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Flood Wave-Tide Wave Interaction on the James River During the Agnes Flood

John P. Jacobson

C. S. Fang
Virginia Institute of Marine Science

The Effects of Tropical Storm Agnes on the Chesapeake Bay Estuarine System

The Chesapeake Research Consortium, Inc.

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THE CHESAPEAKE RESEARCH CONSORTIUM, INC.

The Johns Hopkins University
Smithsonian Institution
University of Maryland
Virginia Institute of Marine Science

Project Coordinator, Jackson Davis (VIMS)
Volume Coordinator, Beverly Laird (VIMS)

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Preface

During June 1972 Tropical Storm Agnes released record amounts of rainfall on the watersheds of most of the major tributaries of Chesapeake Bay. The resulting floods, categorized as a once-in-100-to-200-year occurrence, caused perturbations of the environment in Chesapeake Bay, the nation's greatest estuary.

This volume is an attempt to bring together analyses of the effects of this exceptional natural event on the hydrology, geology, water quality, and biology of Chesapeake Bay and to consider the impact of these effects on the economy of the Tidewater Region and on public health.

It is to be hoped that these analyses of the event will usefully serve government agencies and private sectors of society in their planning and evaluation of measures to cope with and ameliorate damage from estuarine flooding. It is also to be hoped that the scientific and technical sectors of society will gain a better understanding of the fundamental nature of the myriad and interrelated phenomena that is the Chesapeake Bay ecosystem. Presumably much of what was learned about Chesapeake Bay will be applicable to estuarine systems elsewhere in the world. Most of the papers comprising this volume were presented at a symposium held May 6–7, 1974, at College Park, Maryland, under the sponsorship of the Chesapeake Research Consortium,Inc., with support from the Baltimore District, U.S. Army Corps of Engineers (Contract No. DACW 31-73-C-0189). An early and necessarily incomplete assessment, *The Effects of Hurricane Agnes on the Environment and Organisms of Chesapeake Bay* was prepared by personnel from the Chesapeake Bay Institute (CBI), the Chesapeake Biological Laboratory (CBL), and the Virginia Institute of Marine Science (VIMS) for the Philadelphia District, U.S. Army Corps of Engineers. Most of the scientists who contributed to the early report conducted further analyses and wrote papers forming a part of this report on the effects of Agnes. Additional contributions have been prepared by other scientists, most notably in the fields of biological effects and economics.

The report represents an attempt to bring together all data, no matter how fragmentary, relating to the topic. The authors are to be congratulated for the generally high quality of their work. Those who might question, in parts of the purse, the fineness of the silk must keep in mind the nature of the sow's ears from which it was spun. This is not to disparage the effort, but only to recognize that the data were collected under circumstances which at best were less than ideal. When the flood waters surged into the Bay there was no time for painstaking experimental design. There were not enough instruments to take as many measurements as the investigators would have desired. There were not enough containers to obtain the needed samples or enough reagents to analyze them. There were not enough technicians and clerks to collect and tabulate the data. While the days seemed far too short to accomplish the job at hand, they undoubtedly seemed far too long to the beleaguered field parties, vessel crews, laboratory technicians, and scientists who worked double shifts regularly and around the clock on many occasions. To these dedicated men and women, whose quality of performance and perseverance under trying circumstances were outstanding, society owes an especial debt of gratitude.

It should be noted that the Chesapeake Bay Institute, the Chesapeake Biological Laboratory, and the Virginia Institute of Marine Science, the three major laboratories doing research on Chesapeake Bay, undertook extensive data-gathering programs, requiring sizable commitments of personnel and equipment, without assurance that financial support would be provided. The emergency existed, and the scientists recognized both an obligation to assist in ameliorating its destructive effects and a rare scientific opportunity to better understand the ecosystem. They proceeded to organize a coordinated program in the hope that financial arrangements could be worked out later. Fortunately, their hopes proved well founded. Financial and logistic assistance was provided by a large number of agencies

that recognized the seriousness and uniqueness of the Agnes phenomenon. A list of those who aided is appended. Their support is gratefully acknowledged.

This document consists of a series of detailed technical reports preceded by a summary. The summary emphasizes effects having social or economic impact. The authors of each of the technical reports are indicated. To these scientists, the editors extend thanks and commendations for their painstaking work.

Several members of the staff of the Baltimore District, U.S. Army Corps of Engineers, worked with the editors on this contract. We gratefully acknowledge the helpful assistance of Mr. Noel E. Beegle, Chief, Study Coordination and Evaluation Section, who served as Study Manager; Dr. James H. McKay, Chief, Technical Studies and Data Development Section; and Mr. Alfred E. Robinson, Jr., Chief of the Chesapeake Bay Study Group.

The editors are also grateful to Vickie Krahn for typing the Technical Reports and to Alice Lee Tillage and Barbara Crewe for typing the Summary.

The Summary was compiled from summaries of each section prepared by the section editors. I fear that it is too much to hope that, in my attempts to distill the voluminous, detailed, and well-prepared papers and section summaries, I have not distorted meanings, excluded useful information or overextended conclusions. For whatever shortcomings and inaccuracies that exist in the Summary, I offer my apologies.

Jackson Davis
Project Coordinator

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The Chesapeake Research Consortium, Inc. is indebted to the following groups for their logistic and/or financial aid to one or more of the consortium institutions in support of investigations into the effects of Tropical Storm Agnes.

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- Naval Ordnance Laboratory
- Coastal River Squadron Two, Little Creek, Virginia
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- Explosive Ordnance Disposal Unit Two, Fort Story, Virginia
- Naval Ordnance Laboratory, White Oak, Maryland

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- Coast Guard Station, Little Creek, Virginia
- Portsmouth Supply Depot
- Light Towers (Diamond Shoal, Five Fathom Bank, and Chesapeake)

National Oceanic and Atmospheric Administration
- National Marine Fisheries Service (Woods Hole, Massachusetts and Sandy Hook, New Jersey)

The National Science Foundation

Food and Drug Administration

Environmental Protection Agency

U. S. Office of Emergency Preparedness

State of Maryland, Department of Natural Resources

Commonwealth of Virginia, Office of Emergency Preparedness

TABLE OF CONTENTS

C. Water Quality Effects

D. Biological Effects

FLOOD WAVE-TIDE WAVE INTERACTION ON THE JAMES RIVER DURING THE AGNES FLOOD[1]

John P. Jacobson[2]
C. S. Fang[2]

ABSTRACT

During the Agnes flood hourly tidal height data were collected at seven locations along the tidal James River and currents were measured at two transects in the lower James. A comparison between actual tides and currents and the predicted tidal features as given by the tide and tidal current tables of NOAA was made. Results of this comparison show that Agnes did significantly affect water levels in the upper portion of the tidal James, especially near Richmond. However in the lower portion of the James no discernible rise was evident due to the passage of the flood crest. A small storm surge (<2 feet) was noted on the day of the passage of Agnes, 21 June, throughout the tidal James. A phase shift in times of high and low water due to the interaction of the two wave systems was not observed. In the freshwater portion of the tidal James currents continually ebbed during the passage of the flood crest. In the saline portion of the system, the flood effect on the currents was limited to the surface portion of the channel.

INTRODUCTION

The James River, the largest river in Virginia, is approximately 400 miles in length with a drainage area of over 10,000 square miles. It is tidal from its mouth at Hampton Roads to Richmond, a distance of about 100 miles with an average tidal range of 3 feet. The tides at Richmond lag those at the mouth by 5 hours, the time it takes the shallow water wave to travel up the river. The average depth of the tidal portion of the James is approximately 20 feet. The average saltwater intrusion reaches to Jamestown Island, 40 miles upstream. The flood wave generated by Agnes also was a shallow water wave. The interaction of these two wave systems, the tide wave traveling upstream and the flood wave moving downstream, is studied using tide gage data, current meter data and the tide and tidal current prediction tables of NOAA.

METHODS

During the Agnes flood, 7 tide gages on the James remained operational. These data were provided to the Virginia Institute of Marine Science (VIMS) by the Baltimore District Corps of Engineers. In addition, current velocity and direction were measured at two transects in the lower James using savonius rotor current meters (Fig. 1). These meters were placed in the river on 24 June 1972 and remained operational for over one month. By comparing the recorded data

[1]Contribution No. 757, Virginia Institute of Marine Science
[2]Virginia Institute of Marine Science, Gloucester Point, Va. 23062

against the predicted tides and currents from the NOAA tide tables, the wave interaction was determined.

WATER LEVELS AT RICHMOND

Records available at Richmond indicate that the James started rising on the afternoon of 21 June 1972 (Fig. 2). The observed crest was 36.5 feet, 27.5 feet above flood stage, which occurred at 4PM on 23 June 1972. By 27 June the river at Richmond had fallen to normal water levels. The crest travelled downstream as a kinematic wave at a speed of somewhat less than 5 MPH. Thus the maximum effect of the flood wave on the tidal James should be seen during the period 23-25 June. Flows on the tributaries to the James below Richmond were less than 1/10 those at Richmond and are therefore neglected in the analysis.

WATER LEVELS

At Hopewell, river mile 76, the tide gage record (Fig. 3) shows two distinct peaks in the difference between the predicted and actual tide, one on 21 June when Agnes passed and the other on 24 June due to the passage of the flood wave. The peak on the 21st is probably due to the combined effects of low barometric pressure, wind and local rainfall and runoff causing a small storm surge (<2 feet) which was observed throughout the tidal portion of the river. The major feature, on 24 June, due to the flood, shows large oscillations (>3 feet) in the difference between actual and predicted tides. Looking at the actual water surface there is very little tidal fluctuation (<0.5 foot) whereas the tide range is usually about 3 feet. The flood wave is interacting with the tide wave almost totally washing out the tidal oscillation. Thus when a difference is taken between the observed and predicted tidal heights the normal tidal oscillation is misleadingly emphasized. The maximum difference of 5 feet was observed on 24 June. A phase shift due to the interaction of the wave systems was not obvious.

Further downstream, at Wilcox Wharf, (Fig. 4) river mile 69, a similar situation exists. Two peaks are again observed, on the 21st and on the 24th. However the anomaly on the 24th is less severe than at Hopewell, approximately 3 feet, due to the larger cross-sectional area and thus a larger volume in this segment of river to accept the flood waters. No phase shift in time of high and low water was noted.

At Claremont, (Fig. 5) river mile 52, two peaks are still discernible, but now they are equal in height, approximately one foot. No phase shift occurred. At Scotland, (Fig. 6) by Jamestown Island at river mile 42, two distinct peaks of about one foot remain discernible and again occur on the 21st and 24th. No phase shift was detectable at this location. This tide gage is located near the normal limit of saltwater intrusion. However, the flood waters of Agnes moved this intrusion limit 20 miles downstream. Current measurements were taken near this point which will be commented on later.

The flood crest was not discernible from tide records at the lower 3 stations, Holliday Point (Fig. 7) on the Nansemond River (river mile 10) Sewells Point (Fig. 8, river mile 3), and Old Point Comfort (Fig. 9) at the mouth. The storm surge on the 21st is again noticeable as it was throughout the tidal portion of the James. Thus a rare hydrological event such as the flood of Agnes, the worst flood on record at Richmond, had no appreciable effect on the water surface elevation of the lower tidal James. It appears that water levels in the lower tidal James are much more affected by storm surge associated with hurricanes than the flood water that may be released.

CURRENTS

Current meters were set by VIMS at two transects in the James on 24 June 1972 shortly after Agnes left the area. One transect was located at Jamestown Island, river mile 40, and the other was off Newport News just below the James River Bridge at river mile 11. The current meters were set just prior to the passage of the Agnes flood crest.

At the Jamestown transect two current meter stations were occupied. On the south side, in the flats part of the river, flood current was recorded for only one hour during each of the first two tidal cycles after emplacement (top, Fig. 10). This is due to the passage of the flood crest. On the afternoon of 25 June the current returned to a more normal duration of ebb and flood. A phase shift may be noticed here but this probably is due to increased friction and decreased wave speed in the shallows rather than wave interaction. In the channel (bottom, Fig. 10), the current at all depths ebbed continuously for the one full tidal cycle recorded on the 24th. On 25 June the current returns to near predicted values. Thus, at this freshwater transect currents due to the flood wave were large enough to keep the tide from flooding over the whole cross-section for at least one full tidal cycle. The effect of the flood wave is evident longer in the shallows due to a slower time of travel caused by the lesser depth. No phase shift is evident in the main channel.

Near the mouth of the James, a different situation prevailed. In the flats area on the south side of the river, the predicted and recorded currents coincided closely (top, Fig. 11). This is despite the fact that salinity recorded in conjunction with the current measurements indicate that the water is less than 2 ppt (usually greater than 15 ppt) at that station during 24-26 June. In the main channel, near the surface (3 feet), the tide does not flood for the first two tidal cycles recorded, on the 24th and 25th (bottom, Fig. 11). However at the lower depths, 15 feet and 26 feet, the tide floods and ebbs as predicted. Thus in this saline portion of the river, the influence of the flood wave is found mainly in the channel and only in the essentially fresh surface layer that is overriding the salt water. Currents return quickly to correspond with predictions after the passage of the flood. No phase shift was evident.

SUMMARY AND CONCLUSIONS

Agnes did significantly affect water levels in the upper portion of the tidal James, especially near Richmond. In the lower portion of the James no discernible rise was evident due to the passage of the flood wave. A small storm surge (<2 feet) was evident throughout the tidal James on 21 June, the day Agnes passed through this area. A phase shift due to the interaction of the two wave systems was not obvious, probably because the frequencies of the two wave systems were significantly different. In the freshwater portion of the tidal James, currents continually ebbed during passage of the flood crest. In the saline portion the flood effect on the currents was limited to the surface portion of the channel with the fresh water essentially overriding the salty water.

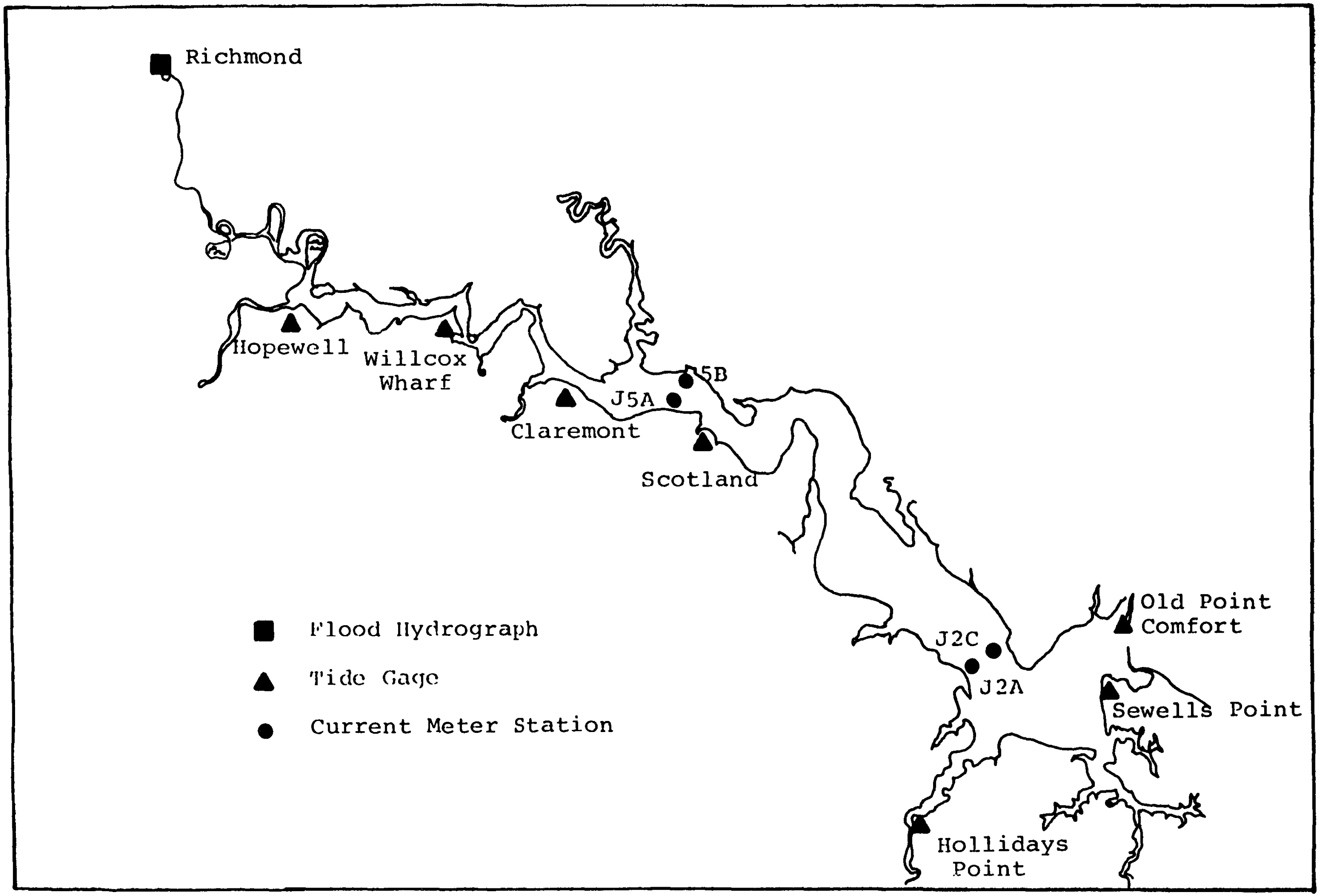

Figure 1. James River showing locations of the gauging station, tide gages, and current meters.

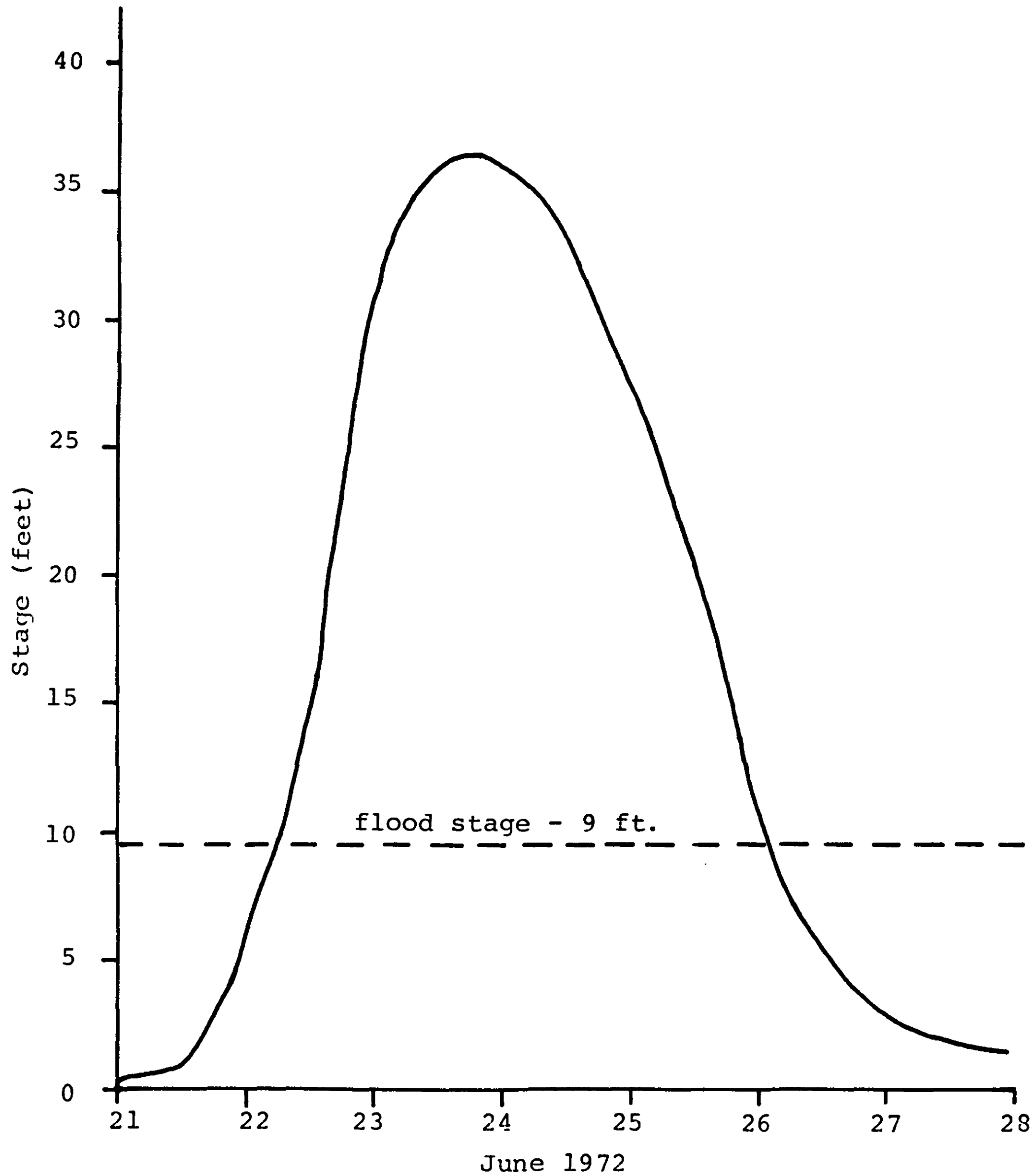

Figure 2. Flood hydrograph at Richmond during Agnes.

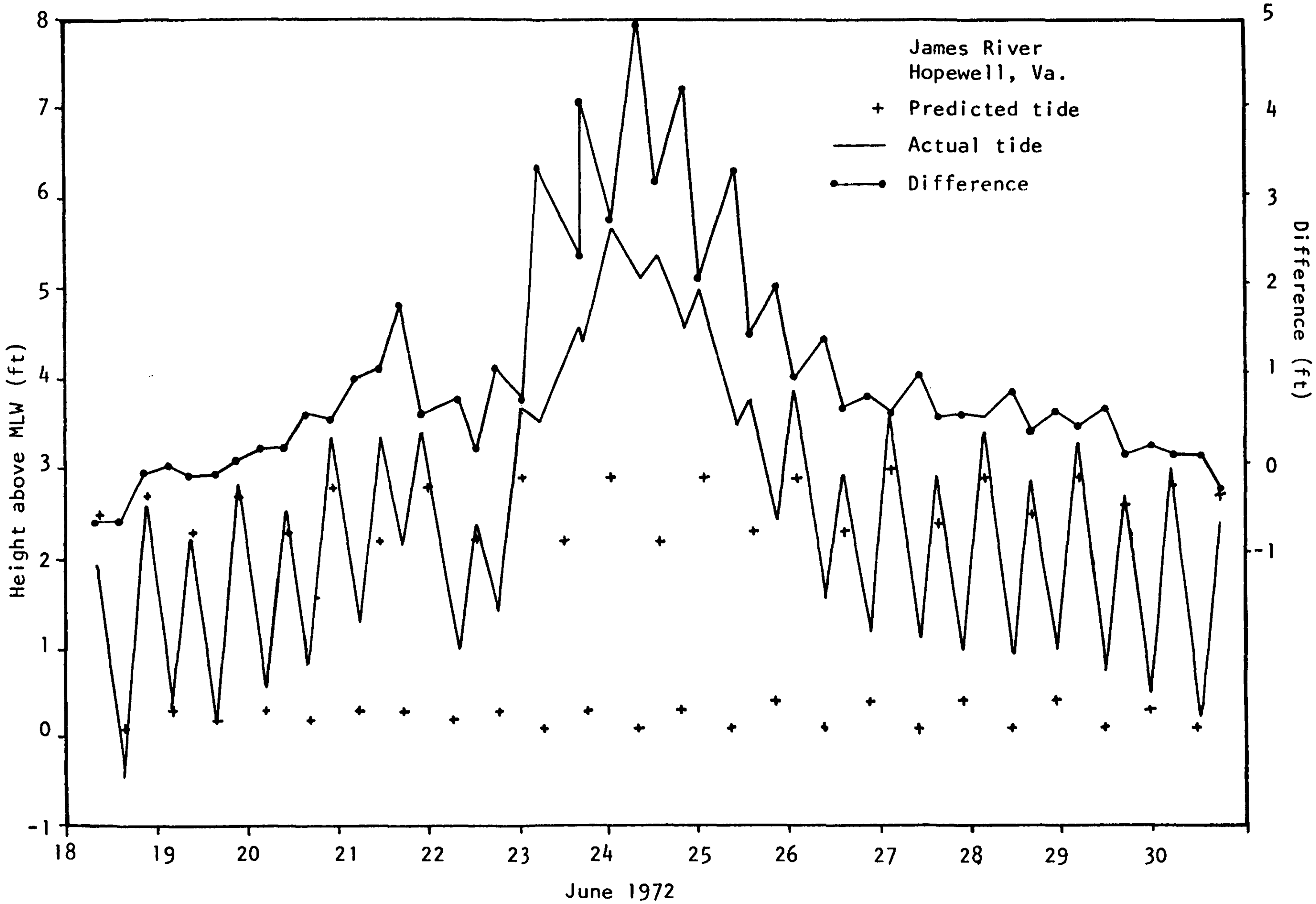

Figure 3. Predicted, recorded, and difference between recorded and predicted tidal heights at Hopewell, Va. during the Agnes flood.

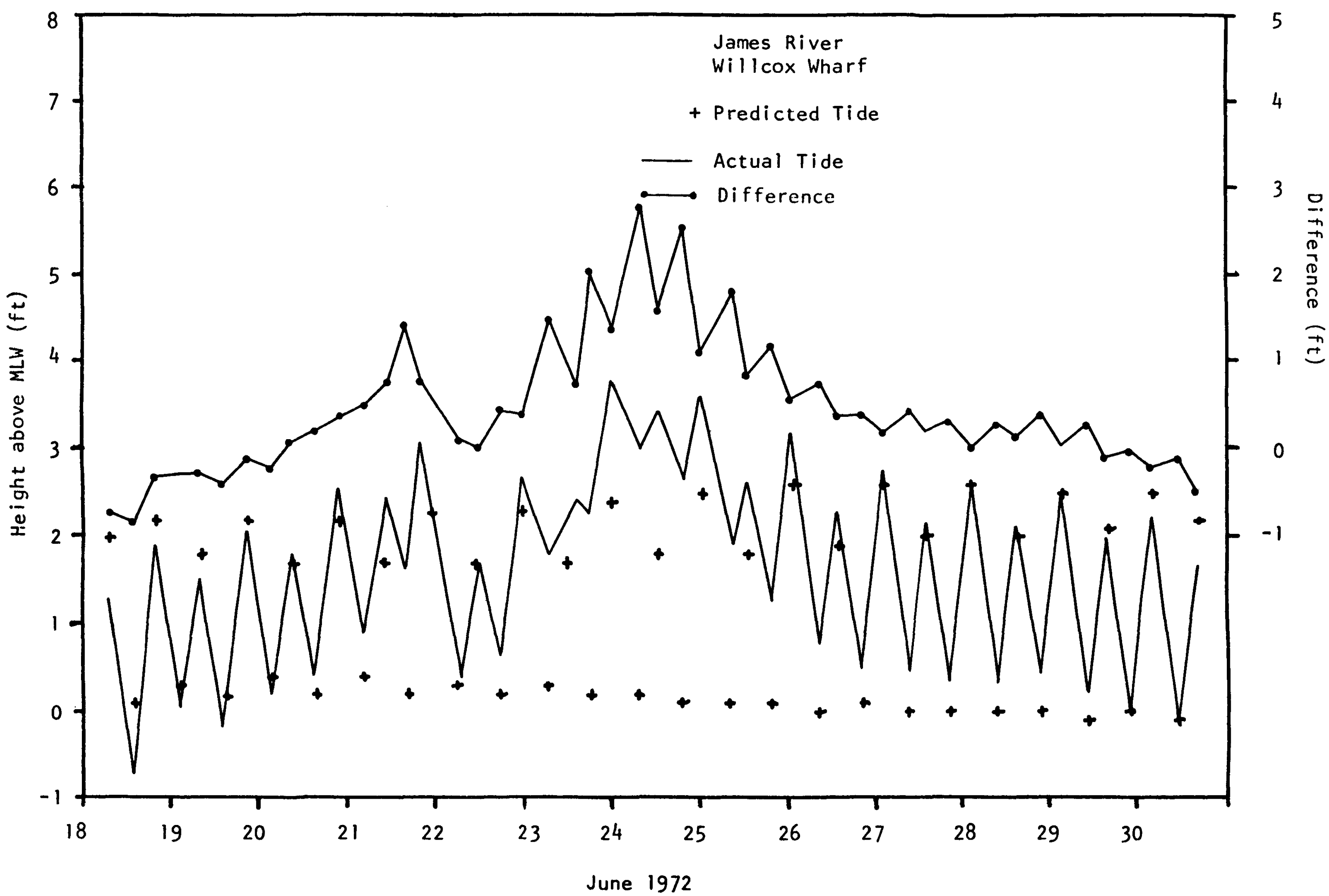

Figure 4. Predicted, recorded, and difference between recorded and predicted tidal heights at Willcox Wharf, Va. during the Agnes flood.

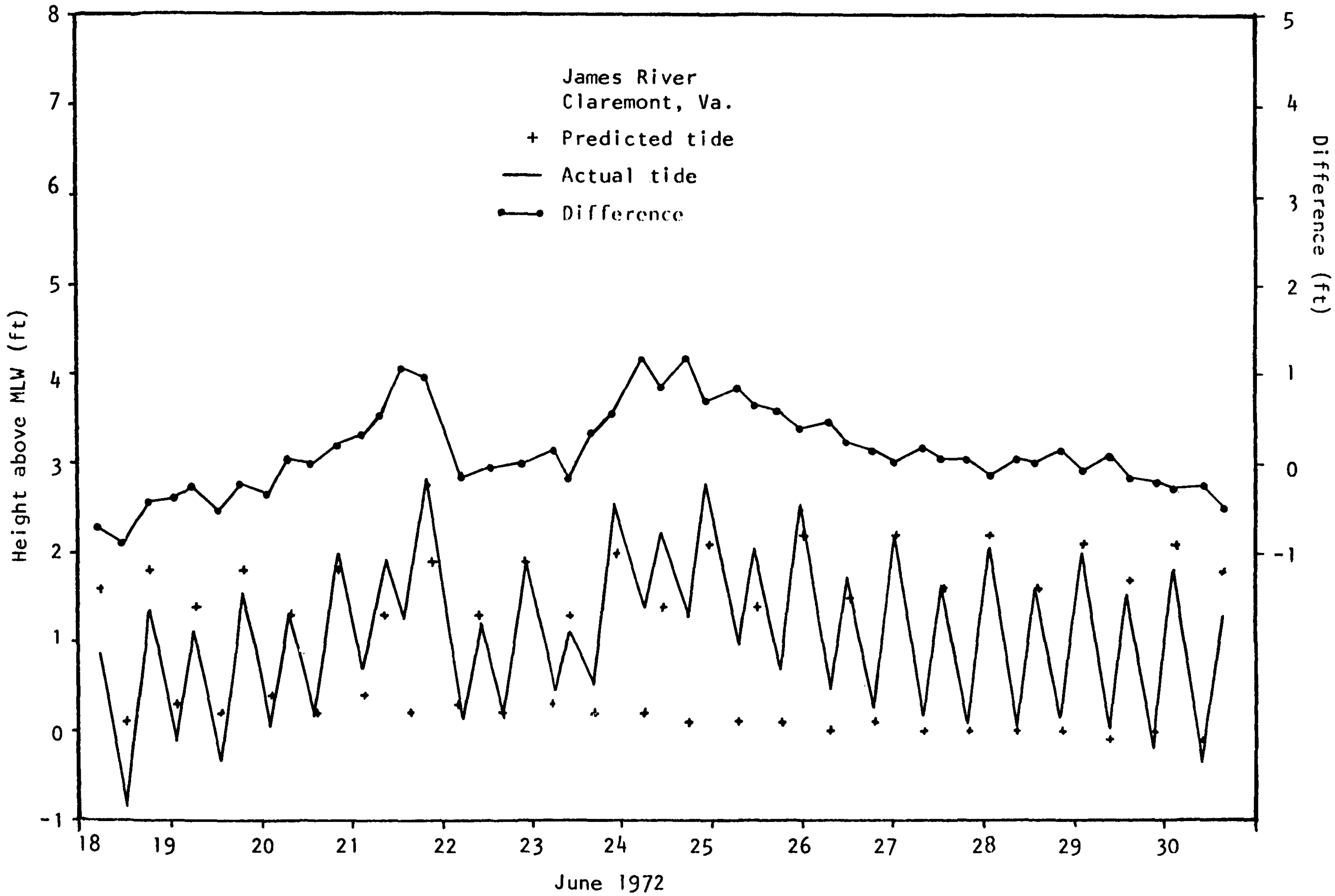

Figure 5. Predicted, recorded, and difference between recorded and predicted tidal heights at Claremont, Va. during the Agnes flood.

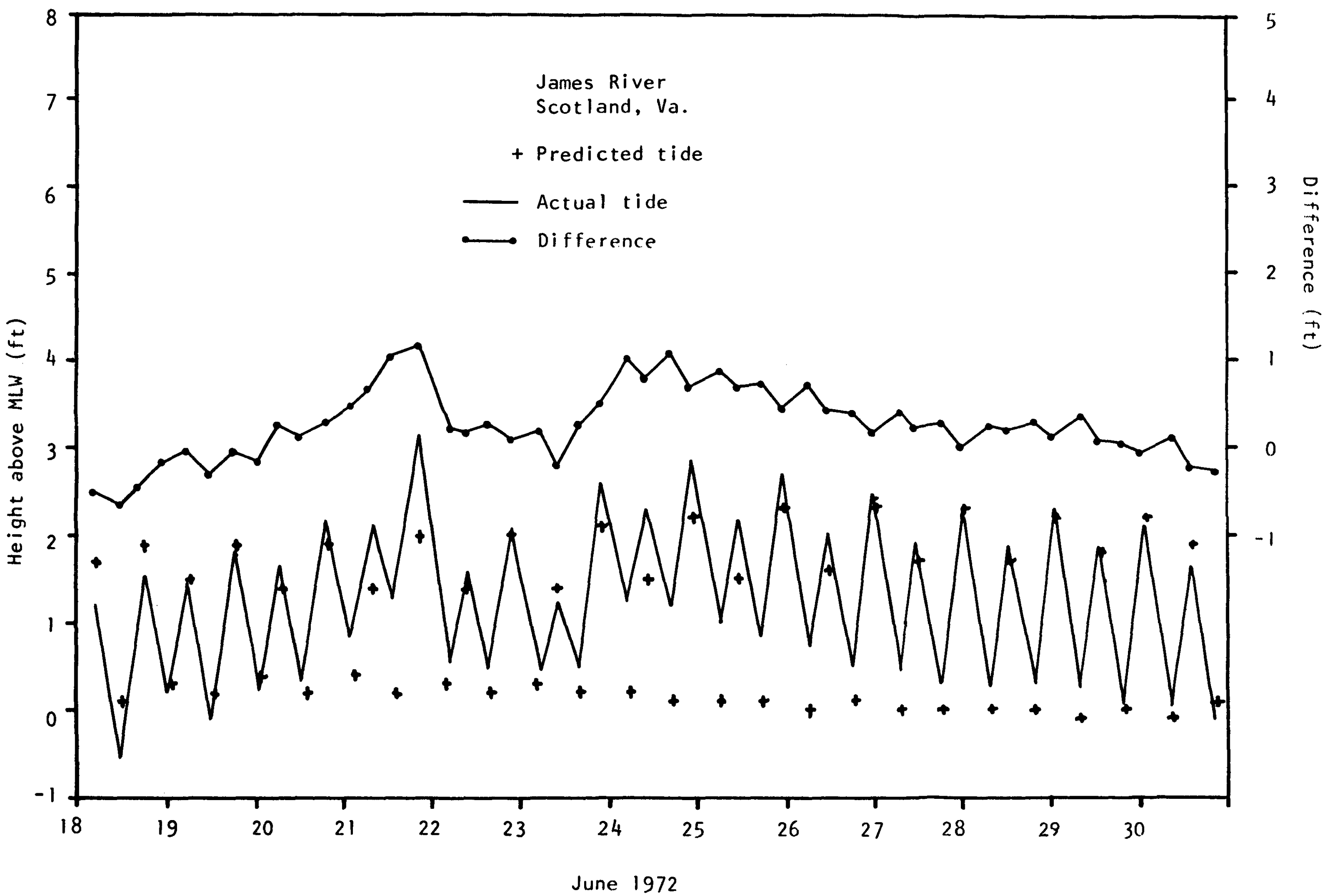

Figure 6. Predicted, recorded, and difference between recorded and predicted tidal heights at Scotland, Va. during the Agnes flood.

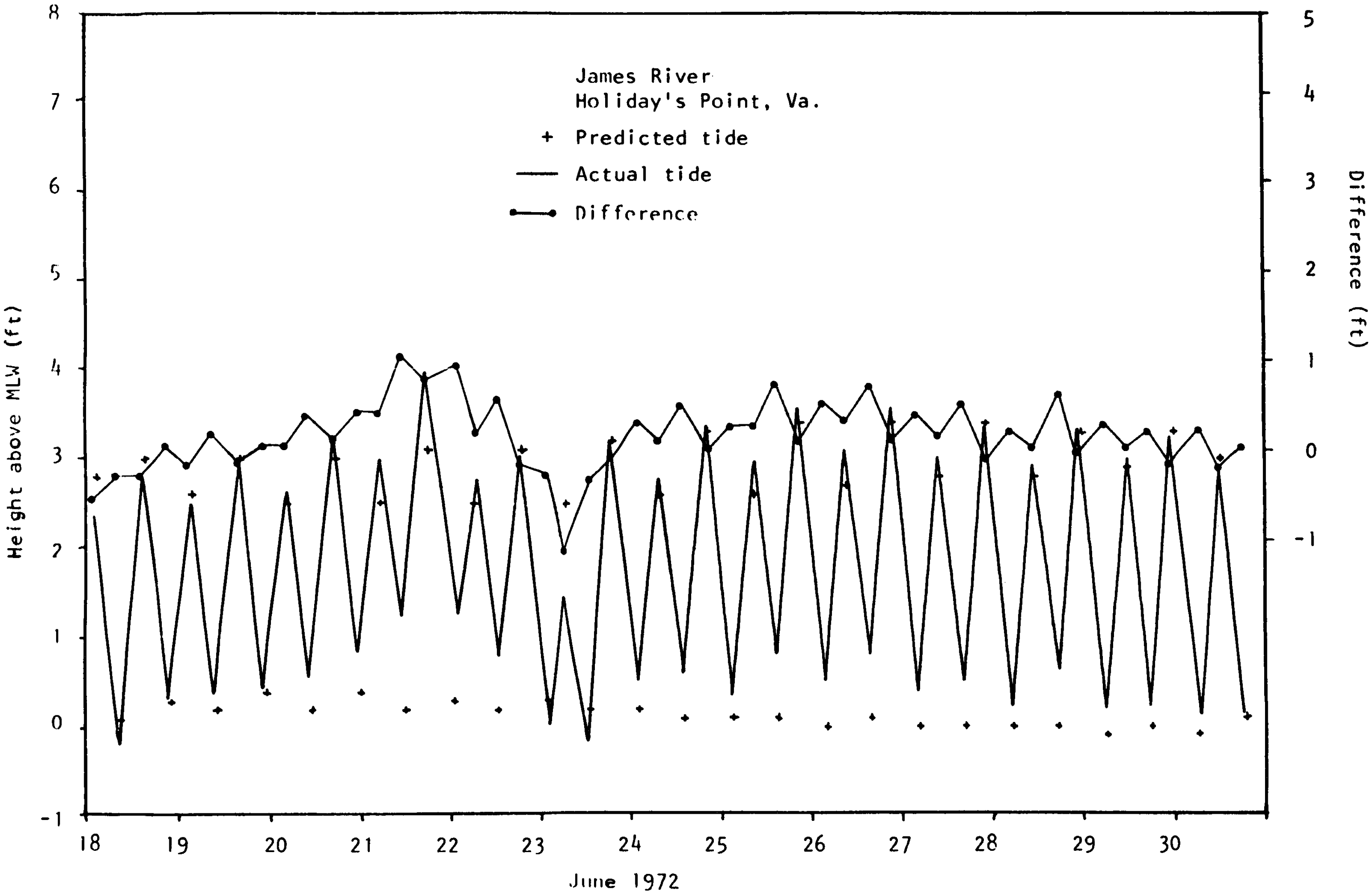

Figure 7. Predicted, recorded, and difference between recorded and predicted tidal heights at Holiday's Point, Va. during the Agnes flood.

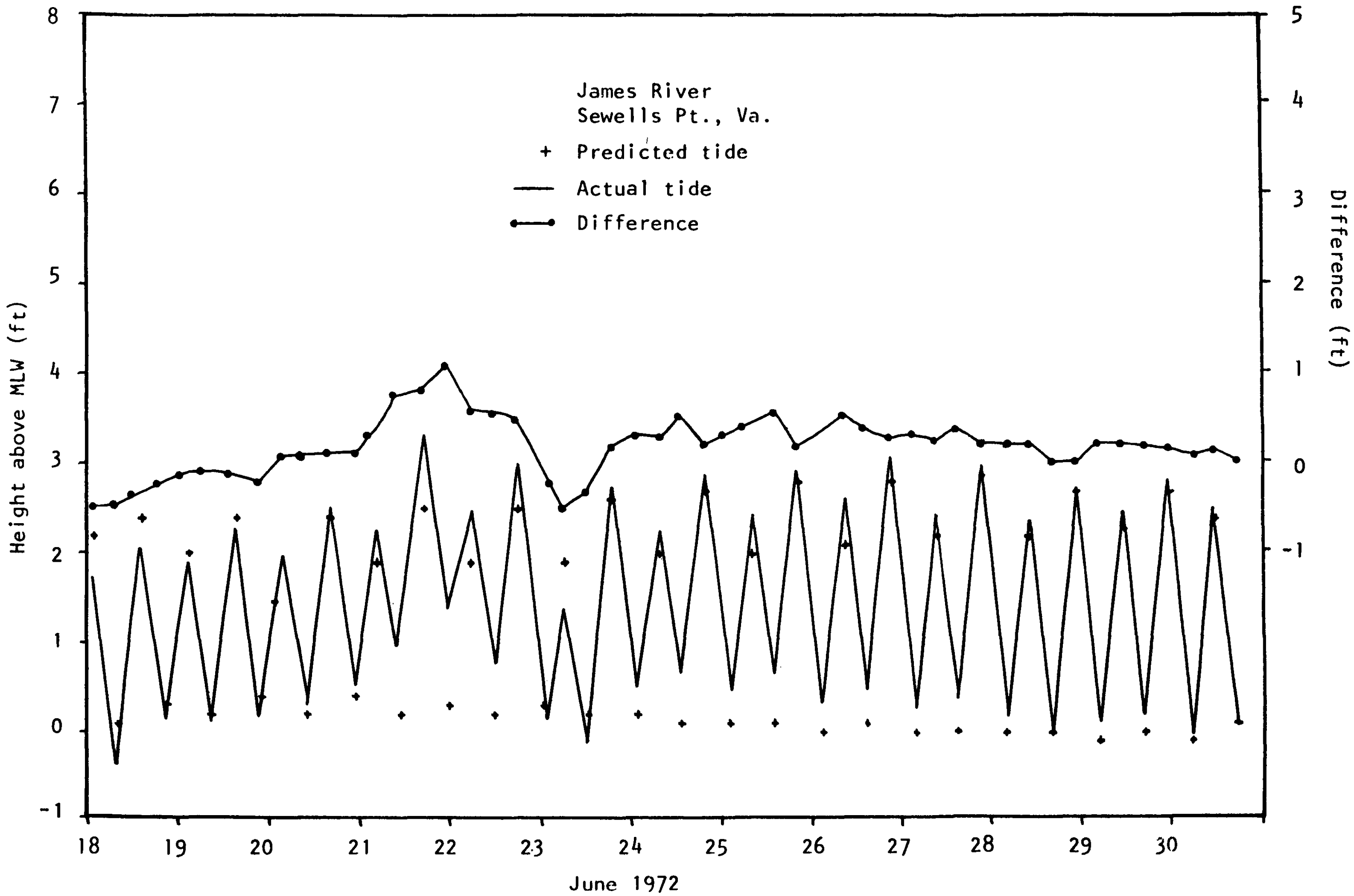

Figure 8. Predicted, recorded, and difference between recorded and predicted tidal heights at Sewells Pt., Va. during the Agnes flood.

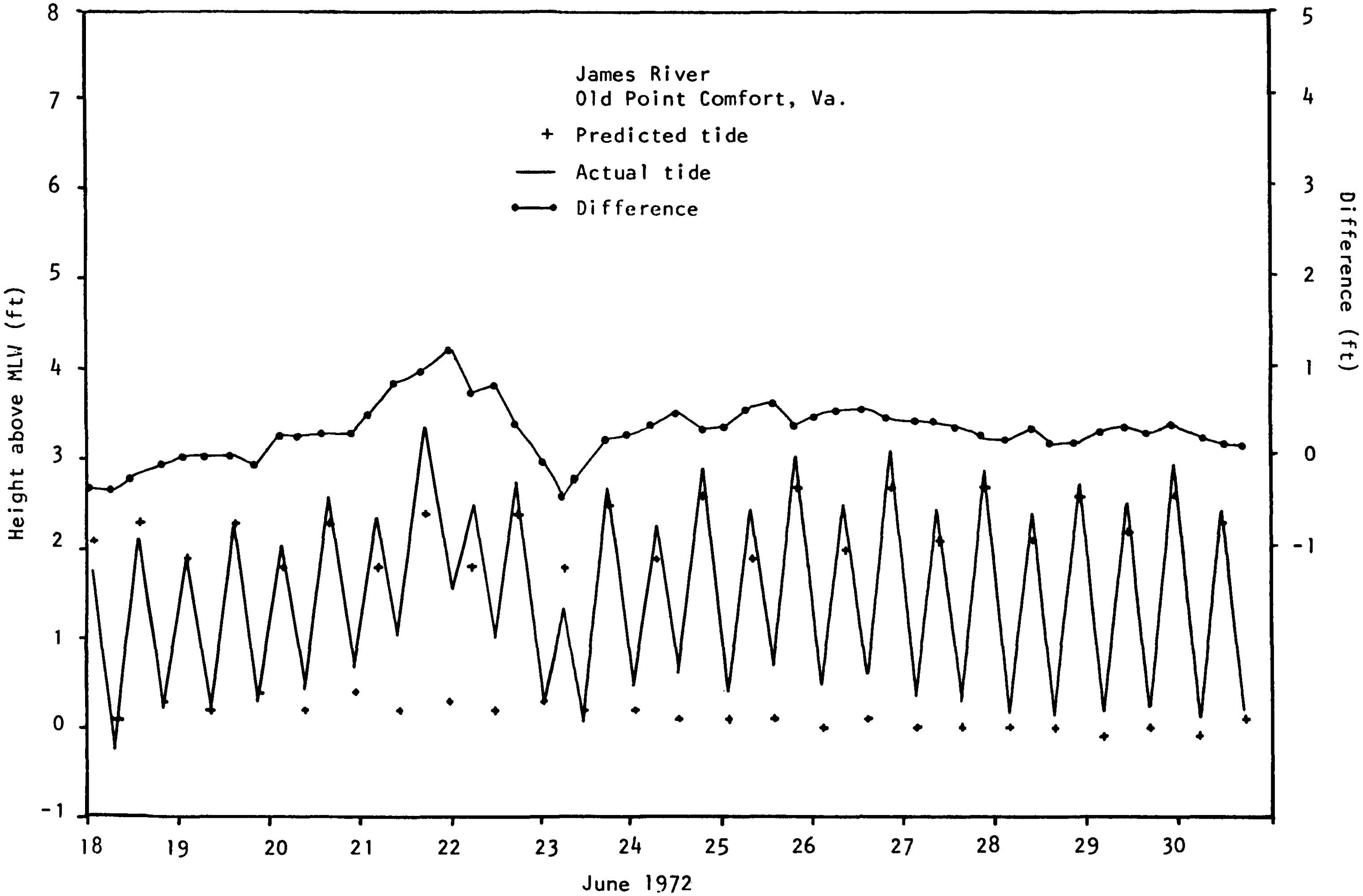

Figure 9. Predicted, recorded, and difference between recorded and predicted tidal heights at Old Point Comfort, Va. during the Agnes flood.

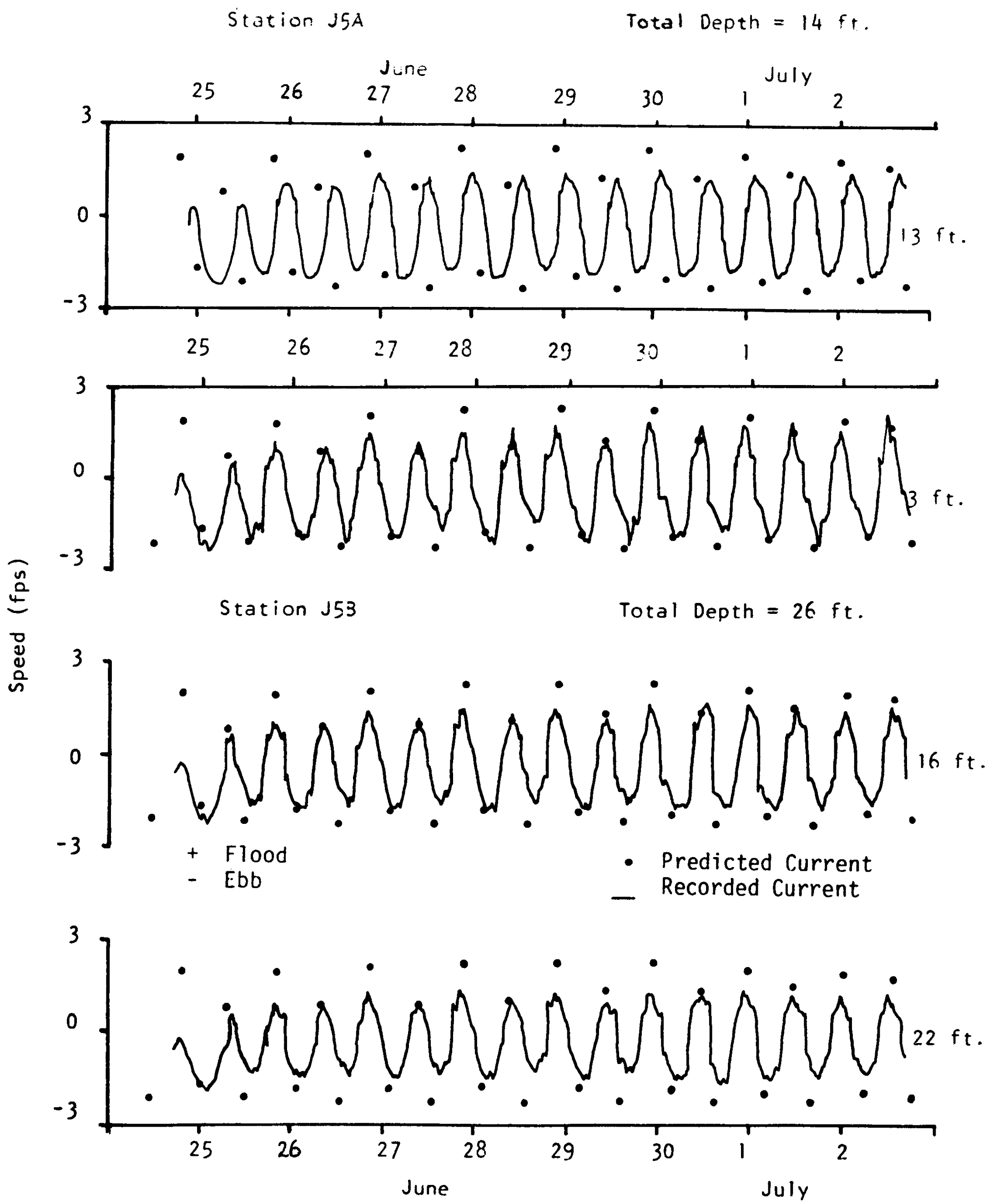

Figure 10. Predicted and recorded currents at Jamestown Island during the Agnes flood.

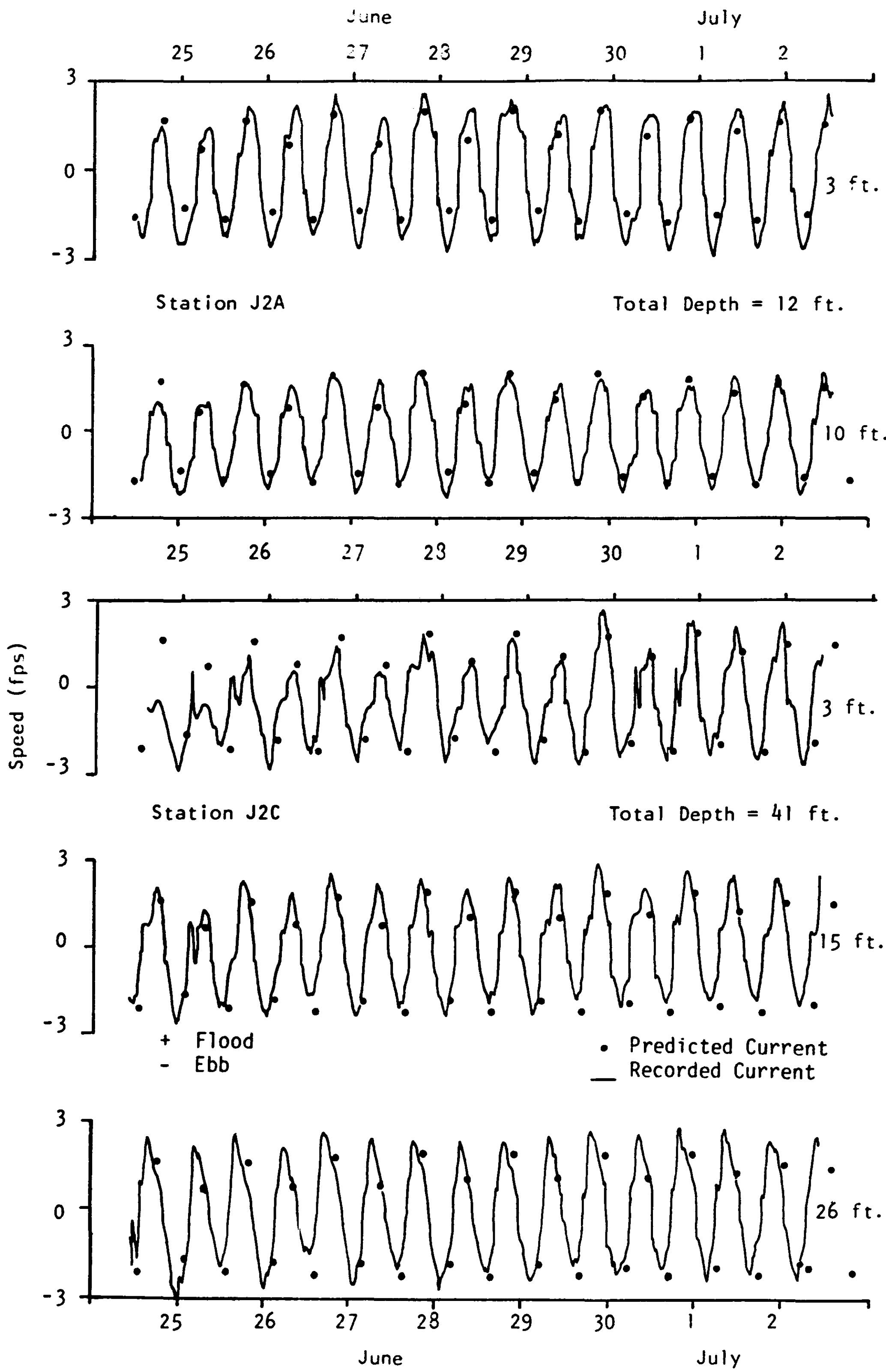

Figure 11. Predicted and recorded currents off Newport News during the Agnes flood.