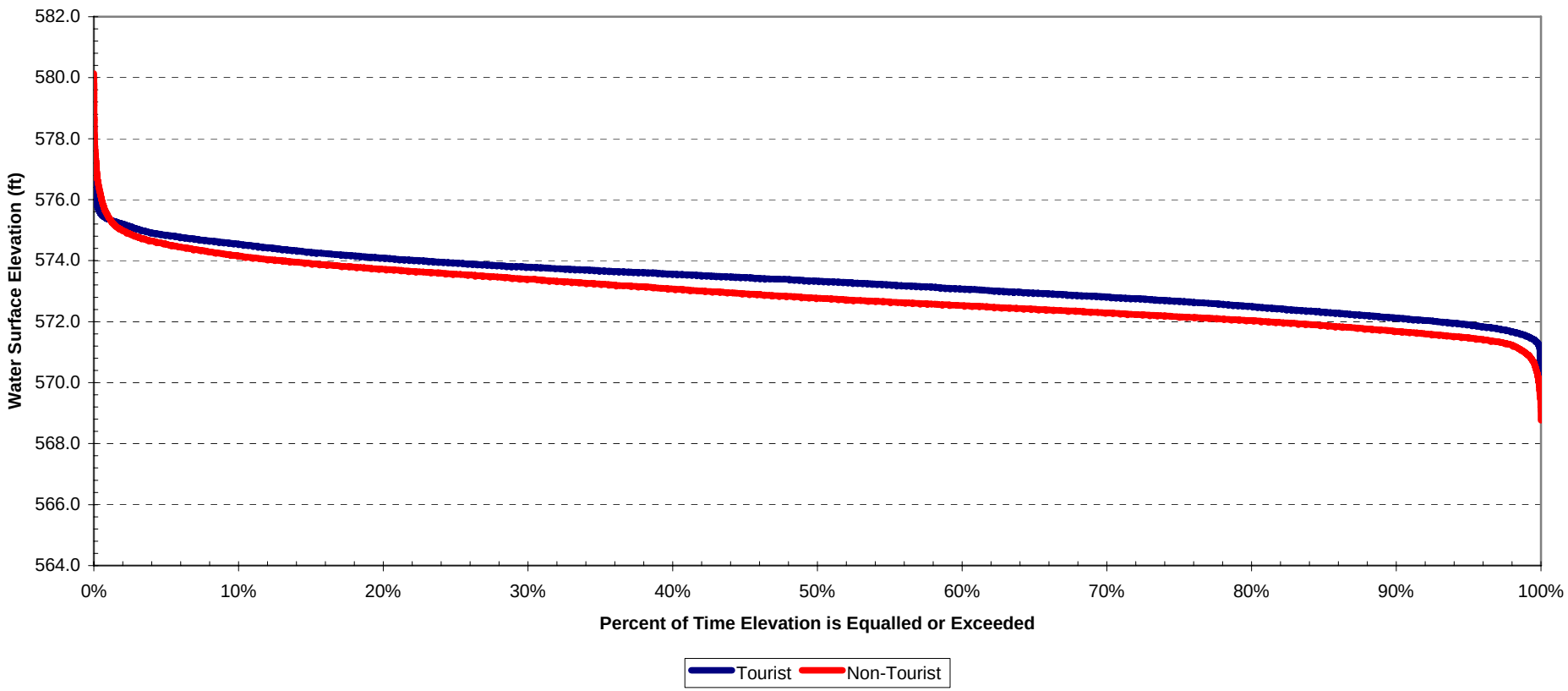

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FIGURE 4.3.1-2

FORT ERIE – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

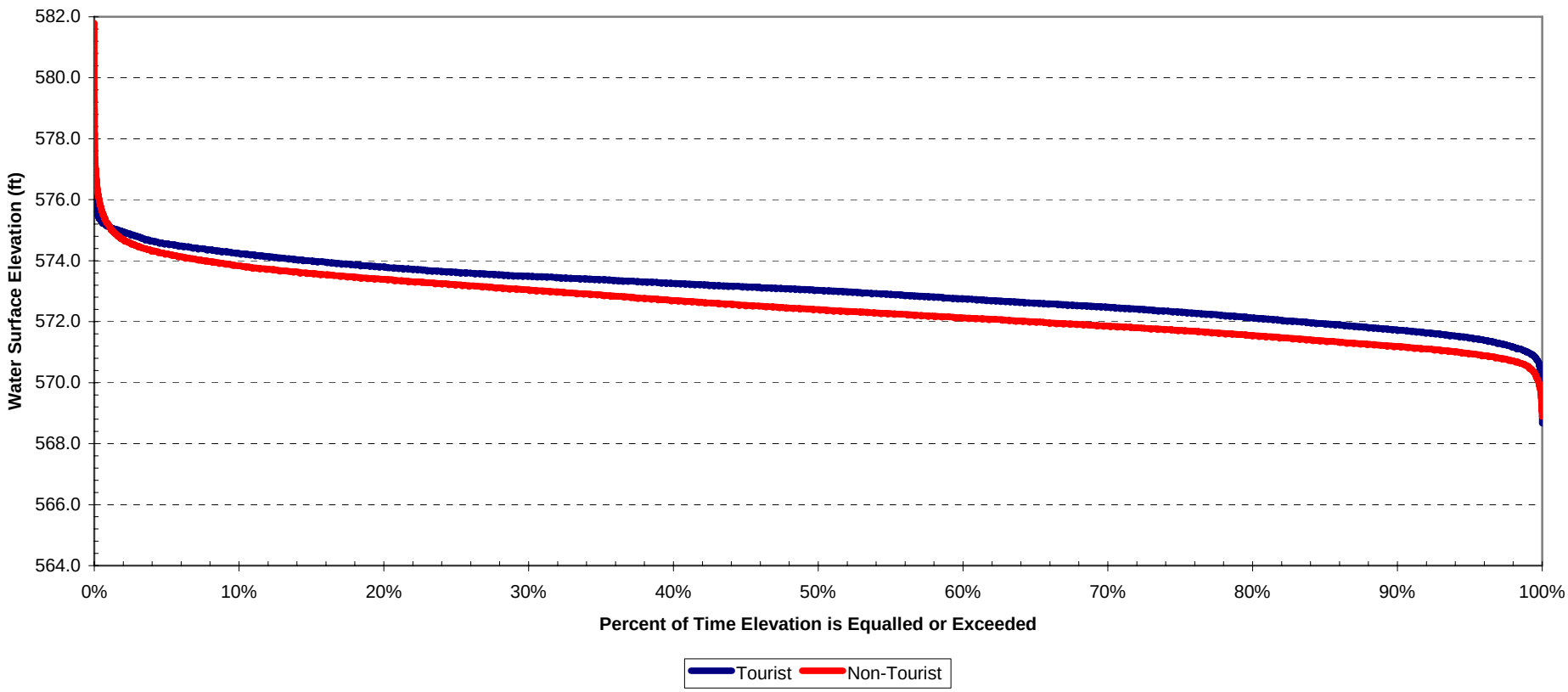

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FIGURE 4.3.1-3

PEACE BRIDGE – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (JULY 1999 – 2002)

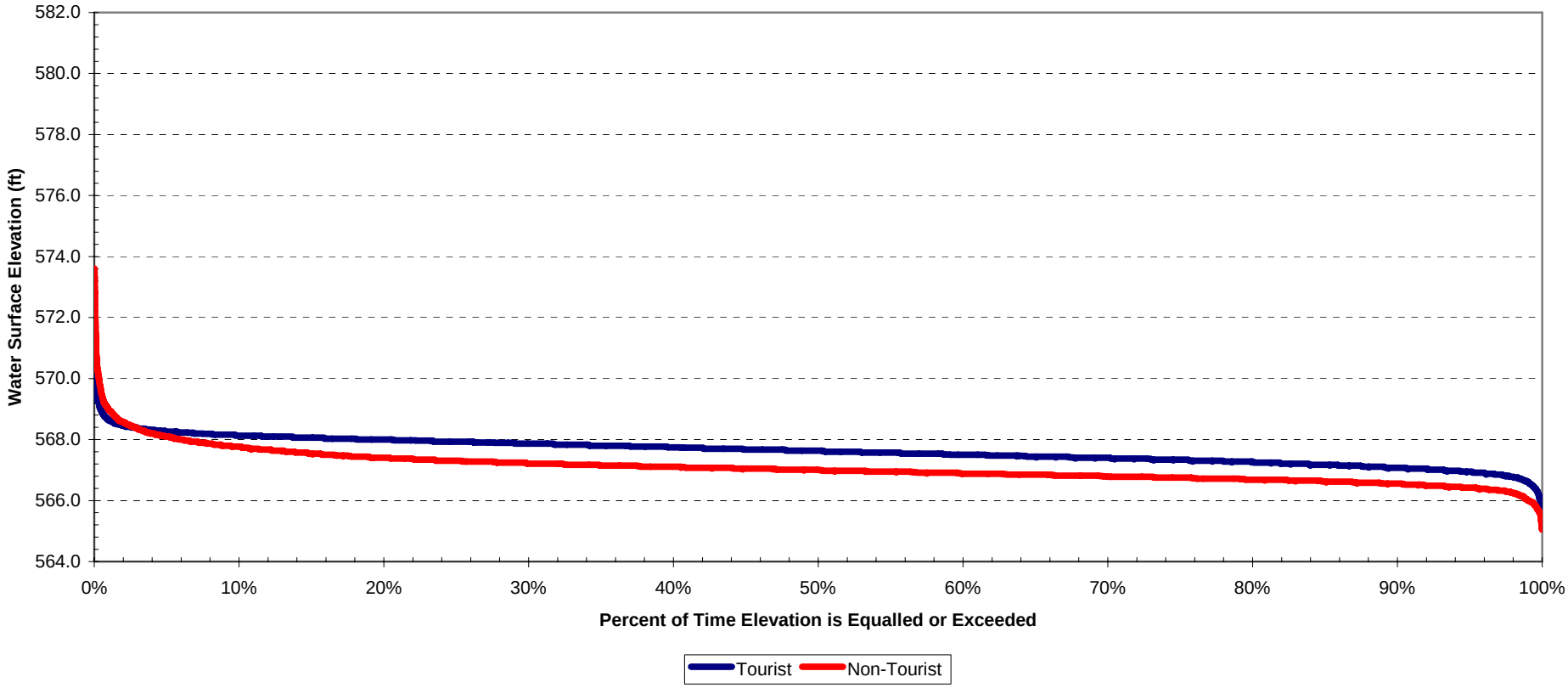

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FIGURE 4.3.1-4

FRENCHMEN'S CREEK – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

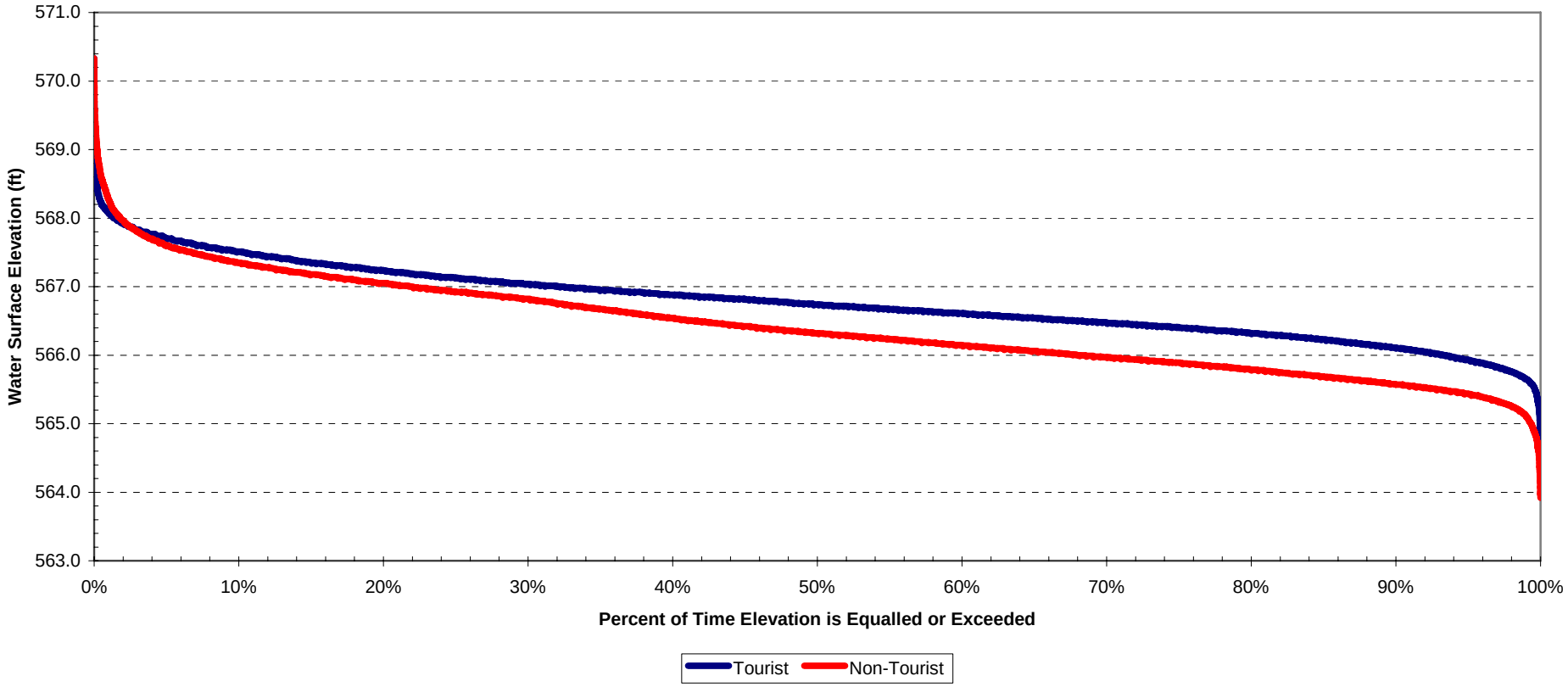

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FIGURE 4.3.1-5

HUNTLEY – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

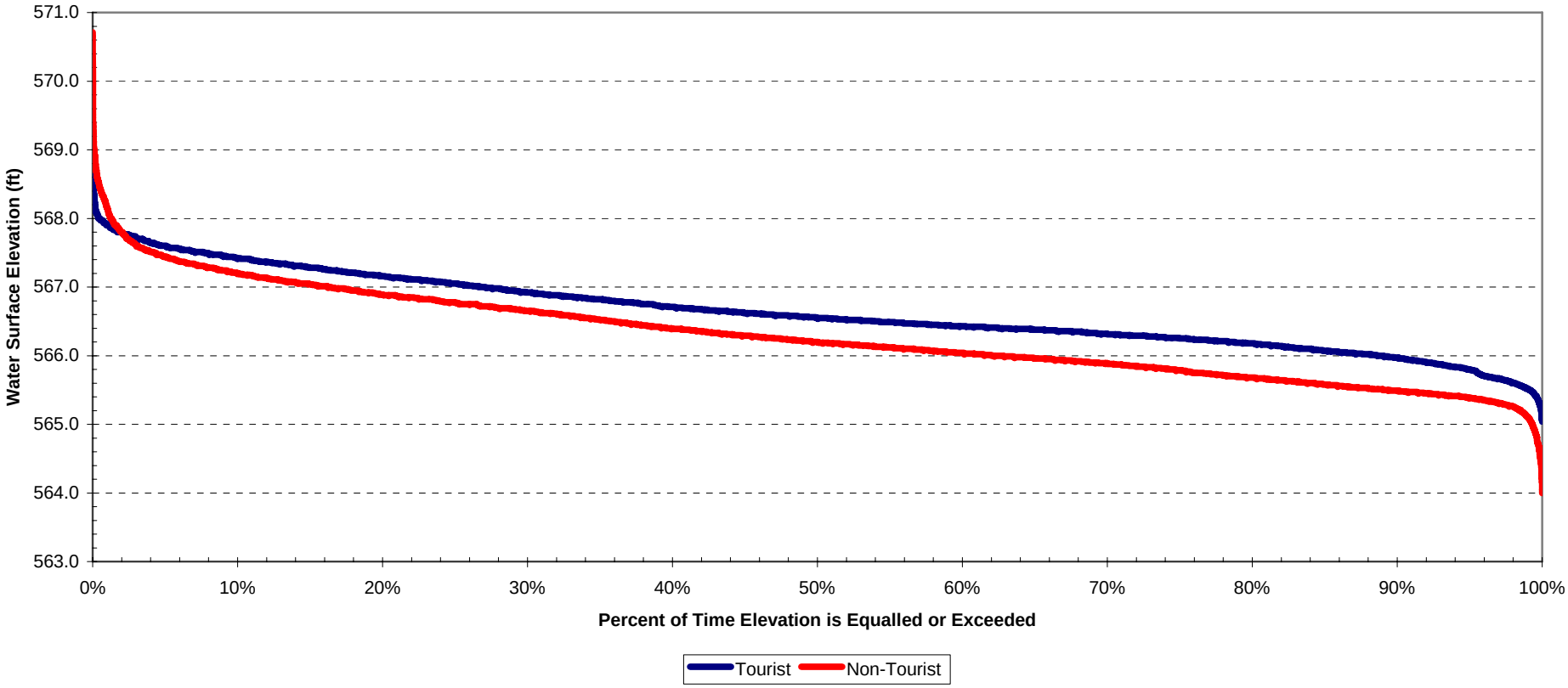

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FIGURE 4.3.1-6

BLACK CREEK – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

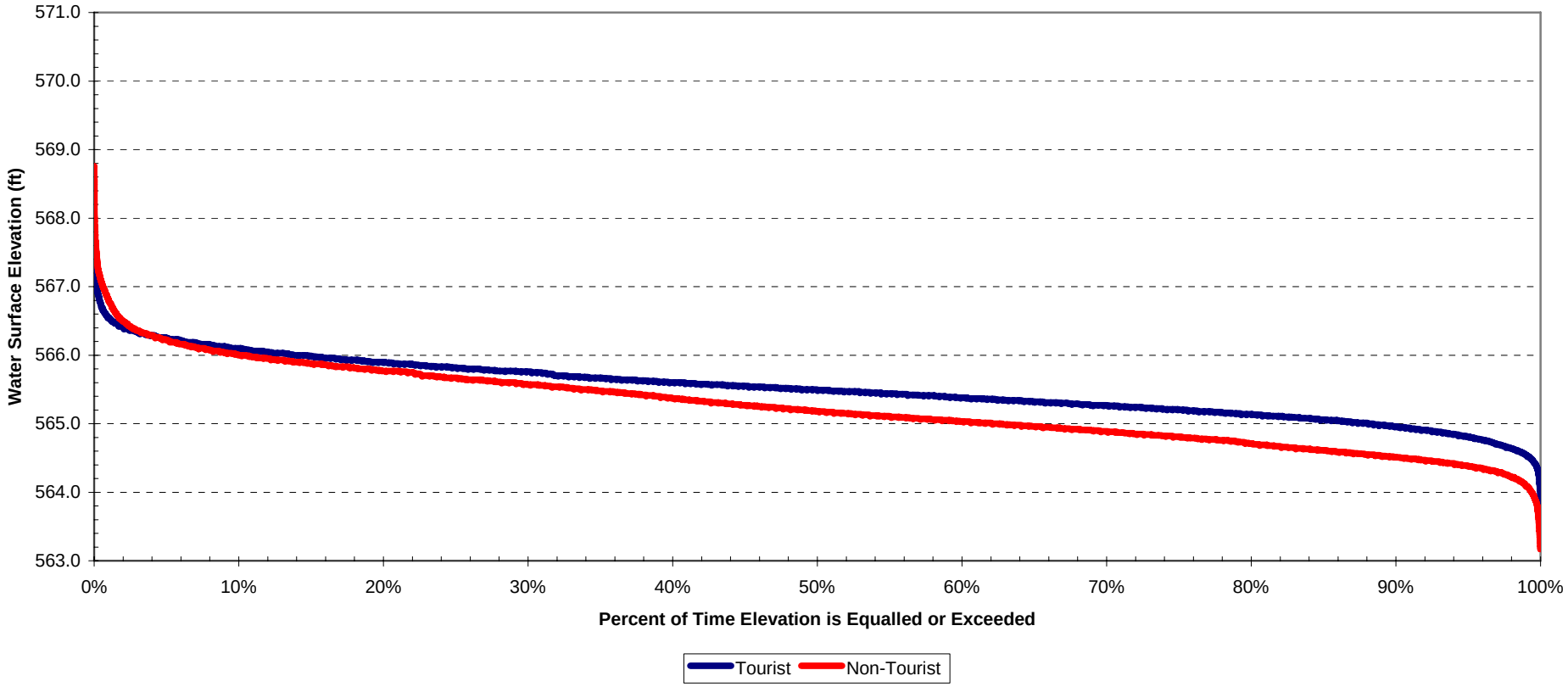

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FIGURE 4.3.1-7

TONAWANDA ISLAND – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

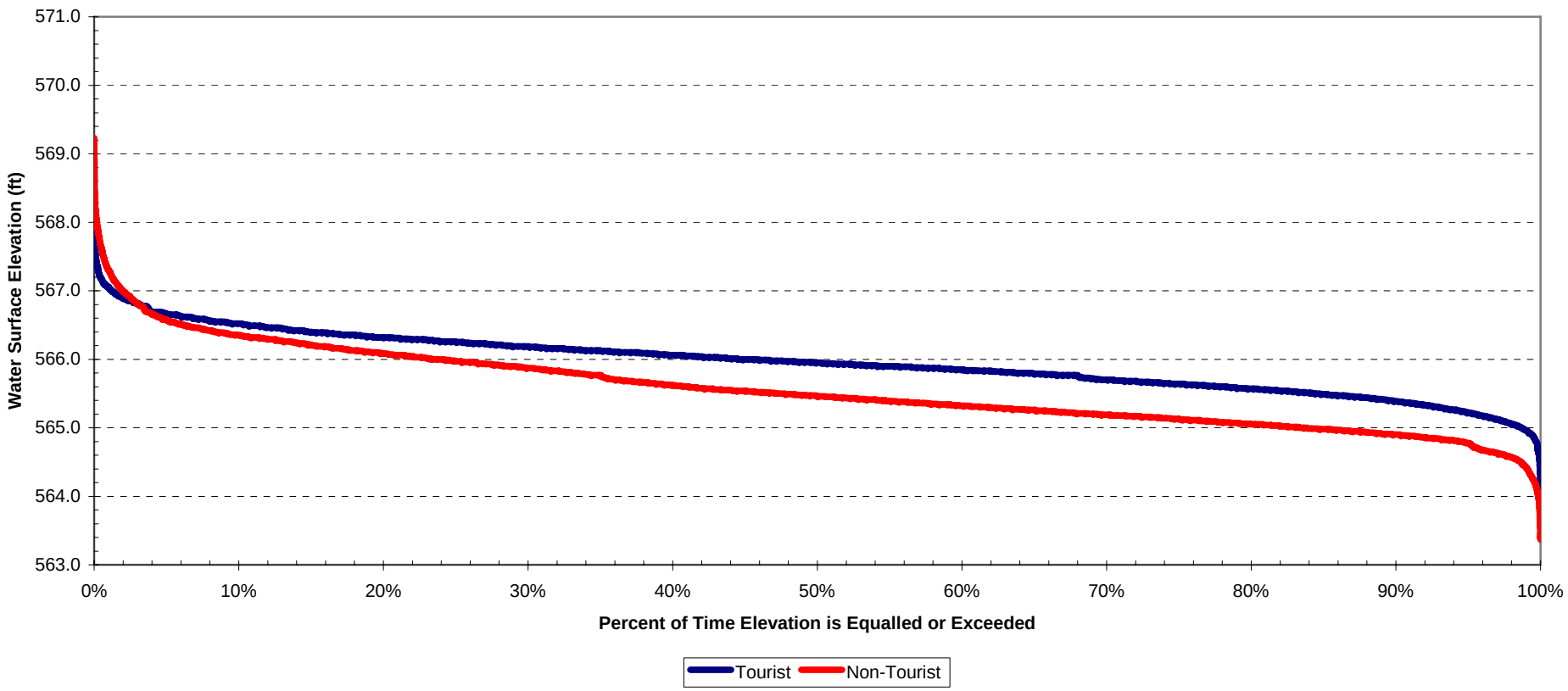

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FIGURE 4.3.1-8

LASALLE – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

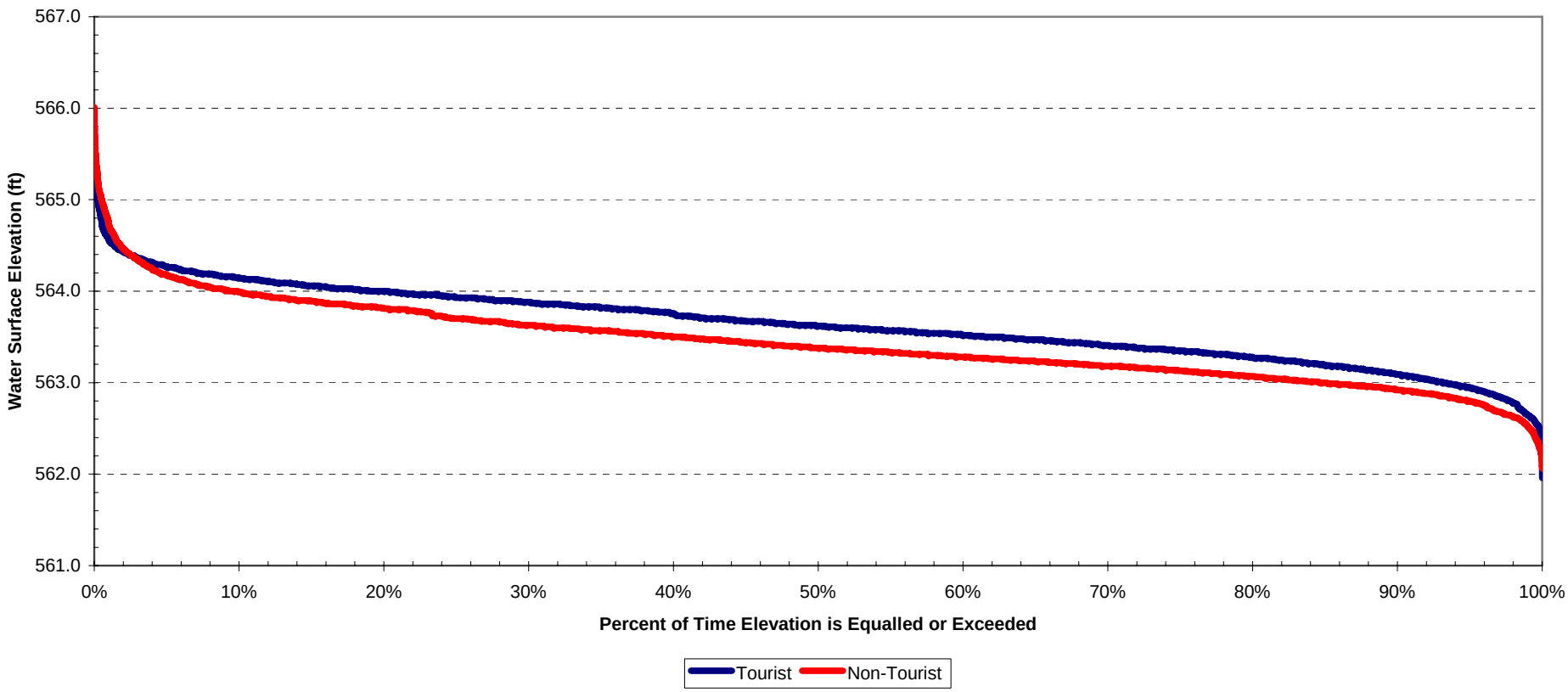

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FIGURE 4.3.1-9

SLATER'S POINT – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

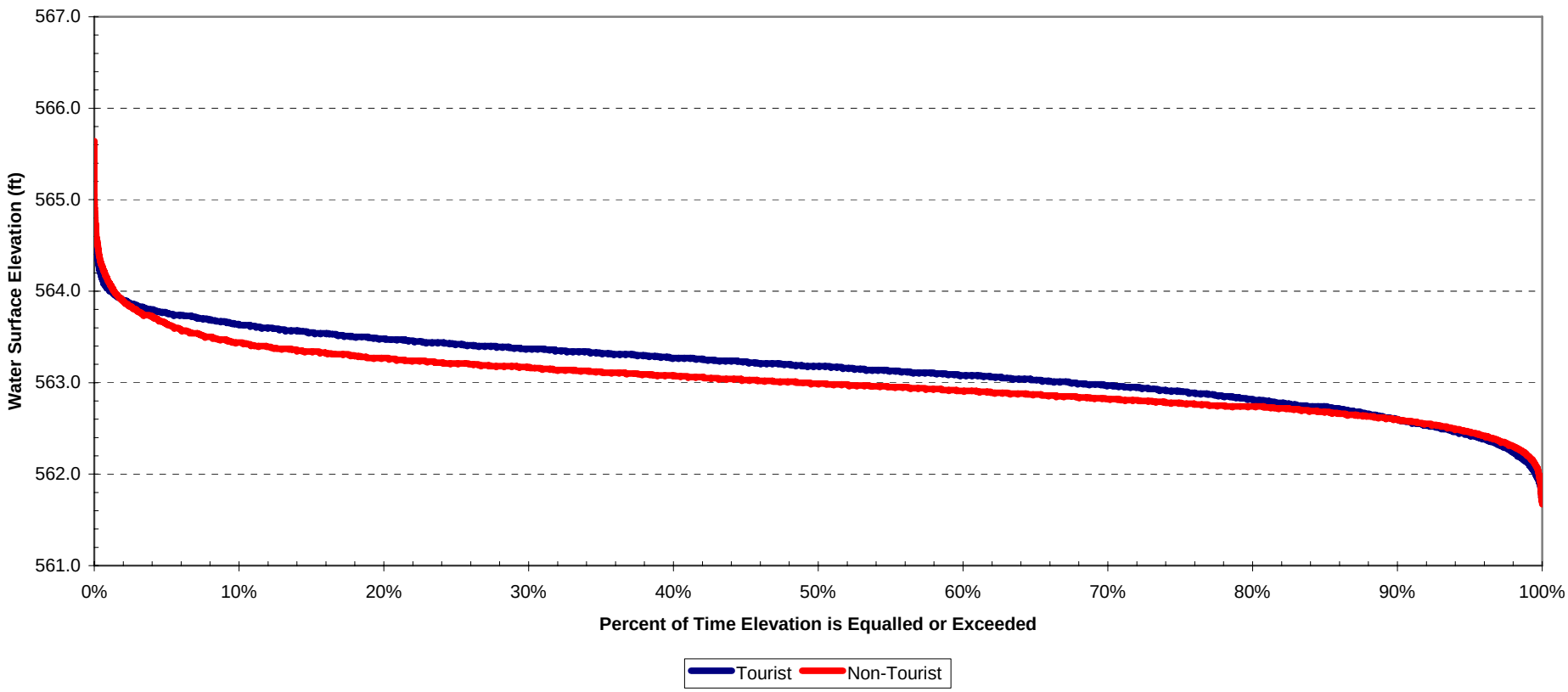

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FIGURE 4.3.1-10

NYPA INTAKE – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

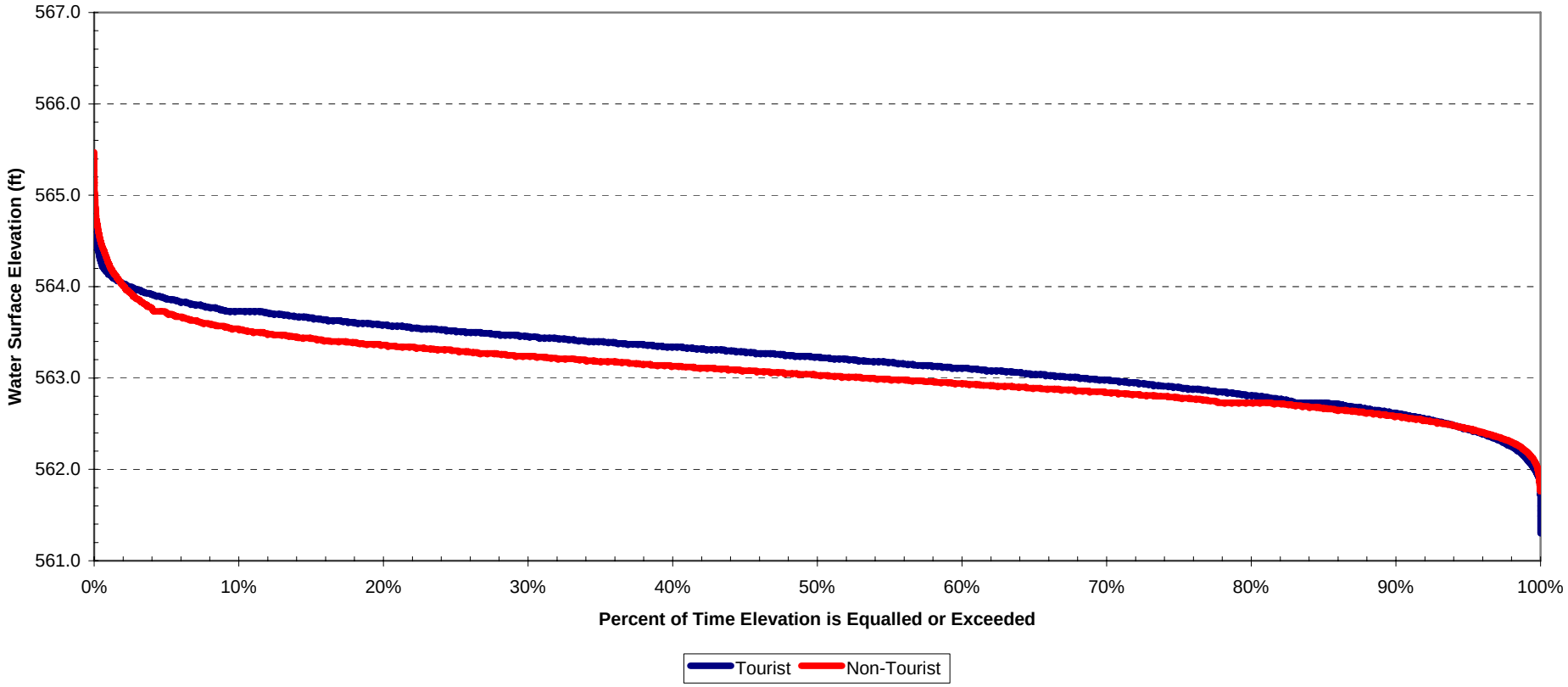

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FIGURE 4.3.1-11

MATERIAL DOCK – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

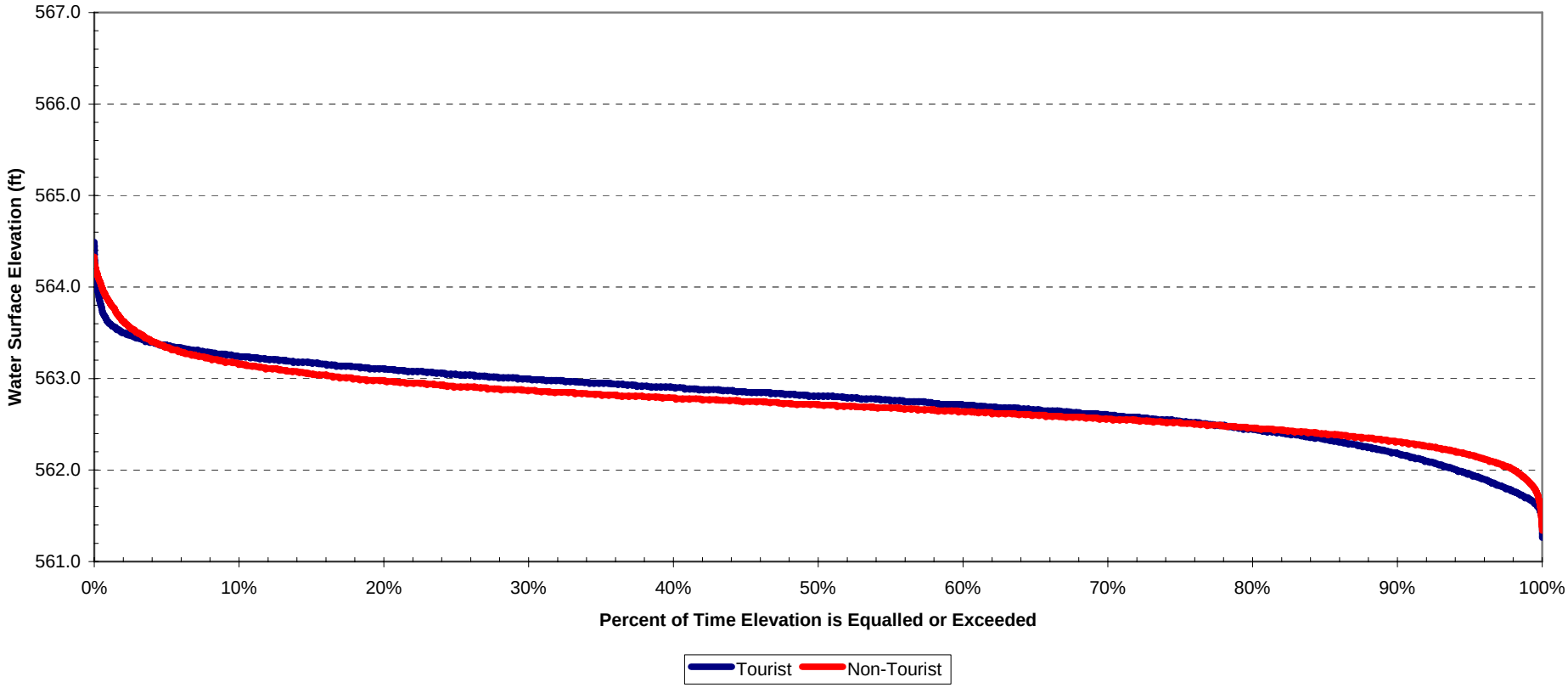

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FIGURE 4.3.1-12

AMERICAN FALLS – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

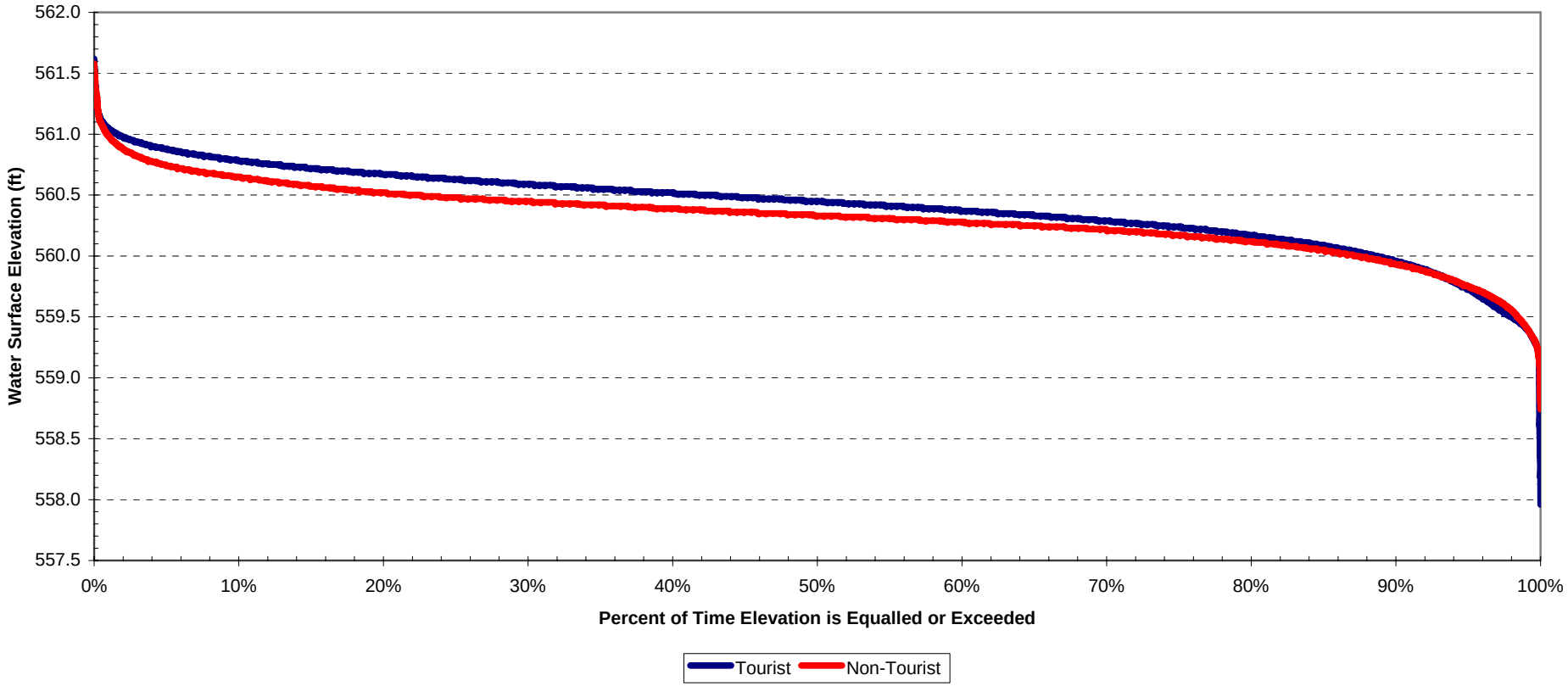

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FIGURE 4.3.2-1

ASHLAND AVENUE – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

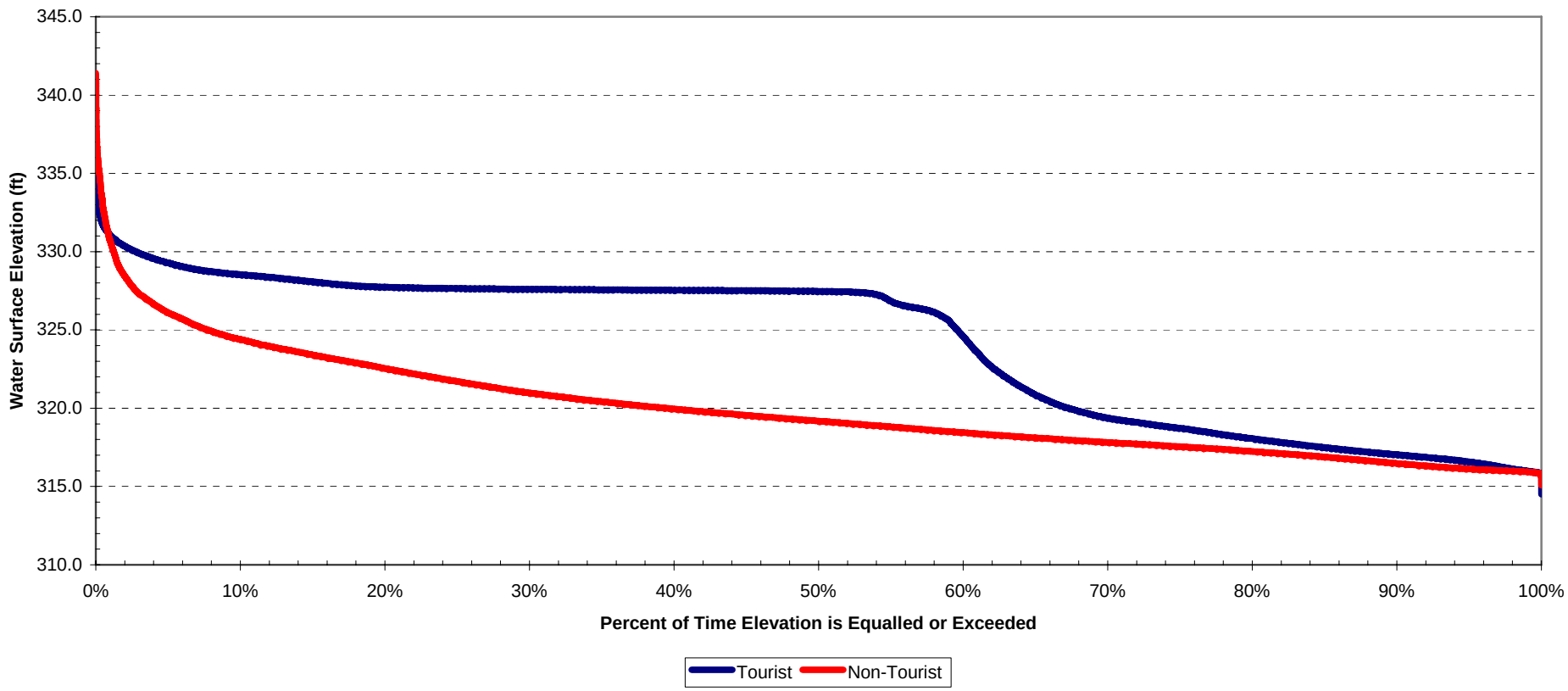

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FIGURE 4.3.2-2

PORT WELLER – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

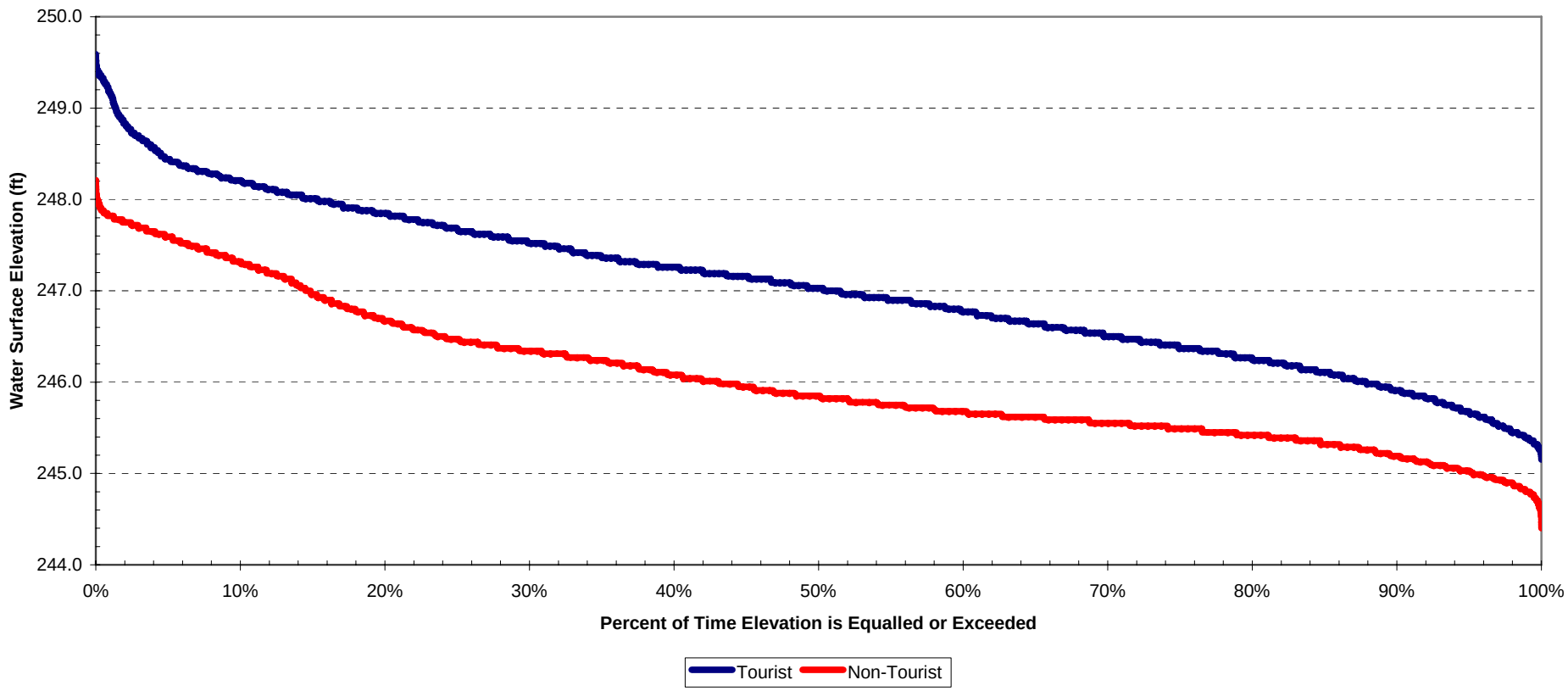

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FIGURE 4.3.3-1

LEWISTON RESERVOIR – WATER LEVEL DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

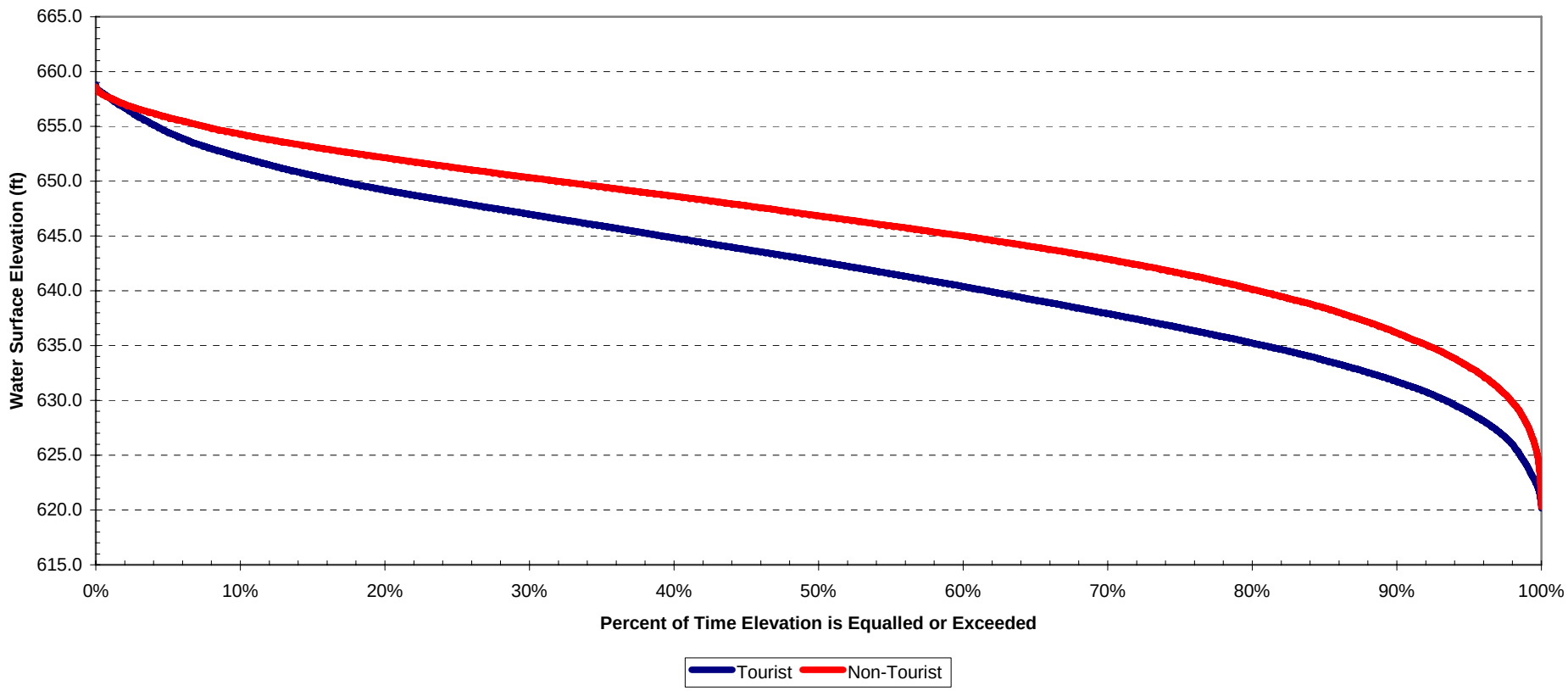

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FIGURE 4.3.4-1

FORT ERIE - FLOW DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

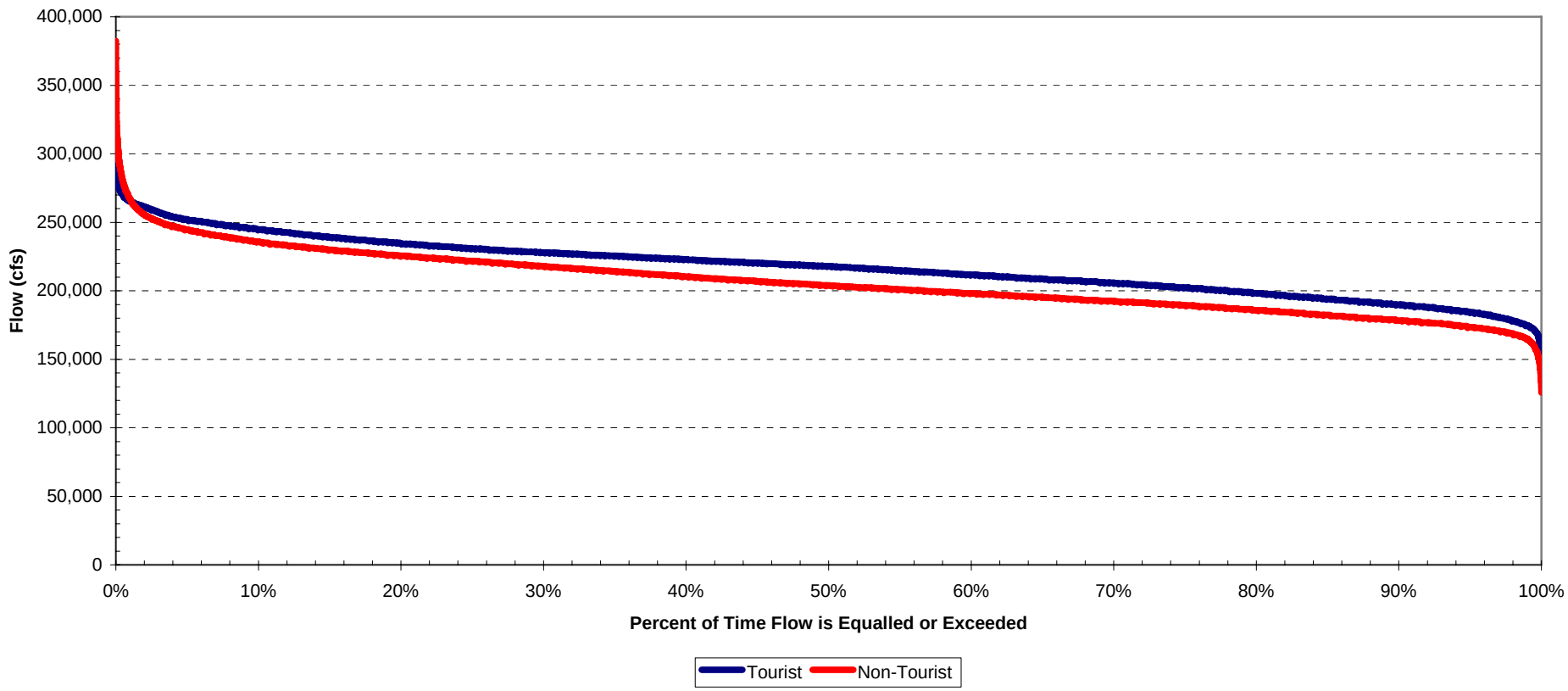

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FIGURE 4.3.4-2

LOWER NIAGARA RIVER – FLOW DURATION ANALYSIS FOR TOURIST AND NON-TOURIST PERIOD (1991 – 2002)

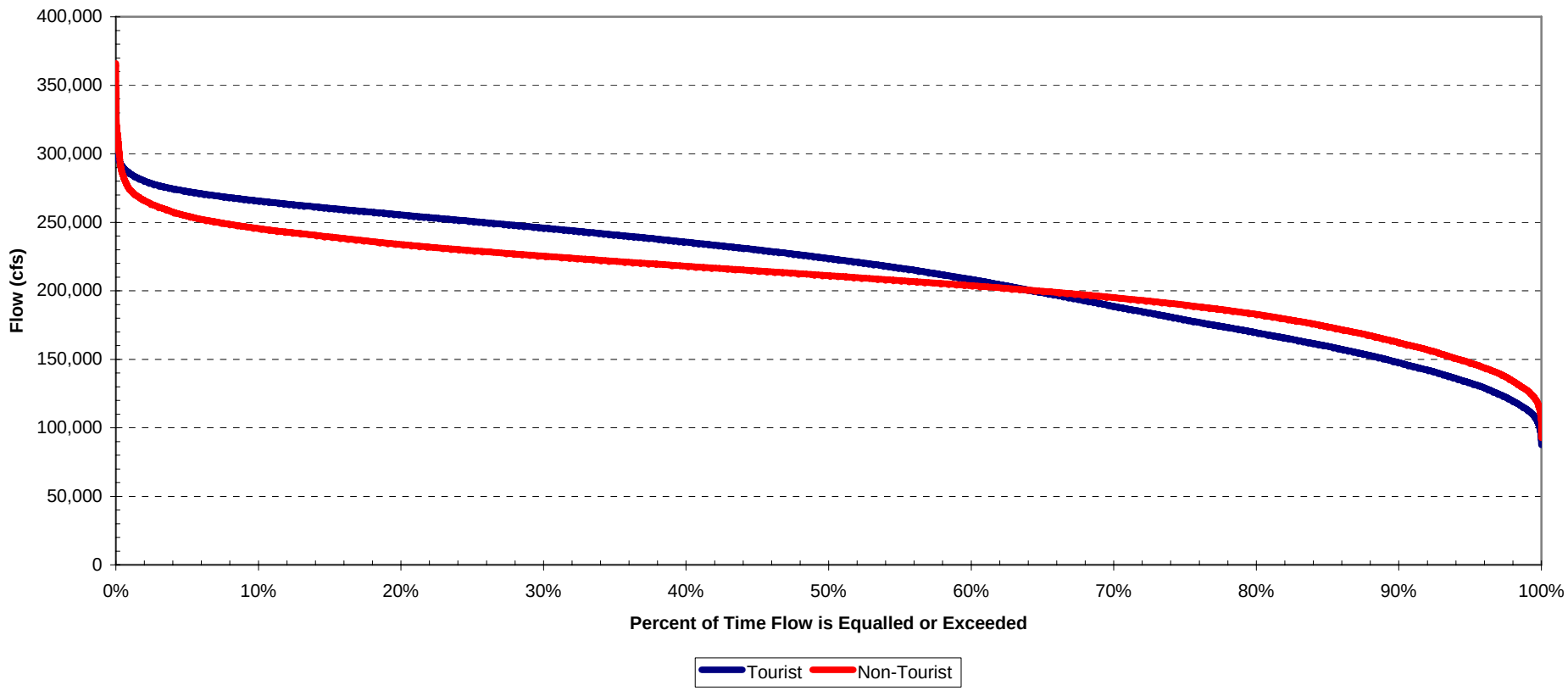

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FIGURE 4.5.1-1

BUFFALO – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

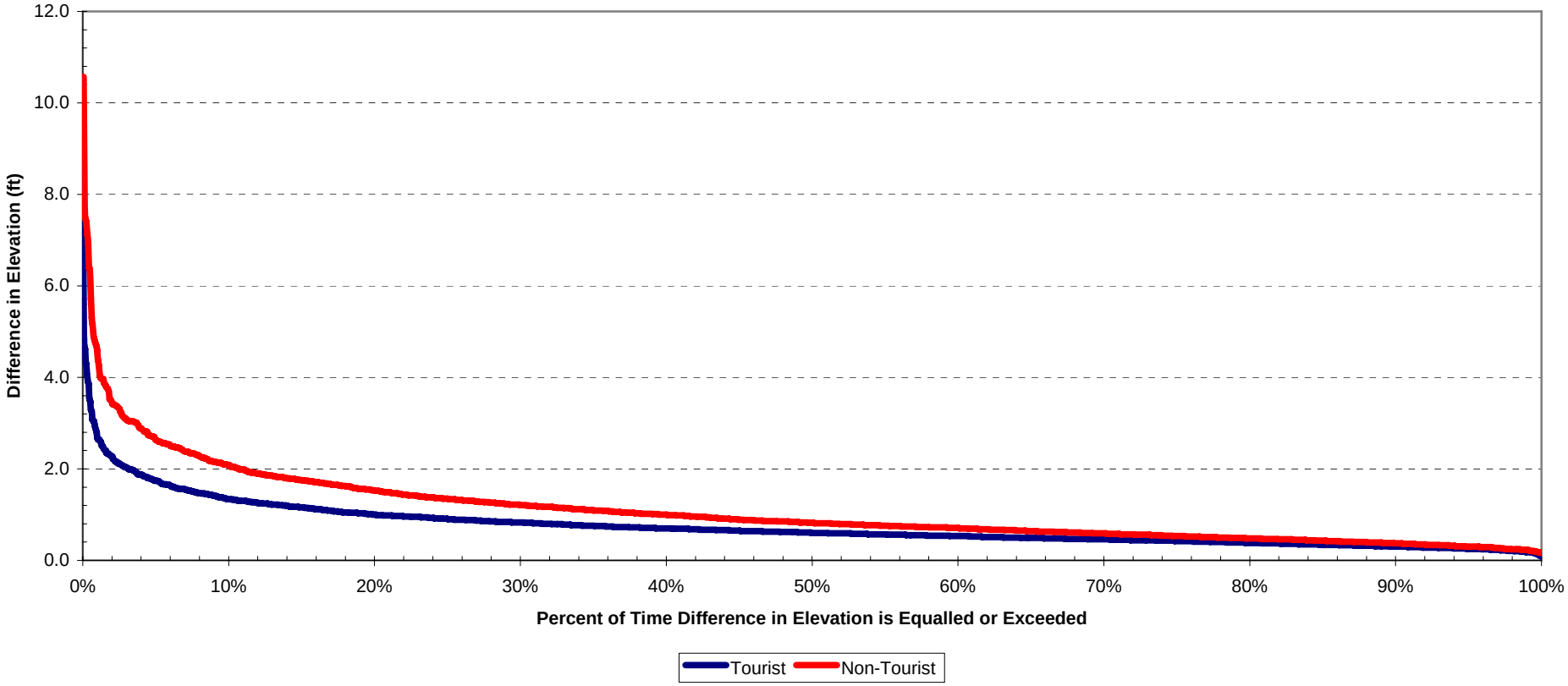

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FIGURE 4.5.1-2

FORT ERIE – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

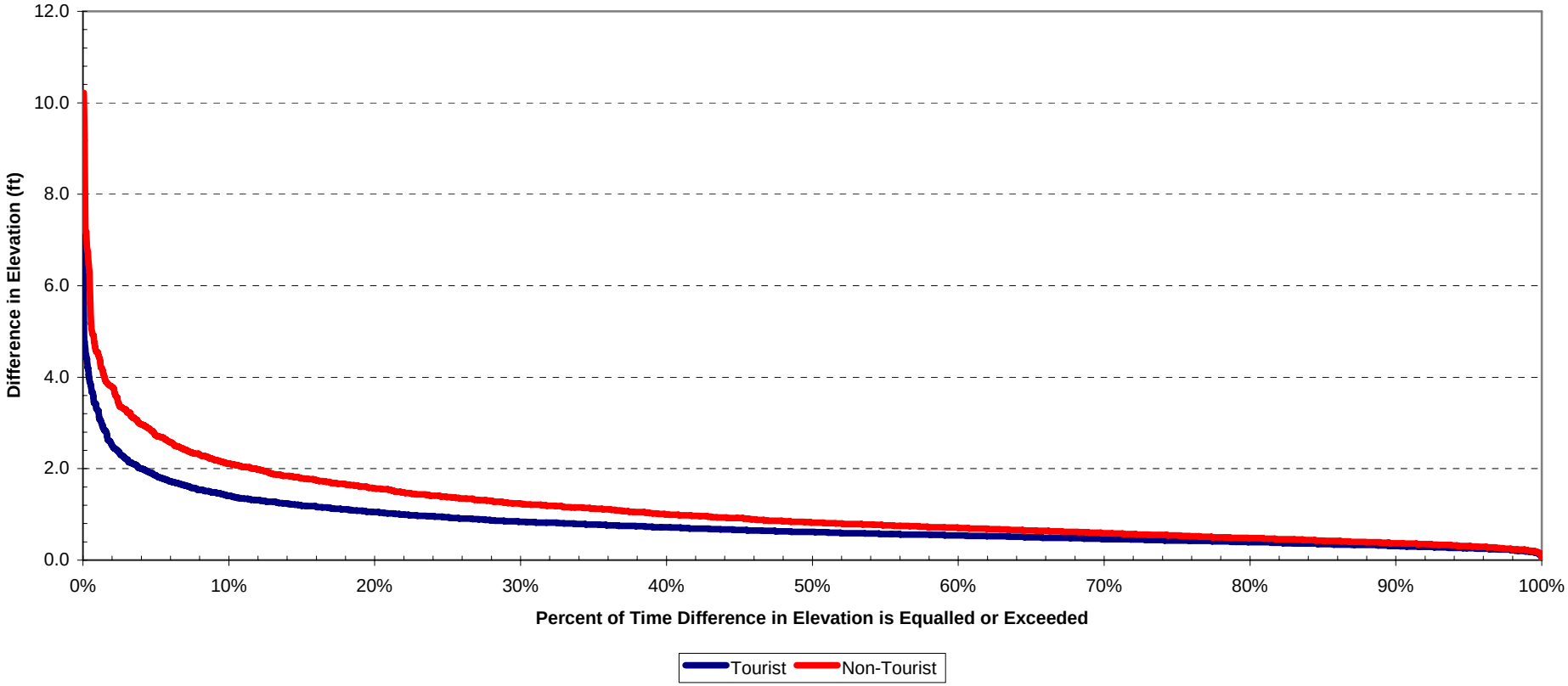

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FIGURE 4.5.1-3

PEACE BRIDGE – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (JUN 1999-DEC 2002)

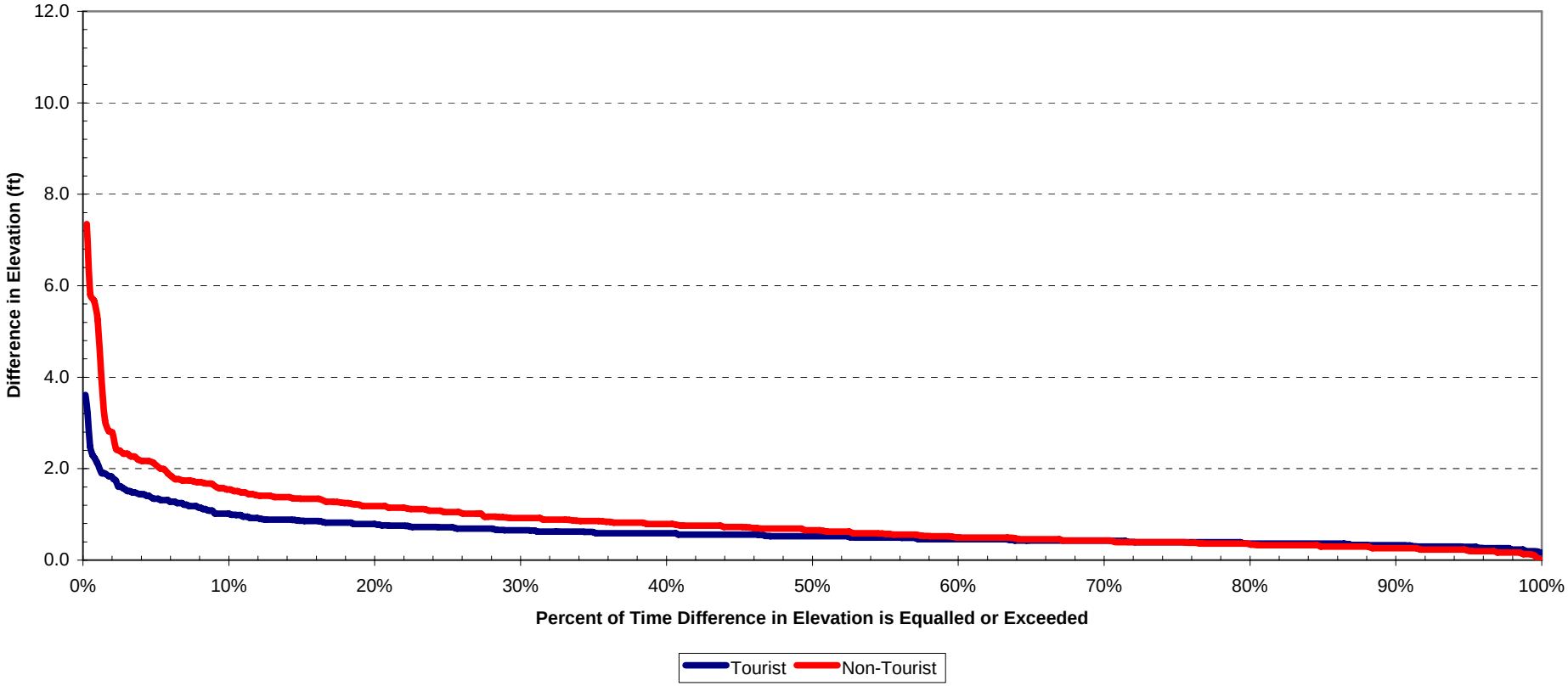

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FIGURE 4.5.1-4

FRENCHMAN'S CREEK – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

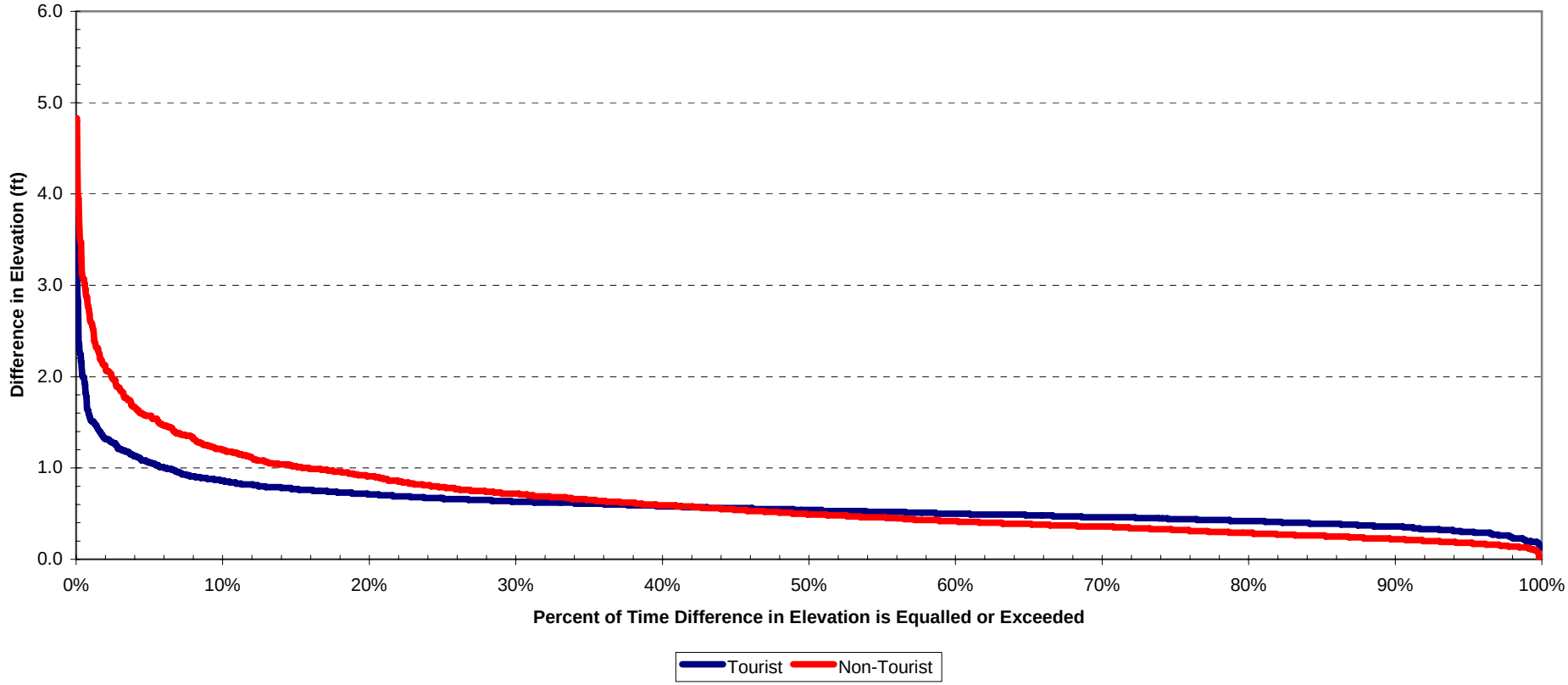

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FIGURE 4.5.1-5

HUNTLEY – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

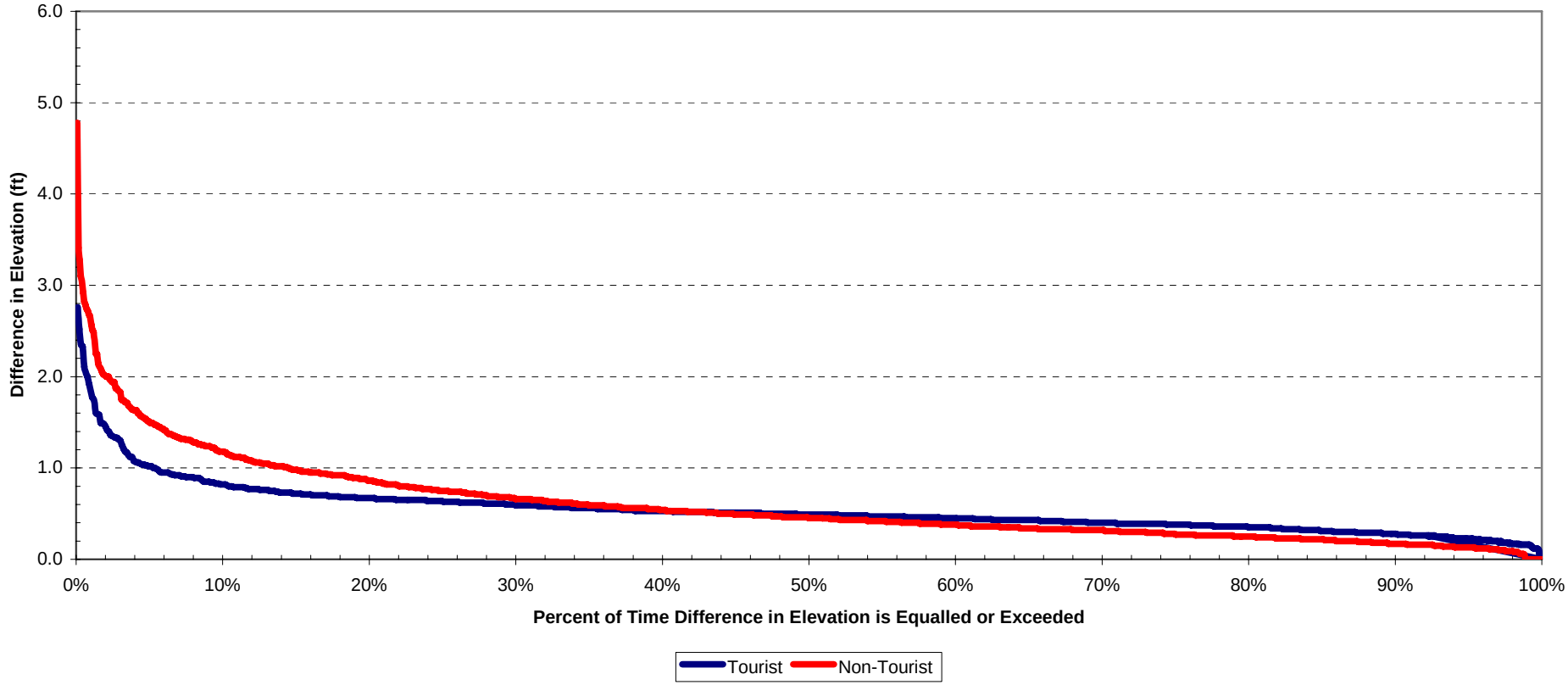

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FIGURE 4.5.1-6

BLACK CREEK – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

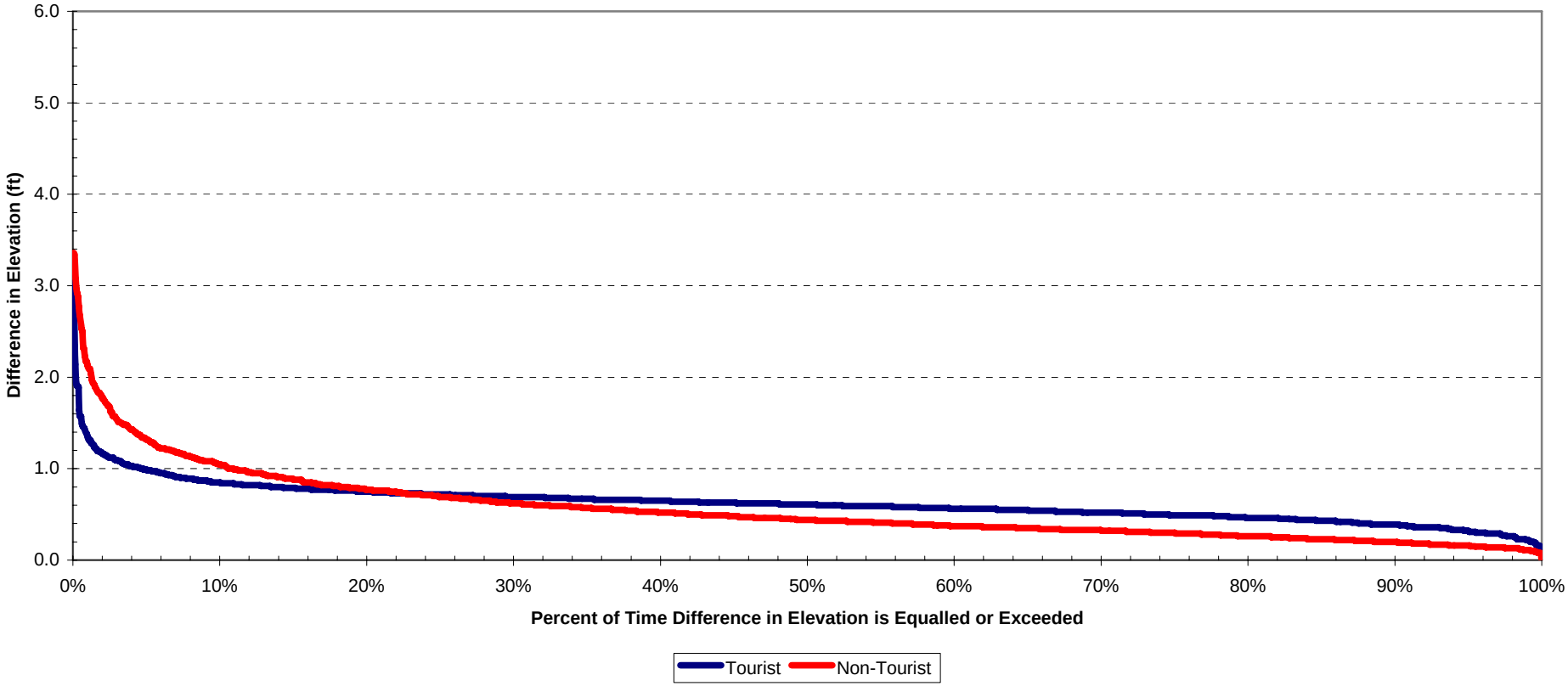

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FIGURE 4.5.1-7

TONAWANDA ISLAND – DURATION ANALYSIS OF MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

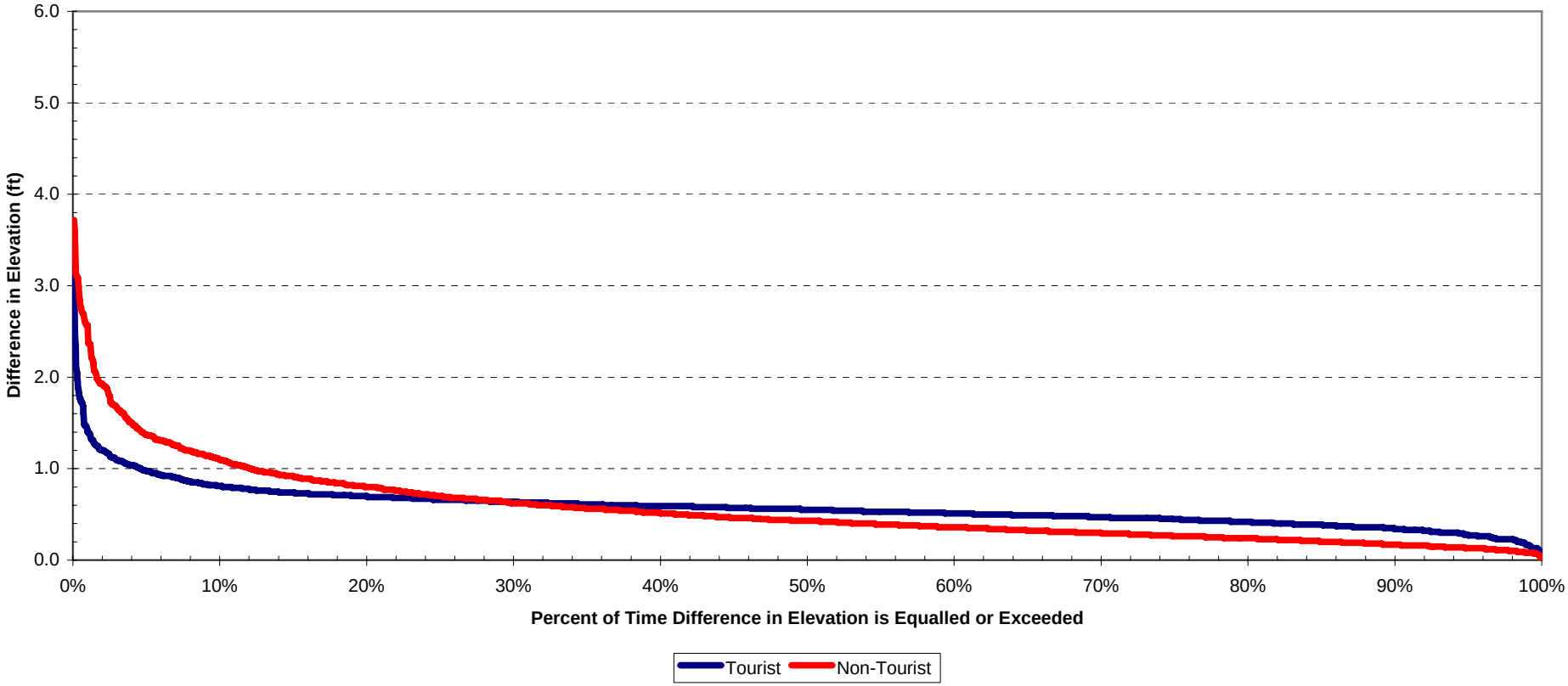

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FIGURE 4.5.1-8

LASALLE – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

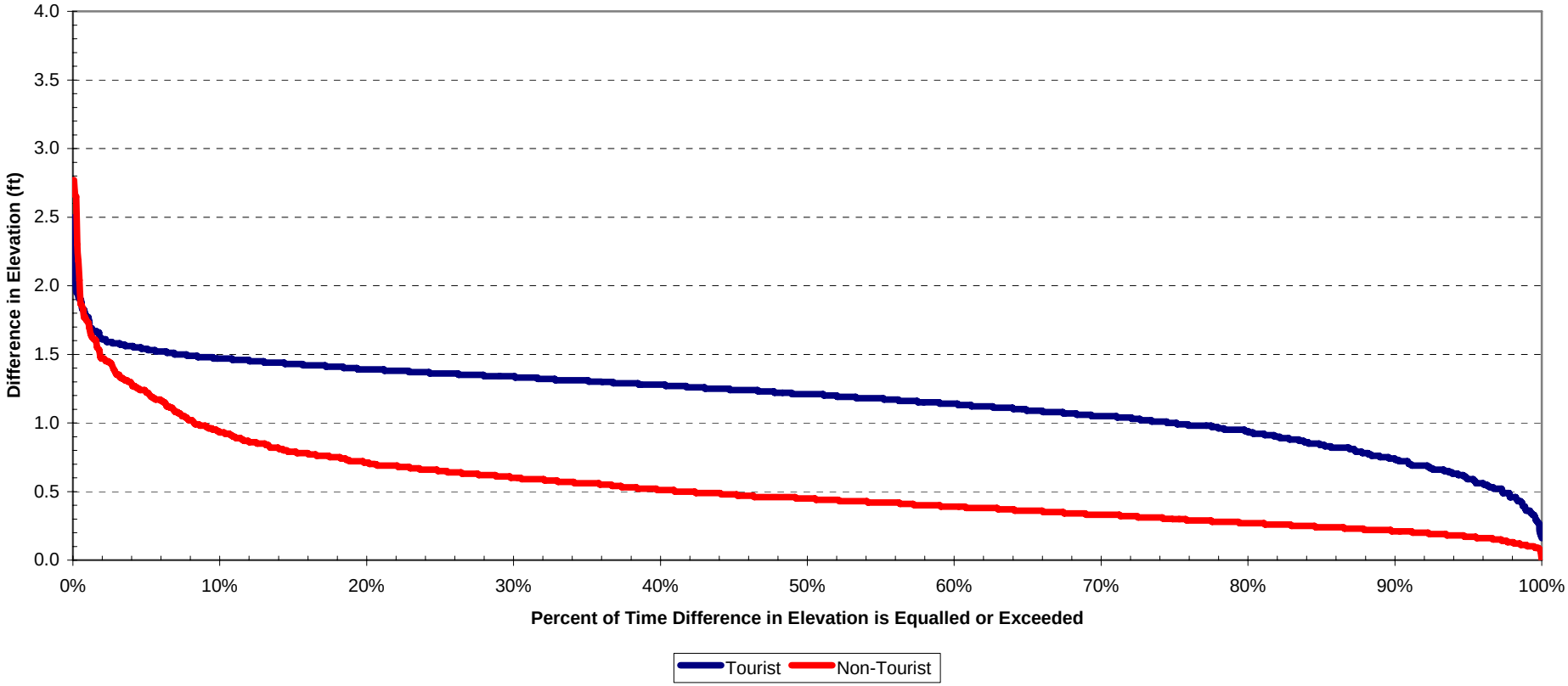

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FIGURE 4.5.1-9

SLATER'S POINT – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

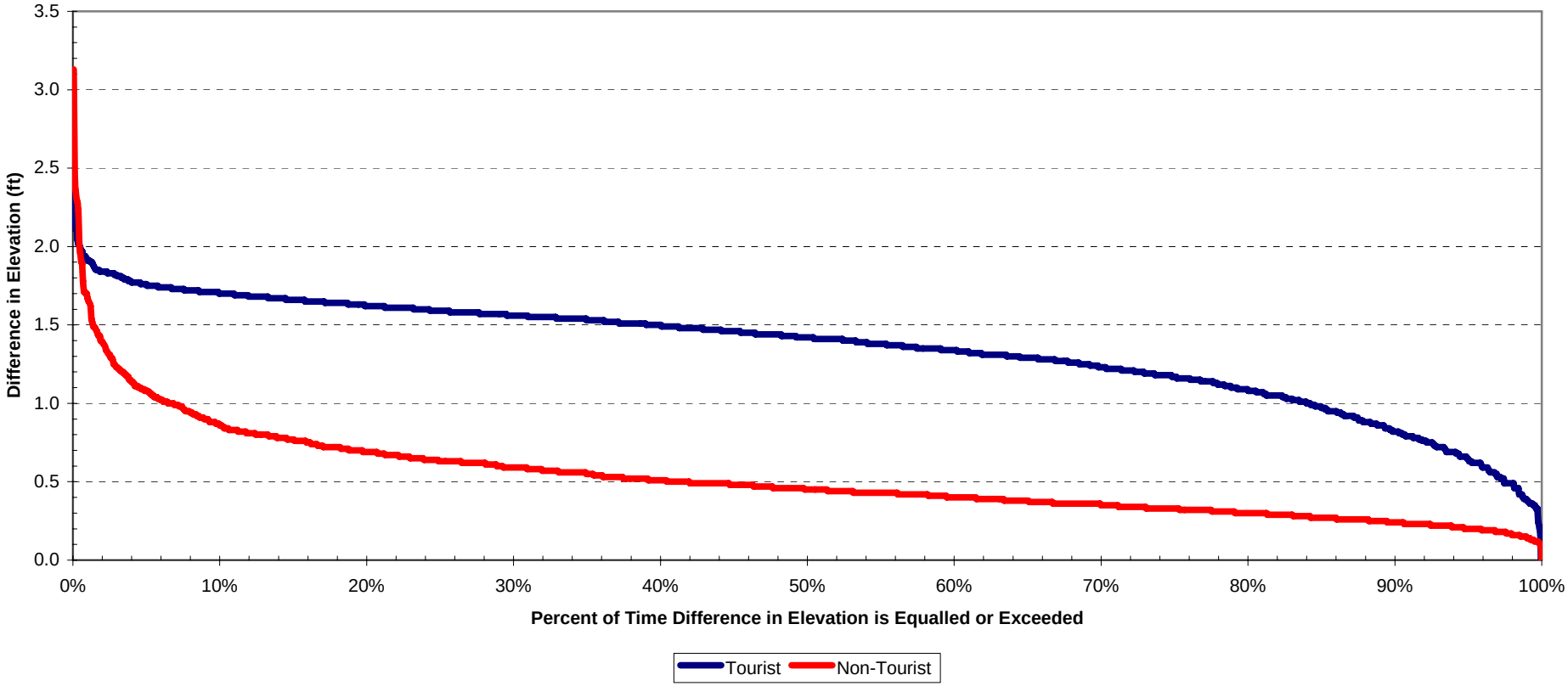

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FIGURE 4.5.1-10

NYPA INTAKE – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

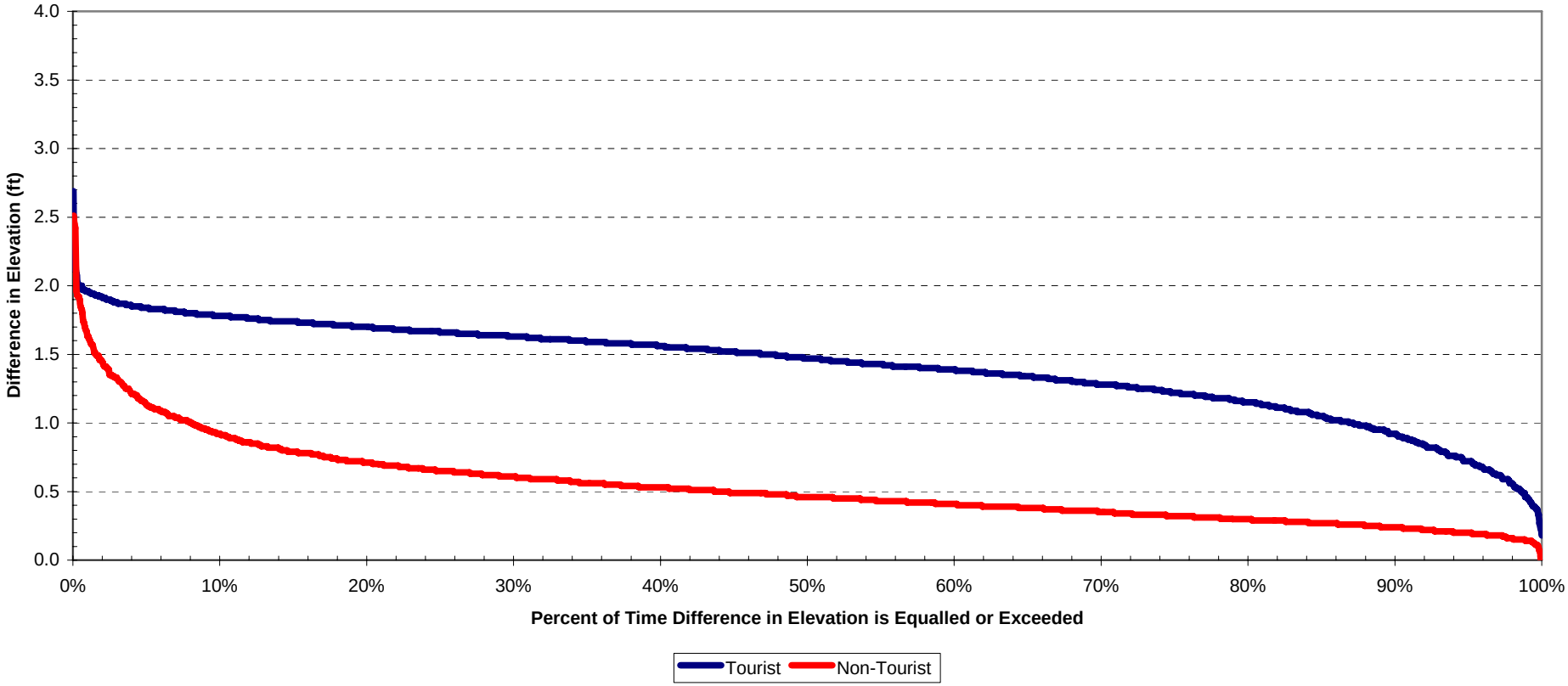

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FIGURE 4.5.1-11

MATERIAL DOCK – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

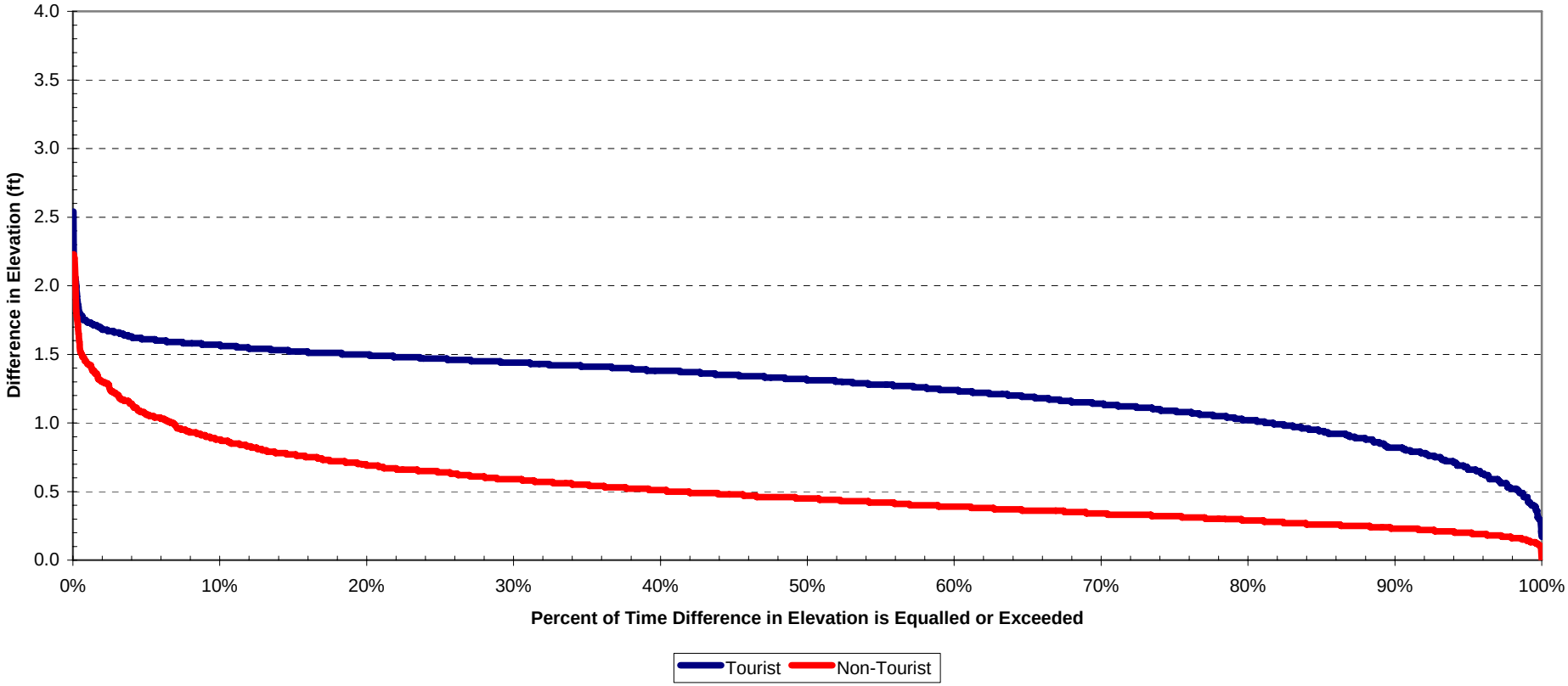

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FIGURE 4.5.1-12

AMERICAN FALLS – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

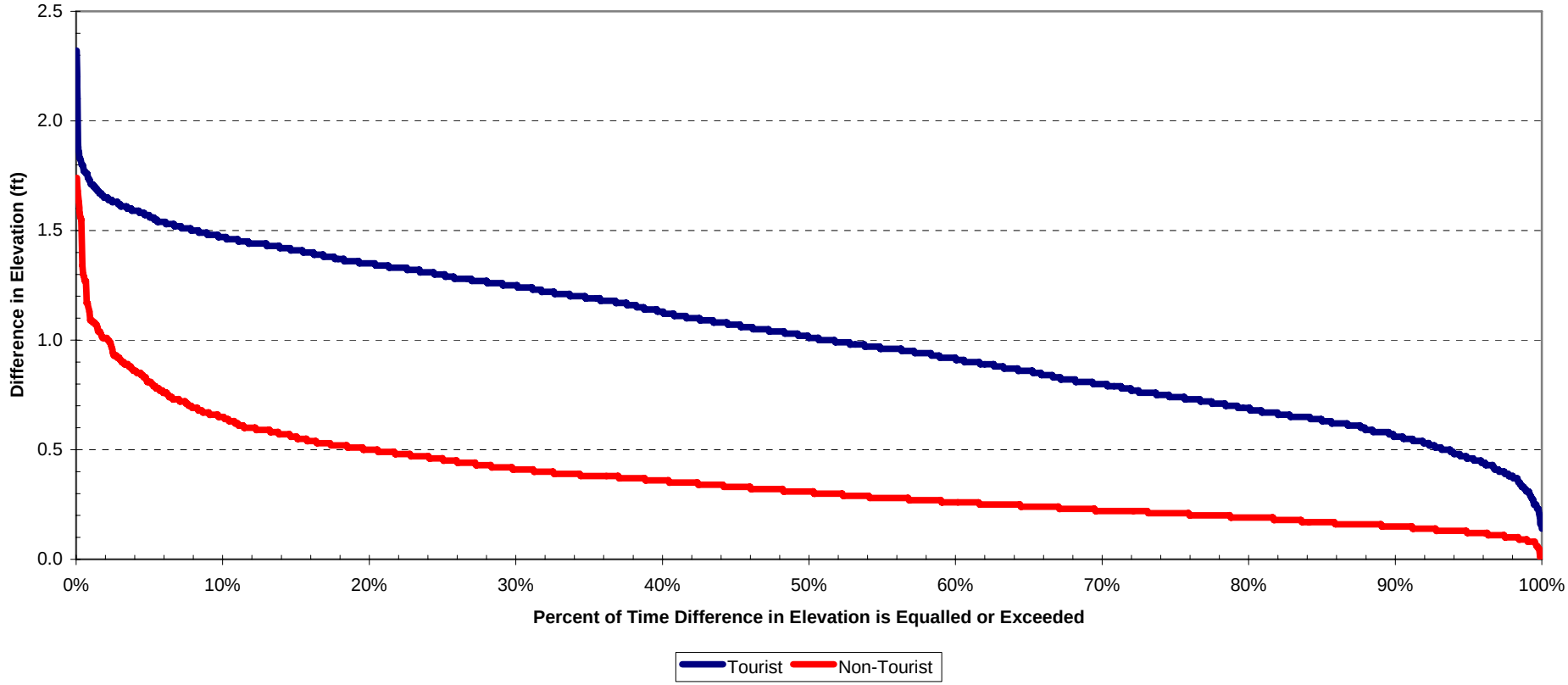

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FIGURE 4.5.2-1

LEWISTON RESERVOIR – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

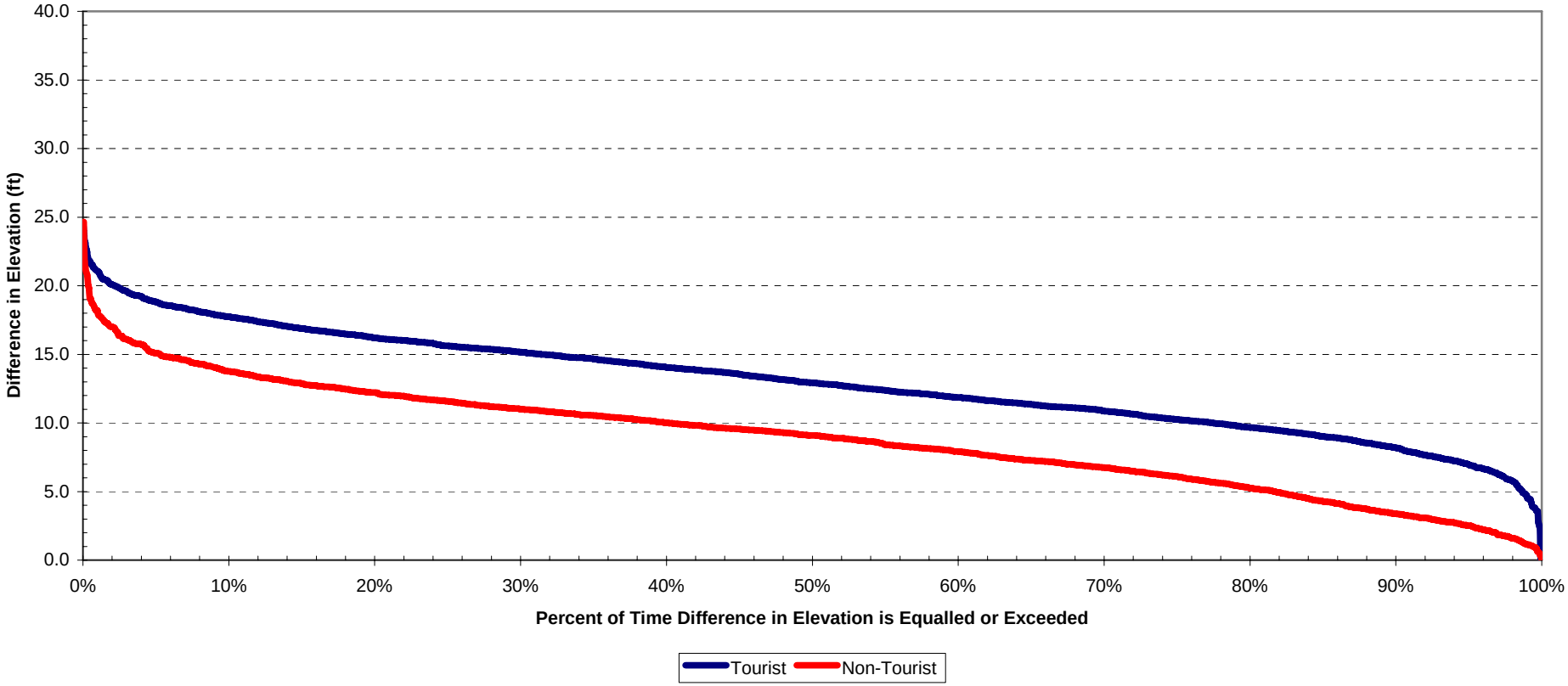

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FIGURE 4.5.2-2

LEWISTON RESERVOIR – DURATION ANALYSIS OF WEEKLY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

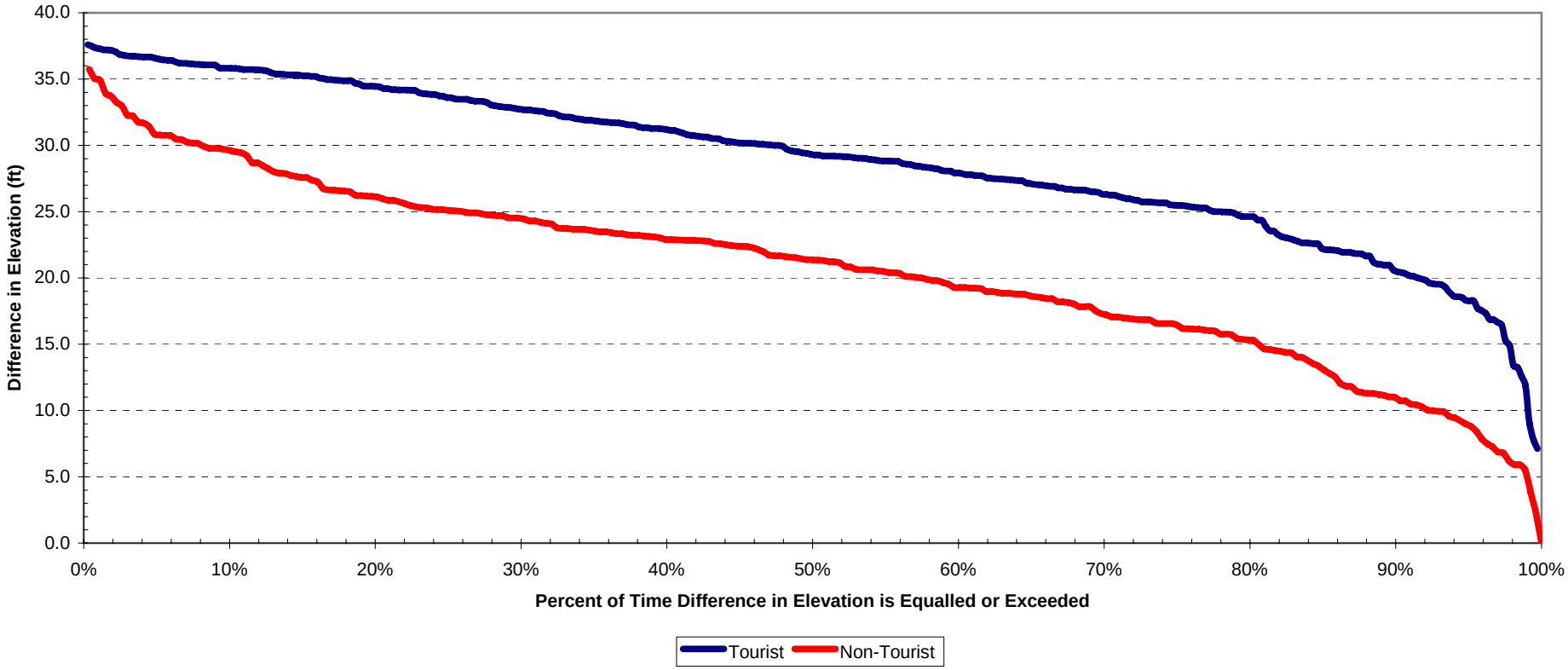

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FIGURE 4.5.3-1

ASHLAND AVE. (GN-ASHLAND) – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

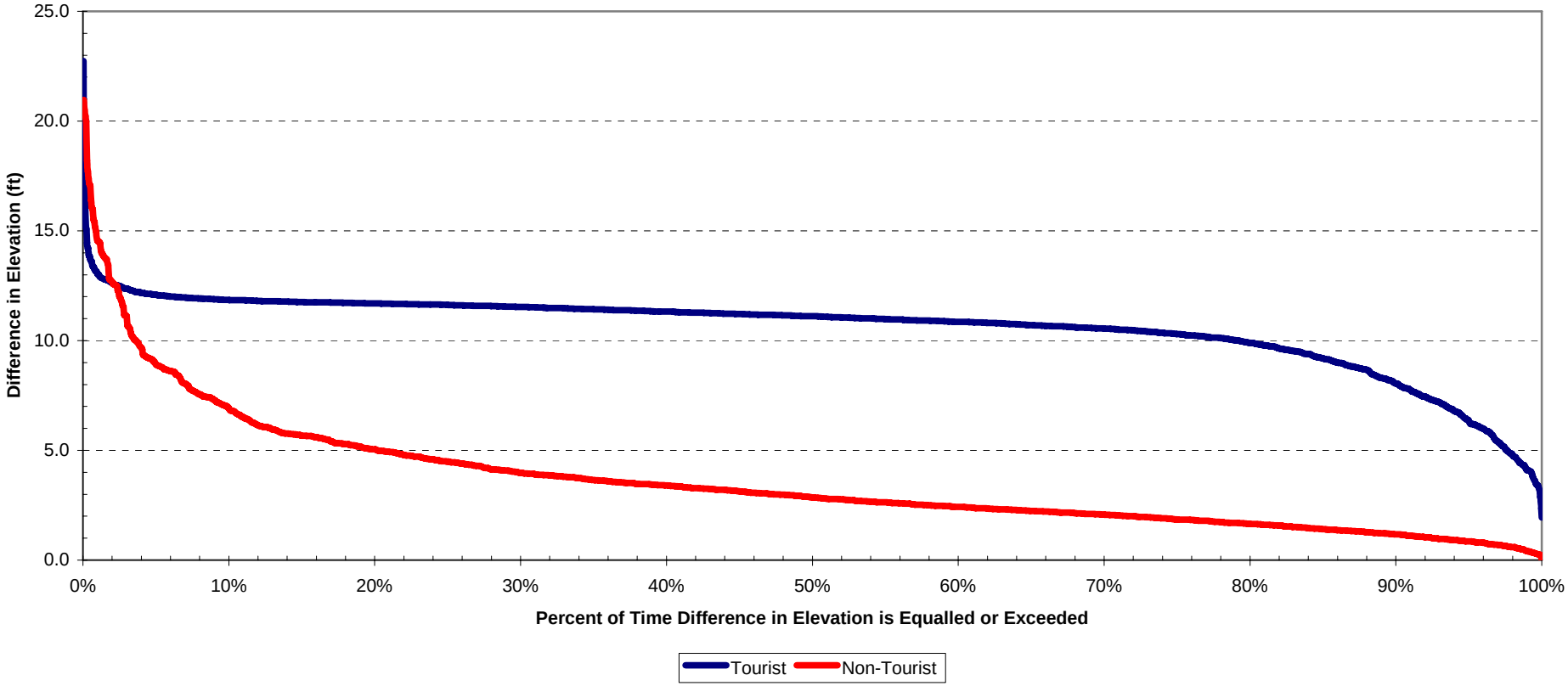

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FIGURE 4.5.3-2

PORT WELLER – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM WATER SURFACE ELEVATION DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

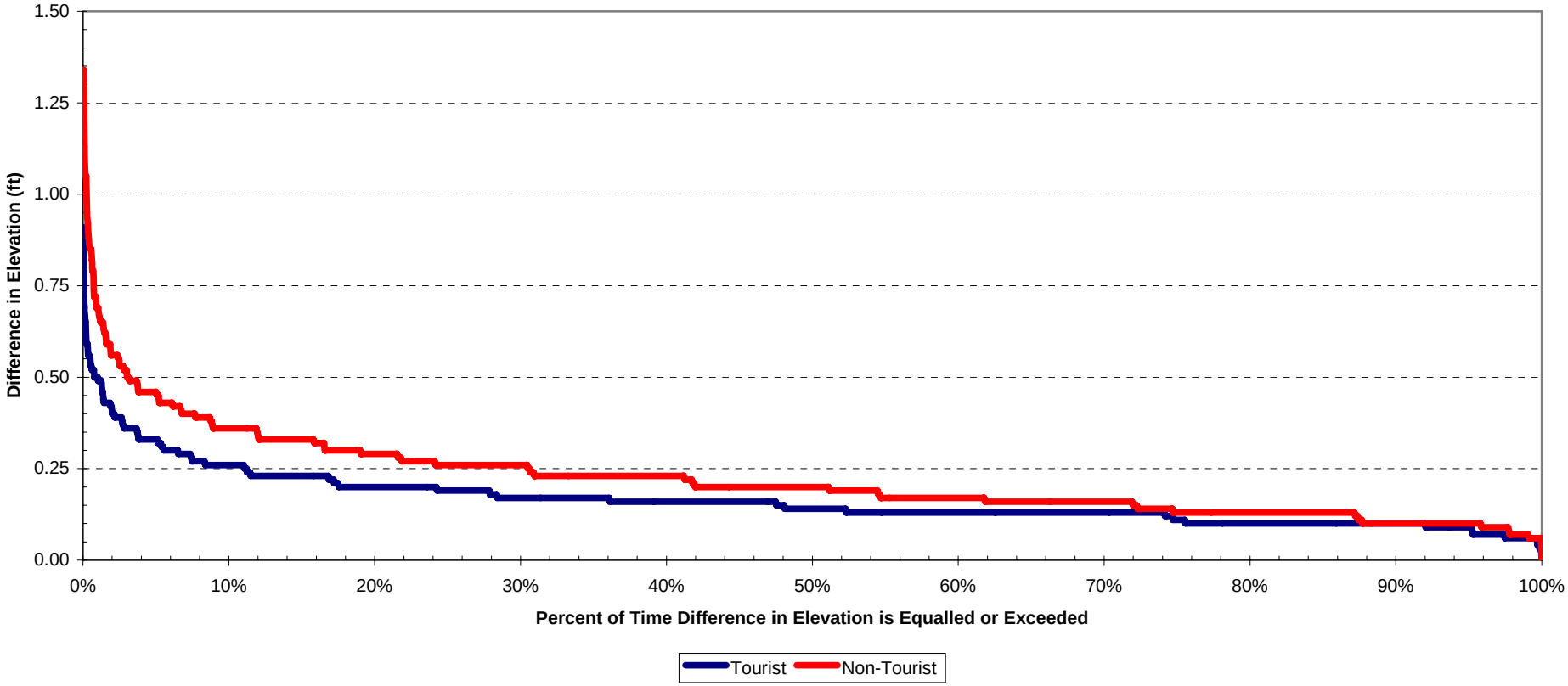

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FIGURE 4.5.4-1

FORT ERIE – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM FLOW DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)

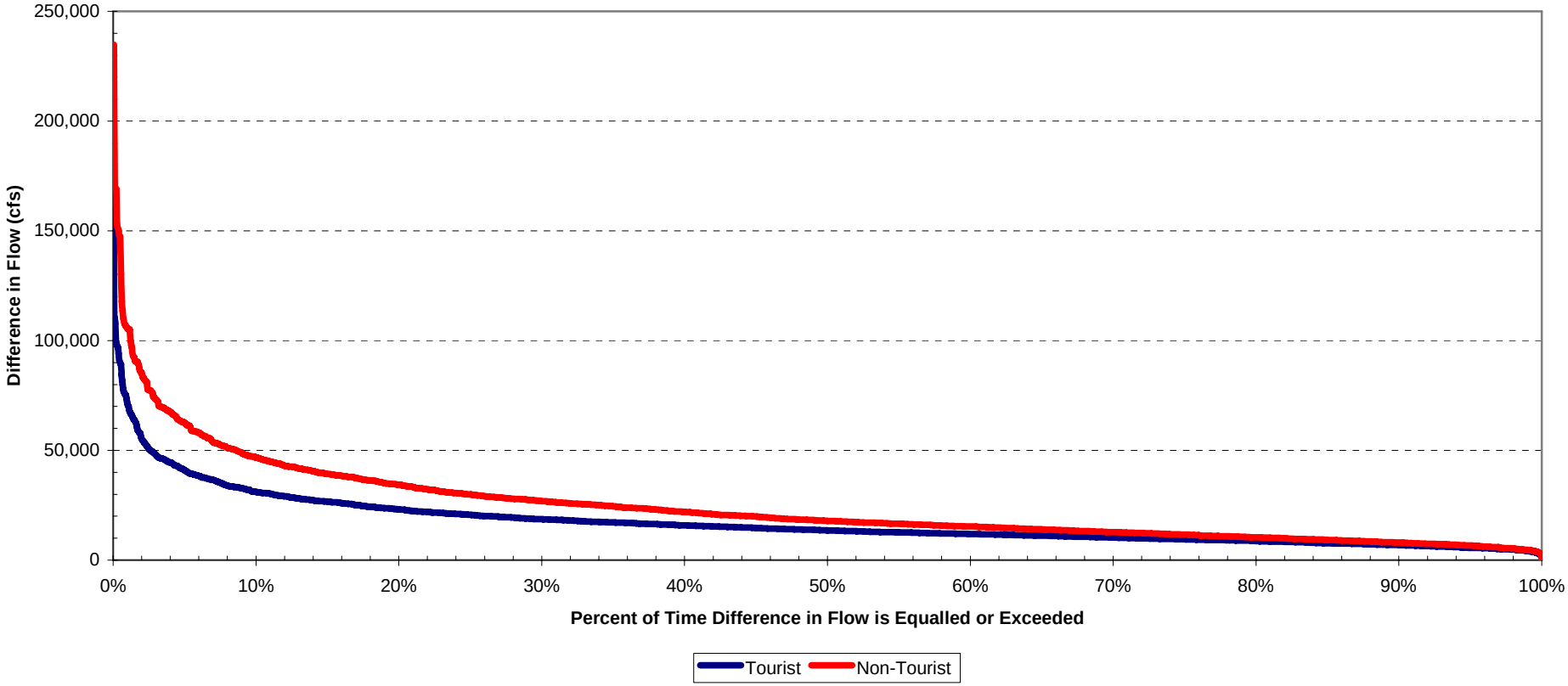

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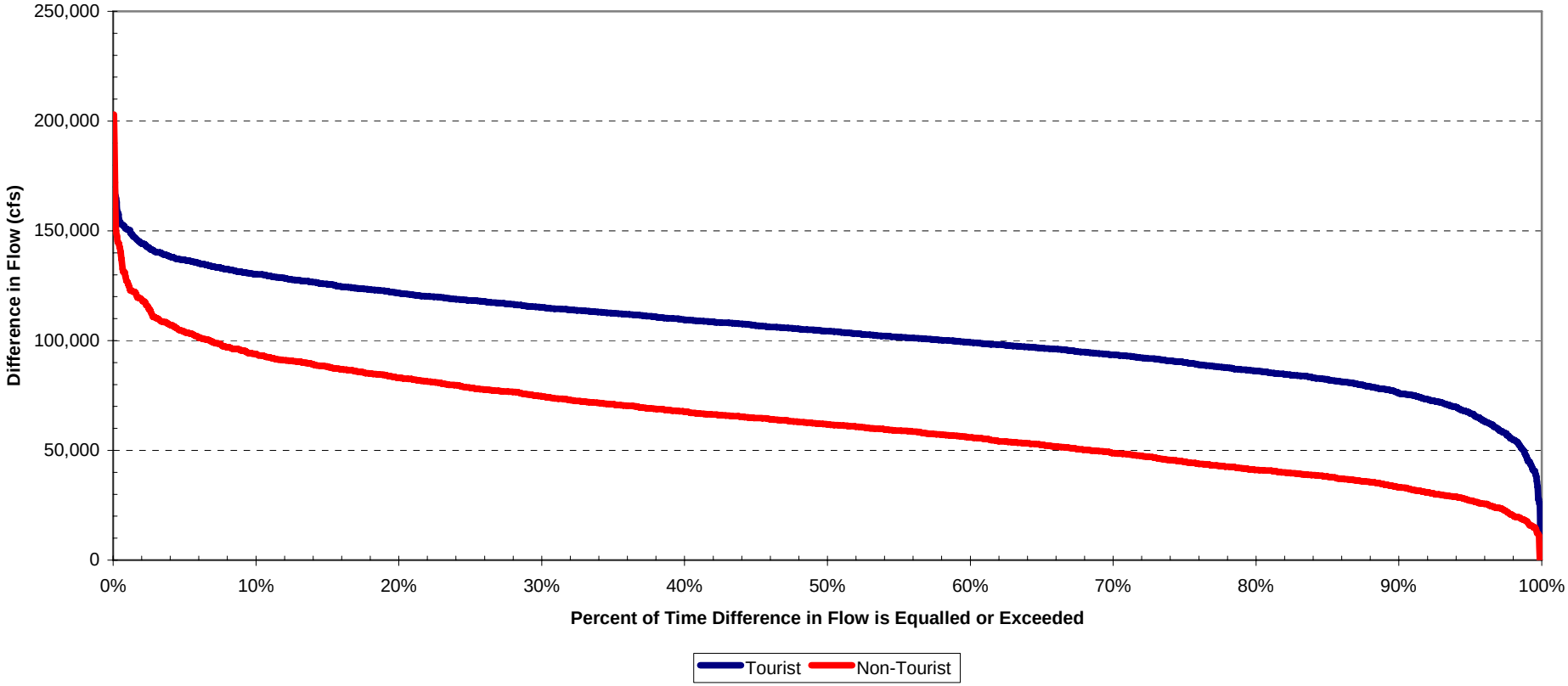
FIGURE 4.5.4-2

LOWER NIAGARA – DURATION ANALYSIS OF DAILY MAXIMUM AND MINIMUM FLOW DIFFERENCES FOR TOURIST AND NON-TOURIST PERIOD (1991-2002)



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This material is contained in:
Volume 2
Section: Niagara River Water Level and Flow Fluctuation Study Final Report

FIGURE 4.6.1-1

PROFILE AND WATER LEVEL FLUCTUATION - NIAGARA RIVER EXTREME EVENT, NOVEMBER 2, 1992

[NIP – General Location Maps]

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FIGURE 4.6.1-2

PROFILE AND WATER LEVEL FLUCTUATION - NIAGARA RIVER EXTREME EVENT, MARCH 9-10, 2002

[NIP – General Location Maps]

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FIGURE 4.8-1

INTERNATIONAL RAILWAY BRIDGE CROSS SECTION ON THE UPPER NIAGARA RIVER

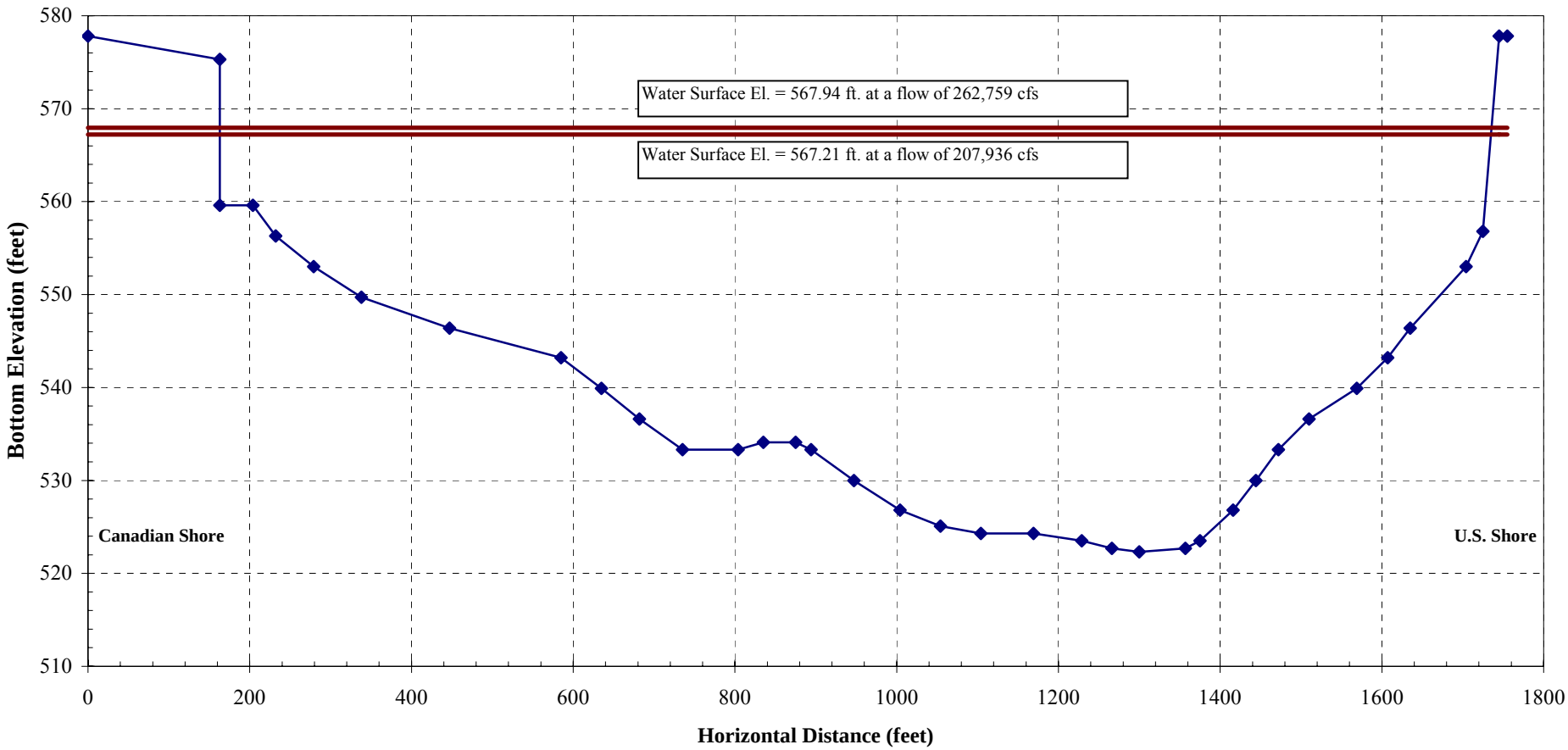

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FIGURE 4.8-2

ROBERT MOSES CABLEWAY CROSS SECTION ON THE LOWER NIAGARA RIVER

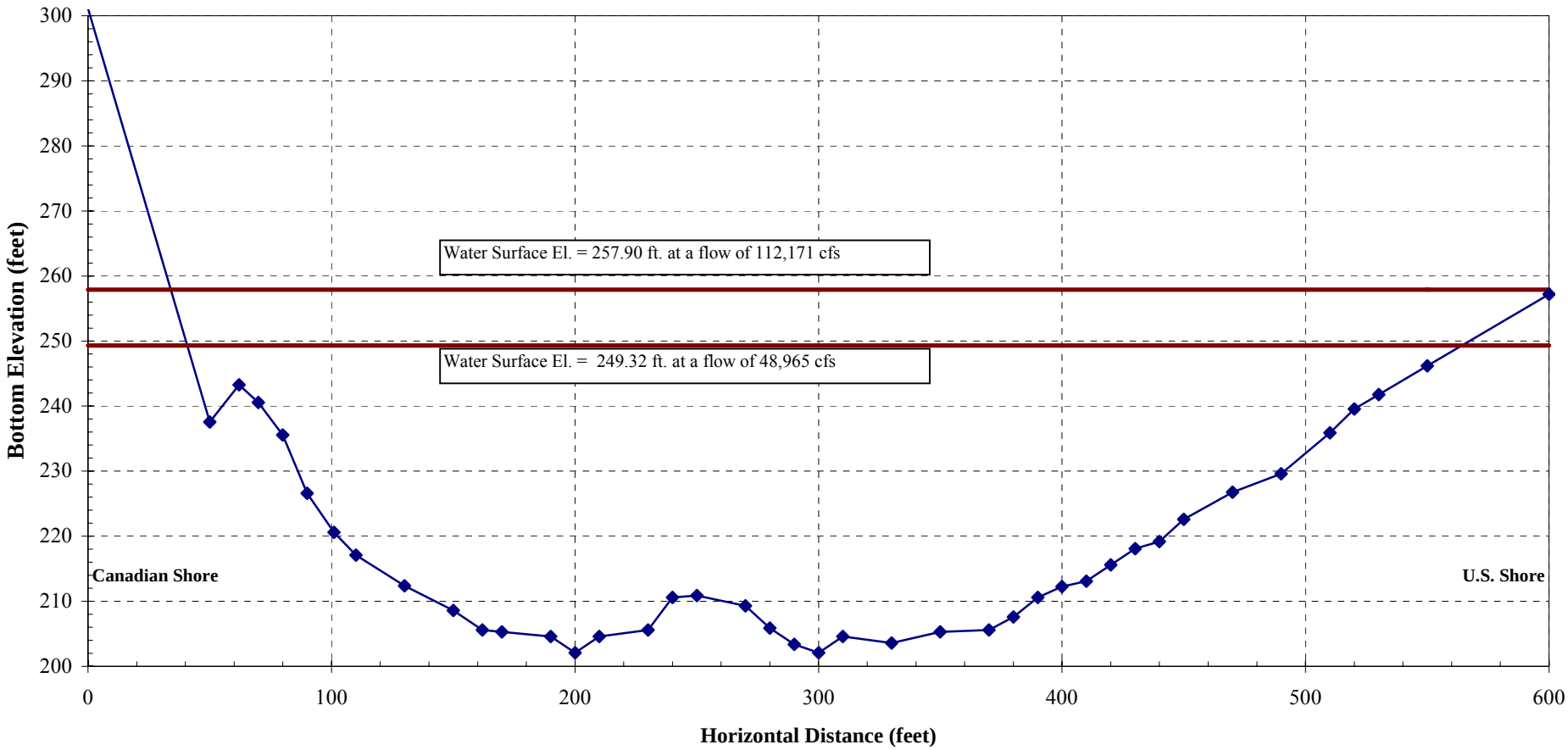

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FIGURE 4.8-3

LOWER NIAGARA RIVER AT ROBERT MOSES CABLEWAY AT 11:35 A.M. ON NOV. 8, 2001, DISCHARGE = 53,464 CFS, LOOKING DOWNSTREAM

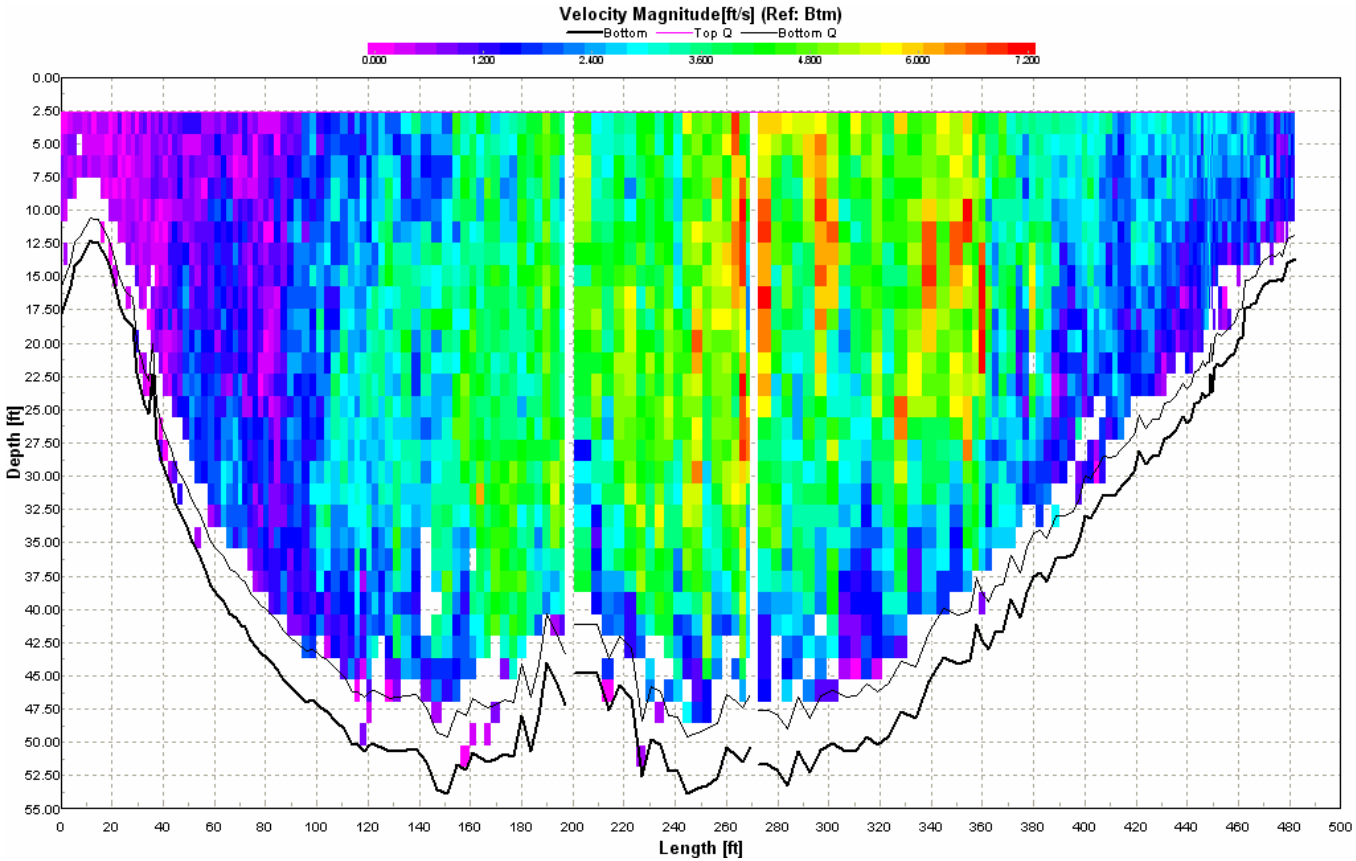

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FIGURE 4.8-4

LOWER NIAGARA RIVER AT ROBERT MOSES CABLEWAY AT 8:55 A.M. ON JUNE 6, 2002, DISCHARGE = 105,191 CFS, LOOKING DOWNSTREAM

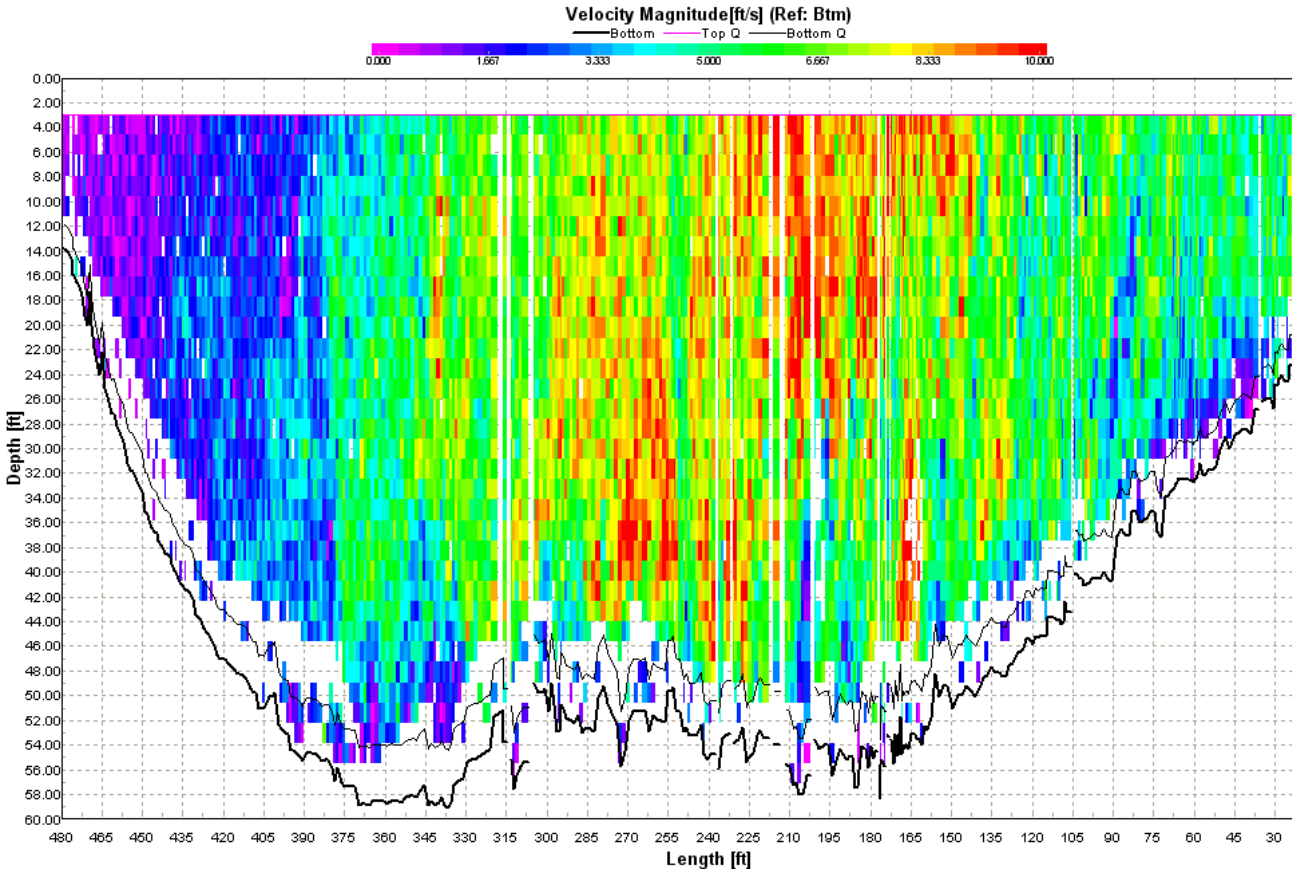

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FIGURE 4.10-1

DURATION CURVES OF WATER LEVELS AT FORT ERIE BEFORE AND AFTER NYISO OPERATIONS AND FOR 1991-2002

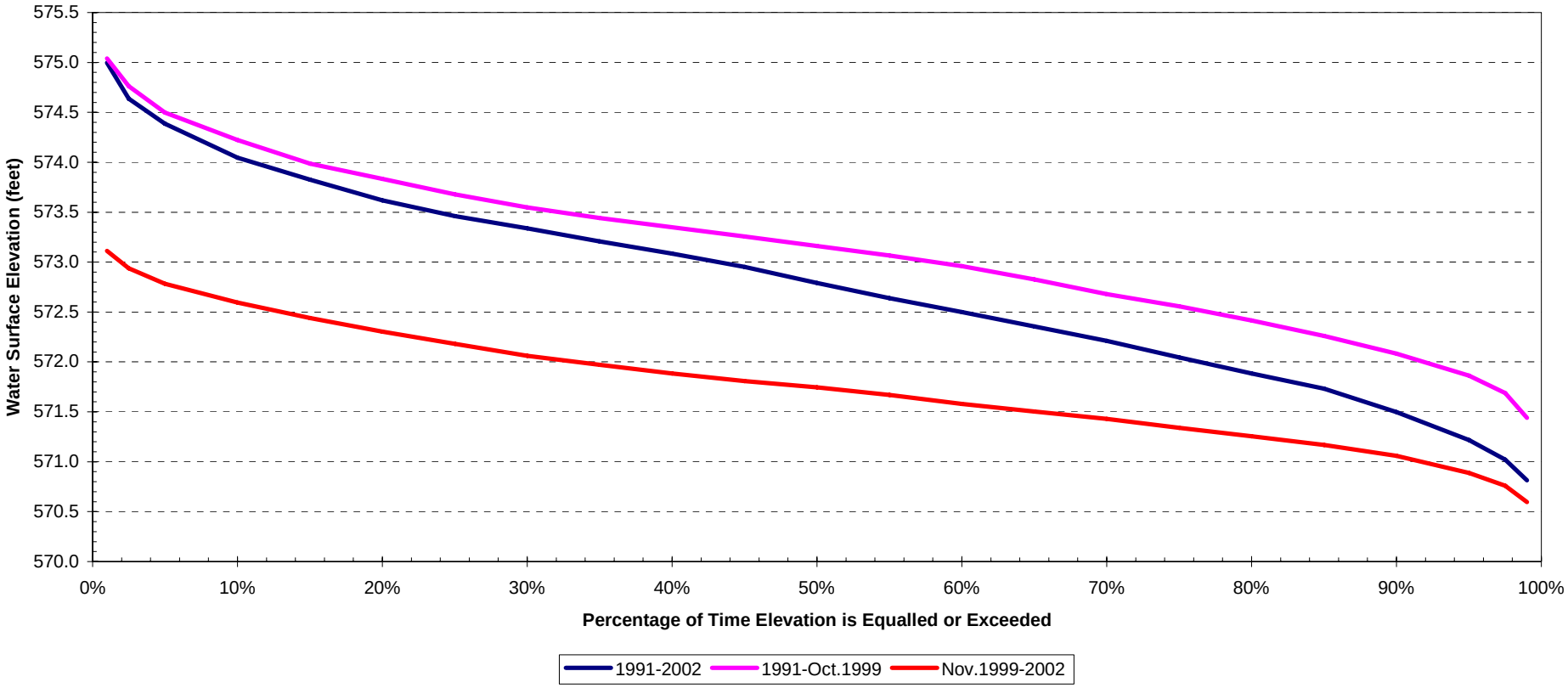

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FIGURE 4.10-2

DURATION CURVES OF WATER LEVELS AT FRENCHMAN'S CREEK BEFORE AND AFTER NYISO OPERATIONS AND FOR 1991-2002

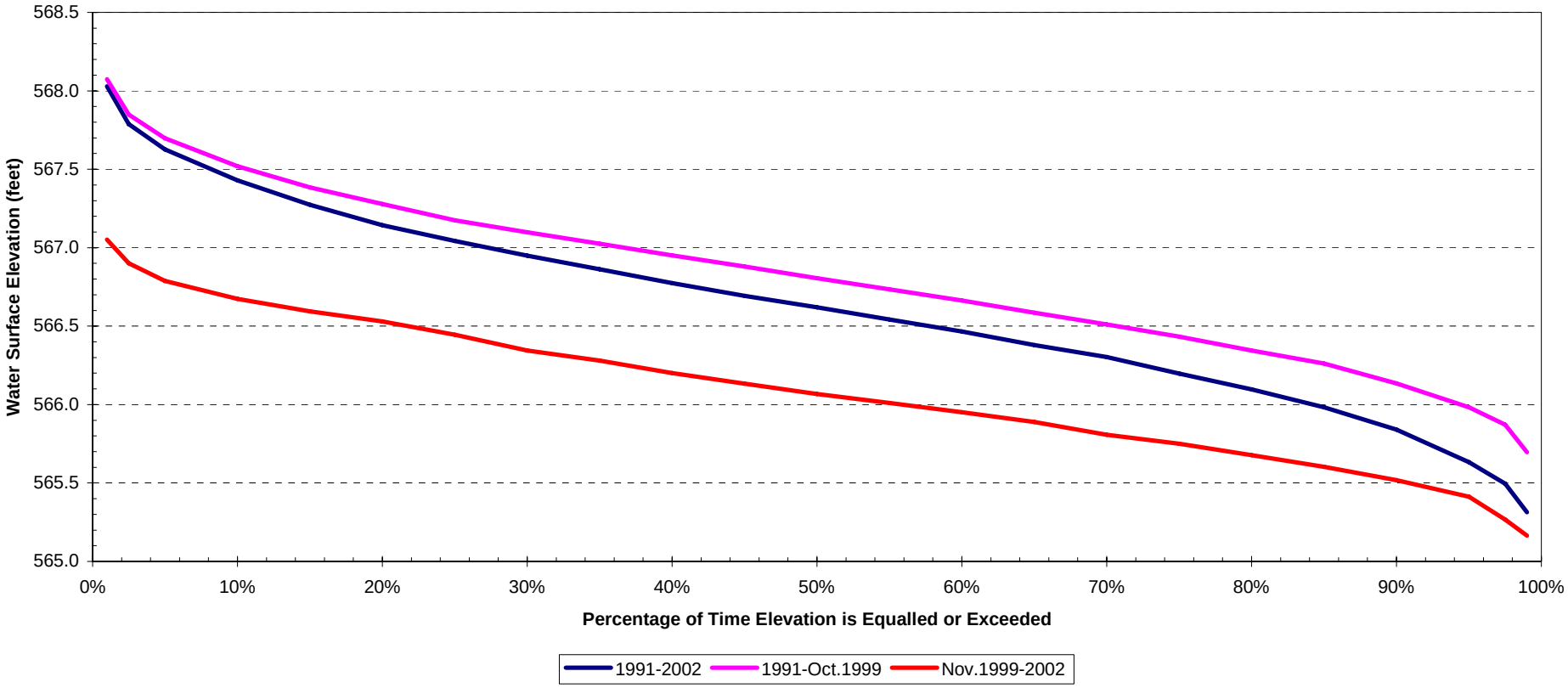

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FIGURE 4.10-3

DURATION CURVES OF WATER LEVELS AT MATERIAL DOCK BEFORE AND AFTER NYISO OPERATIONS AND FOR 1991-2002

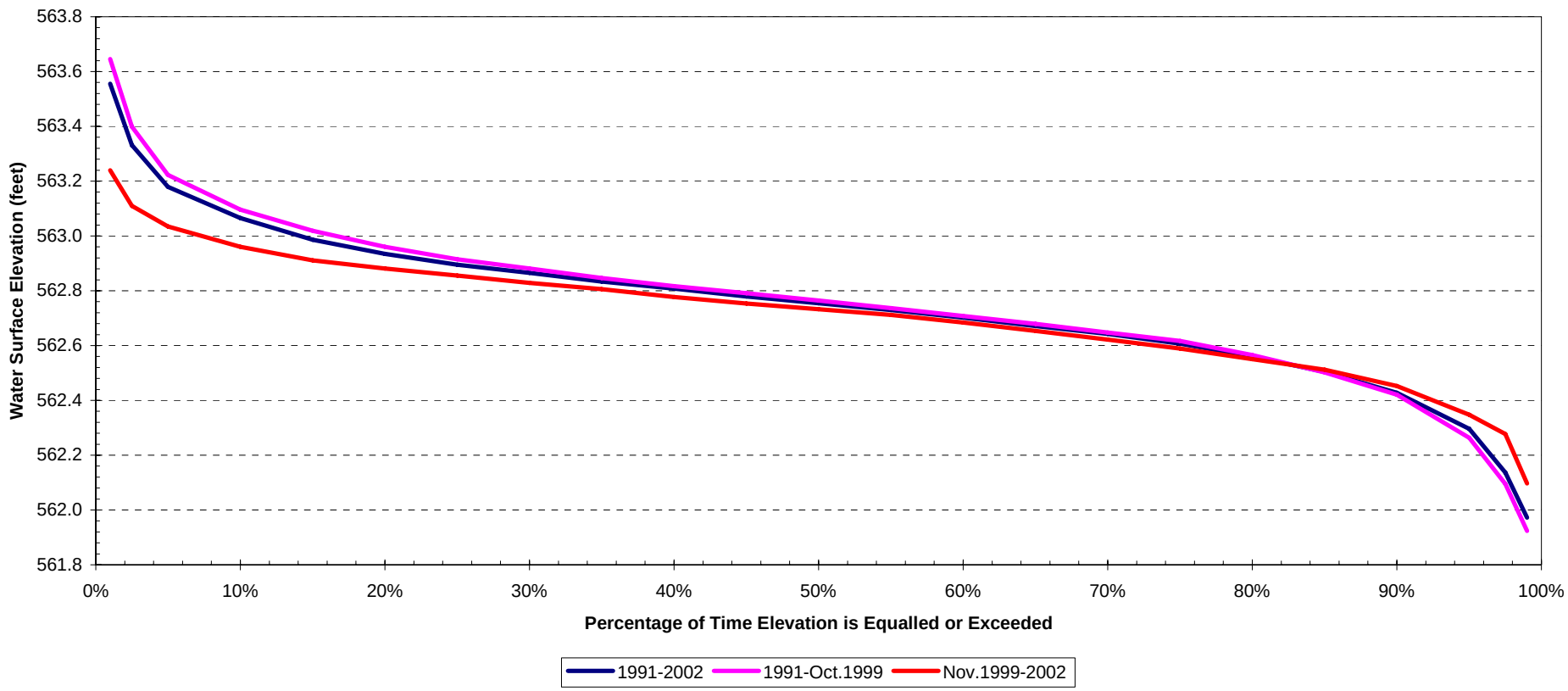

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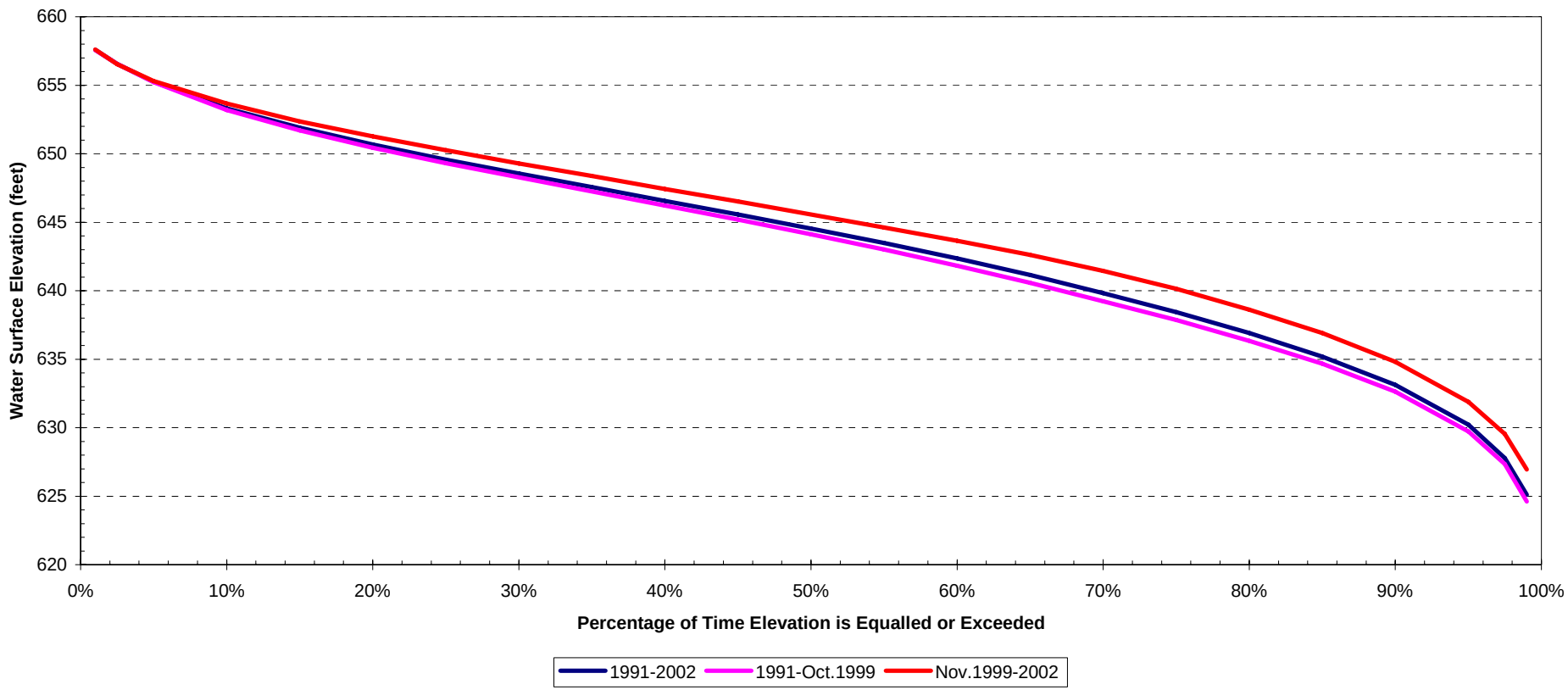
FIGURE 4.10-4

DURATION CURVES OF WATER LEVELS AT LEWISTON RESERVOIR BEFORE AND AFTER NYISO OPERATIONS AND FOR 1991-2002



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5.0 SUMMARY AND CONCLUSIONS

The fluctuation of water levels in the Niagara River is due to natural conditions such as flow surges from Lake Erie, wind, ice, local runoff and regional and long-term precipitation patterns as well as to manmade regulation of flow. Manmade regulation results from treaty-stipulations related to scenic flows over Niagara Falls and the use of Niagara River water for the generation of hydroelectric power. Water level in the Niagara River at any location at any time is therefore a complex function of both natural and human factors. The effects of manmade factors were confounded by natural factors, making a description of manmade effects alone, virtually impossible. So, analyses in this report provide a good description of the combined influence of all factors.

To estimate the relative effects of manmade regulation and natural conditions on water levels and their fluctuations over the length of the Niagara River, historical water level and flow data from 1991 to 2002 were analyzed. This period of record is representative of historic conditions in the Niagara River and includes both wet and dry years. The large database consulted (over 5 million entries) included hourly data for 15 water level and three flow gauges and 5 minute data from ten temporary water level gauges.

5.1 Water Level in the Upper Niagara River

Water level fluctuation in the upper Niagara River from all causes, including power production by both U.S. and Canadian plants and natural events, normally amounts to less than the 1.5 feet per day allowed by the INBC's 1993 Directive. The portion of upper-river water level changes attributable to power production is the result of varying withdrawals of water by the Power Entities, namely, NYPA and Ontario Power Generation. 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 the Pool is cycled more fully during the tourist period. 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.

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Lake Erie water levels and natural conditions, such as wind-generated flow surges and ice, also influence water levels in the upper Niagara River, especially during the non-tourist season. Water levels are higher in the upper Niagara River during the tourist season than the non-tourist season because the natural outflow from Lake Erie is higher. River flows are higher in spring and summer with the highest flows typically being in June. Lower river flows due to the natural water cycle of the Great Lakes characterize the winter months. The difference between median water levels in the tourist and non-tourist season is larger near Lake Erie and lessens as one goes downstream due to water level regulation of the Chippawa-Grass Island Pool. Table 4.1.1-1 and Table 4.1.1-2 list the range of monthly water levels for a typical year and dry year with the significant wind events excluded.

Table 4.5.1-1 compares the difference in daily median water level fluctuations for the tourist and non-tourist seasons at various gauges in the upper Niagara River. The amount of daily median water level fluctuation from all causes is highest at the gauges in the Chippawa-Grass Island Pool (NYPA Intake, Material Dock, LaSalle, and Slater's Point). The amount of daily fluctuation decreases as one proceeds upstream as the influence of regulation of water in the Chippawa-Grass Island Pool on Niagara River water levels lessens. The amount of median daily water level fluctuation during the tourist season is lowest at Huntley, Frenchman's Creek, and Peace Bridge gauges. The amount of daily fluctuation then increases as one travels upstream towards Lake Erie as the influence of storm surges from the lake increases.

Water levels in Buckhorn Marsh (inside the west and east weirs) on Grand Island are influenced by precipitation, flow surges from Lake Erie, and to a lesser extent daily water level fluctuations caused by hydroelectric power operations. Each of the two weirs in the marsh holds the water level fairly constant so that there is open water available in the marsh, while downstream of the weirs, the water level in the tributaries and surrounding marsh generally tends to follow the fluctuation patterns present in the river.

5.2 Water Level in the Lower Niagara River

During the tourist season, water levels in the lower Niagara River between Niagara Falls and the Sir Adam Beck and Robert Moses tailraces fluctuate 10-12 feet daily because of the 50,000 cfs difference in

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daytime and nighttime Falls flow. Since this reach of the river runs through a narrow gorge, a 50,000 cfs change in flow changes water level (or depth) more than stream width. Nine of the ten largest daily fluctuations, which were between 17 and 23 feet, were caused by high flow surges from Lake Erie.

Water levels downstream of the Robert Moses tailrace fluctuate much less than 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, water levels fluctuate in the lower Niagara River with the same pattern of flow fluctuations. Flows fluctuate due to changes in the Treaty flow and Canadian and U.S. hydroelectric generation. This effect is lessened as the flow travels downstream of the hydroelectric project tailraces.

In addition, the average water levels in the lower Niagara River downstream of the Robert Moses tailrace have a seasonal cycle related to the water level of Lake Ontario, since lake levels influence upstream water levels. Lake Ontario water levels are unrelated to Niagara River hydroelectric operations.

Water levels in the entire lower Niagara River downstream of the Falls are more constant during the non-tourist season because the Falls flow remains constant at 50,000 cfs during both daytime and nighttime hours and generation flows at the Niagara Power Project and OPG's Sir Adam Beck Project fluctuate less. Any large fluctuations in water level or flow in this reach during the non-tourist season are due primarily to natural events such as ice jams or very high flows (namely, those that exceed NYPA and OPG plant capacities) throughout the entire river.

5.3 Extent of Influence of Regulation of Chippawa-Grass Island Pool Water Levels on Water Level Fluctuation in the Upper Niagara River

The influence that water levels in the Chippawa-Grass Island Pool have on upstream water levels varies depending on river conditions. If there is a flow surge traveling down the river, the influence does not extend far upstream. On the other hand, for calm conditions on Lake Erie, this influence can extend to somewhere between the Frenchman's Creek and the Peace Bridge gauges. Impact of water level regulation at the Chippawa-Grass Island Pool on Fort Erie water levels (immediately upstream of the Peace Bridge) is virtually undetectable. Water level fluctuations at Fort Erie appear to be wholly caused

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by prevailing weather conditions, particularly wind speed and direction. These conclusions are based on a review of water surface profiles at different pool levels, plots of hourly water level data, timing of minimum and maximum water levels at different gauges, duration distribution analysis of daily water fluctuations, and analysis of extreme events.

This finding agrees with other evidence. There is an approximate 4-5 foot drop in water surface elevation between the Fort Erie and Peace Bridge gauges and another 1-2 foot drop in water surface elevation between the Peace Bridge and Frenchman's Creek gauges. It is no coincidence that Black Lock Rock is located here to facilitate navigation through this stream reach. The NRCC has also located its gauge to monitor water levels to calculate flows at Fort Erie. In order to obtain accurate readings for flow, water level gauges must be located where they are independent of backwater effects. Also this agrees with a previous study involving water level profiles. In 1969, while the Chippawa-Grass Island Pool was drawn down to dewater the American Falls for purposes of aerial photography and channel cleanup, water level data were collected at several locations (from upstream of Frenchman's Creek to the Fort Erie gauge) at different water levels for the Chippawa-Grass Island Pool. Although water levels changed at Fort Erie, the resulting water level profiles from Fort Erie to just above the Peace Bridge paralleled the changes that occurred in Lake Erie water levels. This would indicate that the effect of regulation of the Chippawa-Grass Island Pool was diminished in the reach downstream of the Peace Bridge (INWC 1988). It also has been reported by the Canadian Inland Water Directorate (1985) based on a field survey of the upper Niagara River, that there is a "shallow rock ledge or shoal area in the vicinity of the Peace Bridge that acts as a submerged weir controlling Lake Erie's outflow."

5.4 Extent of Influence of Regulation on Water Level Fluctuation in the Lower Niagara River

Because no permanent gauges have been established in the lower Niagara River between the tailrace and Lake Ontario, it is difficult to determine with certainty the extent of water level fluctuation downstream of the Robert Moses tailrace attributable to U.S. and Canadian power operations. From the temporary gauges that were employed in 2001 and 2002, it is apparent that water level fluctuations in the lower Niagara River are dampened over a relatively short distance downstream from the Robert Moses tailrace.

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The average daily water level fluctuation during the 2002 tourist season at the gauge closest to the tailrace is approximately 1.5 feet, with a range of 1.1 to 2.1 feet. The daily fluctuations decrease progressively at the temporary gauges located further downstream. At the most downstream temporary gauge near the river's mouth, the average daily fluctuation during this time was 0.6 feet. For comparison, the average daily water level fluctuation observed at the Port Weller gauge in Lake Ontario for the tourist season period of record (1991-2002) was 0.16 feet. Treaty flows and Canadian and U.S. hydroelectric generation have an effect on water levels and flows in the lower Niagara River to its mouth with Lake Ontario.

5.5 Lewiston Reservoir

Niagara Power Project operations determine the level of Lewiston Reservoir. Project operations react to the demand for energy and the Niagara River flow. Lewiston Reservoir water levels are higher during the non-tourist season, when storage in the lowest part of the reservoir is held in reserve in case it is needed to compensate for reduced diversion caused by ice problems. As a direct result, water level fluctuations are less during the non-tourist season.

Operation of the Niagara Power Project can result in water level fluctuations in the Lewiston Reservoir of 3-18 feet per day, and approximately 11-36 feet per week depending on the season and river flows. Weekly drawdowns are typically greater (21-36 feet) during the tourist season than the non-tourist season (11-30 feet).

5.6 Flows

Flow duration curves for tourist and non-tourist seasons were developed for the Fort Erie gauges as well as for the flow calculated in the lower Niagara River. Flows are usually higher during the tourist season, with the exception of severe winter storms causing high flow events during the non-tourist season. Flows in the tourist season range between 190,000 to 245,000 cfs in the upper Niagara River at Fort Erie and between 148,000 to 266,000 cfs in the lower Niagara River. The larger range of flows in the lower Niagara River shows the effect of Falls flow regulation and power generation on the lower Niagara River

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flows. Consequently, daily flow fluctuations in the upper Niagara River are less than those in the lower Niagara River.

During the non-tourist season, the range of flows in the lower Niagara River is more similar to those observed at Fort Erie.

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