FINAL

# Hydrodynamic and Water Quality Hindcasting at Parlee Beach, New Brunswick

Submitted to:

**New Brunswick Department of Environment and Local Government**

Environmental Sciences and Protection Division

P.O. Box 6000

Fredericton, NB E3B 5H1

Submitted by:


**Wood Environment & Infrastructure Solutions,**

**a Division of Wood Canada Limited**

50 Troop Avenue, Unit 300

Dartmouth, NS B3B 1Z1


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**IMPORTANT NOTICE**

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# 1.0 INTRODUCTION

Wood Environment & Infrastructure Solutions, a division of Wood Canada Limited (Wood) has prepared the following desktop modelling study of hydrodynamics and pollutant transport near Parlee Beach, NB, to support the New Brunswick Department of Environment and Local Government in understanding how bacteria have been transported through the coastal environment during selected historical periods.

This study builds on the previously implemented modelling study by Wood (previously operating under as Amec Foster Wheeler) conducted in 2017, by leveraging and further expanding the capabilities of the previously developed model to represent recent historical met-ocean conditions and include a wider range of potential sources that could have contributed to observed past water quality guideline exceedance events.

## 1.1 Objectives

In its Final Report submitted to the Government of New Brunswick in April 2018, the Steering Committee for Parlee Beach Water Quality concluded that:

*"Parlee Beach is vulnerable to periodic episodes of poor water quality; likely due to sources of bacteria originating from within the watershed, that make their way to Parlee beach under certain combinations of meteorological and oceanographic conditions. There does not appear to be a strong correlation between bacteria counts and most parameters, but information collected to date suggests that wind direction (and possibly tidal height) may be important factors."*

The present study aims to support recommendation number 2 of the Steering Committee, referencing the model initially presented by the Amec Foster Wheeler (2017) study:

*"Apply the hydrodynamic model to validate the transport paths related to actual discharges into the Bay (concentrations, volumes, weather conditions)."*

The present study was therefore guided by two main objectives:

1. Model the transport paths of pollutants from potential sources for identified exceedance events, as well as for good water quality conditions
2. Assess the plausibility of identifying oceanographic and meteorological conditions that may contribute to elevated bacterial levels at Parlee Beach.

### 1.1.1 Report Outline

The report is organized as follows. The following Section 2.0 presents an overview of the relevant water quality processes, and available data to support the development of hindcast scenarios for recent historical water quality guideline exceedance events. Section 3.0 describes the modelling methodology used to hindcast historical hydrodynamic conditions and pollutant transport for selected hindcasting events. Section 4.0 presents the modelling results for the hindcasted events, and Section 5.0 summarizes the conclusions and recommendations from the study.

# 2.0 WATER QUALITY PROCESSES AND SCENARIO DEVELOPMENT FOR HINDCASTING

The scenarios selected for hydrodynamic and water quality hindcasting were selected based on a review of the available water quality (bacterial levels) measurements at Parlee Beach, as well as local and regional meteorological data. Three historical periods (events) were selected based on measured exceedances of the water quality guidelines for E. coli or Enterococci, as well as a period of observed good water quality conditions (no exceedance of guidelines) at Parlee Beach. During this period of observed good water quality, apparent sources of contamination existed within Shediac Bay and adjacent coastal areas.

The following sections provide an overview of the water quality processes considered, features and limitations of the available datasets, and descriptions of the conditions during the selected historical events.

## 2.1 Overview of Water Quality Processes in Shediac Bay

The concentrations of Escherichia coli (E. coli) and enterococci bacteria influencing water quality at Parlee Beach are expected to be driven by several processes. The source of bacterial contamination in the coastal environment could originate from a number of potential sources of faecal matter, including sewage discharges from septic systems, dispersed sources such as animals and birds, as well as precipitation-induced storm water runoff from agricultural and populated areas. The transport of the released bacteria and resulting downstream concentrations are further influenced by the pathways through which the bacteria enter the receiving environment, including riverine flow, runoff from the land during precipitation events and other discharges. The water quality in the recreational waters of Parlee Beach are evaluated based on the guidelines for Canadian recreational water quality (Table 2-1).

**Table 2-1: Guidelines for Canadian Recreational Water Quality**

| **E. Coli** | | **Enterococcus** | |
|---|---|---|---|
| Single Sample Maximum | Geometric Mean of 5 most recent samples | Single Sample Maximum | Geometric Mean of 5 most recent samples |
| 400 MPN/100ml | 200 MPN/100 ml | 70 MPN/100ml | 35 MPN/100 ml |

The proliferation or decay of the bacterial concentrations in the coastal ocean environment over time are further determined by a number of factors, including the turbidity of the coastal waters, the concentration and composition of total suspended solids, seawater properties like salinity and PH, solar irradiance, vertical mixing rates, etc. Furthermore bacteria could settle if attached to coastal sediments and be remobilized by weather disturbances or human activity, and may represent an additional source of observed elevated bacterial levels in some locations. Finally, the coastal ocean circulation features influence the transport and dispersion of bacteria through the environment, potentially bringing it to Parlee Beach when the right conditions for transport from the source locations are established. The data availability and implications for modelling historical events associated with these processes are summarized in Table 2-2.

While the daily measurements of bacterial concentrations at Parlee Beach provide a good basis for evaluation of water quality and comparison to modelling results, the potential influx of bacteria at plausible source locations is poorly constrained due to lack of discharge flow rates, as well as relatively infrequent sampling. Furthermore, the in-situ data that could support estimates of bacterial proliferation or decay in the receiving environment is also limited.

In order to work around the data limitations, the present study takes the approach of introducing nominal bacterial fluxes at a number of potential source locations, and the full range of potential transport paths to Parlee Beach are studied. The discharges from each source location and day of release are distinct and separately trackable, therefore they do not mix in the model and any bacterial concentrations detected at the beach can be traced back to the time and location of origin. The daily measurements at Parlee Beach therefore provide a basis for evaluating the relative plausibility of each source having contributed to the bacterial levels on any given day, based on the timing and concentration of the plume arriving from each source.

Given the limited knowledge of potential bacterial proliferation or decay in Shediac Bay during any given historical period, the present study assumes no decay rate, with concentrations being a function of the physical advection and dispersion of the released bacterial plumes through the duration of the simulations.

**Table 2-2: Summary of processes and datasets related to water quality in Shediac Bay and Parlee Beach**

| Process | Data available | Implications for Modelling |
|---|---|---|
| **Riverine and land runoff flow rates** | No recent historical data available; Historical average riverine discharges available | Contaminated discharge fluxes into coastal environment are not well defined |
| **Bacterial concentrations in riverine and runoff sources** | Data available at a range of ETF[1] and WRP[2] sites once or twice per month; many sources are upstream from Shediac Bay with unknown paths to receiving environment | Due to temporal low frequency of sampling, concentrations are poorly defined for modelling scenarios (hourly or daily sampling needed) |
| **Bacterial concentrations at Parlee Beach** | Daily measurements are available at 5 locations along the beach | Data provide a good basis for detection of guideline exceedance events and model evaluation |
| **Bacterial decay rates** | No in-situ data available | Decay or proliferation rates are not defined/constrained |
| **Total suspended solids concentration in coastal waters** | No in-situ data available | Bacterial decay rates are partly dependent on TSS, and difficult to constrain from literature review |
| **Bacterial concentration and mobilization rates from coastal sediment** | No in-situ data available | Potential for bacterial sources to be present in coastal sediments is unknown |
| **Ocean circulation and transport** | No in-situ current data available; Tidal water level data available for model validation | Rigorous model validation not possible without in-situ current data |

[1] ETF: Environmental Trust Fund
[2] WRP: Watershed Reconnaissance Program

## 2.2 Selected events for water quality modelling

The available historical observations were reviewed and four events were selected for detailed modelling, with the first three representing conditions with elevated bacterial levels resulting in water quality guideline exceedances at Parlee Beach, and one period when the water quality was good despite apparent factors that could have contributed to elevated levels. The dates for the selected events are summarized in Table 2-3, including the range of dates when hypothetical bacterial sources were introduced and studied in the model, during each of the 7 days preceding each event.

The bacterial concentrations for Parlee Beach (geometric means) for each of the selected events are shown in Figure 2-1 through Figure 2-4, along with local and regional precipitation and wind data, as well as snapshots of E.coli concentrations at potential sources in Shediac Bay during the preceding week of the event. There are notable discrepancies between the local wind and precipitation measurements at Parlee Beach, and the regional datasets (CFSv2 reanalysis winds by NCEP (2019), and CMORPH remotely sensed precipitation data by NOAA (2019)), highlighting the need to consider a wider range of sources influencing the coastal ocean processes on a wider scale within the context of the model.

**Table 2-3: Summary of events for water quality hindcasting at Parlee Beach**

| Event ID | Description | Dates of potential source releases (7 consecutive days) |
|---|---|---|
| Event 1: 23 July 2017 | Guideline exceedance for both E.coli and enterococcus | July 16 – July 22, 2017 |
| Event 2: 22 August 2017 | Guideline exceedance for both E.coli and enterococcus | August 15 – August 21, 2017 |
| Event 3: 2 September 2017 | Guideline exceedance for enterococcus, elevated E.coli levels below guideline | August 26 – September 1, 2017 |
| Event 4: 7 September 2017 | Non-exceedance levels for both E.coli and enterococcus, with potential contamination sources present | August 31 – September 6, 2017 |

For the first event, bacterial concentration data at the Shediac Bay sampling sites on July 19 indicate a number of potential sources along the coastline prior to the exceedance event, possibly related to the precipitation events during the preceding days on July 16, 17 or on July 19. Given the limitations of the data at the sampling sites that could define the influx of bacteria into the receiving environment, hypothetical discharges of equal nominal strength are considered for all plausible source locations during each of the 7 days preceding the observed guideline exceedance.

The second modelled event represents an exceedance of both guidelines on August 22, 2017 at Parlee Beach. Elevated bacteria levels had been recorded at some sampling sites in the south of Shediac Bay on August 21, possibly associated with the rain events in the preceding days. This scenario includes hypothetical discharges at all locations from August 15 to August 21, with the aim to produce predictions for the observed event on August 22.

The third event is based on the guideline exceedance for enterococcus on September 2, 2017, and the concurrent elevated E.coli levels at the beach on the same day. The sparse data from the sampling sites at potential source locations did not indicate elevated concentrations, however the rain events throughout the preceding week may have generated contaminated discharges into the coastal environment. The hypothetical discharges included in the model spanned the period of August 26 through September 1, with model results being generated on September 2 for comparison to the observed data at Parlee Beach.

Finally, the fourth event is centered on the observed good water quality at Parlee Beach on September 7, when bacterial levels were below both water quality guidelines. On the same day, elevated bacterial levels were recorded at most sites along the Shediac Bay coastline. Therefore the lack of guideline exceedances at Parlee Beach was identified as an opportunity to study the meteorological and oceanographic conditions that may prevent contaminants from being transported to Parlee Beach during certain periods in time, even if they are present within Shediac Bay.

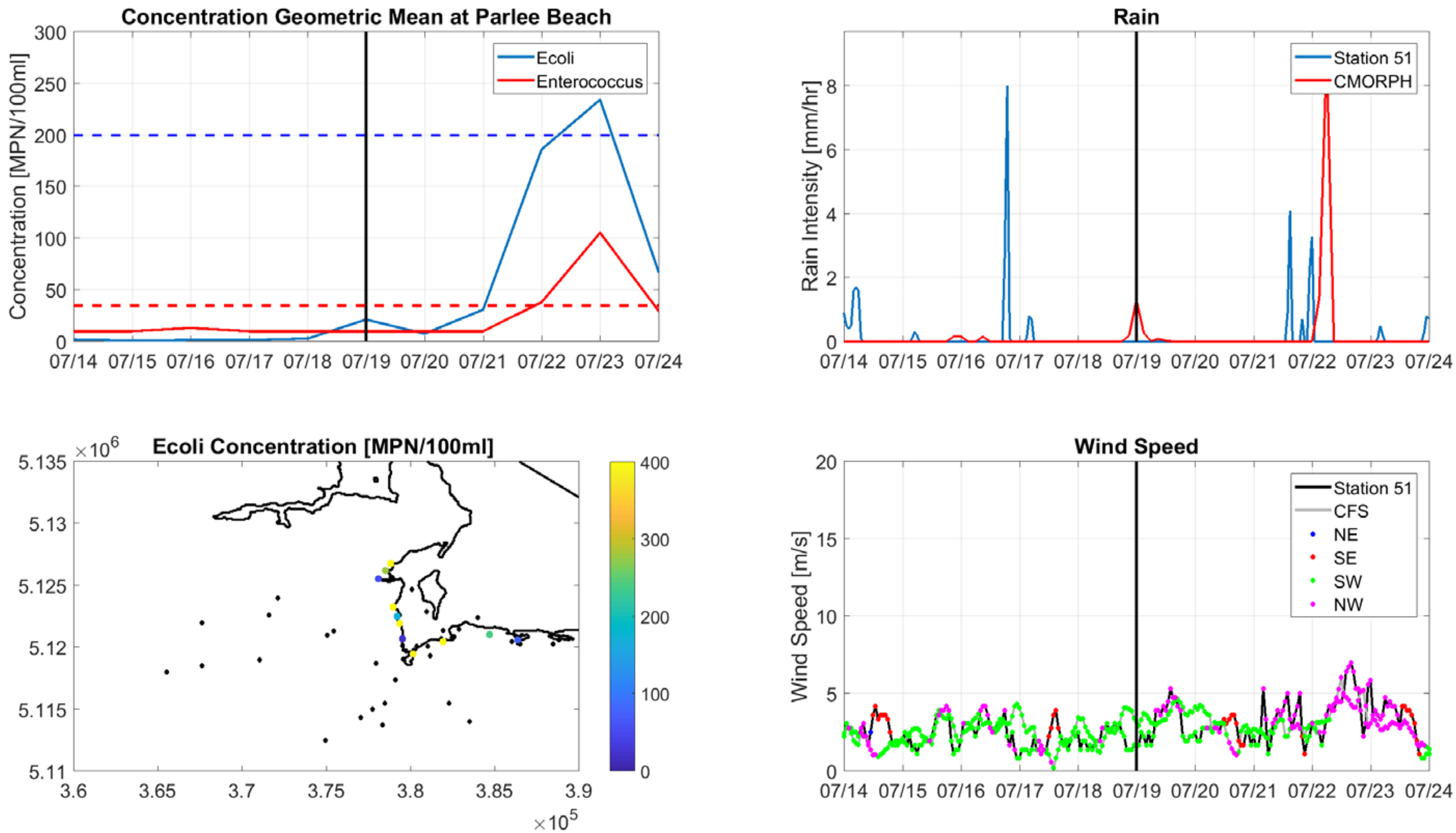



**Figure 2-1 Bacterial and meteorological data for the exceedance event on July 23, 2017.**

**Notes: Upper left: geometric mean of bacterial concentrations at Parlee Beach. Lower left: E.coli concentration at potential sources on July 19. Upper right: local (Station 51) and regional (CMORPH) precipitation time series. Lower right: local (Station 51) and regional (CFS) wind speed, with colour coding for directional sector (from).**

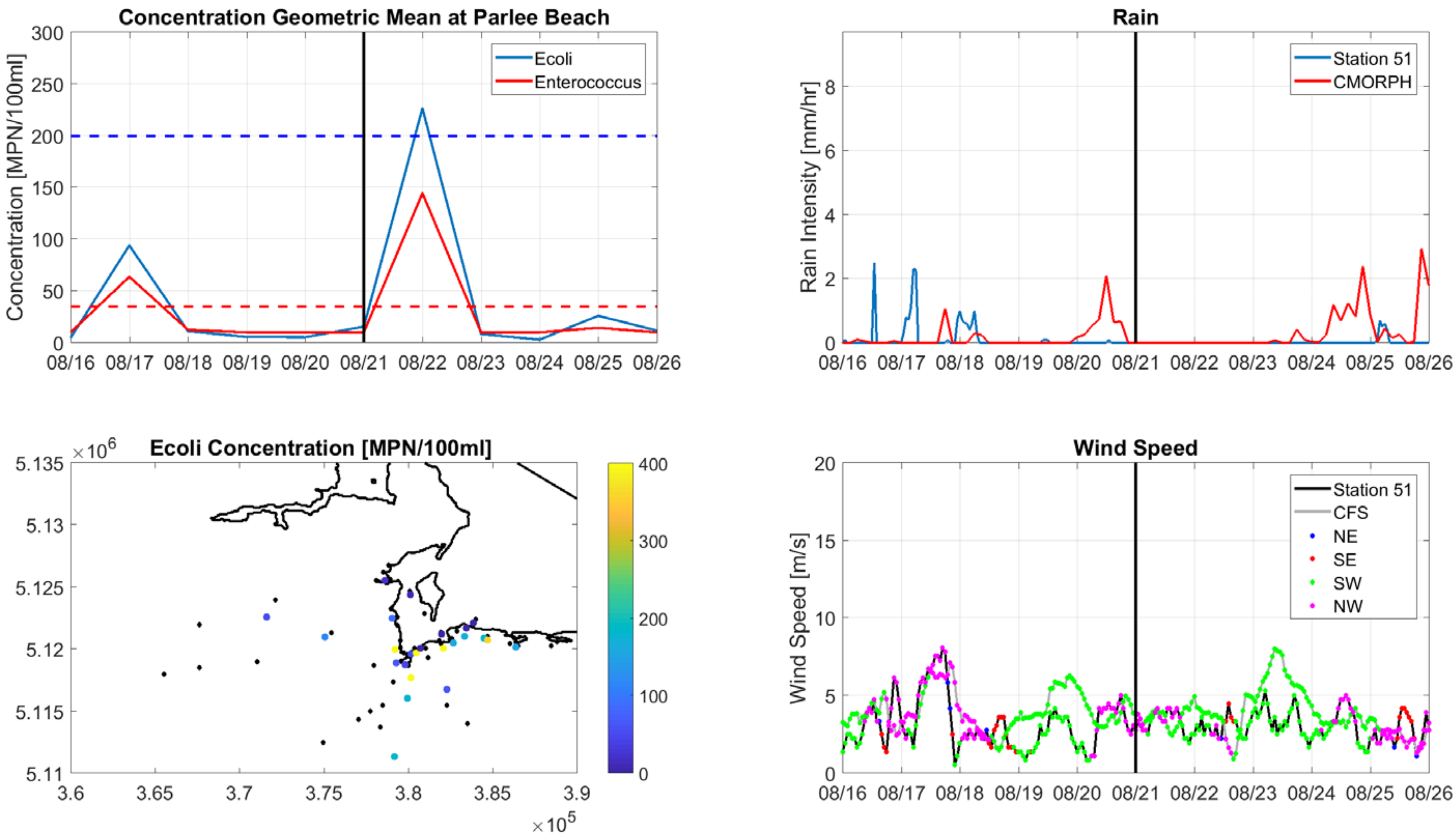



**Figure 2-2 Bacterial and meteorological data for the exceedance event on August 22, 2017.**

**Notes: Upper left: geometric mean of bacterial concentrations at Parlee Beach. Lower left: E.coli concentration at potential sources on August 21. Upper right: local (Station 51) and regional (CMORPH) precipitation time series. Lower right: local (Station 51) and regional (CFS) wind speed, with colour coding for directional sector (from).**

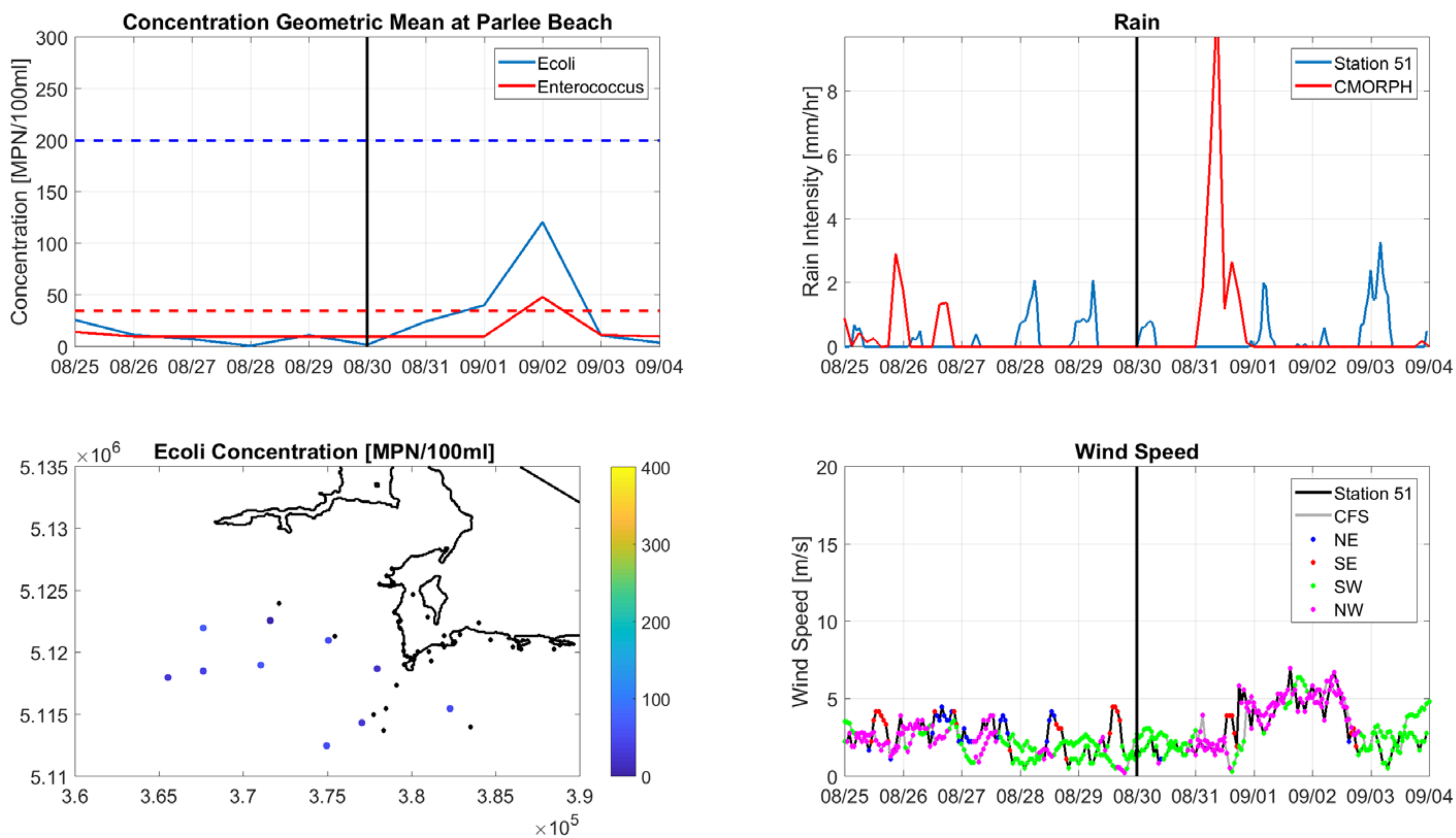



**Figure 2-3 Bacterial and meteorological data for the exceedance event on September 2, 2017.**

**Notes: Upper left: geometric mean of bacterial concentrations at Parlee Beach. Lower left: E.coli concentration at potential sources on August 30. Upper right: local (Station 51) and regional (CMORPH) precipitation time series. Lower right: local (Station 51) and regional (CFS) wind speed, with colour coding for directional sector (from).**

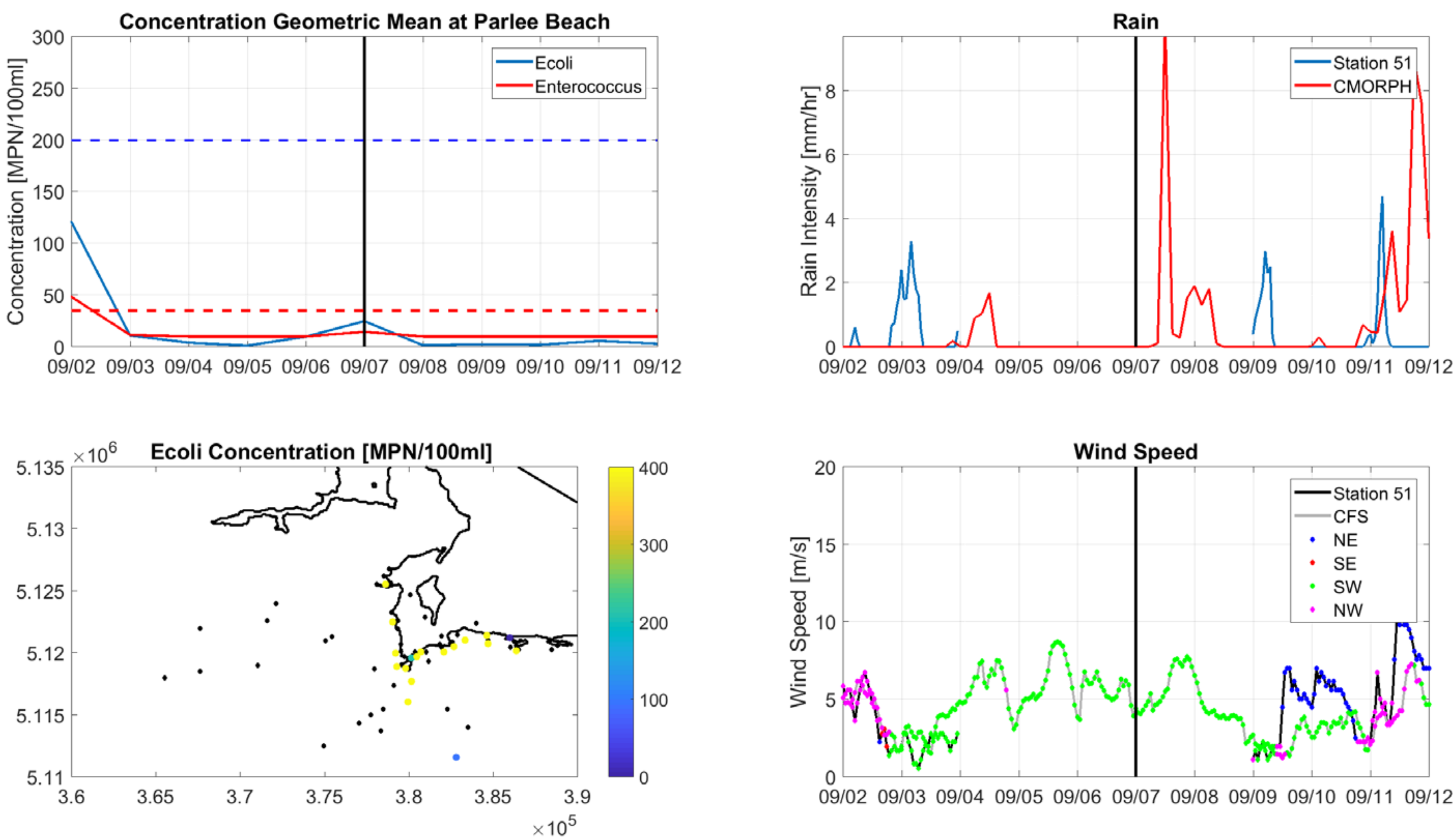



**Figure 2-4 Bacterial and meteorological data for the non-exceedance event on September 7, 2017.**

**Notes: Upper left: geometric mean of bacterial concentrations at Parlee Beach. Lower left: E.coli concentration at potential sources on September 7. Upper right: local (Station 51) and regional (CMORPH) precipitation time series. Lower right: local (Station 51) and regional (CFS) wind speed, with colour coding for directional sector (from).**

# 3.0 MODELLING METHODOLOGY

## 3.1 Delft3D Hydrodynamic Model Setup

Wood has developed a coupled hydrodynamic and wave model of the coastal ocean encompassing Shediac Bay and the coastal areas to the east and north, including Parlee Beach, using the comprehensive Delft3D modelling suite by Deltares (domain extent is shown in Figure 3-1). The Delft3D suite consists of a highly-integrated set of modules to compute water levels and ocean currents by using the shallow water equations, as well as to employ the advection-diffusion equations for computations of dissolved and particulate tracers. The hydrodynamic model is coupled with the third-generation spectral wave model SWAN (Simulating Waves in the Nearshore), which provides the capability to simulate the local wave conditions due to offshore incident waves combined with locally wind-generated waves, as well as provide wave forcing terms to the hydrodynamic model. These features make the Delft3D suite an ideal platform for coastal ocean studies of potential pollutant transport for idealized or historical conditions, that could support the investigation of likely sources of contamination for a given geographic location.

The hydrodynamic model has been previously used to investigate the predominant transport patterns for diluted tracers from two source locations, as well as virtual drogue releases, for idealized constant atmospheric forcing conditions spanning all directional sectors (Amec Foster Wheeler, 2017). While current data were not available for site-specific model validation, the performance of the Delft3D hydrodynamic model has been previously evaluated based on the available historical tide gauge datasets at two stations (Shediac Bay, Station 1805; and Cap de Caissie, Station 1810). The model exhibited consistently good performance in terms of resolving the tidal amplitudes and phases, indicating that the model captures the dynamics of the coastal system and its response to forcing inputs.

In the present hindcasting study, the model has been further updated to include spatially and temporally varying wind forcing and atmospheric pressure for recent historical conditions using the CFSv2 (Climate Forecasting System) reanalysis by the U.S. National Centers for Environmental Prediction (NCEP, 2019). The wind and pressure fields are therefore updated in the model on an hourly basis throughout the simulation, and in conjunction with the tidal forcing at the model boundaries the model is therefore capable of representing the dominant forcing factors for coastal circulation around Shediac Bay and Parlee Beach. Additional sensitivity testing conducted with the coupled wave model for the selected hindcast periods indicated that the effects of the wave-induced forcing on coastal transport would be relatively small, with the wind and pressure forcing being the dominant factor in addition to the astronomical tides.

In the present implementation, the hydrodynamic model is initiated and allowed to spin up for at least one week prior to any discharges being initiated in the model, in order to allow the model to fully capture the response of the coastal ocean to the forcing terms. All simulations were then extended for seven additional days when hypothetical discharges are released, and one additional day when model predictions are captured at Parlee Beach for comparison to the observed daily data.

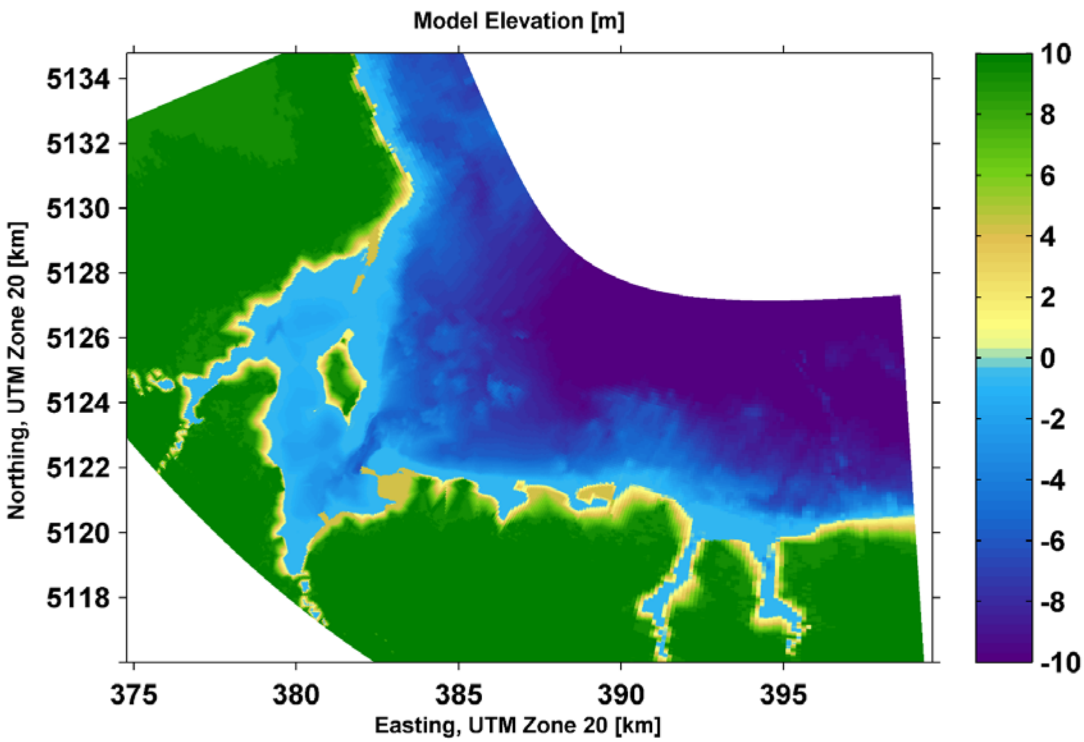



**Figure 3-1 Bed elevation in the Delft3D hydrodynamic and water quality model.**

## 3.2 Water Quality Model Setup

In order to model the potential transport paths of pollutants from identified potential sources within the domain, 14 pollutant discharge locations were introduced at various locations within Shediac Bay and adjacent to Parlee Beach (Figure 3-2). For each location, a pollutant discharge was prescribed for each of the seven days prior to the observed exceedance (or non-exceedance) at Parlee Beach.

Due to the limited data available to quantify the bacterial fluxes during any given event, the present study is based on introducing nominal bacterial fluxes and concentrations at the potential source locations that are equal among the locations. Thus a continuous discharge with a flow rate of 0.1 $m^3/s$ is prescribed at each of the sources for seven days prior to the simulation, and the discharges are stopped at 00:00 hours on the day of the exceedance (or non-exceedance) event when the prediction is made. The bacterial contaminants are simulated with a distinct tracer for each location and day of release, with a nominal concentration of 1 mg/L at the point of discharge.

In order to relate the output from the model to the observations at least in a relative manner, the model outputs were scaled during post-processing of the results by a factor of 250,000. This scaling factor was selected so as to yield nominal bacterial unit values in the order of 100 to 1000 in most cases for the distinct bacterial plumes in the receiving environment of the model, both within the vicinity of the release locations and for peak concentrations at Parlee Beach, so as to be broadly comparable to the relative levels of E.coli measured at the source locations and Parlee Beach (in the order of hundreds of MPN/100ml when elevated). Therefore, while it is not possible to directly convert the modelled nominal units to either E.coli or enterococcus concentrations, within the framework of the model nominal units of 100 or more are considered elevated and likely to be associated with water quality guideline exceedances at Parlee Beach, while values in the range of 0-50 are considered to be low to moderate in terms of the water quality guidelines.

The water quality model results were saved on an hourly basis throughout the simulations, by recording the predicted distributions (maps) of pollutant concentrations over the entire domain, as well as time series of concentrations at Parlee Beach for all 98 identifiable pollutants within the simulation.

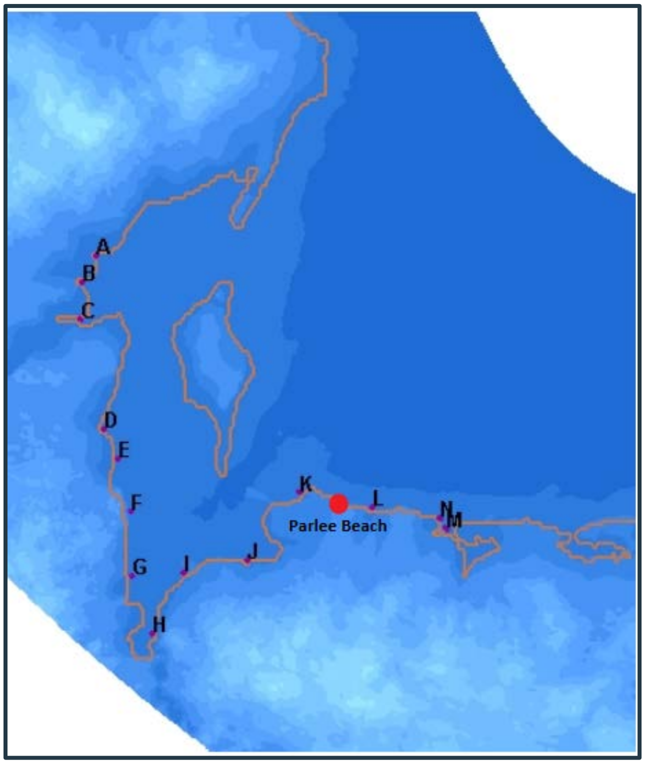



**Figure 3-2 Potential source locations where discharges are released within the Delft3D water quality model. Locations are included in the north of Shediac Bay (A, B, C), central Shediac Bay (D, E and F), and in the south of Shediac Bay (G, H, I and J), as well as on the limits of Parlee Beach (K and L), and east of Parlee Beach (M, N).**

# 4.0 MODELLING RESULTS FOR SELECTED EXCEEDANCE AND NON-EXCEEDANCE EVENTS

## 4.1 Probable Transport Paths and Pollutant Source Locations for Exceedance and Non-Exceedance Events

The results from each modelled water quality event were analyzed by extracting the time series of bacterial concentrations at Parlee Beach on the day when the exceedance (or lack of exceedance) was recorded. This was done in order to compare the signals from the 98 potential sources in space and time to the observations at Parlee Beach. The results have been analyzed and presented from three different perspectives, in order to develop an understanding of the most probable transport paths for the pollutants to the beach during each event:

- **Potential source contribution matrix for each event**
- **Time series of modelled bacterial concentrations at Parlee Beach for all 98 discharges per event**
- **Maps of modelled currents and bacterial concentrations through the domain for selected discharges scenarios of exceedance and non-exceedance events**

The potential source contribution matrices for the four events are presented in Figure 4-1 to Figure 4-4 with maps illustrating the layout of the discharge locations. The matrices for the four events are also shown for cross-comparison between the events on Figure 4-5. The matrices present results for each of the source locations (A-N), where separately tracked discharges are released every 24 hours on model days 1-7 (which is 1-7 days before the exceedance). The values in the matrices indicate the peak concentration values captured at Parlee Beach during model day 8, that can be traced to each of the locations and day of release. Given that all 98 discharges have been set up with an equivalent nominal source strength, the matrices allow for the comparison of the likelihood of transport paths from the full range of locations and times of release to the observed concentrations at Parlee Beach.

Time series of modelled bacterial concentration at Parlee Beach for each of the modelled events are presented in Appendices A through D, with each plot representing the 7 daily discharges for each modelled event. The time series provide a preview of the concentrations and time of arrival of the contamination from each discharge. The time series therefore provide additional information on the modelled bacterial concentrations for the full duration of the simulation, including concentration signals that arrive at Parlee Beach either too early, or too late relative to the observed exceedances.

Finally, the maps of modelled currents and bacterial concentrations are presented in the following section, providing illustrations of the pathways that the discharges follow during exceedance and non-exceedance events. Furthermore, the maps provide indications of the ocean circulation features, driven by the met-ocean forcing factors, that contribute to the transport of pollutants to the beach during some events, and impede the transport during the non-exceedance event.

### 4.1.1 Event 1: Exceedance on July 23, 2017

The peak concentrations modelled at Parlee Beach for July 23, 2017 as illustrated in Figure 3-2 indicate that the most likely sources of the observed high bacterial levels would originate on the preceding 3 days within the central and south areas of Shediac Bay, with nominal bacterial concentrations ranging from 96 units (source H5) to 144 units (I7). Sources east of Parlee Beach are much less likely to contribute to this exceedance event, with peak concentrations modelled in the order of 0-6 units for all days. Contributions from sources at the beach (K, L) are also relatively low, in the range of 0-31 units for release days 1-6. Even though they are relatively distant, sources from the north of Shediac Bay are also moderately likely to contribute. Peak concentrations of 30 units (B4) to 41 units (A6) are predicted for discharges on model days 4 through 6, indicating that contributions from these sources for the equivalent release dates are comparable and sometimes stronger than those for the central sources (D,E, and F).

Within south Shediac Bay, source H (located at the mouth of the Scoudouc River) is particularly notable as the source from which a probable transport path appears to persist from model day 1, with higher predicted concentrations than for the other locations. While the discharges from location G (south Shediac Bay) are predicted to be relatively strong for day 5 and 6, the discharge on day 7 (prior to the exceedance) is predicted to be relatively low at only 18 units. These results indicate that the circulation features within Shediac Bay can create transport paths that are quite distinct from one another on relatively small spatial scales.

The bacterial concentration time series at Parlee Beach throughout the simulation (Appendix A), show additional differences between the pathways of the potential sources on the days preceding the exceedance. Namely, the sources from north and central Shediac Bay (A through F released during all days) are predicted to arrive at Parlee Beach concurrently and relatively late on day 7 and day 8 (July 23) or later, while contaminants released from sources G through J start to arrive at Parlee Beach as soon as days 3 and 4.

The wind forcing conditions in the preceding days for the July 23 exceedance event are consistently from the southwest or west directional sectors, generally expected to promote transport paths from south Shediac Bay toward Parlee Beach, but transport paths are also viable from the north of Shediac Bay.

### 4.1.2 Event 2: Exceedance on August 22, 2017

The model results for the peak concentrations at Parlee Beach during the August 22 exceedance event are illustrated in Figure 4-2. The results indicate a narrower range of potential contributing sources compared to Event 1, with values of above 50 units limited to the south of Shediac Bay (G, H, I, J) during model days 6 and 7, corresponding to August 20 and 22, 2017. Sources I and J on day 7 are the most likely contributors to the event, with peak concentrations of 135 and 160 respectively, while on day 6 the only peaks above 50 units are predicted to originate from source G (65 units) and J (89 units). The rest of the potential source contribution matrix indicates relatively lower contributions (below 25 units) from all other sources, including the releases from the south area of Shediac Bay before Day 6.

The concentration time series for this event (Appendix B) show that bacteria from sources A through F are only predicted to reach Parlee Beach by model day 4, with concentrations from those sources dropping sharply at Parlee Beach beyond day 4. Given that high concentrations have not been observed on day 4 (August 18), those early arriving signals can be considered to be false positives, and the sources most likely did not release bacteria during the preceding period.

The wind forcing conditions in the preceding days are split between the west, southwest and northwest sectors (days 1, 3, 4, and 7), promoting transport toward Parlee Beach from Shediac Bay, and from the south or southeast on days 2, 5 and 6. The presence of prolonged periods of southerly and southeasterly winds, particularly on model days 5 and 6, likely impedes many of the transport paths to Parlee Beach from central and north areas of Shediac Bay, as southerly and southeasterly winds tend to promote transport from the south toward the north of Shediac Bay, and transport toward the west at Parlee Beach, often effectively blocking contaminated plumes from Shediac Bay from arriving at the beach.

### 4.1.3 Event 3: Exceedance on September 2, 2017

The peak concentrations modelled for the exceedance event on September 2 are presented in Figure 4-3. The results are broadly similar to those for the July 23 exceedance event, with the most probable transport paths (peak concentrations exceeding 100 and up to 232 units) predicted for the locations in south Shediac Bay on model days 6 and 7 (August 31 and September 1). Relatively strong peak concentrations above 100 units are also predicted to be contributed by source F on day 7, and source H on day 5 as well, while moderate values between 50 and 100 units are also predicted for the central Shediac Bay locations on day 6, and some north Shediac Bay locations between days 3 and 6. Potential sources at Parlee Beach and east of the beach contribute relatively less to the exceedance, with peak values of 0-21 units.

The concentration time series at Parlee Beach for event 3 (Appendix C) reveal that the moderate contributions by sources in the north and central areas of Shediac Bay on the day of exceedance are in fact due to the dispersion of predicted larger concentration peaks due to these sources on model day 7 (September 1). Given that such high concentrations were not observed on that day, these consistently early arrivals are interpreted as an indication that those sources were an unlikely contributor to the guideline exceedance event, with locations in south Shediac Bay being the more likely sources of the event given the timeliness of the arrival of peak concentrations originating there.

The winds over Shediac Bay in the preceding days are generally from the northwest and southwest sectors, expected to promote transport paths from the south of Shediac Bay toward Parlee Beach. The exception to the general trend is model day 6 with wind transitioning from southwesterly through northeasterly to southwesterly again. However, these wind fluctuations do not effectively disrupt the general pattern of eastward transport toward Parlee Beach.

### 4.1.4 Event 4: Non-Exceedance on September 7, 2017

The potential source contribution matrix for the fourth modelled event, with non-exceedance concentration levels observed at Parlee Beach on September 7, is shown in Figure 4-4. The results are consistent with the observations on this day at the beach, indicating that very little contribution from the contaminated discharges would be expected to arrive at Parlee Beach on the day of the observations. The vast majority of the modelled potential discharges are not predicted to be detectable at the beach on that day, and maximum modelled concentrations of 11-36 units are only predicted for the nearest sources in south Shediac Bay (I and J) from model days 6 and 7. Given that discharges had been released consistently with the same source strength during all previous days, the model results indicate that the coastal circulation would lead to potential contaminated plumes arriving to the beach either earlier or later than September 7, or not at all.

The concentration time series at Parlee Beach, shown in Appendix D, indicate that beyond day 5 only potential releases from source I, J and K could be transported to Parlee Beach, however their arrival is too early to contribute to the day 8 concentrations, therefore those predictions are interpreted as false positives in the simulation.

The winds over Shediac Bay in the days preceding the observations were initially transitioning from the northeast to the northwest (model days 1 through 3), and then switched to a south-southwest direction. This south-southwest wind forcing appears to have promoted transport of the contaminated plumes to the north of Shediac Bay and away from Parlee Beach from model day 5 to day 8 for most of the sources. While the previous modelling study by Wood (Amec Foster Wheeler, 2017) had indicated that idealized constant southwesterly winds would create transport paths to Parlee Beach, while idealized southerly winds would impede them, the results from this non-exceedance event point to the possibility that the directional threshold for the transport to be impeded may be between these two directions, and possibly close to south-southwest.

| Potential Source Contribution Matrix (Concentration in Nominal Units) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source ID | Day of Release (Results Shown For Day 8: July 23, 2017) | | | | | | |
| | Jul 16 | Jul 17 | Jul 18 | Jul 19 | Jul 20 | Jul 21 | Jul 22 |
| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | 2 | 5 | 13 | 19 | 38 | 41 | 13 |
| B | 4 | 9 | 16 | 30 | 34 | 22 | 3 |
| C | 10 | 15 | 19 | 25 | 19 | 8 | 7 |
| D | 8 | 13 | 22 | 31 | 26 | 22 | 72 |
| E | 8 | 13 | 22 | 31 | 29 | 23 | 88 |
| F | 9 | 17 | 25 | 30 | 29 | 47 | 129 |
| G | 14 | 24 | 34 | 59 | 70 | 105 | 18 |
| H | 44 | 53 | 66 | 79 | 96 | 118 | 99 |
| I | 19 | 21 | 30 | 41 | 50 | 68 | 144 |
| J | 19 | 23 | 29 | 41 | 42 | 44 | 108 |
| K | 16 | 16 | 28 | 17 | 14 | 31 | |
| L | 7 | 4 | 20 | 4 | 0 | 7 | |
| M | 1 | 0 | 3 | 0 | 0 | 0 | 0 |
| N | 3 | 0 | 6 | 1 | 0 | 0 | 0 |
| Wind Speed Avg (m/s) | 4 | 3 | 5 | 5 | 6 | 3 | 8 |
| Wind Direction Avg (deg) | 177 | 237 | 213 | 211 | 236 | 254 | 274 |
| Rain Local [mm/day] | 10.8 | 1.6 | 0.0 | 0.0 | 0.0 | 7.9 | 3.3 |
| Rain CMORPH [mm/day] | 0.3 | 0 | 0.2 | 1.6 | 0.0 | 0.0 | 11.3 |

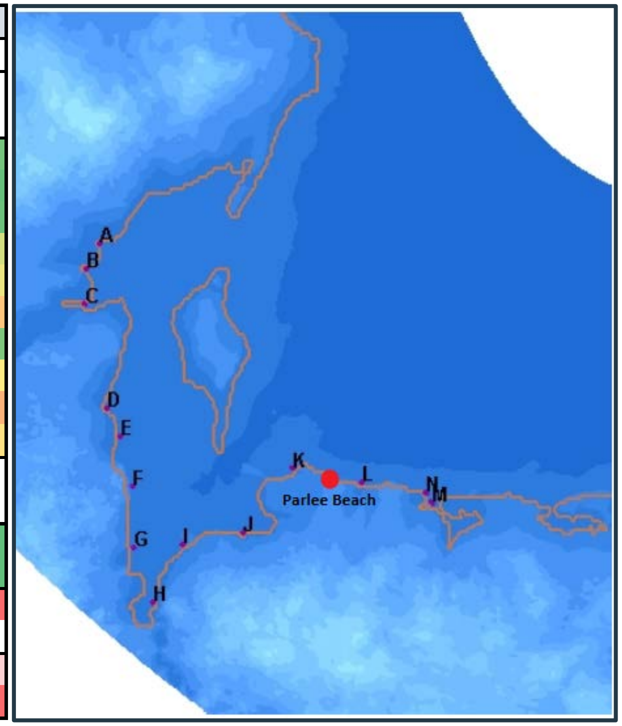



**Figure 4-1 Potential source contribution matrix results for the July 23 exceedance event.**

**Notes:**

**The matrix presents modelled peak concentrations at Parlee Beach on the day of the exceedance (Day 8 in the model), in nominal concentration units, from each of the bacterial sources distributed over 14 locations (A through N). Each source location discharges trackable 24-hour long releases over each of the 7 days before the observed exceedance at Parlee Beach. Source locations include the north of Shediac Bay (A,B,C), central Shediac Bay (D,E,F) and south of Shediac Bay (G,H,I,J).**

**Locations K and L are located at the west and east ends of Parlee Beach, and results for discharges K7 and L7 are excluded due to the close proximity in space and time to the observations.**

**The matrix is color-coded based on nominal unit values scaled from green (0) to yellow (100) to red (200). Wind speed and rain values are color-coded from white to red on a relative basis within the respective rows.**

| Potential Source Contribution Matrix (Concentration in Nominal Units) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source ID | Day of Release (Results Shown For Day 8: August 22, 2017) | | | | | | |
| | Aug 15 | Aug 16 | Aug 17 | Aug 18 | Aug 19 | Aug 20 | Aug 21 |
| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | 6 | 7 | 2 | 1 | 0 | 0 | 0 |
| B | 6 | 5 | 4 | 1 | 0 | 0 | 0 |
| C | 6 | 5 | 5 | 2 | 0 | 0 | 0 |
| D | 6 | 7 | 11 | 6 | 1 | 1 | 0 |
| E | 7 | 8 | 14 | 7 | 2 | 2 | 1 |
| F | 8 | 9 | 15 | 6 | 2 | 2 | 19 |
| G | 10 | 12 | 8 | 5 | 16 | 65 | 13 |
| H | 12 | 14 | 10 | 5 | 8 | 28 | 46 |
| I | 10 | 11 | 14 | 10 | 5 | 44 | 135 |
| J | 8 | 7 | 12 | 11 | 23 | 89 | 160 |
| K | 8 | 5 | 2 | 14 | 17 | 16 | |
| L | 6 | 4 | 3 | 14 | 19 | 8 | |
| M | 4 | 4 | 4 | 15 | 17 | 8 | 0 |
| N | 4 | 4 | 3 | 13 | 15 | 7 | 0 |
| Wind Speed Avg (m/s) | 3 | 6 | 8 | 12 | 6 | 11 | 6 |
| Wind Direction Avg (deg) | 296 | 172 | 283 | 325 | 125 | 177 | 258 |
| Rain Local [mm/day] | 0.0 | 2.6 | 8.3 | 5.2 | 0.3 | 0.1 | 0.0 |
| Rain CMORPH [mm/day] | 0.0 | 0.2 | 1.1 | 0.8 | 0.0 | 4.5 | 0.0 |

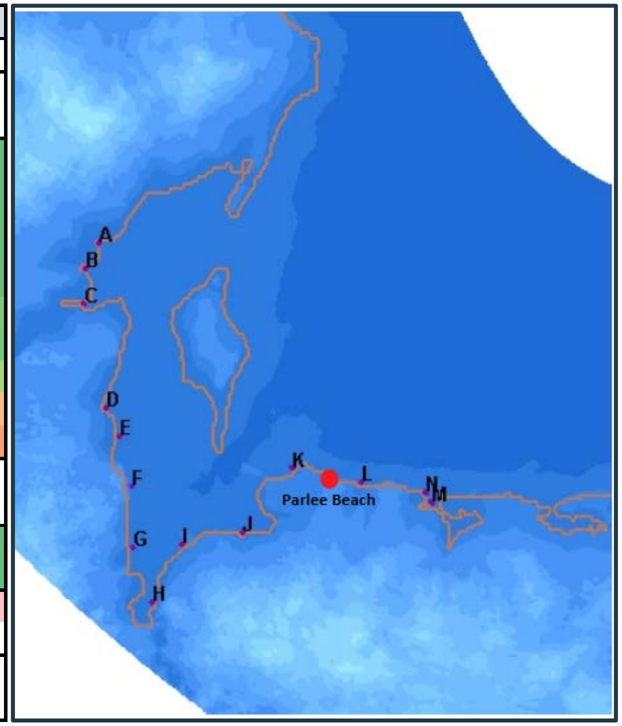



**Figure 4-2 Potential source contribution matrix results for the August 22 exceedance event.**

**Notes:**

**The matrix presents modelled peak concentrations at Parlee Beach on the day of the exceedance (Day 8 in the model), in nominal concentration units, from each of the bacterial sources distributed over 14 locations (A through N). Each source location discharges trackable 24-hour long releases over each of the 7 days before the observed exceedance at Parlee Beach. Source locations include the north of Shediac Bay (A,B,C), central Shediac Bay (D,E,F) and south of Shediac Bay (G,H,I,J).**

**Locations K and L are located at the west and east ends of Parlee Beach, and results for discharges K7 and L7 are excluded due to the close proximity in space and time to the observations.**

**The matrix is color-coded based on nominal unit values scaled from green (0) to yellow (100) to red (200). Wind speed and rain values are color-coded from white to red on a relative basis within the respective rows.**

| Potential Source Contribution Matrix (Concentration in Nominal Units) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source ID | Day of Release (Results Shown For Day 8: September 2, 2017) | | | | | | |
| | Aug 26 | Aug 27 | Aug 28 | Aug 29 | Aug 30 | Aug 31 | Sep 01 |
| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | 39 | 36 | 52 | 65 | 85 | 55 | 49 |
| B | 29 | 34 | 51 | 66 | 80 | 40 | 22 |
| C | 25 | 26 | 37 | 46 | 51 | 56 | 29 |
| D | 10 | 11 | 18 | 23 | 42 | 89 | 57 |
| E | 9 | 9 | 16 | 22 | 31 | 76 | 48 |
| F | 7 | 8 | 15 | 25 | 20 | 74 | 115 |
| G | 8 | 15 | 24 | 44 | 37 | 131 | 133 |
| H | 25 | 36 | 53 | 81 | 128 | 199 | 170 |
| I | 5 | 5 | 9 | 16 | 27 | 74 | 232 |
| J | 4 | 4 | 8 | 12 | 27 | 49 | 207 |
| K | 0 | 0 | 1 | 7 | 6 | 19 | |
| L | 0 | 1 | 1 | 5 | 8 | 16 | |
| M | 1 | 2 | 3 | 9 | 21 | 17 | 0 |
| N | 0 | 1 | 2 | 6 | 17 | 14 | 0 |
| Wind Speed Avg (m/s) | 7 | 4 | 6 | 5 | 4 | 10 | 7 |
| Wind Direction Avg (deg) | 311 | 310 | 349 | 350 | 318 | 60 | 285 |
| Rain Local [mm/day] | 1.4 | 1.2 | 11.0 | 8.4 | 4.4 | 0.2 | 0.0 |
| Rain CMORPH [mm/day] | 4.2 | 0.0 | 0.0 | 0.0 | 0.0 | 25.2 | 0.0 |

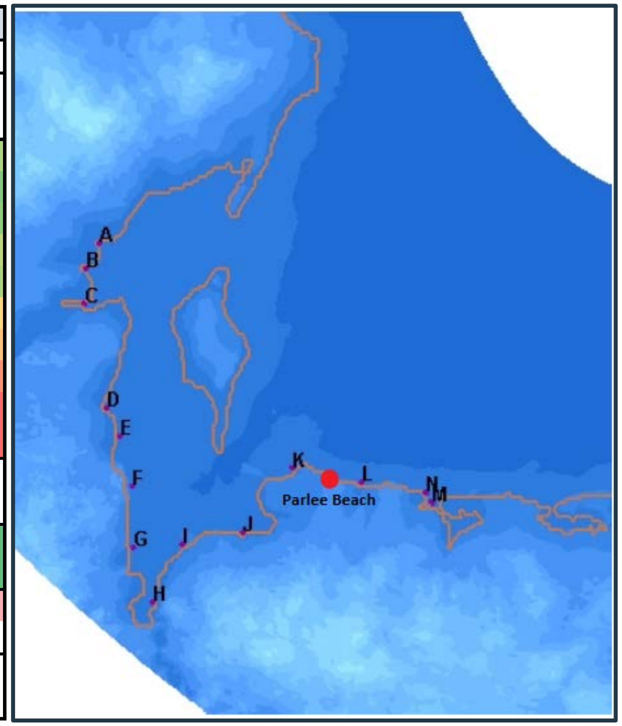



**Figure 4-3 Potential source contribution matrix results for the September 2 exceedance event.**

**Notes:**
**The matrix presents modelled peak concentrations at Parlee Beach on the day of the exceedance (Day 8 in the model), in nominal concentration units, from each of the bacterial sources distributed over 14 locations (A through N). Each source location discharges trackable 24-hour long releases over each of the 7 days before the observed exceedance at Parlee Beach. Source locations include the north of Shediac Bay (A,B,C), central Shediac Bay (D,E,F) and south of Shediac Bay (G,H,I,J).**

**Locations K and L are located at the west and east ends of Parlee Beach, and results for discharges K7 and L7 are excluded due to the close proximity in space and time to the observations.**

**The matrix is color-coded based on nominal unit values scaled from green (0) to yellow (100) to red (200). Wind speed and rain values are color-coded from white to red on a relative basis within the respective rows.**

| Potential Source Contribution Matrix (Concentration in Nominal Units) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source ID | Day of Release (Results Shown For Day 8: September 7, 2017) | | | | | | |
| | Aug 31 | Sep 01 | Sep 02 | Sep 03 | Sep 04 | Sep 05 | Sep 06 |
| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| E | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| F | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| G | 1 | 1 | 1 | 1 | 3 | 1 | 0 |
| H | 1 | 1 | 1 | 2 | 5 | 6 | 0 |
| I | 0 | 0 | 1 | 1 | 3 | 11 | 8 |
| J | 0 | 0 | 1 | 2 | 5 | 14 | 36 |
| K | 0 | 0 | 0 | 2 | 1 | 2 | |
| L | 0 | 0 | 0 | 2 | 1 | 0 | |
| M | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| N | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| Wind Speed Avg (m/s) | 10 | 7 | 11 | 5 | 12 | 10 | 11 |
| Wind Direction Avg (deg) | 60 | 285 | 290 | 349 | 185 | 232 | 210 |
| Rain Local [mm/day] | 0.2 | 6.3 | 5.3 | 17.8 | 0.0 | 0.0 | 0.0 |
| Rain CMORPH [mm/day] | 25.2 | 0.0 | 0.0 | 0.2 | 3.8 | 0.0 | 0.0 |

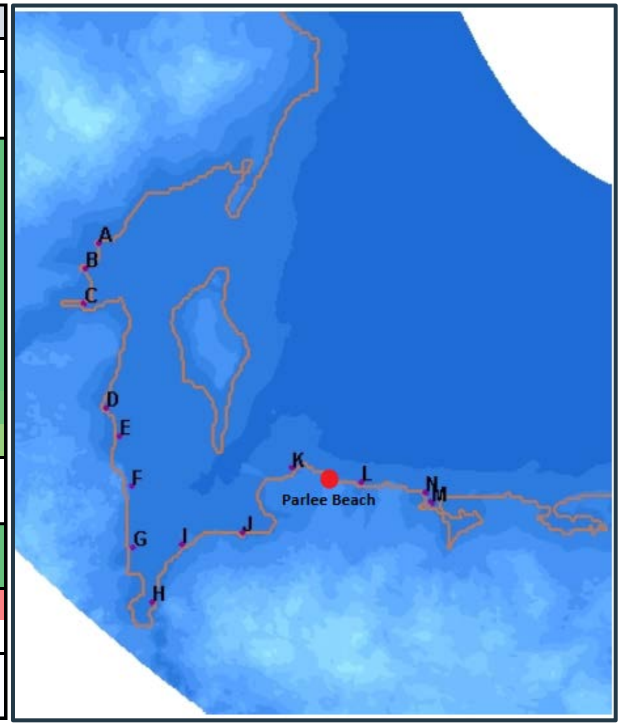



**Figure 4-4 Potential source contribution matrix results for the September 7 non-exceedance event.**

**Notes:**

**The matrix presents modelled peak concentrations at Parlee Beach on the day of the observed non-exceedance (Day 8 in the model), in nominal concentration units, from each of the bacterial sources distributed over 14 locations (A through N). Each source location discharges trackable 24-hour long releases over each of the 7 days before the observed exceedance at Parlee Beach. Source locations include the north of Shediac Bay (A,B,C), central Shediac Bay (D,E,F) and south of Shediac Bay (G,H,I,J).**

**Locations K and L are located at the west and east ends of Parlee Beach, and results for discharges K7 and L7 are excluded due to the close proximity in space and time to the observations.**

**The matrix is color-coded based on nominal unit values scaled from green (0) to yellow (100) to red (200). Wind speed and rain values are color-coded from white to red on a relative basis within the respective rows.**

| Potential Source Contribution Matrix (Concentration in Nominal Units) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source ID | Day of Release (Results Shown For Day 8: July 23, 2017) | | | | | | |
| | Jul 16 | Jul 17 | Jul 18 | Jul 19 | Jul 20 | Jul 21 | Jul 22 |
| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | 2 | 5 | 13 | 19 | 38 | 41 | 13 |
| B | 4 | 9 | 16 | 30 | 34 | 22 | 3 |
| C | 10 | 15 | 19 | 25 | 19 | 8 | 7 |
| D | 8 | 13 | 22 | 31 | 26 | 22 | 72 |
| E | 8 | 13 | 22 | 31 | 29 | 23 | 88 |
| F | 9 | 17 | 25 | 30 | 29 | 47 | 129 |
| G | 14 | 24 | 34 | 59 | 70 | 105 | 18 |
| H | 44 | 53 | 66 | 79 | 96 | 118 | 99 |
| I | 19 | 21 | 30 | 41 | 50 | 68 | 144 |
| J | 19 | 23 | 29 | 41 | 42 | 44 | 108 |
| K | 16 | 16 | 28 | 17 | 14 | 31 | |
| L | 7 | 4 | 20 | 4 | 0 | 7 | |
| M | 1 | 0 | 3 | 0 | 0 | 0 | 0 |
| N | 3 | 0 | 6 | 1 | 0 | 0 | 0 |
| Wind Speed Avg (m/s) | 4 | 3 | 5 | 5 | 6 | 3 | 8 |
| Wind Direction Avg (deg) | 177 | 237 | 213 | 211 | 236 | 254 | 274 |
| Rain Local [mm/day] | 10.8 | 1.6 | 0.0 | 0.0 | 0.0 | 7.9 | 3.3 |
| Rain CMORPH [mm/day] | 0.3 | 0 | 0.2 | 1.6 | 0.0 | 0.0 | 11.3 |

| Potential Source Contribution Matrix (Concentration in Nominal Units) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source ID | Day of Release (Results Shown For Day 8: August 22, 2017) | | | | | | |
| | Aug 15 | Aug 16 | Aug 17 | Aug 18 | Aug 19 | Aug 20 | Aug 21 |
| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | 6 | 7 | 2 | 1 | 0 | 0 | 0 |
| B | 6 | 5 | 4 | 1 | 0 | 0 | 0 |
| C | 6 | 5 | 5 | 2 | 0 | 0 | 0 |
| D | 6 | 7 | 11 | 6 | 1 | 1 | 0 |
| E | 7 | 8 | 14 | 7 | 2 | 2 | 1 |
| F | 8 | 9 | 15 | 6 | 2 | 2 | 19 |
| G | 10 | 12 | 8 | 5 | 16 | 65 | 13 |
| H | 12 | 14 | 10 | 5 | 8 | 28 | 46 |
| I | 10 | 11 | 14 | 10 | 5 | 44 | 135 |
| J | 8 | 7 | 12 | 11 | 23 | 89 | 160 |
| K | 8 | 5 | 2 | 14 | 17 | 16 | |
| L | 6 | 4 | 3 | 14 | 19 | 8 | |
| M | 4 | 4 | 4 | 15 | 17 | 8 | 0 |
| N | 4 | 4 | 3 | 13 | 15 | 7 | 0 |
| Wind Speed Avg (m/s) | 3 | 6 | 8 | 12 | 6 | 11 | 6 |
| Wind Direction Avg (deg) | 296 | 172 | 283 | 325 | 125 | 177 | 258 |
| Rain Local [mm/day] | 0.0 | 2.6 | 8.3 | 5.2 | 0.3 | 0.1 | 0.0 |
| Rain CMORPH [mm/day] | 0.0 | 0.2 | 1.1 | 0.8 | 0.0 | 4.5 | 0.0 |

| Potential Source Contribution Matrix (Concentration in Nominal Units) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source ID | Day of Release (Results Shown For Day 8: September 2, 2017) | | | | | | |
| | Aug 26 | Aug 27 | Aug 28 | Aug 29 | Aug 30 | Aug 31 | Sep 01 |
| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | 39 | 36 | 52 | 65 | 85 | 55 | 49 |
| B | 29 | 34 | 51 | 66 | 80 | 40 | 22 |
| C | 25 | 26 | 37 | 46 | 51 | 56 | 29 |
| D | 10 | 11 | 18 | 23 | 42 | 89 | 57 |
| E | 9 | 9 | 16 | 22 | 31 | 76 | 48 |
| F | 7 | 8 | 15 | 25 | 20 | 74 | 115 |
| G | 8 | 15 | 24 | 44 | 37 | 131 | 133 |
| H | 25 | 36 | 53 | 81 | 128 | 199 | 170 |
| I | 5 | 5 | 9 | 16 | 27 | 74 | 232 |
| J | 4 | 4 | 8 | 12 | 27 | 49 | 207 |
| K | 0 | 0 | 1 | 7 | 6 | 19 | |
| L | 0 | 1 | 1 | 5 | 8 | 16 | |
| M | 1 | 2 | 3 | 9 | 21 | 17 | 0 |
| N | 0 | 1 | 2 | 6 | 17 | 14 | 0 |
| Wind Speed Avg (m/s) | 7 | 4 | 6 | 5 | 4 | 10 | 7 |
| Wind Direction Avg (deg) | 311 | 310 | 349 | 350 | 318 | 60 | 285 |
| Rain Local [mm/day] | 1.4 | 1.2 | 11.0 | 8.4 | 4.4 | 0.2 | 0.0 |
| Rain CMORPH [mm/day] | 4.2 | 0.0 | 0.0 | 0.0 | 0.0 | 25.2 | 0.0 |

| Potential Source Contribution Matrix (Concentration in Nominal Units) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Source ID | Day of Release (Results Shown For Day 8: September 7, 2017) | | | | | | |
| | Aug 31 | Sep 01 | Sep 02 | Sep 03 | Sep 04 | Sep 05 | Sep 06 |
| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| E | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| F | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| G | 1 | 1 | 1 | 1 | 3 | 1 | 0 |
| H | 1 | 1 | 1 | 2 | 5 | 6 | 0 |
| I | 0 | 0 | 1 | 1 | 3 | 11 | 8 |
| J | 0 | 0 | 1 | 2 | 5 | 14 | 36 |
| K | 0 | 0 | 0 | 2 | 1 | 2 | |
| L | 0 | 0 | 0 | 2 | 1 | 0 | |
| M | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| N | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| Wind Speed Avg (m/s) | 10 | 7 | 11 | 5 | 12 | 10 | 11 |
| Wind Direction Avg (deg) | 60 | 285 | 290 | 349 | 185 | 232 | 210 |
| Rain Local [mm/day] | 0.2 | 6.3 | 5.3 | 17.8 | 0.0 | 0.0 | 0.0 |
| Rain CMORPH [mm/day] | 25.2 | 0.0 | 0.0 | 0.2 | 3.8 | 0.0 | 0.0 |

**Figure 4-5 Comparison of potential source contribution matrix results for the four modelled events.**

## 4.2 Meteorological and Oceanographic Factors for Pollutant Transport Paths to Parlee Beach

A review of the model results in the form of ocean current vectors and bacterial concentrations, presented in Figure 4-6 to Figure 4-14, indicates the ocurrence of several coastal circulation features under different oceanographic and meteorological conditions that either support or impede the transport paths from the potential sources to Parlee Beach:

- **Recirculation areas within Shediac Bay:** particularly important in the south of Shediac Bay, where contaminated plumes from the recirculation area may be readily transported to Parlee Beach under the right tidal and wind conditions;
- **Tidal currents at the entrances of Shediac Bay**: tidal currents impede transport paths toward Parlee Beach during the incoming flood tide, and promote export paths out of the bay during the ebb tide;
- **Wind-induced currents in Shediac Bay, and the surf zone adjacent to Parlee Beach:** wind-induced nearshore currents promote transport paths toward Parlee Beach when winds are from the southwest, west or northwest, and impede transport paths when winds are from the south, southeast, east and northeast directions;
- **The interaction between tides and winds:** the relative strength of the tide and wind induced circulation features depends on the time of day and month (relative strength of the tides within the daily and spring-neap cycles), as well as the relative timing and persistence of the wind speeds and directions;
- **The timing of discharges relative to the changes in tidal stage and wind conditions:** the timing, location and duration of any contaminated discharges relative to the meteorological and oceanographic features are also a determining factor in the viability and efficiency of the transport paths available for those releases to reach the beach.

The main features of one of the most probable transport paths (event H6) from Shediac Bay to Parlee Beach for the third exceedance event on September 2 are illustrated in Figure 4-6 to Figure 4-9. The figures show that contaminated plumes may accumulate and recirculate in the south area of Shediac Bay during flood tides, and they could then be available to be transported out when the tidal currents at the bay entrance turn during ebb tide. The ebb stage of the tide is therefore one of the determining factors for transport out of Shediac Bay where the plumes could be further transported toward or away from Parlee Beach, depending on the current direction in the surf zone adjacent to Parlee Beach.

The surf zone currents in Figure 4-8 and Figure 4-9 for exceedance event 3 were favourable for transport toward the beach, while Figure 4-10 to Figure 4-12 for the non-exceedance event illustrate how the westward surf zone currents can impede or block the transport of the plumes toward Parlee Beach, even in conditions when the tidal current jet has exported them outside of Shediac Bay. During the non-exceedance event simulation, the winds from the south-southwest direction also tended to promote northward transport along the coastline of Shediac Bay, thus reducing the availability of bacterial contaminants in the southern recirculation area, where they could have been exported to Parlee Beach during periods when the tidal currents and surf zone currents may have opened that transport path. The transport paths for sources from the north of Shediac Bay (Figure 4-13 and Figure 4-14) include either transport trough the south of Shediac Bay, or through the northern channel, followed by further transport to Parlee Beach. Therefore the contaminated plumes originating in the are north less likely to reach the beach, and more likely to be diluted when they do compared to the central and southern sources.

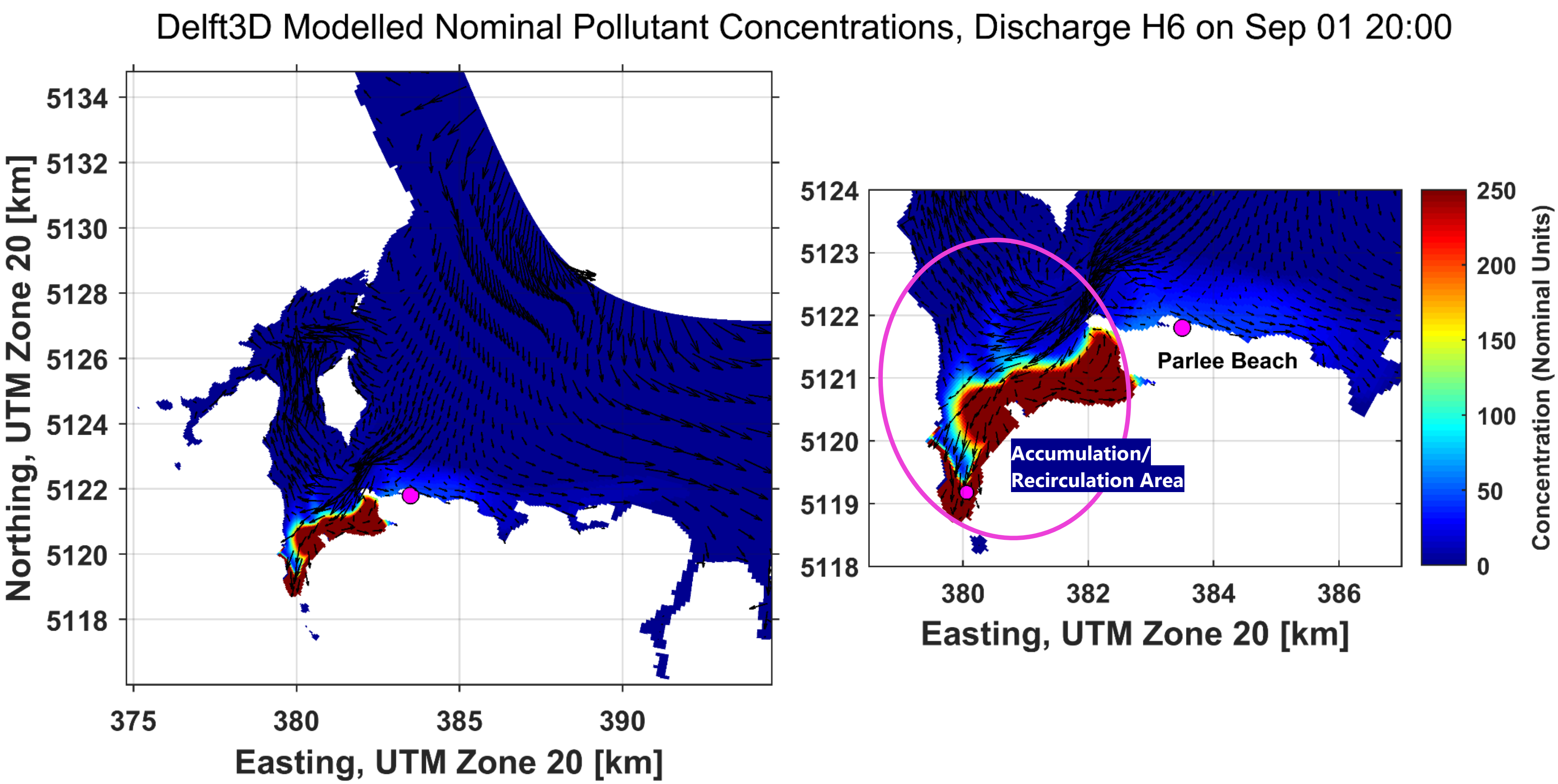



**Figure 4-6 Map of modelled current vectors and bacterial concentrations for source H6 preceding the September 2 exceedance event, on September 1 at 20:00 o'clock.**

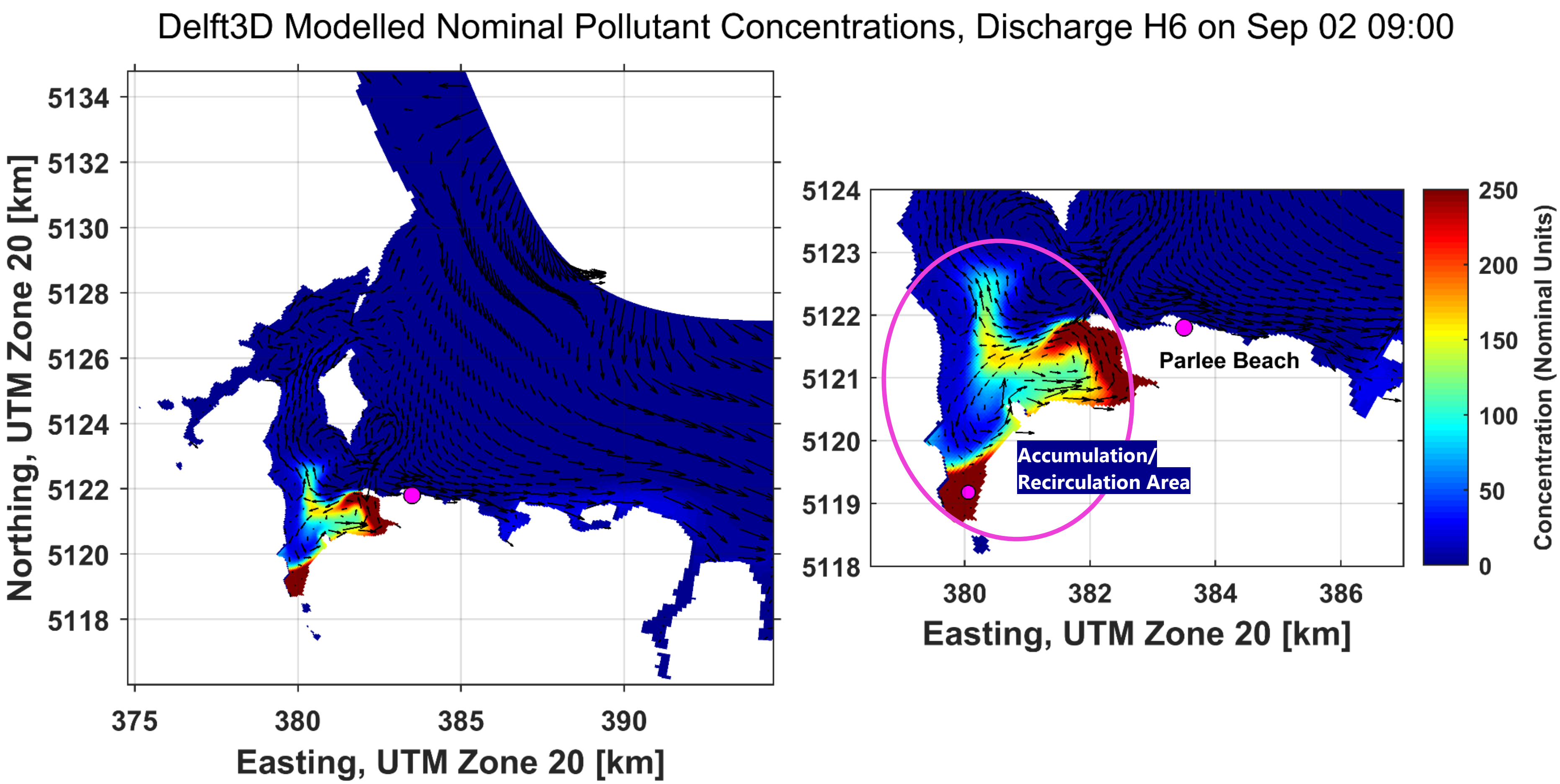



**Figure 4-7 Map of modelled current vectors and bacterial concentrations for source H6 preceding the September 2 exceedance event, on September 2 at 09:00 o'clock.**

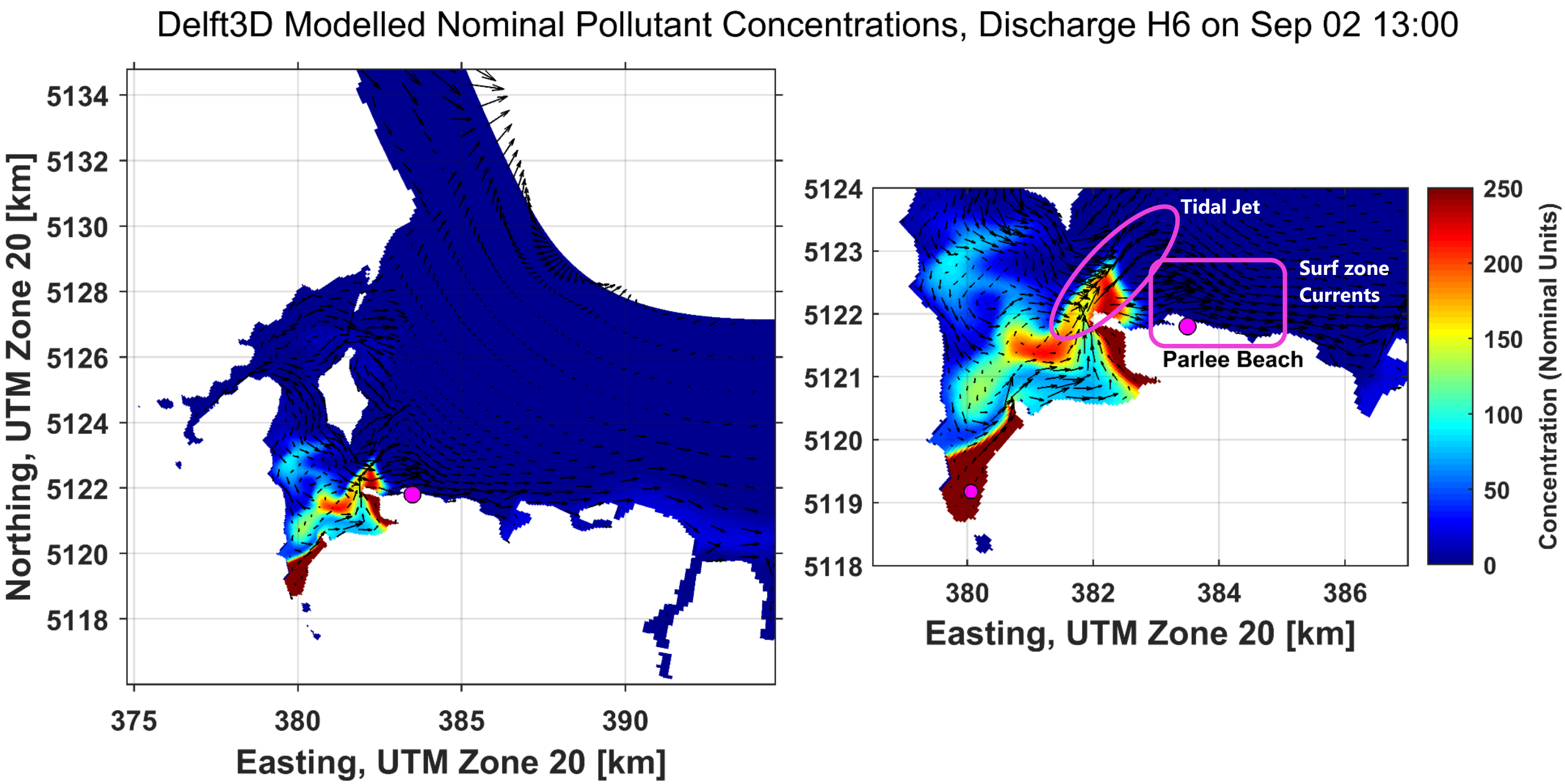



**Figure 4-8 Map of modelled current vectors and bacterial concentrations for source H6 preceding the September 2 exceedance event, on September 2 at 13:00 o'clock.**

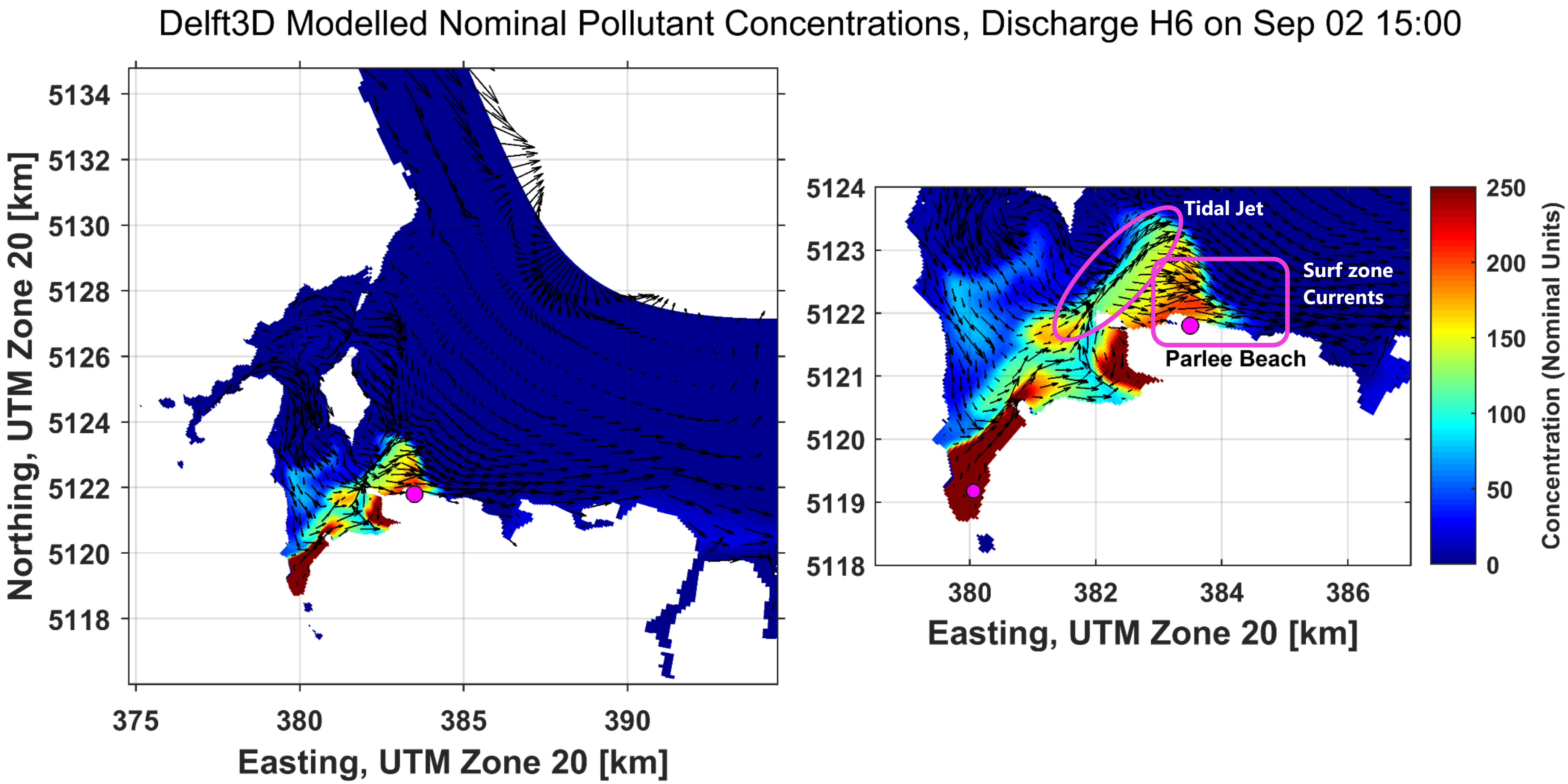



**Figure 4-9 Map of modelled current vectors and bacterial concentrations for source H6 preceding the September 2 exceedance event, on September 2 at 15:00 o'clock.**

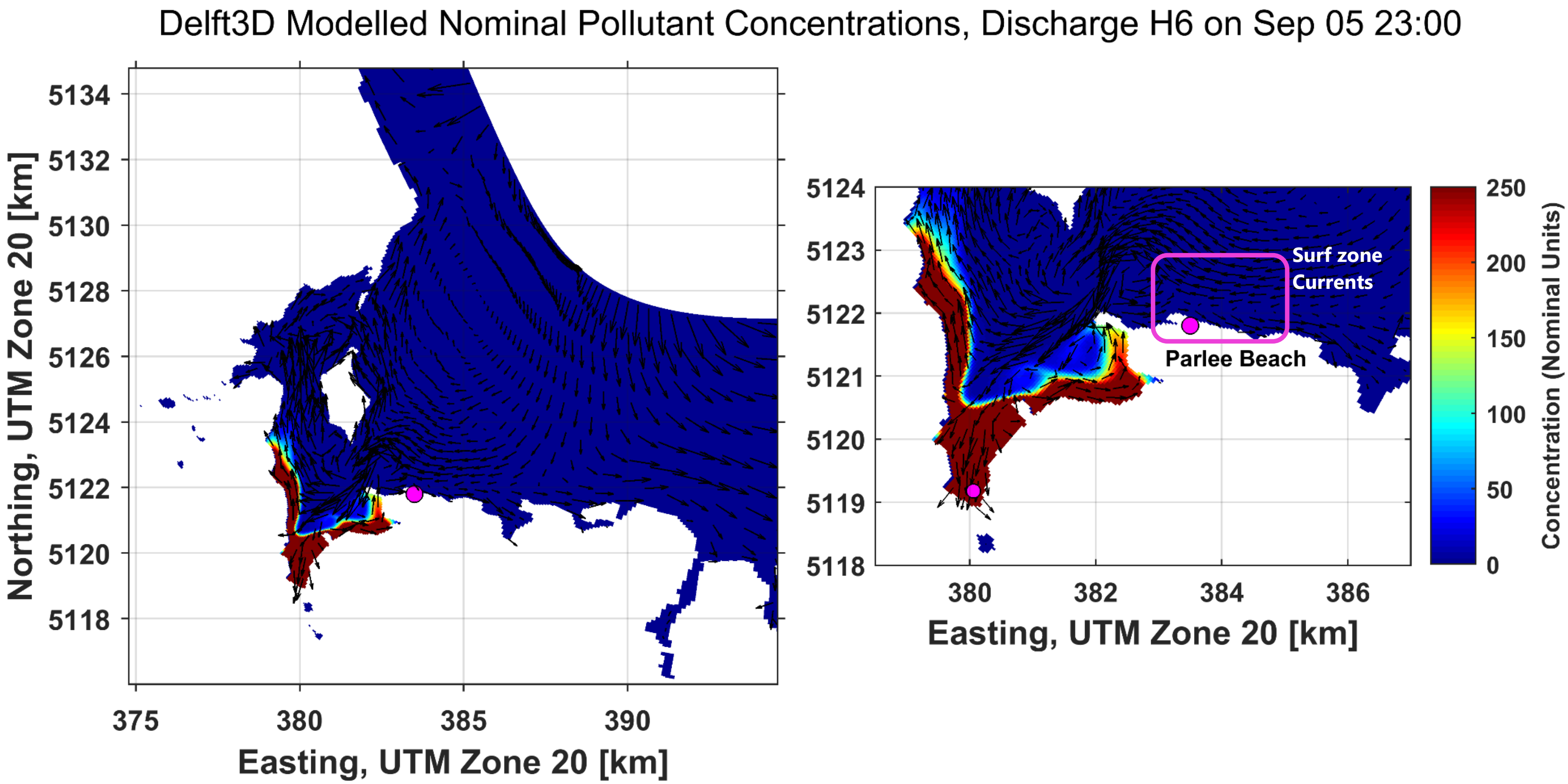



**Figure 4-10 Map of modelled current vectors and bacterial concentrations for source H6 preceding the September 7 non-exceedance event, on September 5 at 23:00 o'clock.**

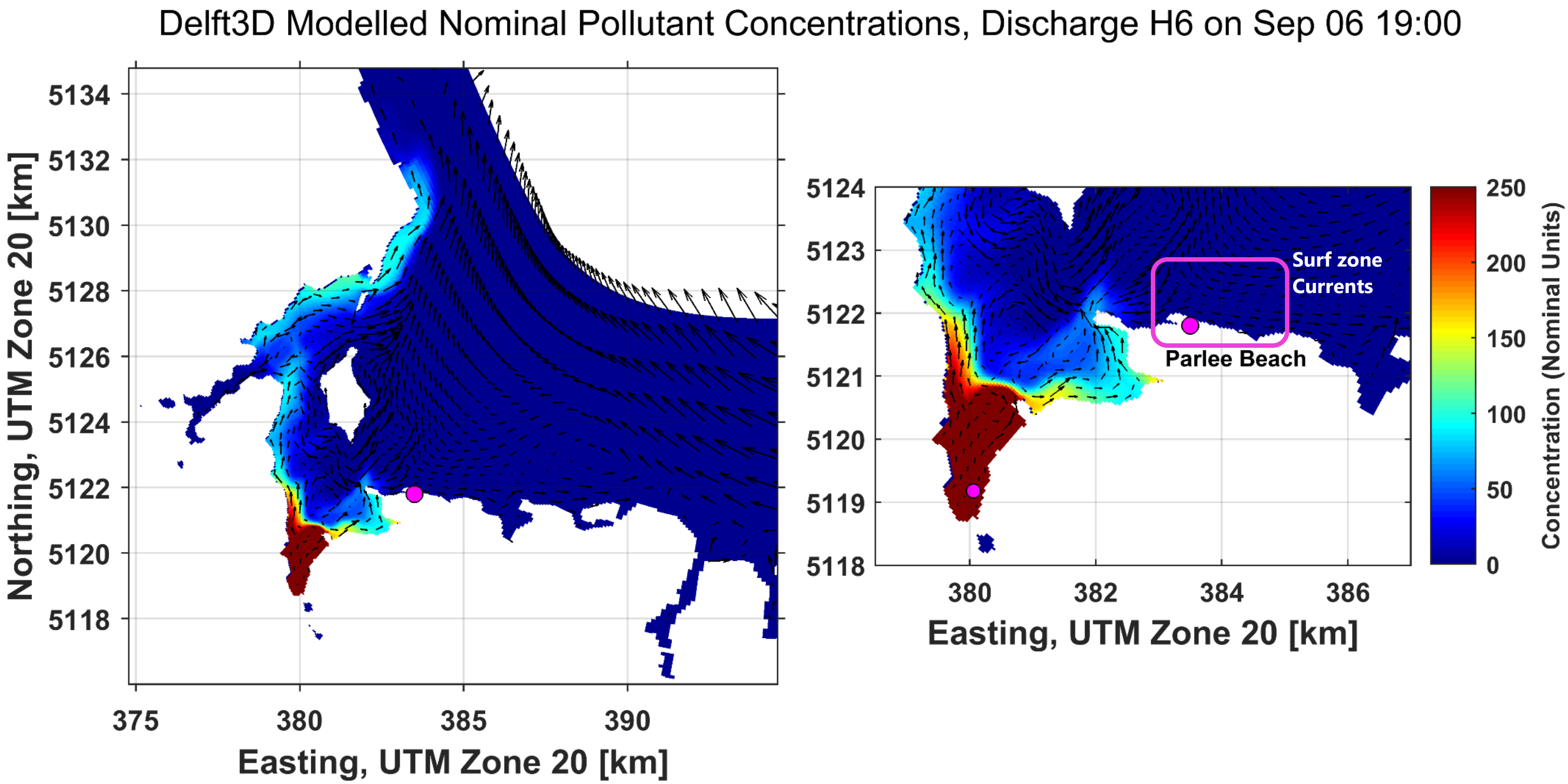



**Figure 4-11 Map of modelled current vectors and bacterial concentrations for source H6 preceding the September 7 non-exceedance event, on September 6 at 19:00 o'clock.**

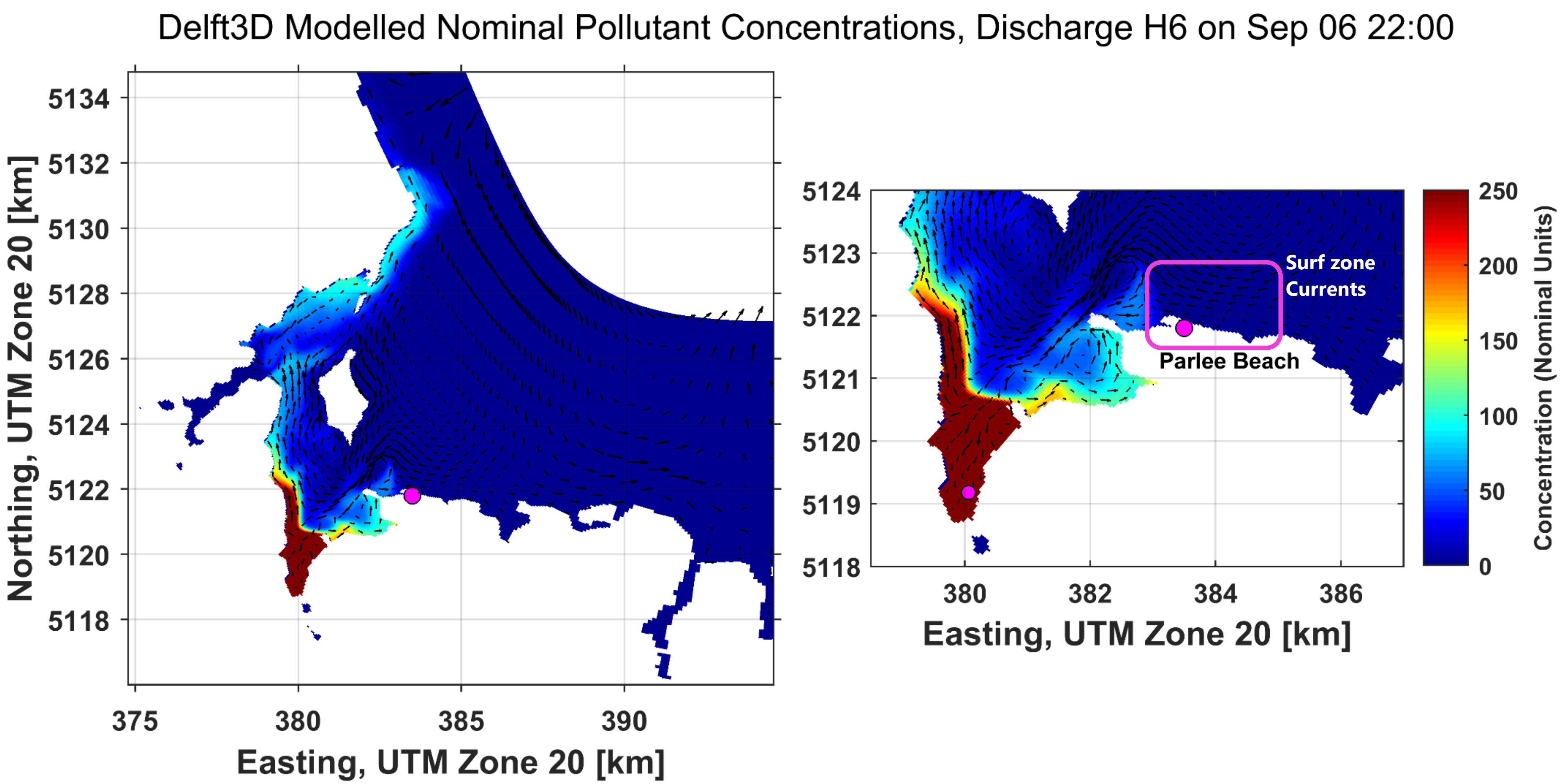



**Figure 4-12 Map of modelled current vectors and bacterial concentrations for source H6 preceding the September 7 non-exceedance event, on September 6 at 22:00 o'clock.**

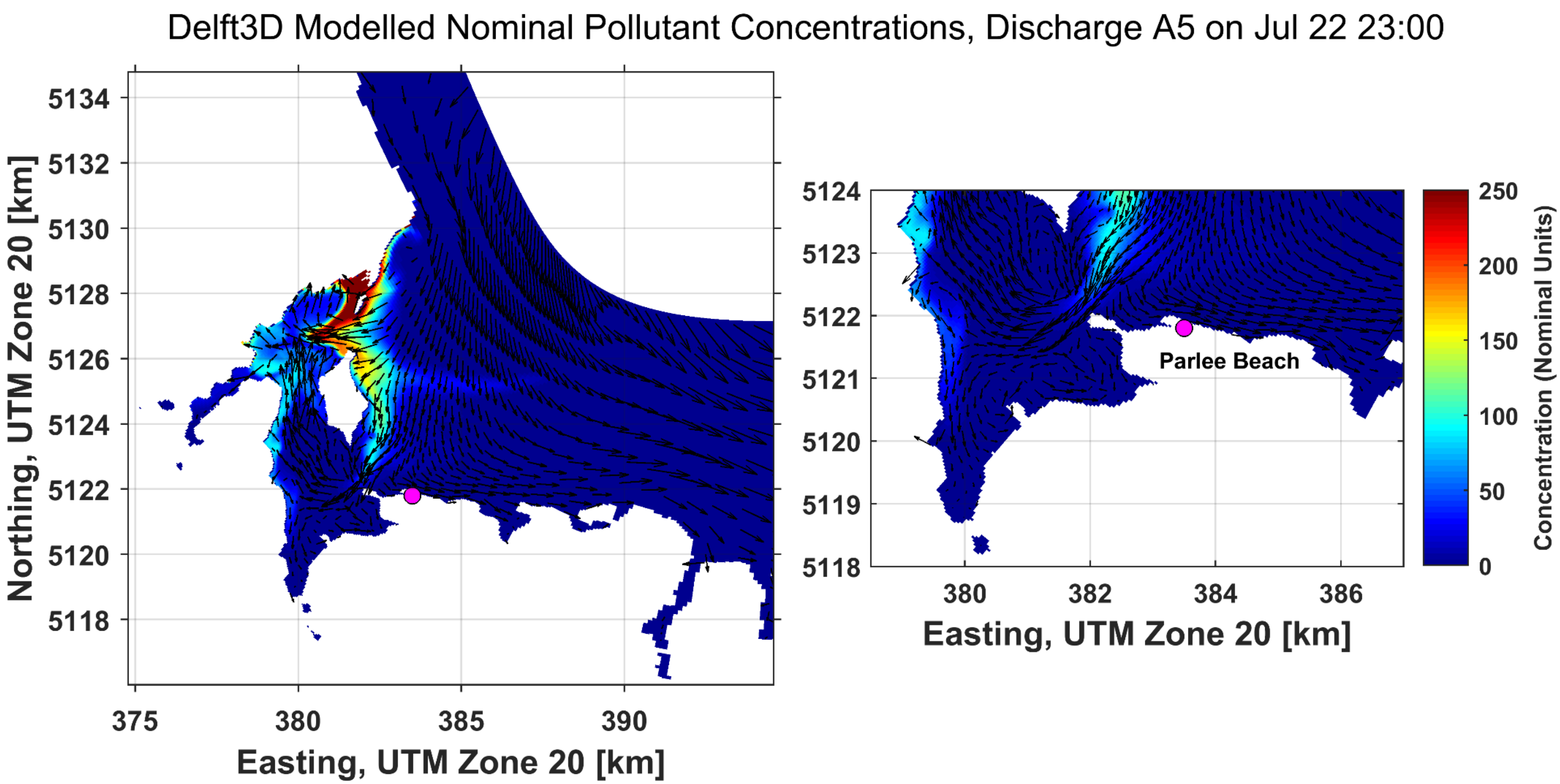



**Figure 4-13 Map of modelled current vectors and bacterial concentrations for source A5 preceding the July 23 exceedance event, on July 22 at 23:00 o'clock.**

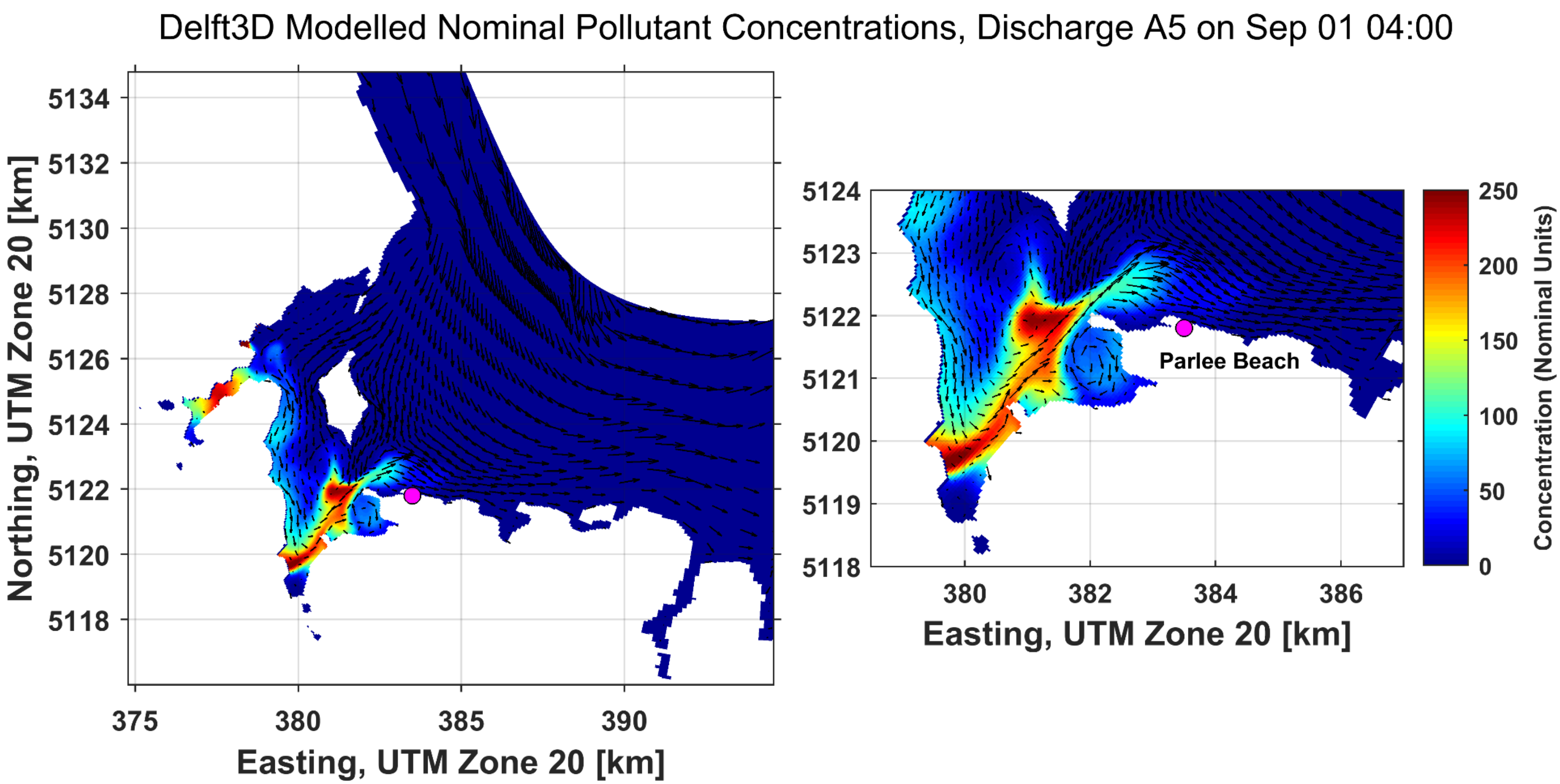



**Figure 4-14 Map of modelled current vectors and bacterial concentrations for source A5 preceding the September 2 exceedance event, on September 1 at 04:00 o'clock.**

# 5.0 CONCLUSIONS

The four water quality events at Parlee Beach selected for detailed modelling of transport paths include three water quality guideline exceedance events where bacterial concentrations were elevated, and one event where measured bacterial concentrations were below the guidelines even though elevated concentrations had been observed in potential source locations. These observed events provide opportunities to study the potential and probable transport paths for contaminants to Parlee Beach, as well as the oceanographic and meteorological conditions that enhance and impede those paths.

Due to the low temporal frequency of potential bacterial source observations in Shediac Bay, as well as the lack of flow rate data at the sources, the hydrodynamic and water quality model implemented for this study included hypothetical unit strength bacterial sources with an equivalent strength at fourteen potential locations in Shediac Bay, Parlee Beach and the coastline east of Parlee Beach. Bacterial concentrations in the model have not been subjected to proliferation or decay, due to lack of in-situ data that could support the quantification of proliferation or decay rates in the coastal environment of Shediac Bay. Furthermore, the timing and duration of discharges from potential bacterial sources during the modelled events are not known, therefore the model implements distinct 24 hour releases for 7 days prior to the day when the observations and predictions were made. The 24 hour releases are considered discrete enough in time to reflect changes in the daily meteorological forcing conditions, but long enough to span the full diurnal tidal cycle, providing inputs to the environment at each stage of the tide from each distinct source.

The modelling study therefore likely includes a wider range of potential bacterial sources in space and time than occurred during the historical periods. The most probable transport paths are identified based on the physical advection and dispersion of potential bacterial discharges, and the timing of their arrival to Parlee Beach compared to the observed bacterial concentrations. The following conclusions could be drawn based on the results presented in the previous section:

1. The model results illustrate that there are very distinct transport paths for bacterial releases from each location and discrete 24 hour release period, therefore indicating the importance of measuring the contamination levels at key potential sources frequently in time (daily or more frequently);
2. The model indicates that some locations and times of release are much more likely to have contributed to the observed bacterial guideline exceedance events, with source locations in the south and central areas of Shediac Bay being the most likely contributors. Furthermore, releases during the preceding 48 to 72 hours prior to the day of observation were most likely to contribute to the levels measured at Parlee Beach on the day of observation;
3. The model indicates that bacterial discharges from a number of sources in central and south Shediac Bay could accumulate in the south of Shediac Bay within an area of recirculation, particularly during periods of flood tide when export out of the bay is impeded, and when wind conditions do not promote transport of these discharges to the north of Shediac Bay. This recirculation area could therefore represent a key location for more frequent sampling, that could provide an earlier indication of possible later contamination at Parlee Beach, depending on favourability of transport conditions;
4. A review of the coastal circulation features during the three exceedance events and one non-exceedance event are broadly consistent with previous modelling results (Amec Foster Wheeler, 2017), indicating

that the wind speed and direction, combined with the stage of the tide tend to generate circulation features that either promote or impede transport of contaminants from Shediac Bay to Parlee Beach. The results further indicate the presence of a meaningful wind direction threshold close to south-southwest, with winds from the southwest and west promoting transport toward the beach, and winds from the south and southeast impeding transport from the bay toward the beach. The directional threshold for reversal of the wind-induced transport paths at any given time is expected to be somewhat variable, depending on the speed and persistence of the wind from each of the preceding directions, as well as the stage of the tide within the diurnal and lunar cycles;

5. The ability of the implemented hindcast model to distinctly indicate the presence or absence of favourable transport paths for the three exceedance and one non-exceedance event indicates that it may be plausible to develop a forecasting system to support decision making, based on predictions or observations of the favourability of the coastal circulation for transport, as well as more frequent sampling at a small number of key locations within Shediac Bay.

Based on the results and conclusions presented above, the following requirements and limitations could be considered in determining the ultimate plausibility of the development of a forecasting or decision making tool:

a. A forecasting tool would aim to provide the prediction or observation of the favourability of transport conditions, coupled with knowledge of the presence of potential contamination sources.

b. Given that favourable transport paths for contamination at Parlee Beach from Shediac Bay may exist significantly more frequently than bacterial discharges occur, reducing or eliminating the possibility of false alarms would be a significant challenge in developing a forecasting tool.

c. Frequent sampling of bacterial levels in key locations in Shediac Bay could provide a basis for predictions and decisions to be made for Parlee Beach conditions earlier than currently possible by daily sampling at Parlee Beach. The sampling should be conducted at least on a daily basis, either continuously or triggered by events likely to result in elevated probability of contamination. The modelling results indicate that the recirculation area in the south of Shediac Bay could represent a key frequent sampling location for early indications of potential contamination at Parlee Beach.

d. In addition to the requirement of frequent sampling at key potential bacterial sources, prediction or observation of the favourability of the current conditions for transport paths is required for developing effective forecasts. A water quality forecasting system would require the knowledge of past and present current conditions, as well as a prediction of future current conditions for the desired time window, based on forecasts of meteorological and oceanographic conditions.

e. The past and present coastal current conditions could be determined either through ongoing current monitoring with instruments deployed in key locations, such as the west end of Parlee Beach, or through the ongoing use of a validated hindcast model in an operational manner. Given the lack of in-situ current data for model validation to date, gathering of current data at least for a period of time of a month or longer would be recommended as a minimum for model validation.

f. In considering the potential investment in current monitoring and forecasting capabilities to support water quality predictions and decision making, it may be beneficial to consider additional value of such systems, for example in enhancing visitor safety through detecting or forecasting hazardous oceanographic conditions such as rip currents.

## 6.0 CLOSURE

This report presents the findings of the modelling assessment of water quality for selected historical periods of interest, in support of the DELG initiatives to ensure the best possible water quality at Parlee Beach. Please contact the undersigned with any comments or questions related to this report.

Yours sincerely,

**Wood Environment & Infrastructure Solutions,**
**a Division of Wood Canada Limited**

Prepared by:

Trajce Alcinov, MSc
Senior Oceanographer

Reviewed by:

Patrick Roussel, MEng, MSc
Associate Oceanographer

Prepared by:

Juan Gonzalez-Lopez, PhD
Oceanographer

Prepared by:

Jamie Morris, MSc
Oceanographer

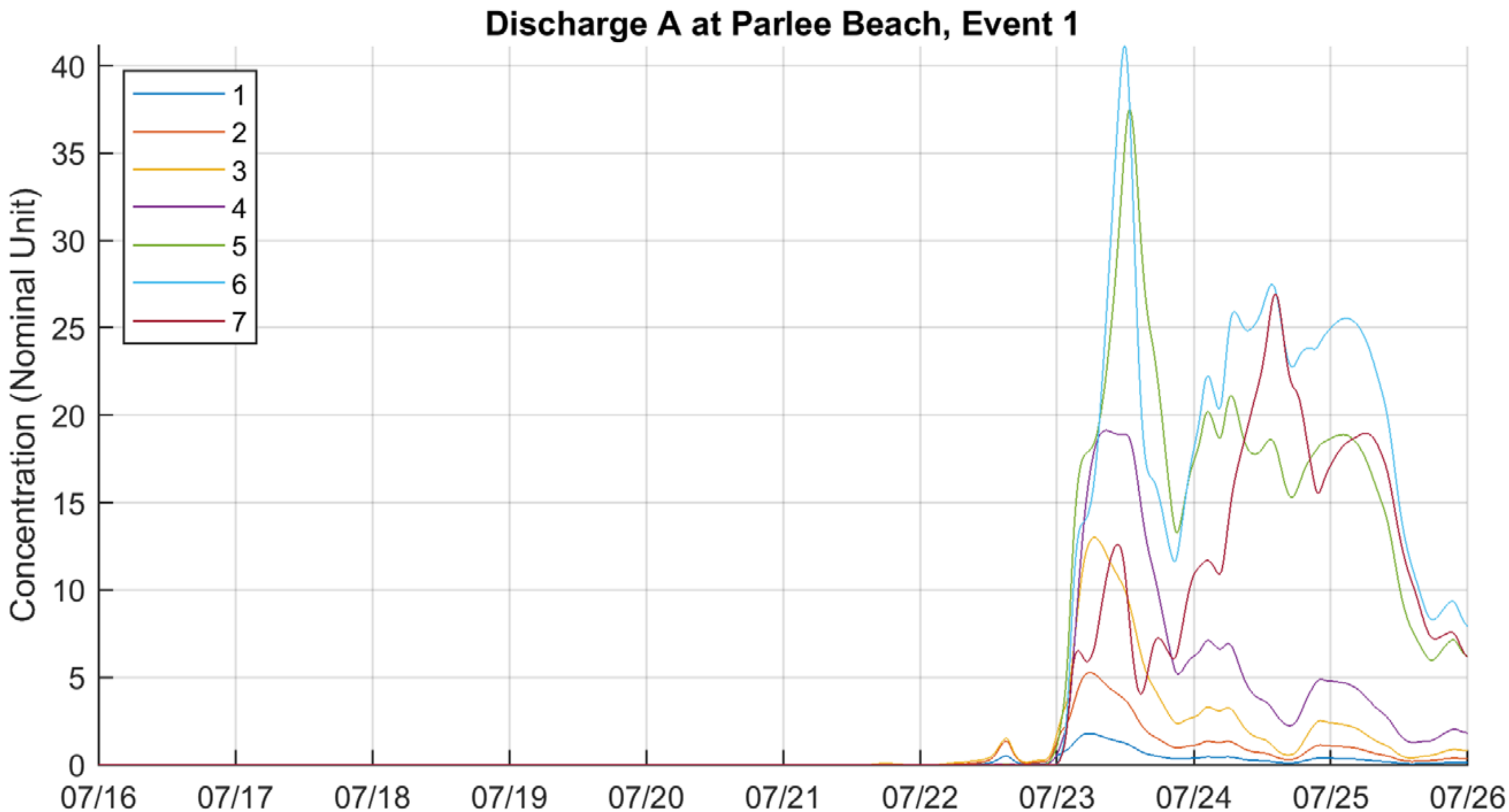
# 7.0 REFERENCES

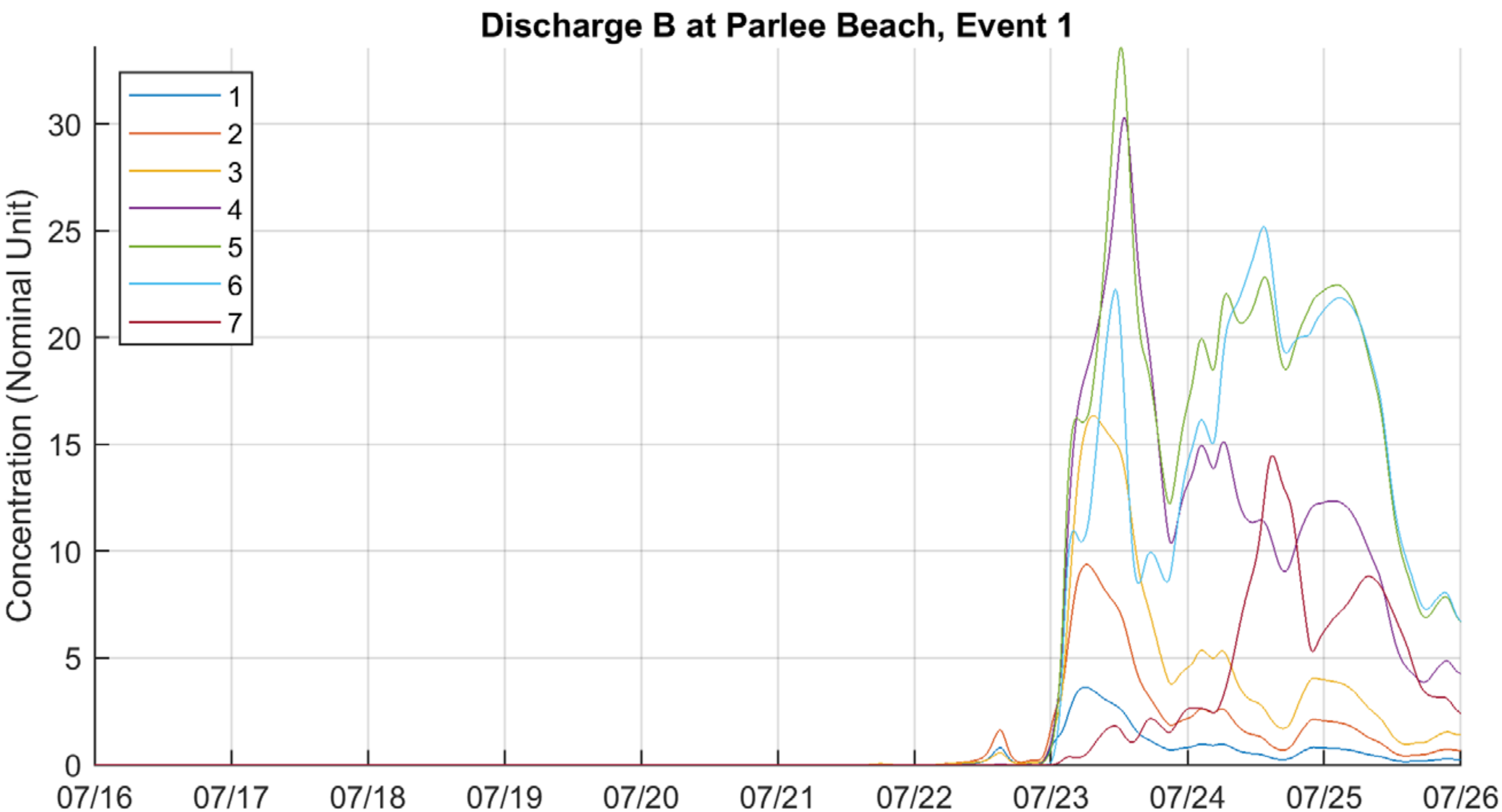
Amec Foster Wheeler (now Wood). 2017. Parlee Beach and Shediac Bay Hydrodynamic Model. Study conducted for the Department of Health, Government of New Brunswick.

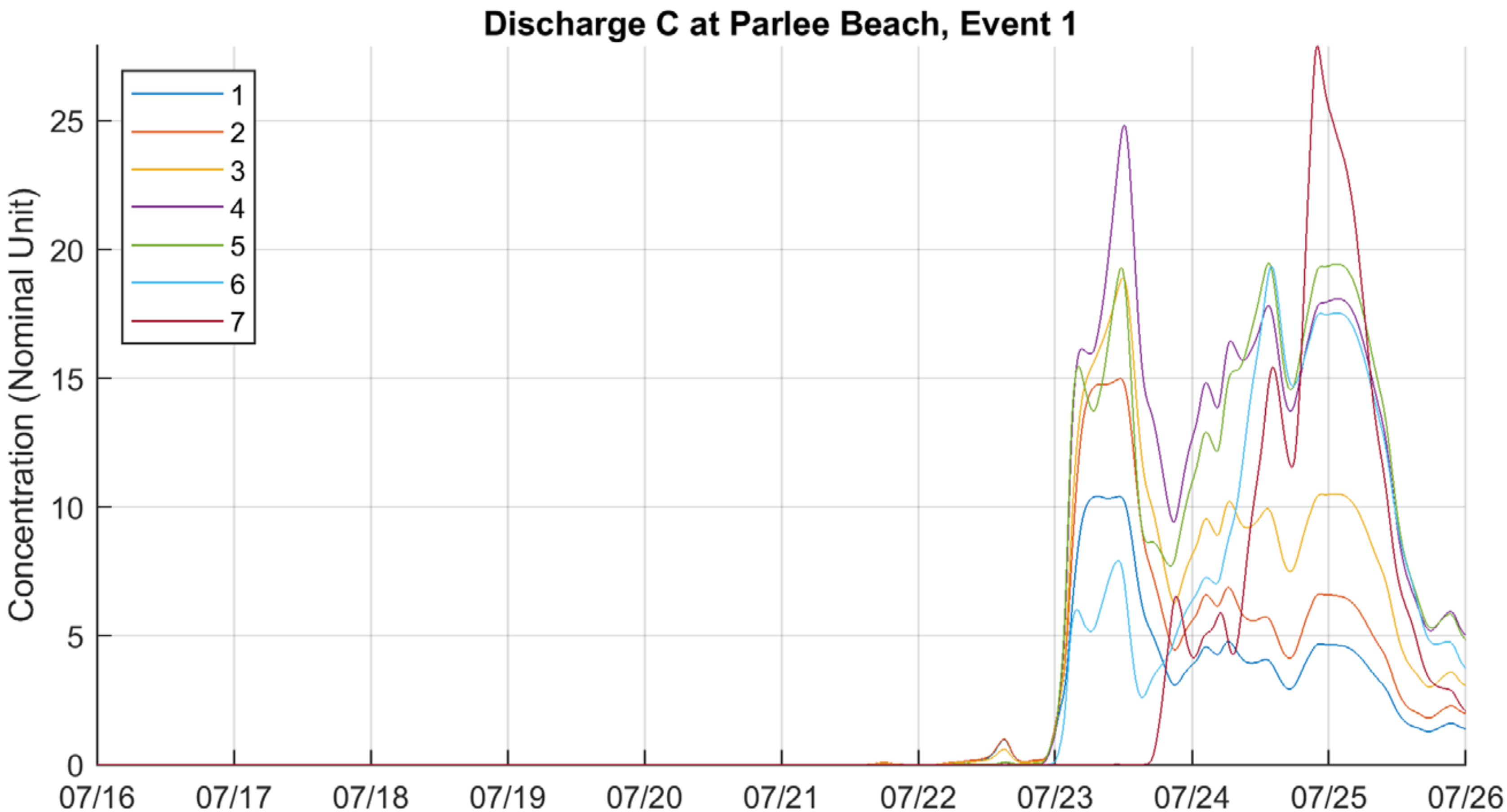
NCEP. 2019. National Centers for Environmental Prediction (NCEP) Climate Forecast System (CFS) version 2. (Accessed online at https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/climate-forecast-system-version2-cfsv2).

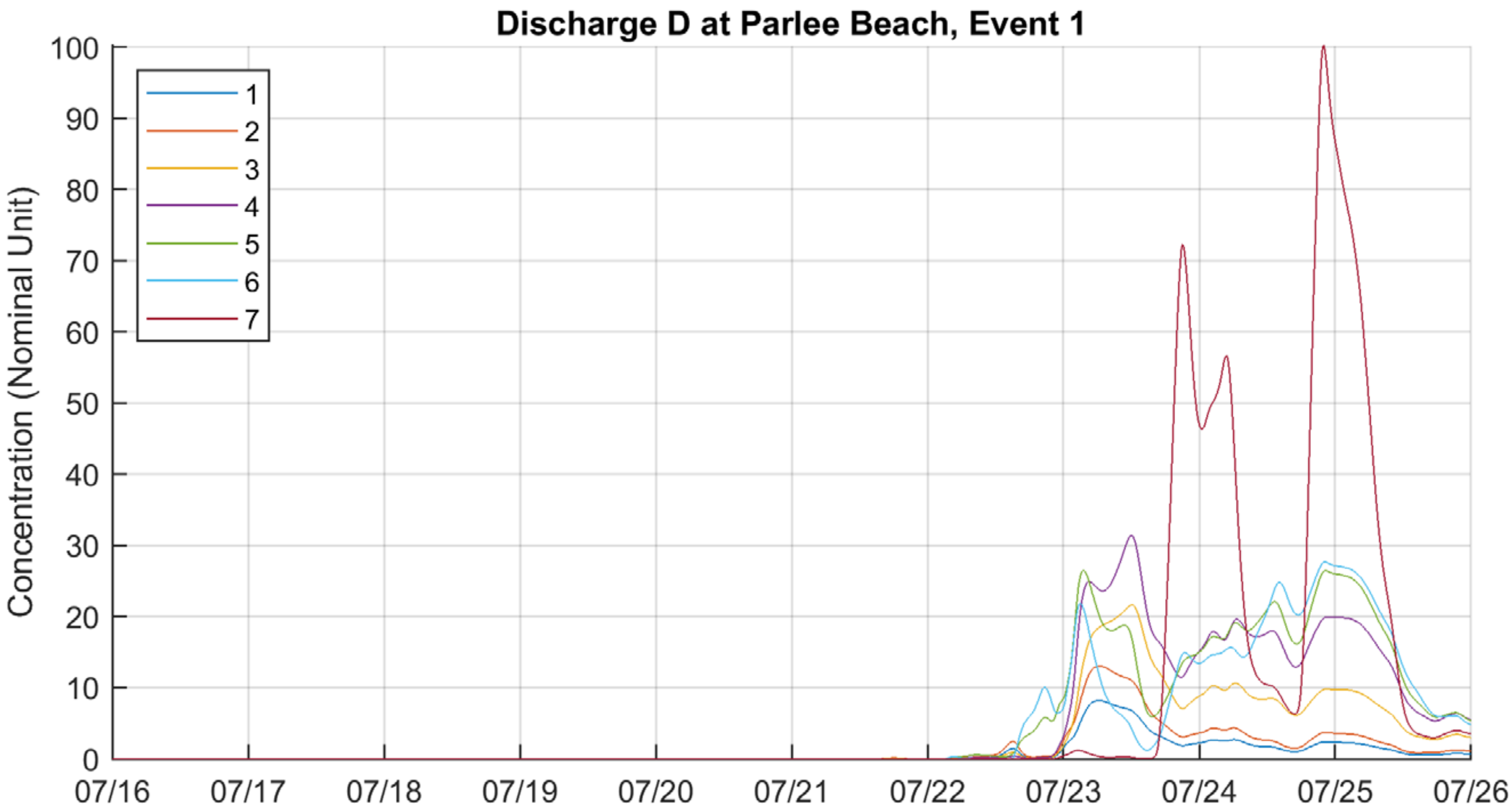
NOAA. 2019. CPC Morphing Technique (CMORPH) Global Precipitation Analyses from low orbiter satellite microwave observations. Accessed online at https://rda.ucar.edu/datasets/ds502.0/).

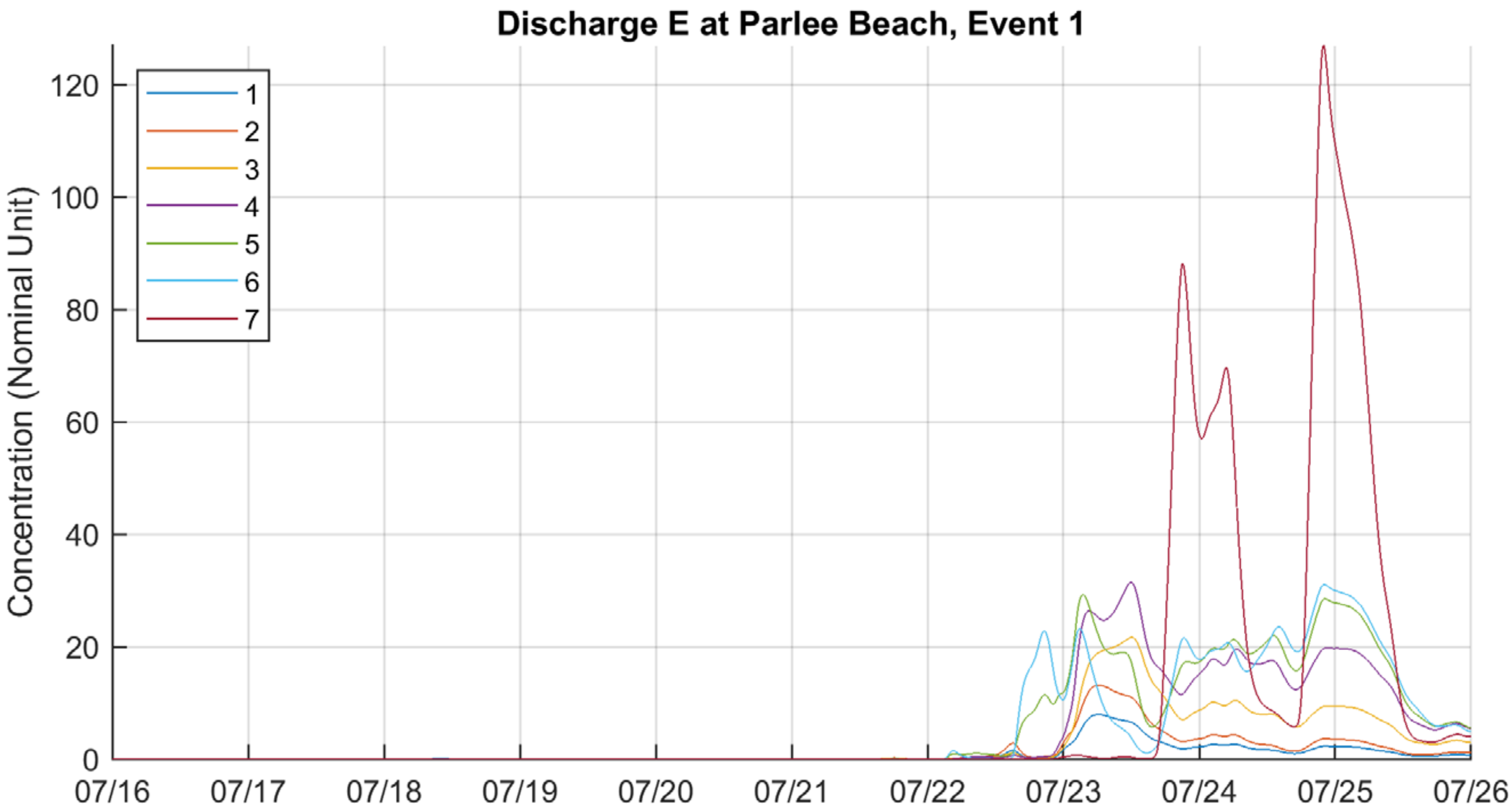
# APPENDIX A: MODELLED BACTERIAL CONCENTRATION (NOMINAL UNIT) TIME SERIES AT PARLEE BEACH FOR ALL POTENTIAL POLLUTANT SOURCES FOR EXCEEDANCE EVENT 1 (JULY 23, 2017)

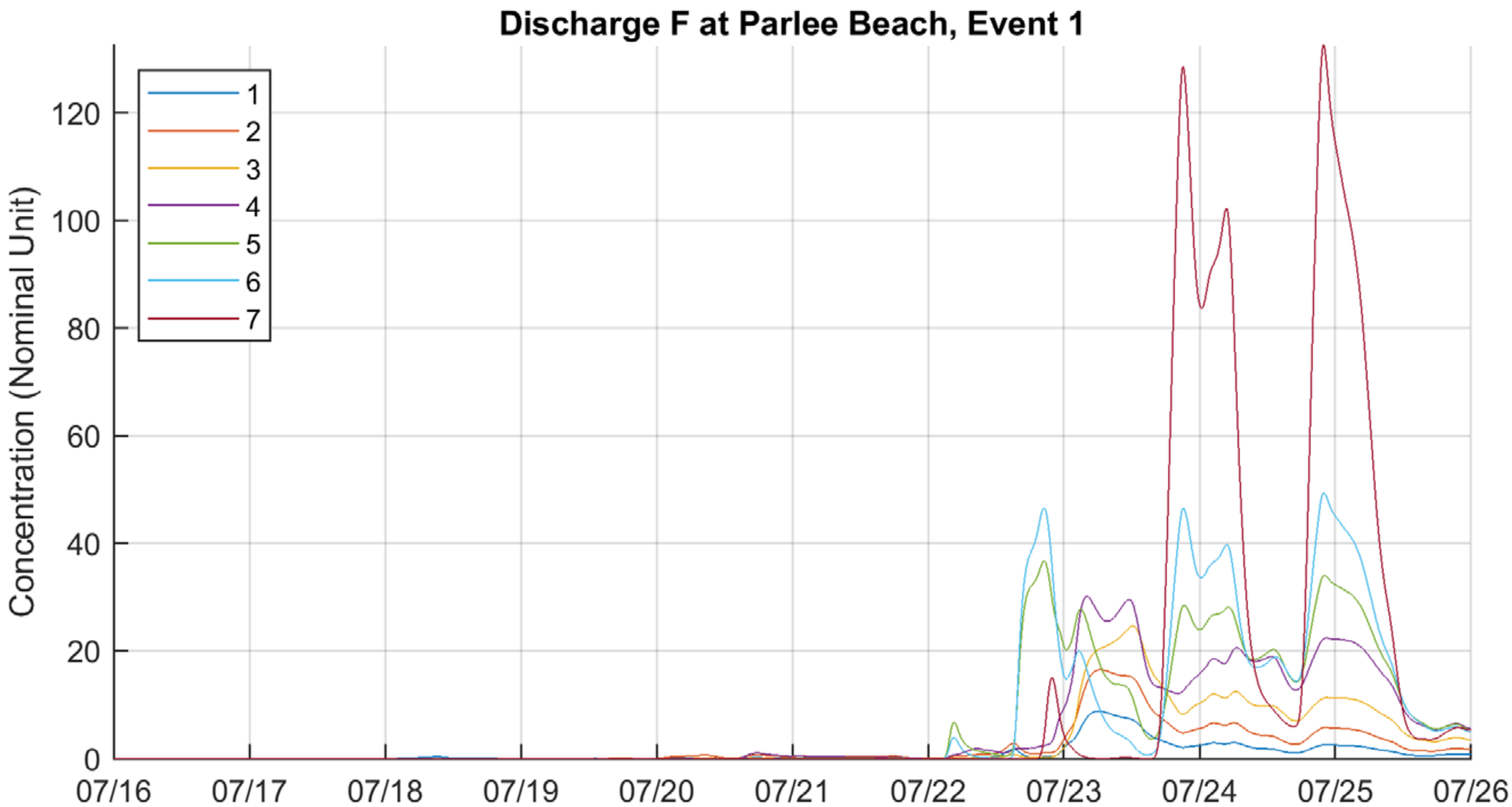

Discharge A at Parlee Beach, Event 1
Concentration (Nominal Unit)
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26

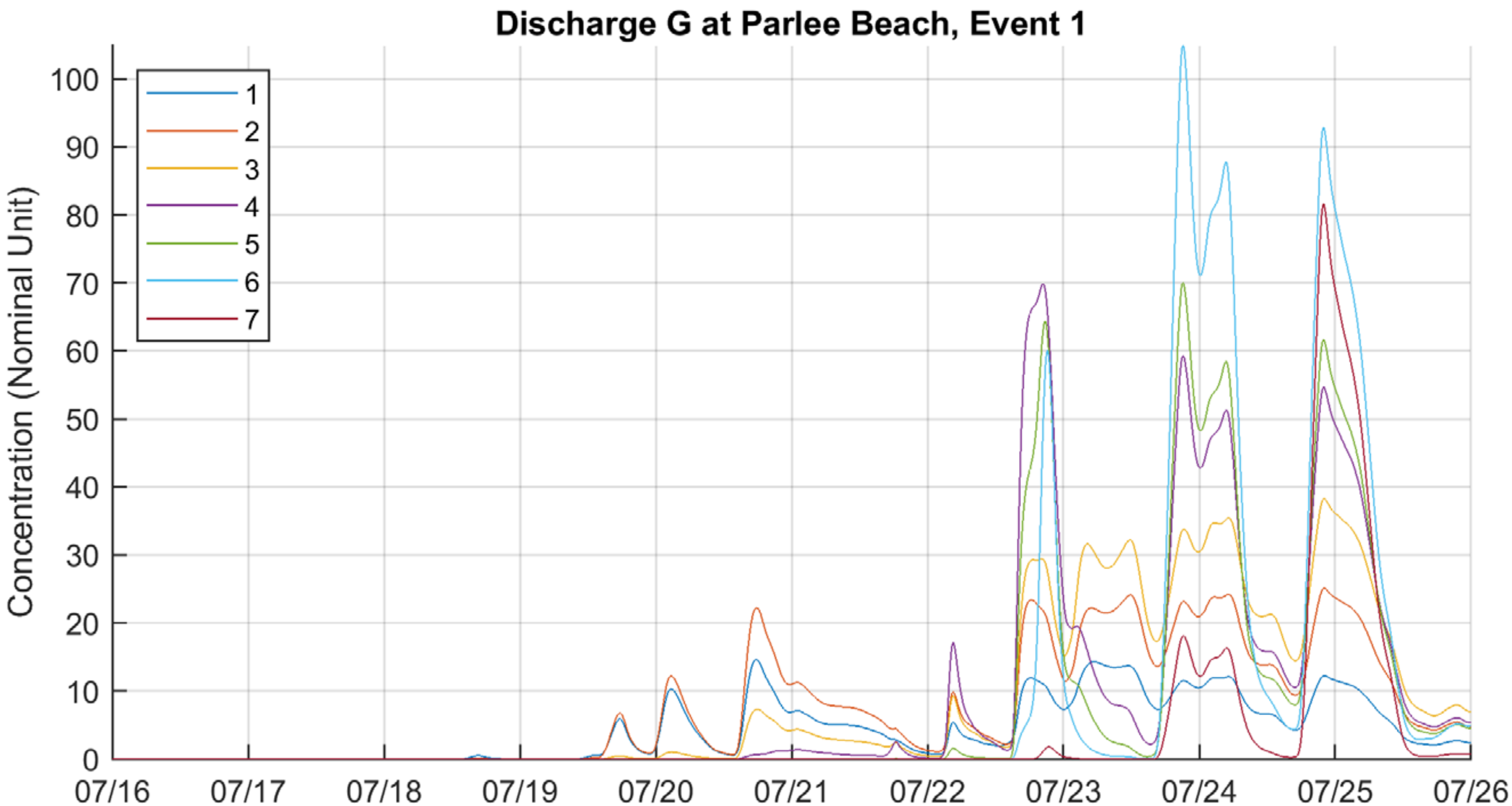

Discharge B at Parlee Beach, Event 1
Concentration (Nominal Unit)
30
25
20
15
10
5
0
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

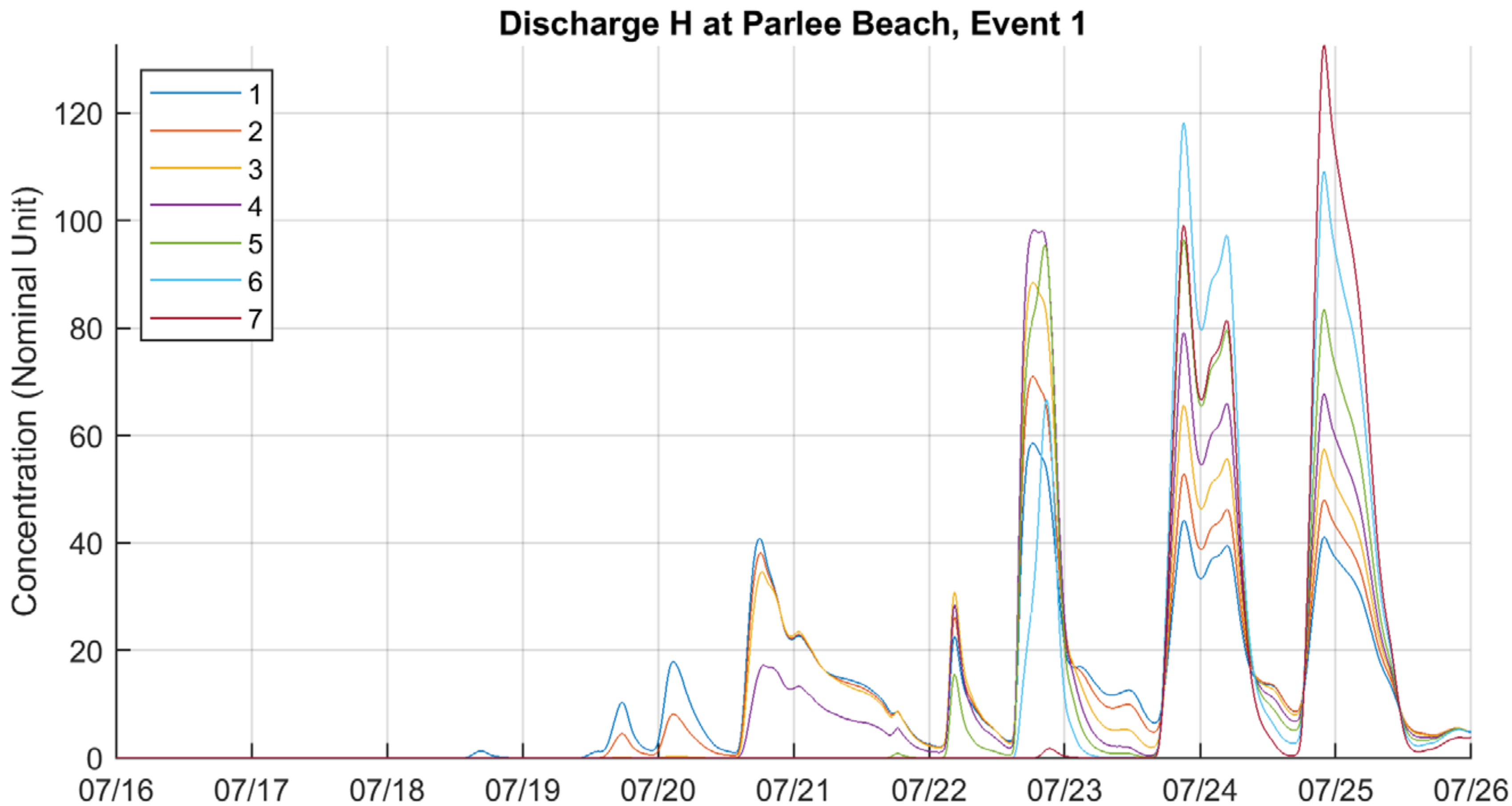

Discharge C at Parlee Beach, Event 1
Concentration (Nominal Unit)
0
5
10
15
20
25
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

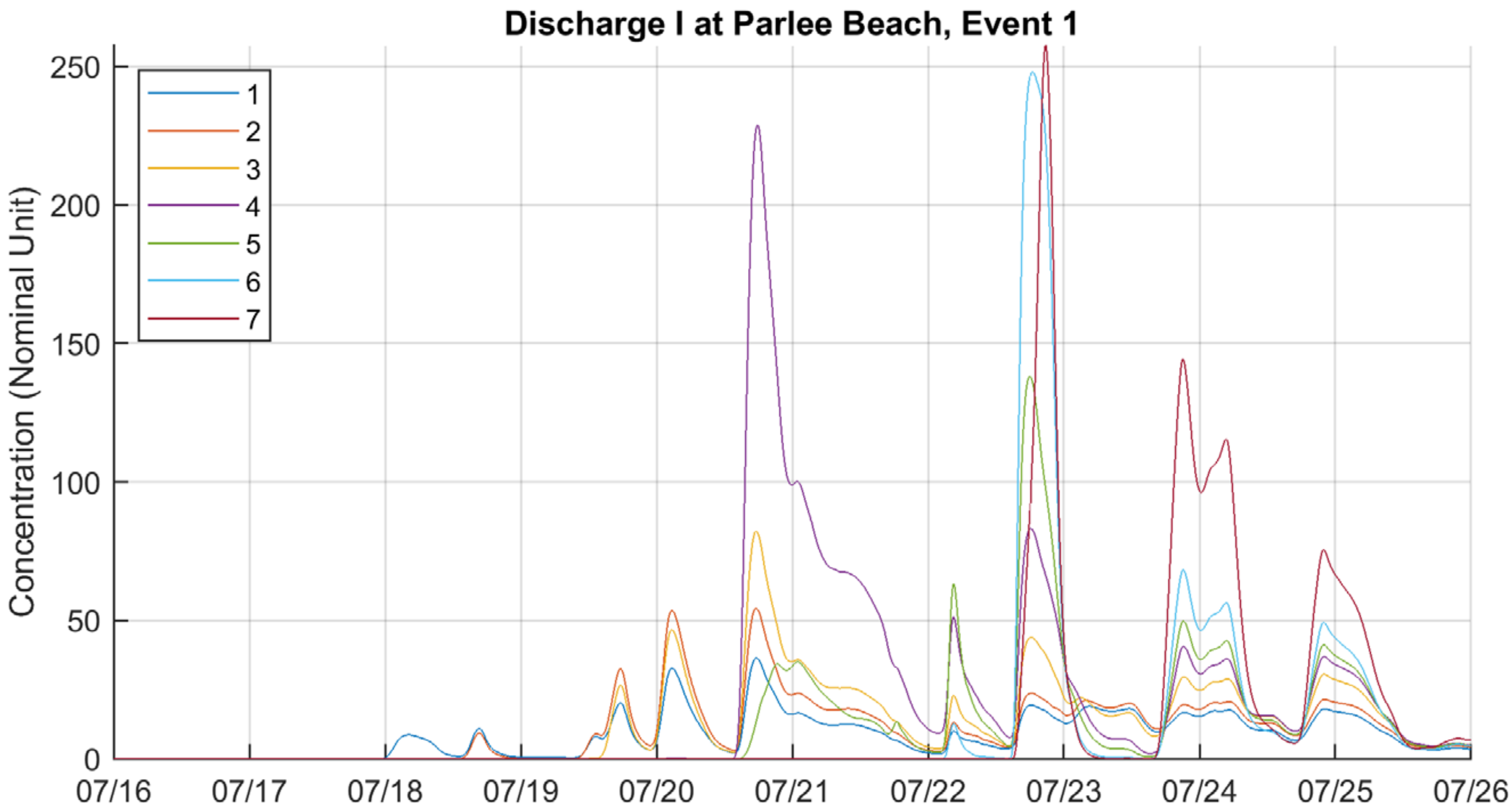

Discharge D at Parlee Beach, Event 1
Concentration (Nominal Unit)
100
90
80
70
60
50
40
30
20
10
0
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

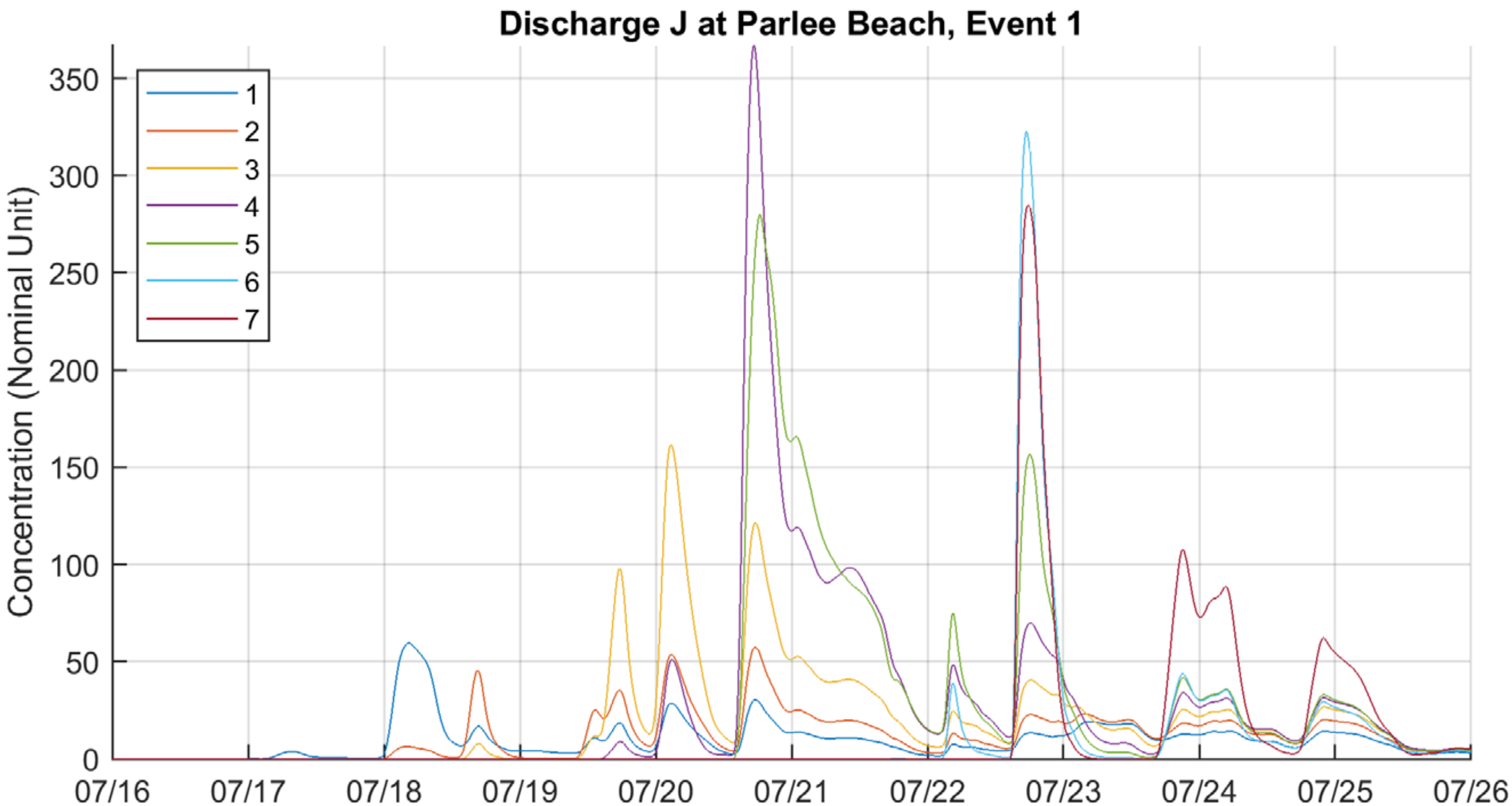

Discharge E at Parlee Beach, Event 1
Concentration (Nominal Unit)
0
20
40
60
80
100
120
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

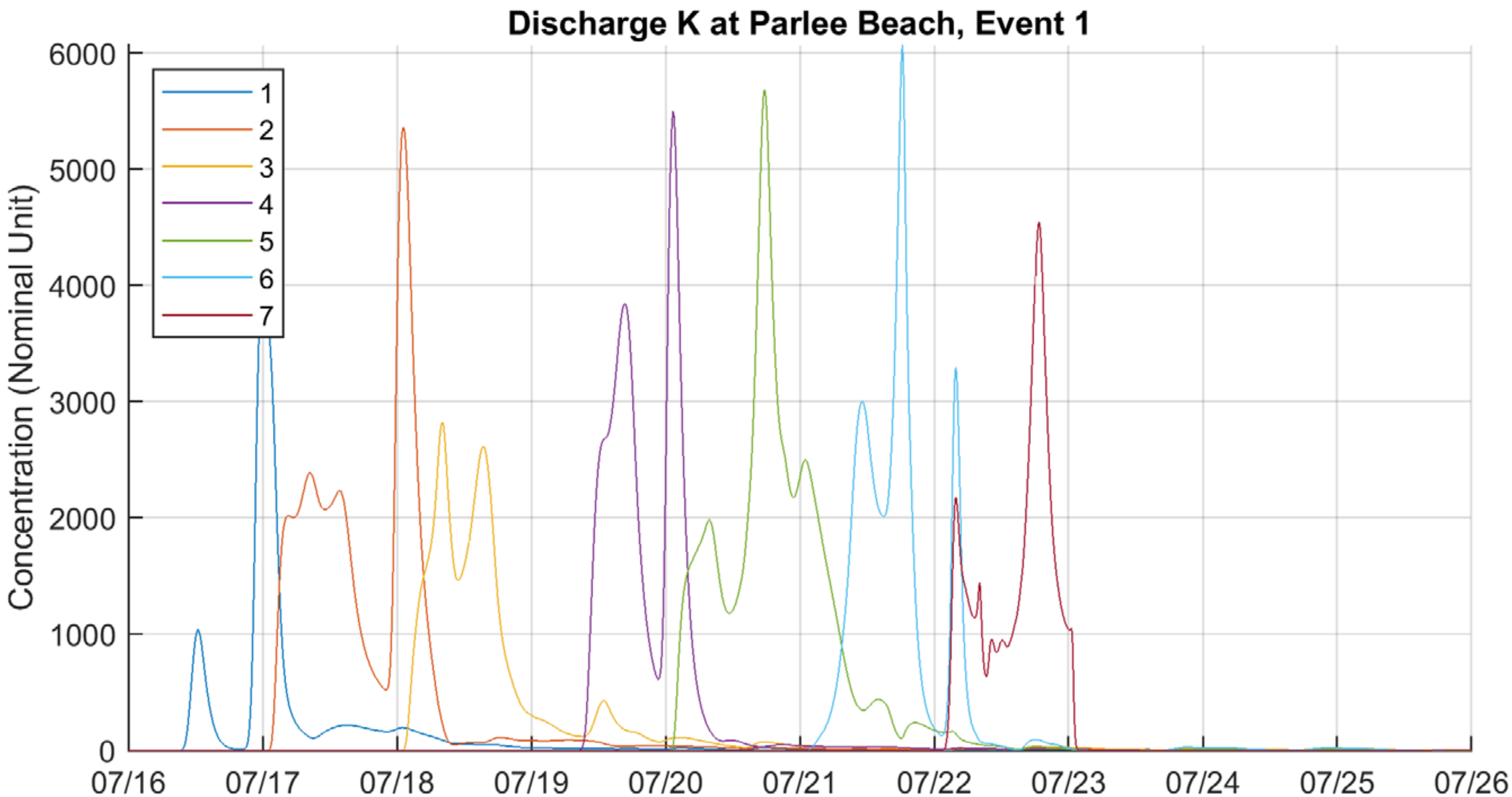

Discharge F at Parlee Beach, Event 1
Concentration (Nominal Unit)
0
20
40
60
80
100
120
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

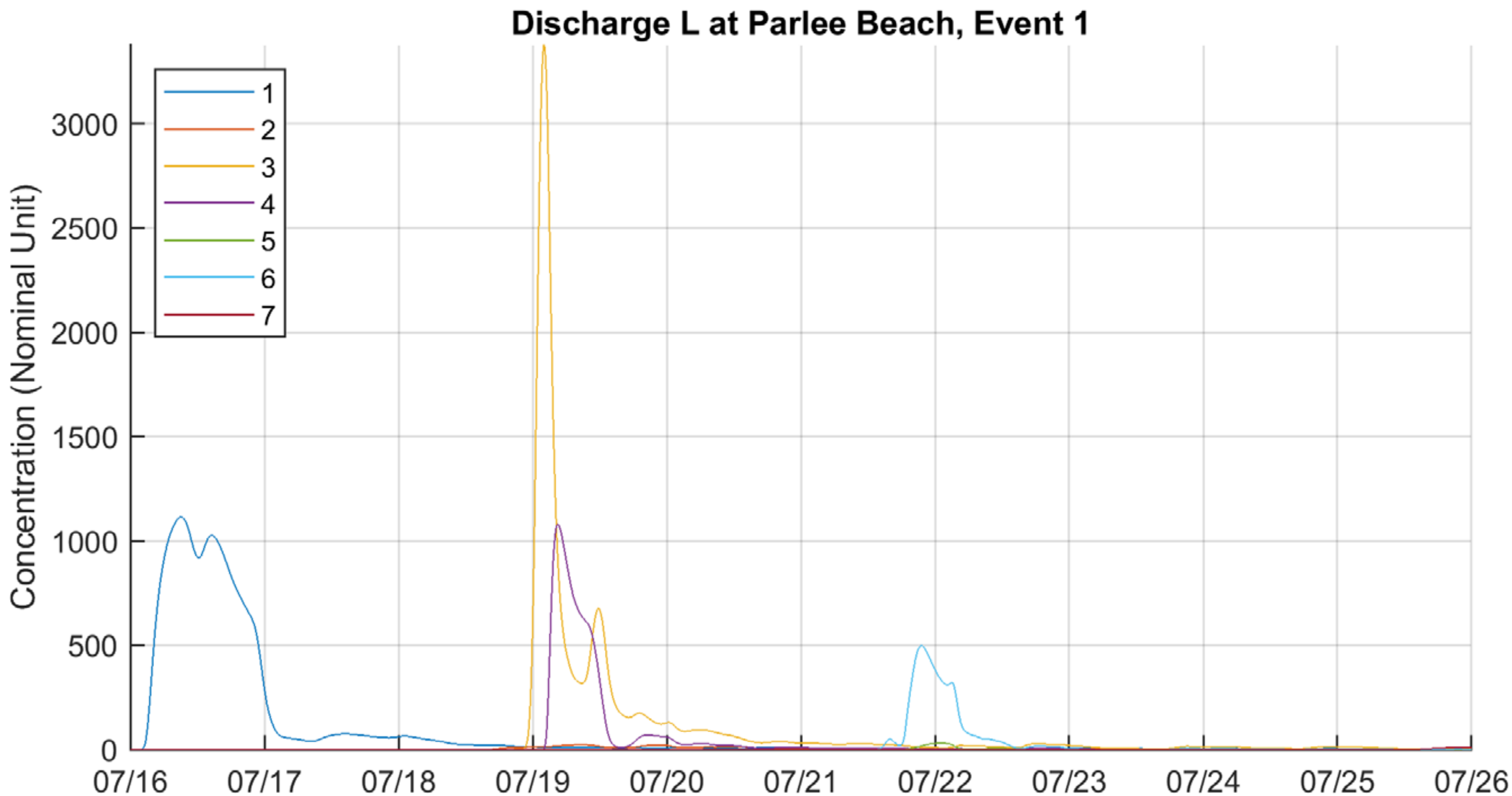

Discharge G at Parlee Beach, Event 1
Concentration (Nominal Unit)
100
90
80
70
60
50
40
30
20
10
0
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

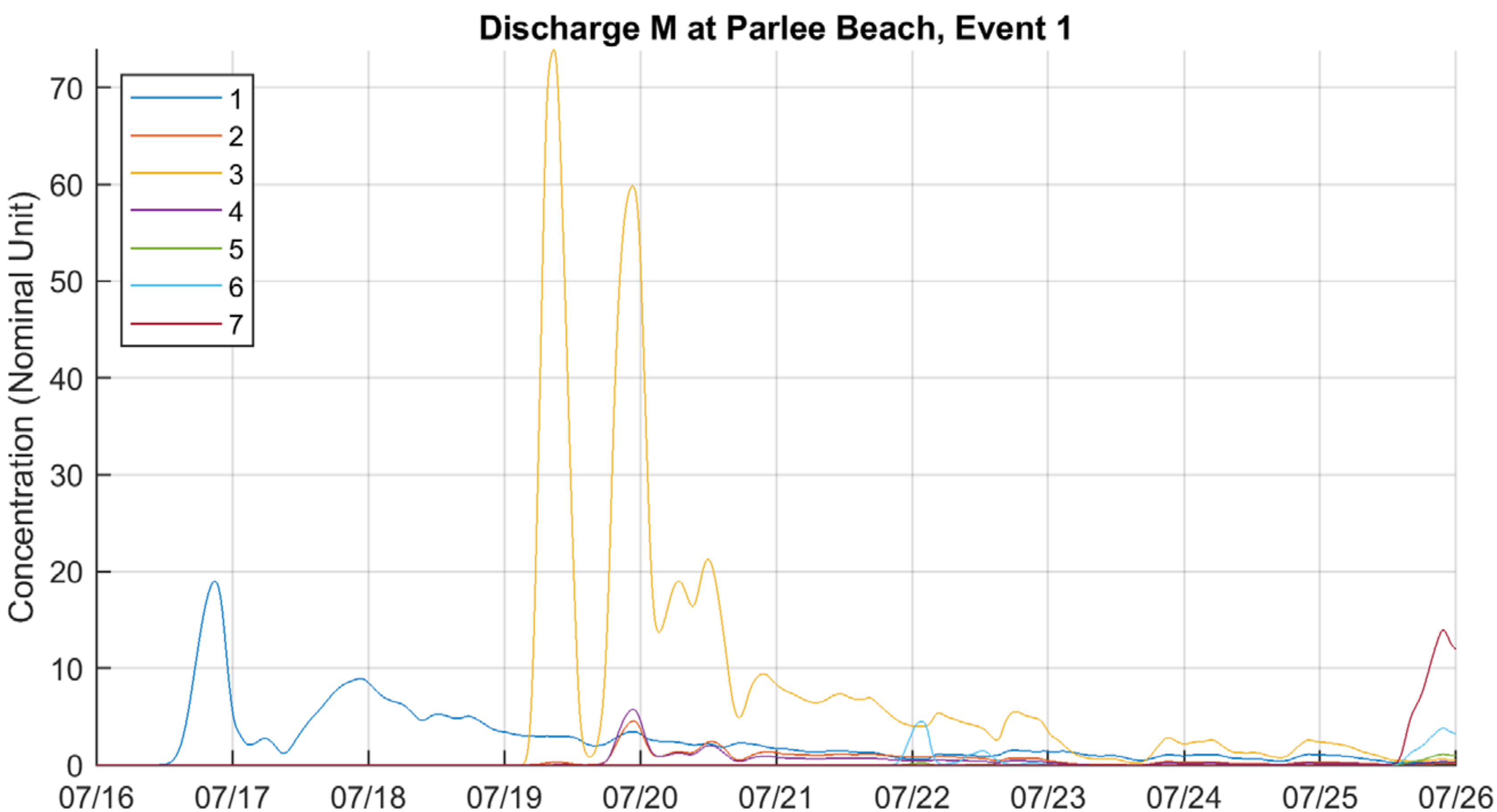

Discharge H at Parlee Beach, Event 1
Concentration (Nominal Unit)
0
20
40
60
80
100
120
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

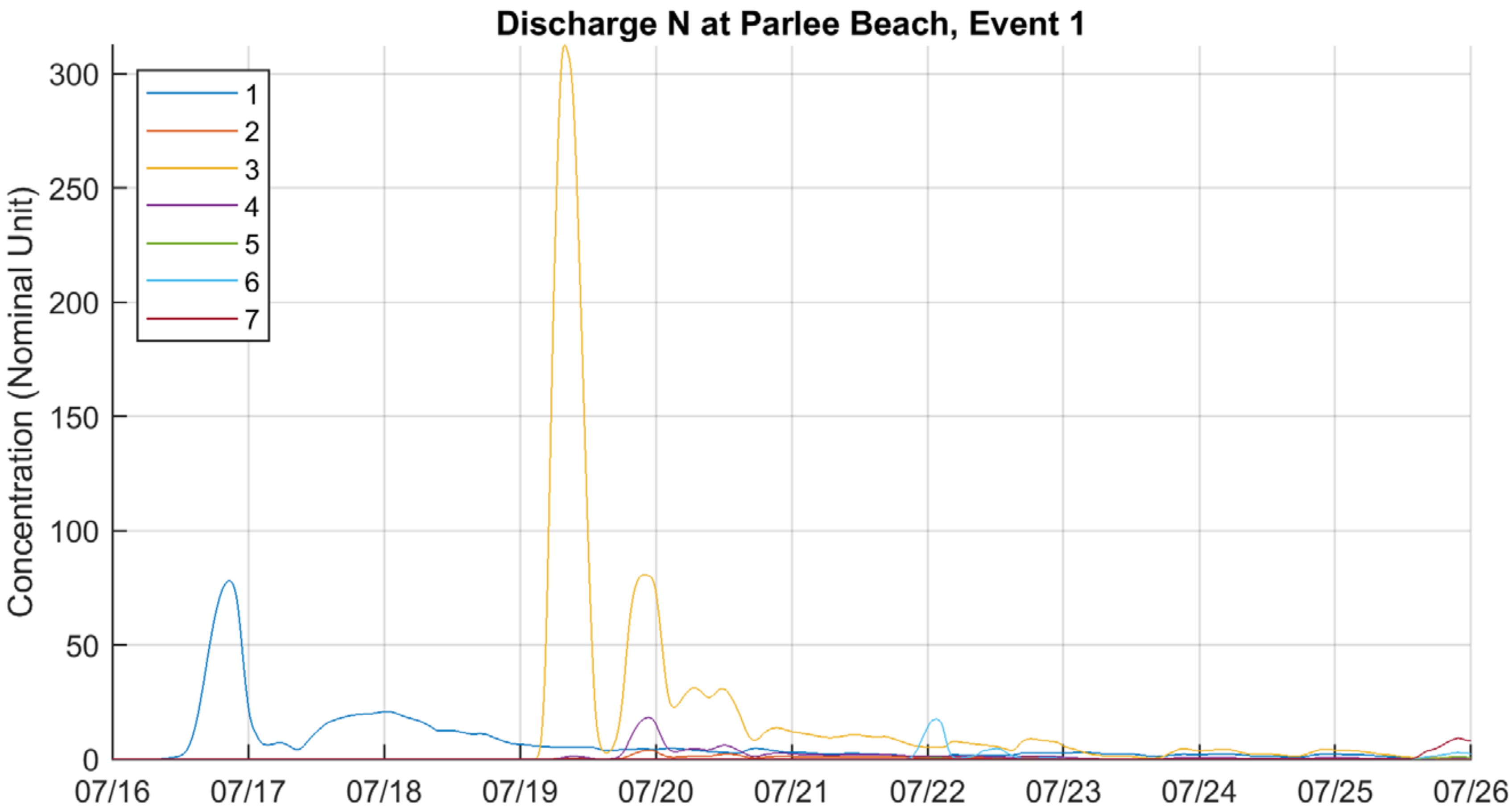

Discharge I at Parlee Beach, Event 1
Concentration (Nominal Unit)
250
200
150
100
50
0
1
2
3
4
5
6
7
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26


Discharge J at Parlee Beach, Event 1
Concentration (Nominal Unit)
350
300
250
200
150
100
50
0
1
2
3
4
5
6
7
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26

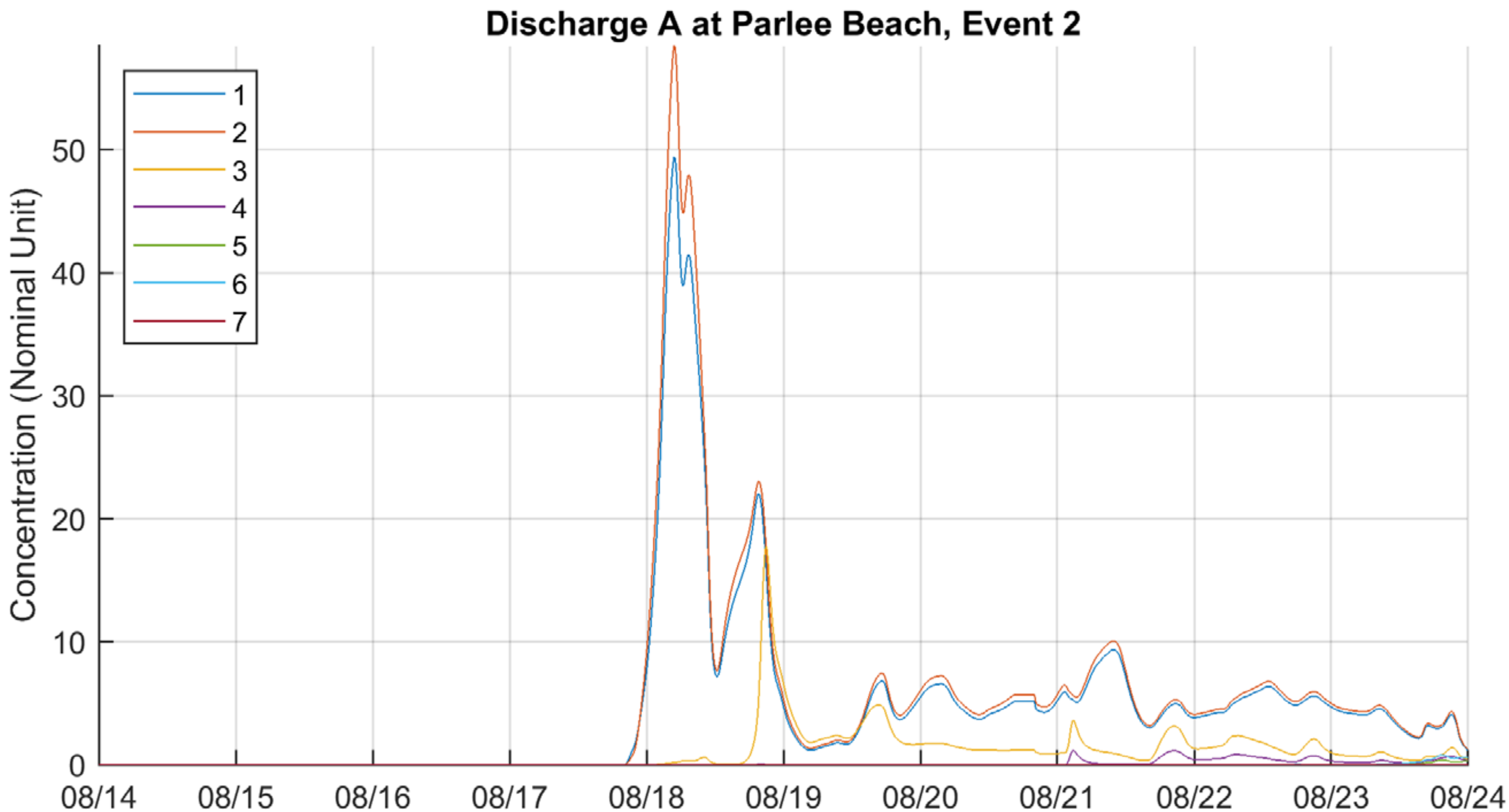

Discharge K at Parlee Beach, Event 1
Concentration (Nominal Unit)
6000
5000
4000
3000
2000
1000
0
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

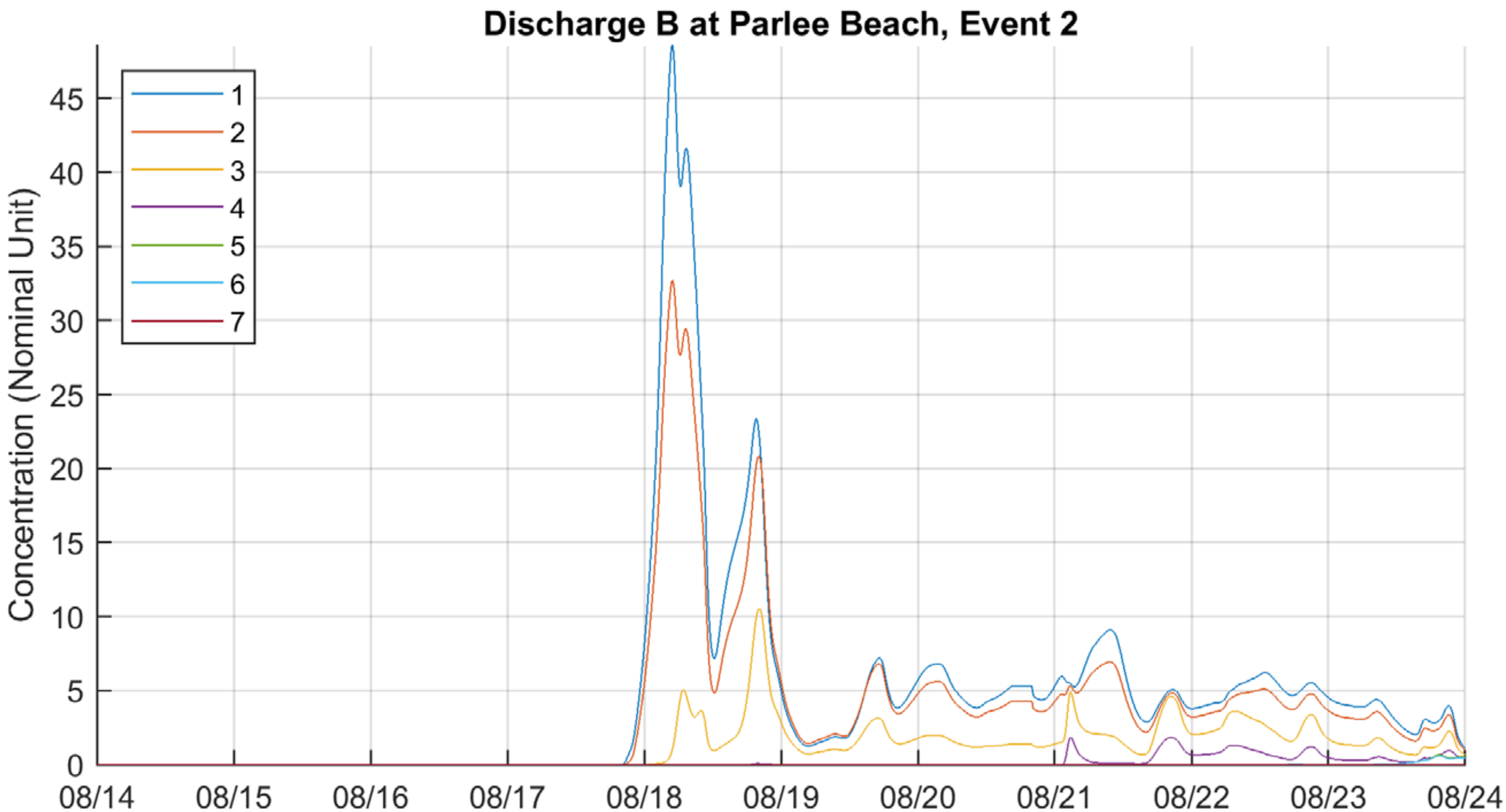

Discharge L at Parlee Beach, Event 1
Concentration (Nominal Unit)
0
500
1000
1500
2000
2500
3000
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

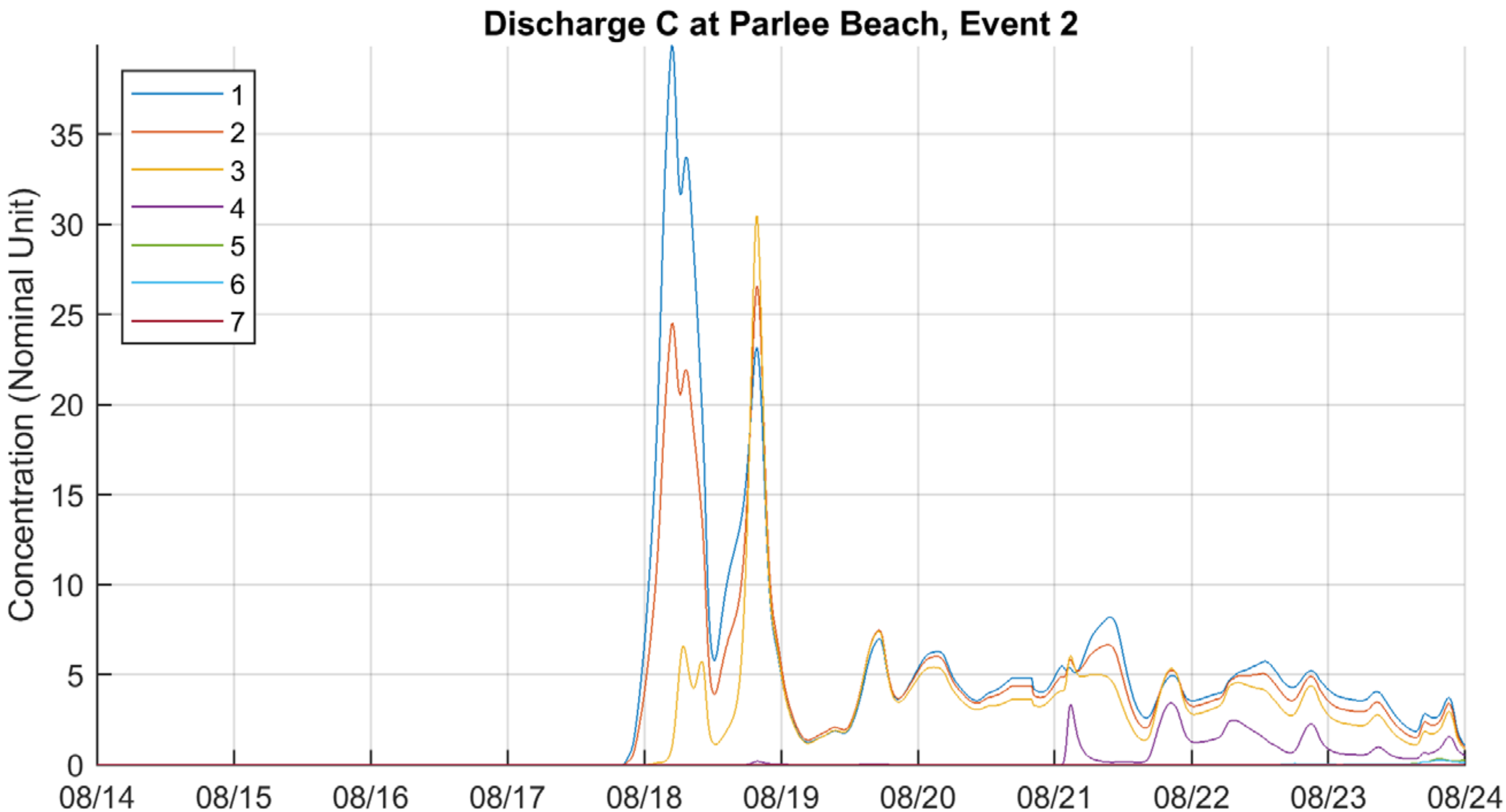

Discharge M at Parlee Beach, Event 1
Concentration (Nominal Unit)
0
10
20
30
40
50
60
70
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

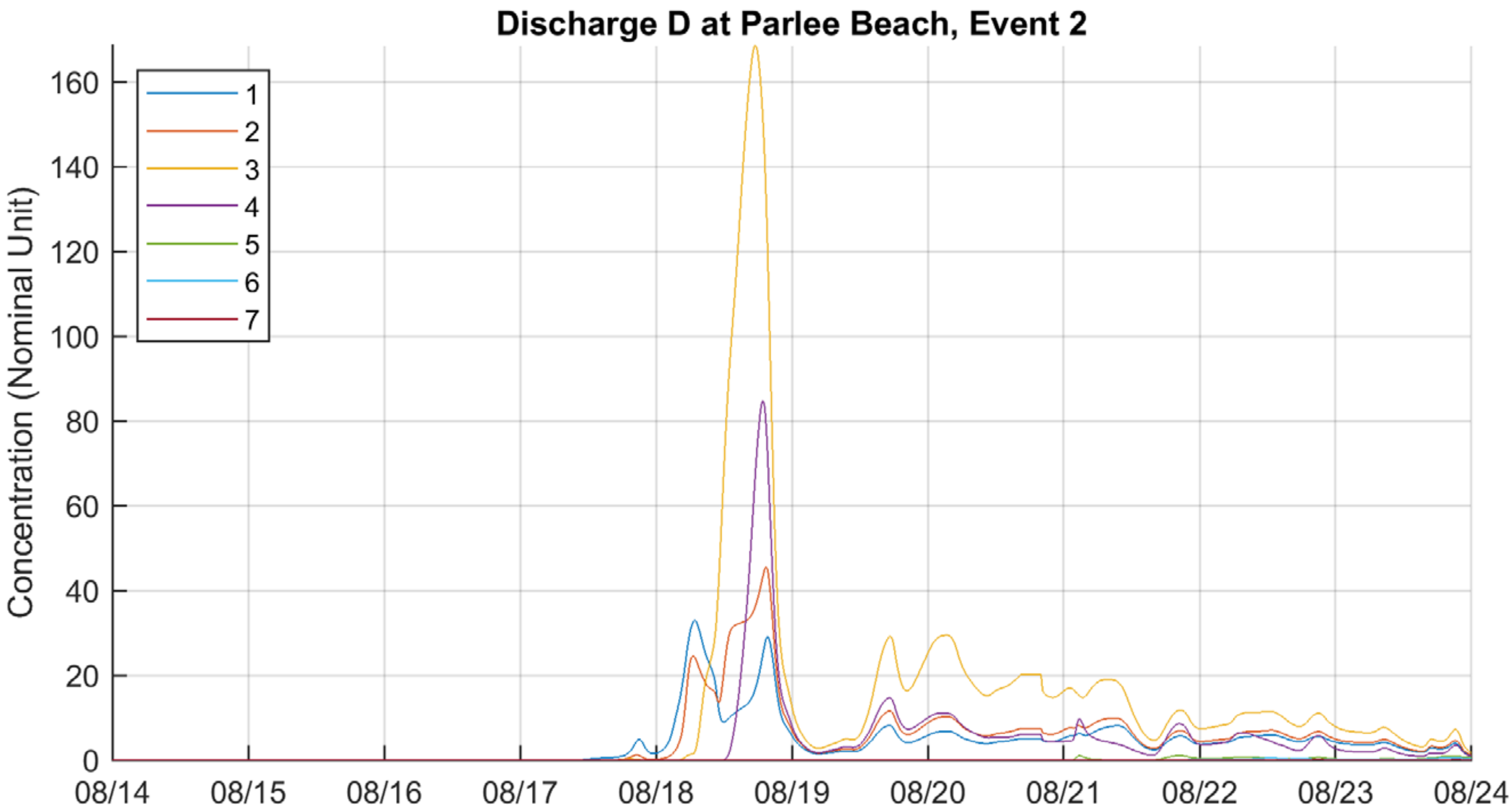

Discharge N at Parlee Beach, Event 1
Concentration (Nominal Unit)
300
250
200
150
100
50
0
07/16
07/17
07/18
07/19
07/20
07/21
07/22
07/23
07/24
07/25
07/26
1
2
3
4
5
6
7

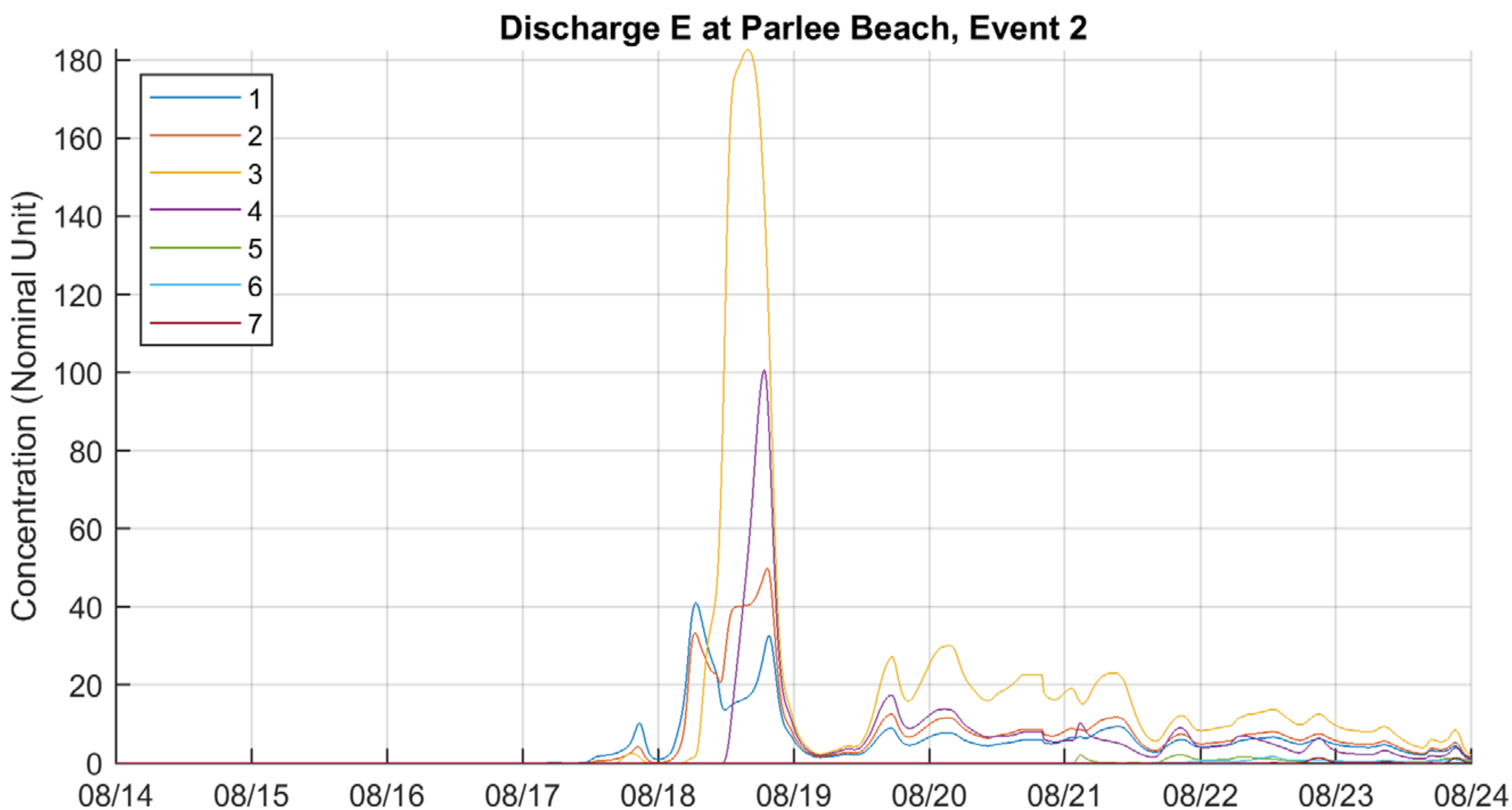
# APPENDIX B: MODELLED BACTERIAL CONCENTRATION (NOMINAL UNIT) TIME SERIES AT PARLEE BEACH FOR ALL POTENTIAL POLLUTANT SOURCES FOR EXCEEDANCE EVENT 2 (AUGUST 22, 2017)

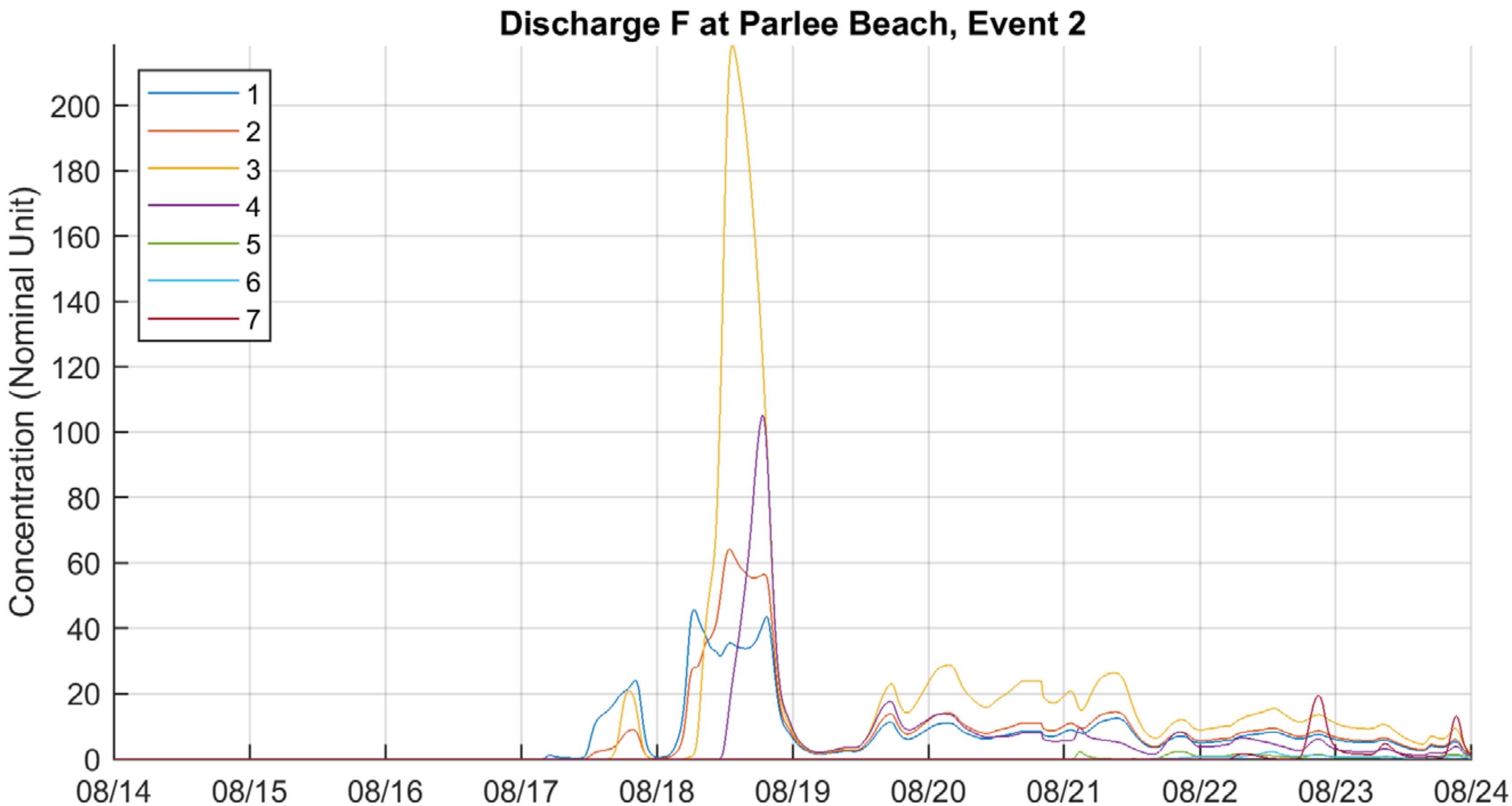

Discharge A at Parlee Beach, Event 2
Concentration (Nominal Unit)
0
10
20
30
40
50
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

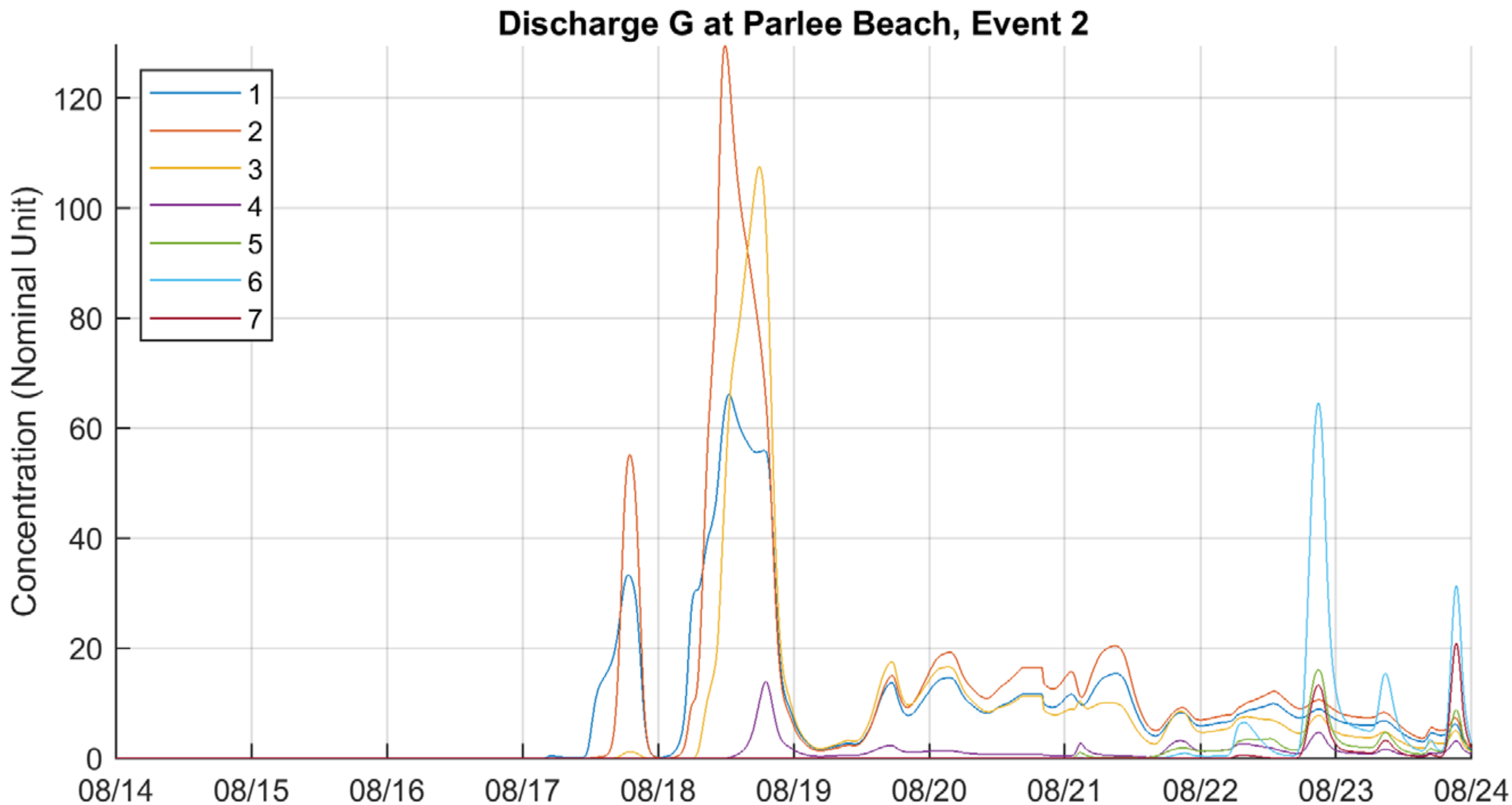

Discharge B at Parlee Beach, Event 2
Concentration (Nominal Unit)
0
5
10
15
20
25
30
35
40
45
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

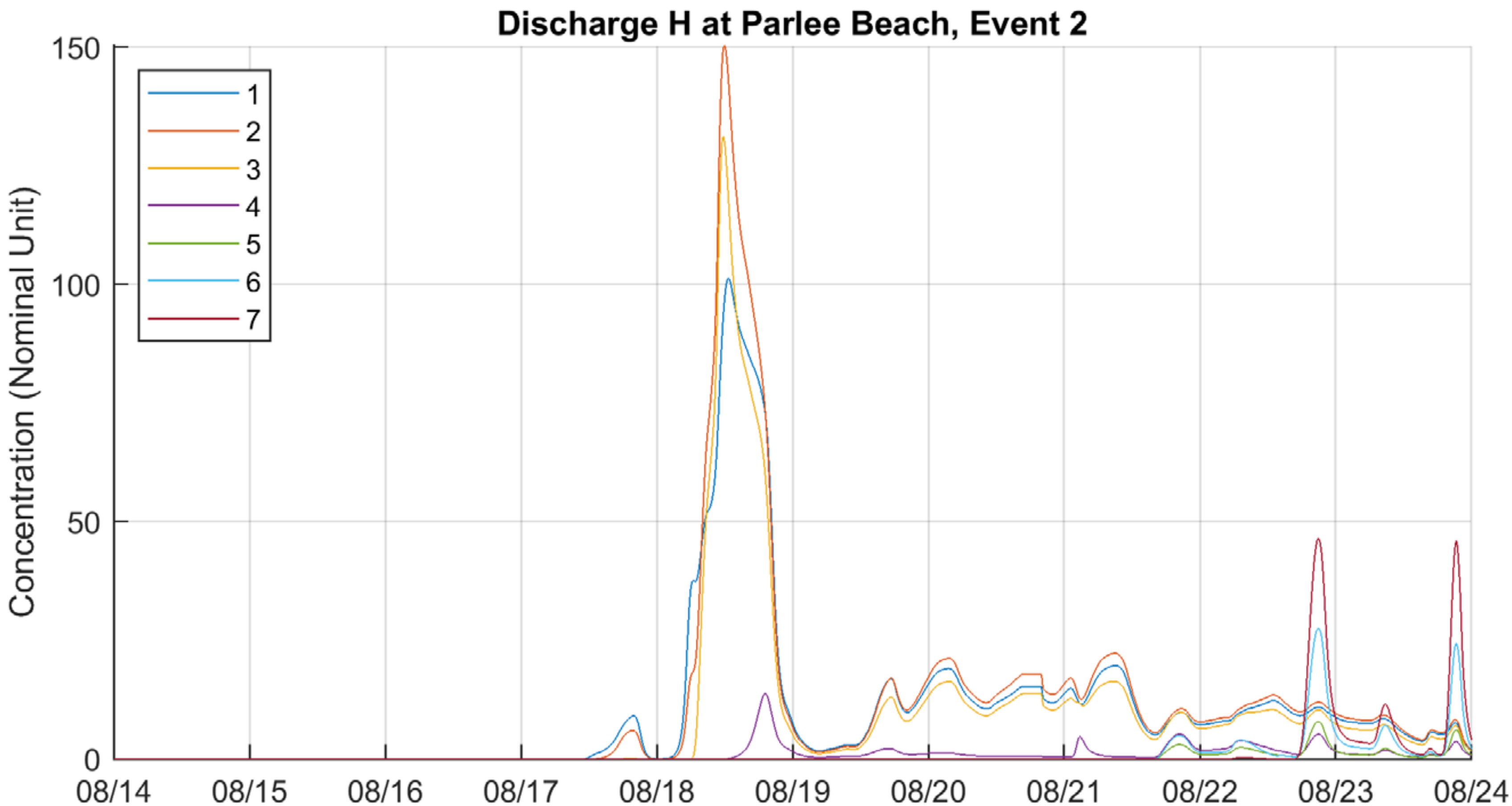

Discharge C at Parlee Beach, Event 2
Concentration (Nominal Unit)
0
5
10
15
20
25
30
35
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

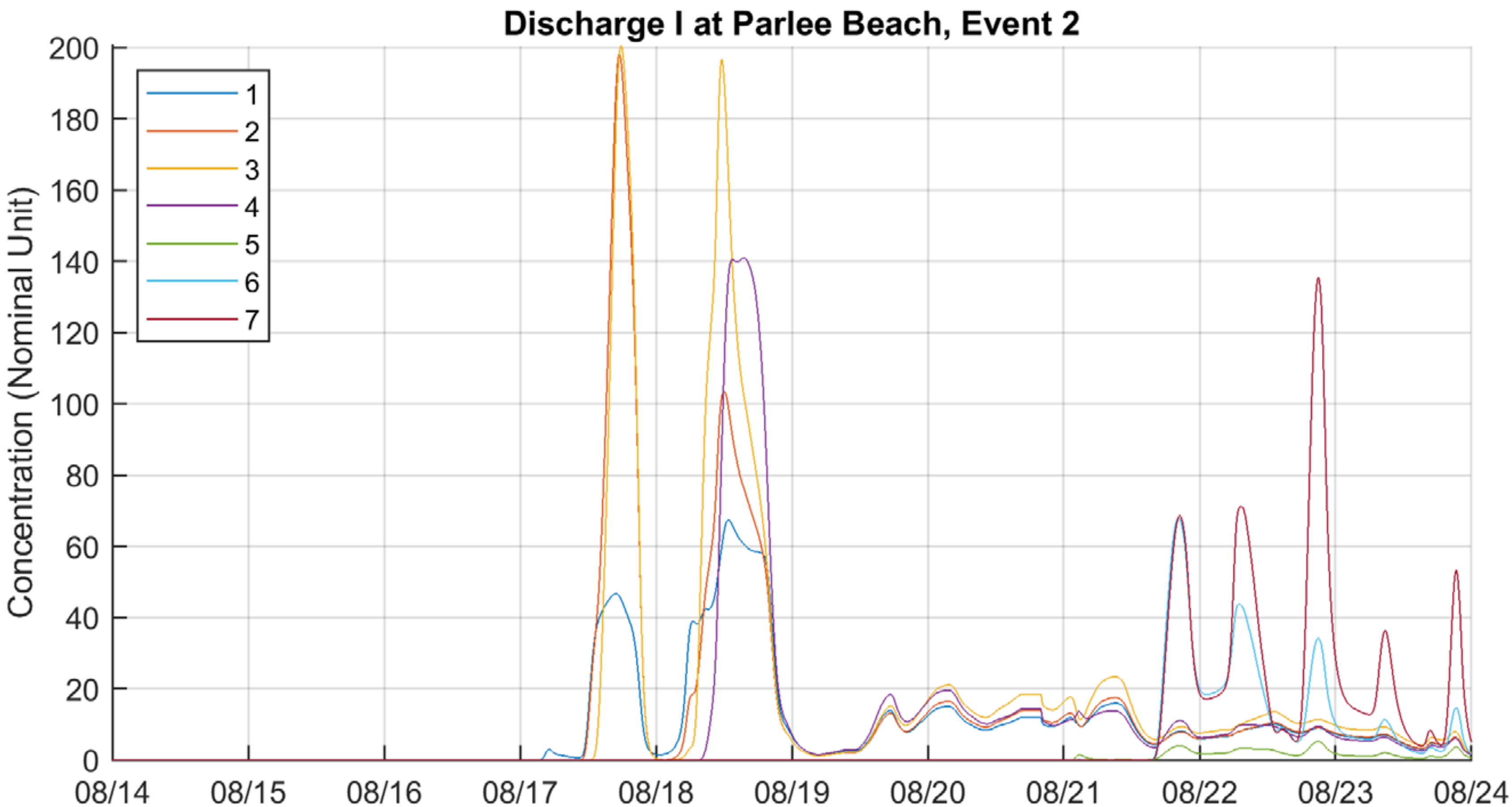

Discharge D at Parlee Beach, Event 2
Concentration (Nominal Unit)
0
20
40
60
80
100
120
140
160
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

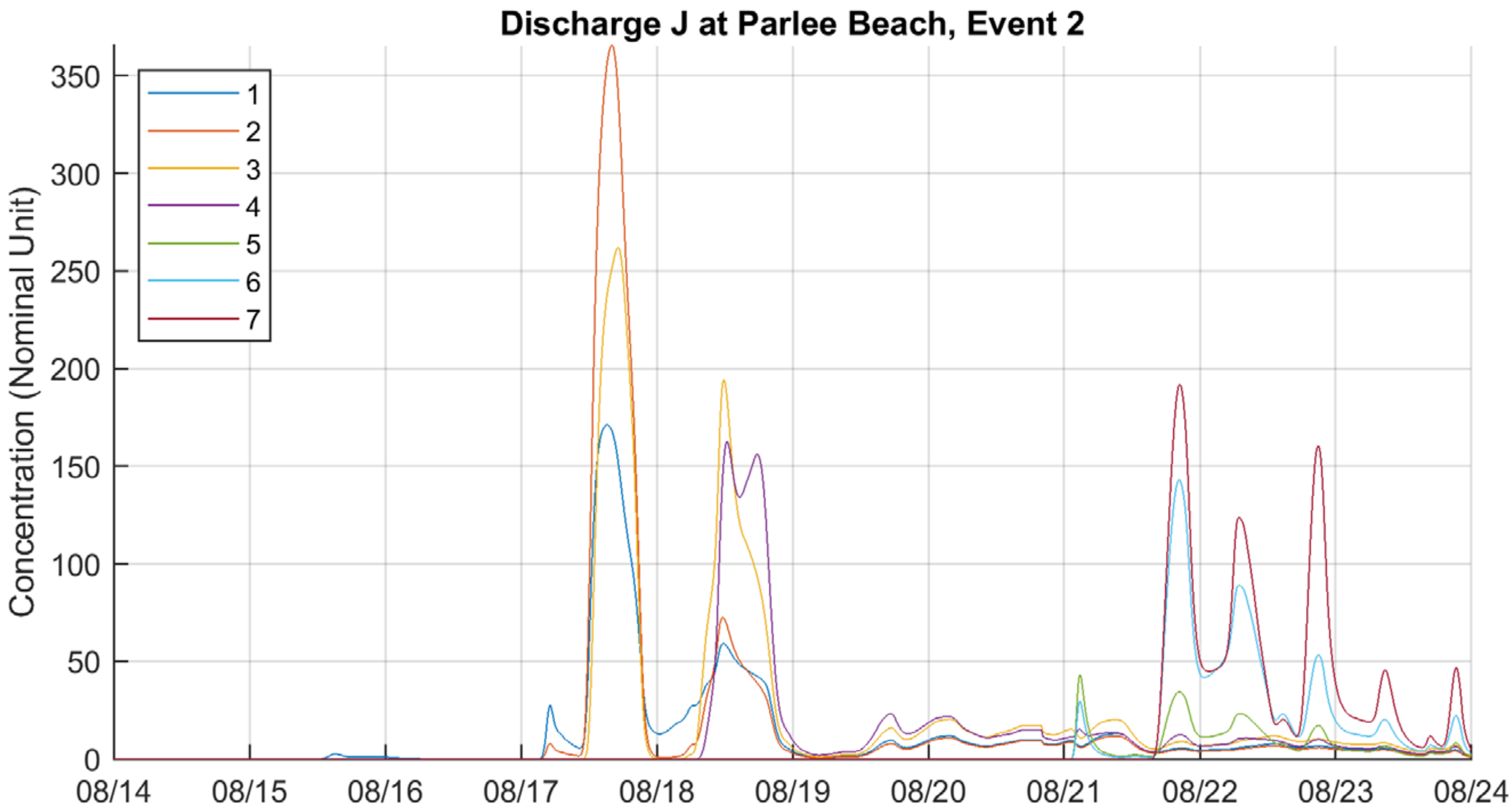

Discharge E at Parlee Beach, Event 2
Concentration (Nominal Unit)
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24

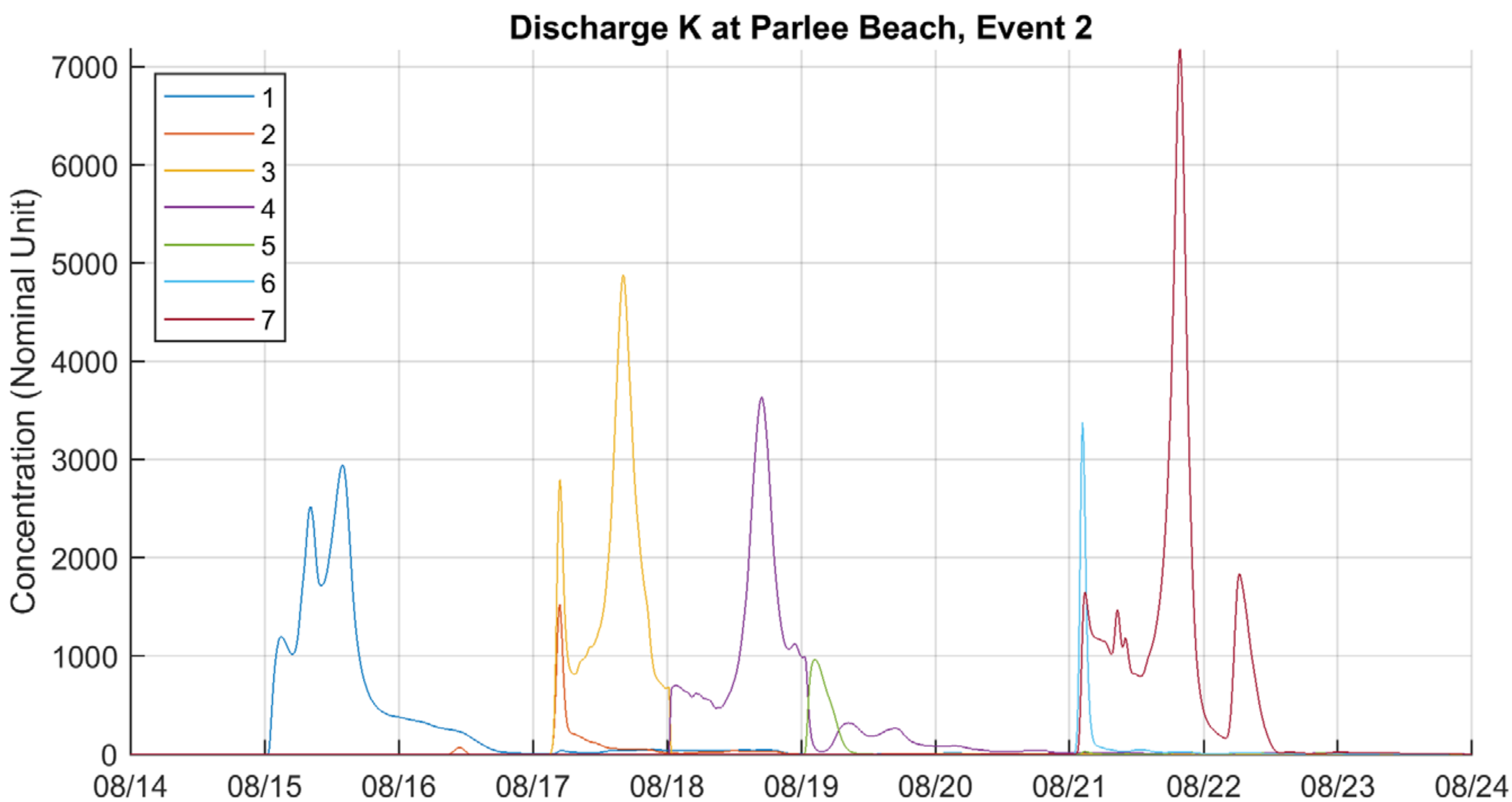

Discharge F at Parlee Beach, Event 2
Concentration (Nominal Unit)
0
20
40
60
80
100
120
140
160
180
200
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

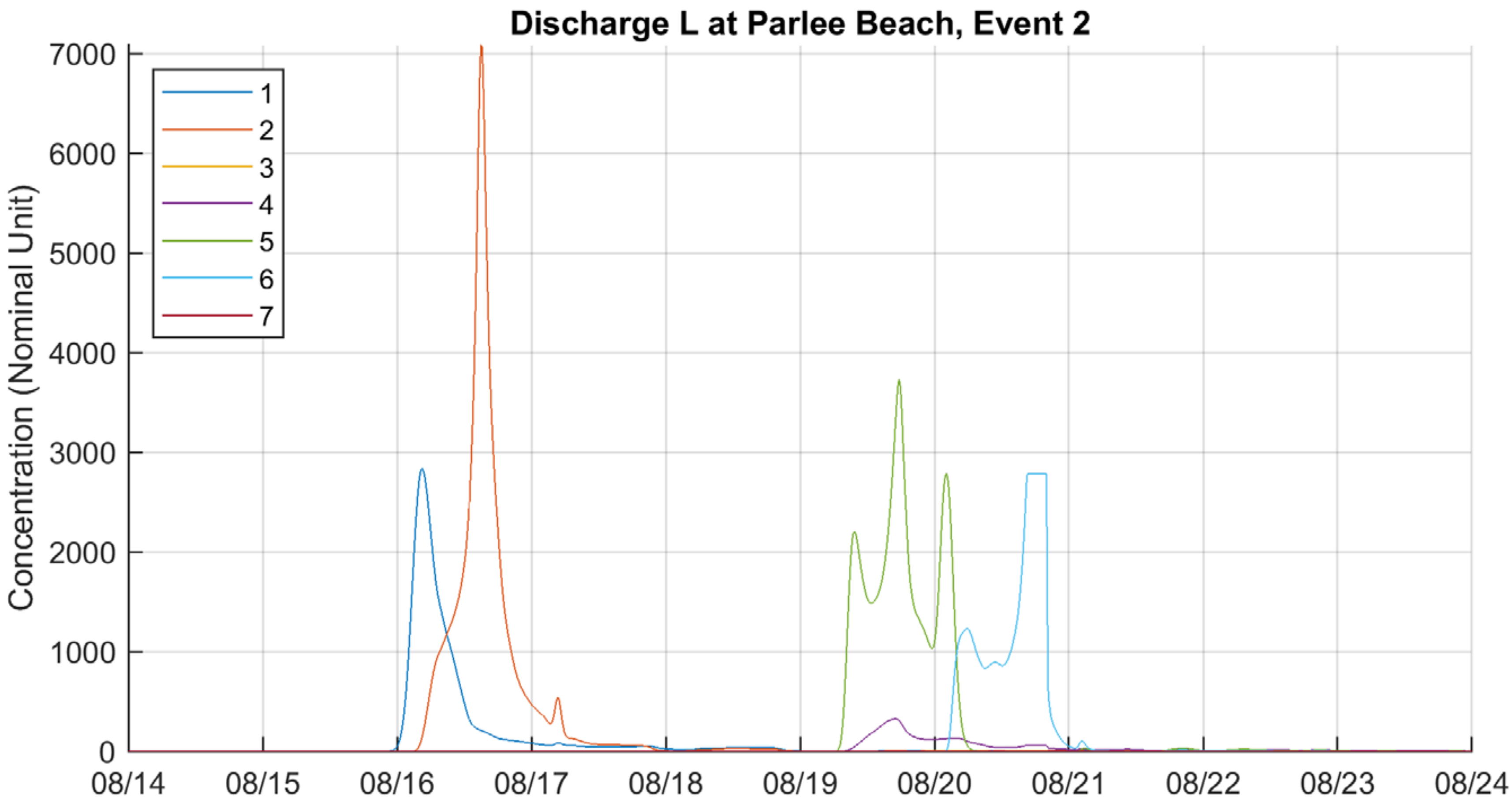

Discharge G at Parlee Beach, Event 2
Concentration (Nominal Unit)
0
20
40
60
80
100
120
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

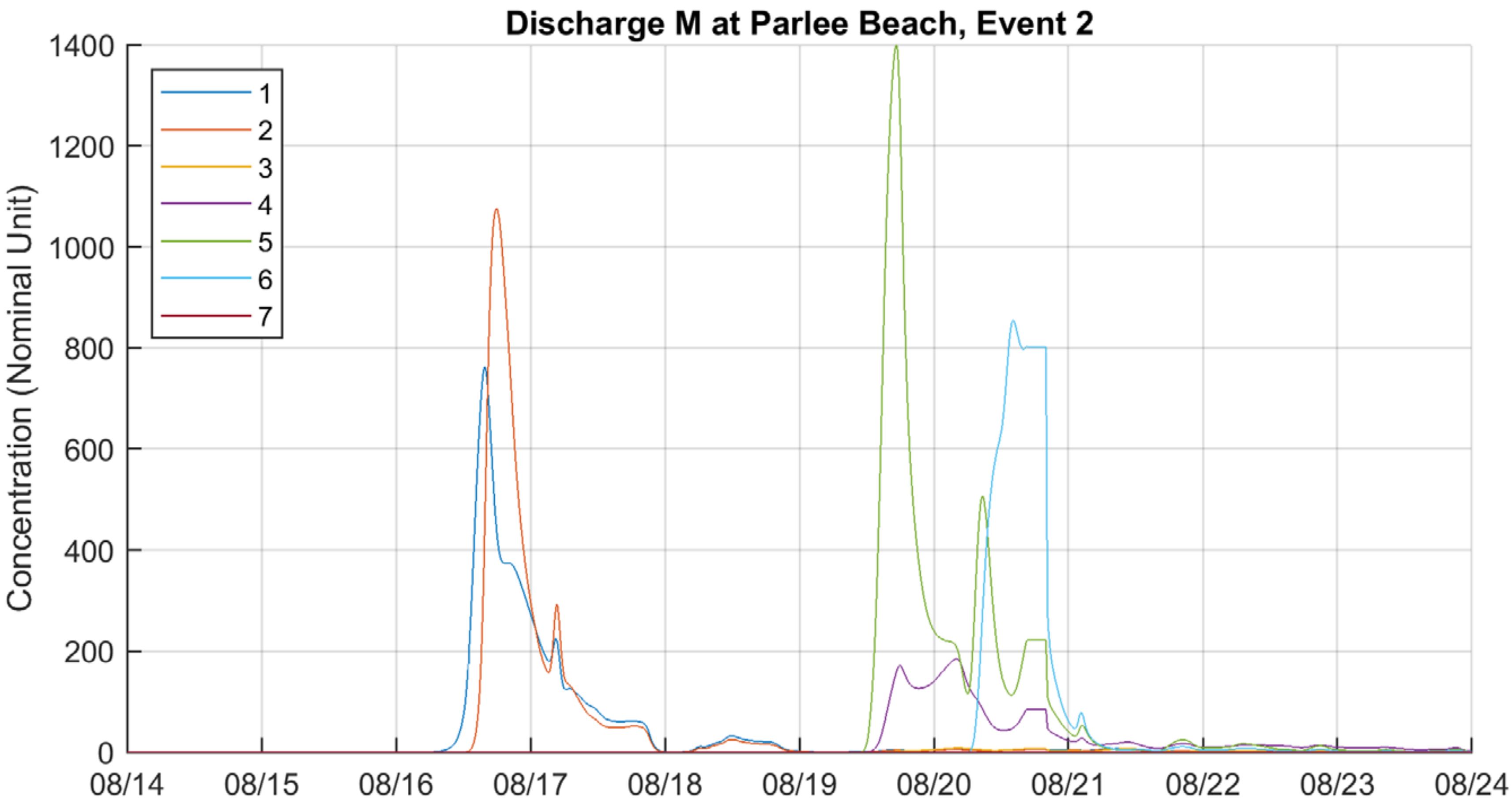

Discharge H at Parlee Beach, Event 2
Concentration (Nominal Unit)
150
100
50
0
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

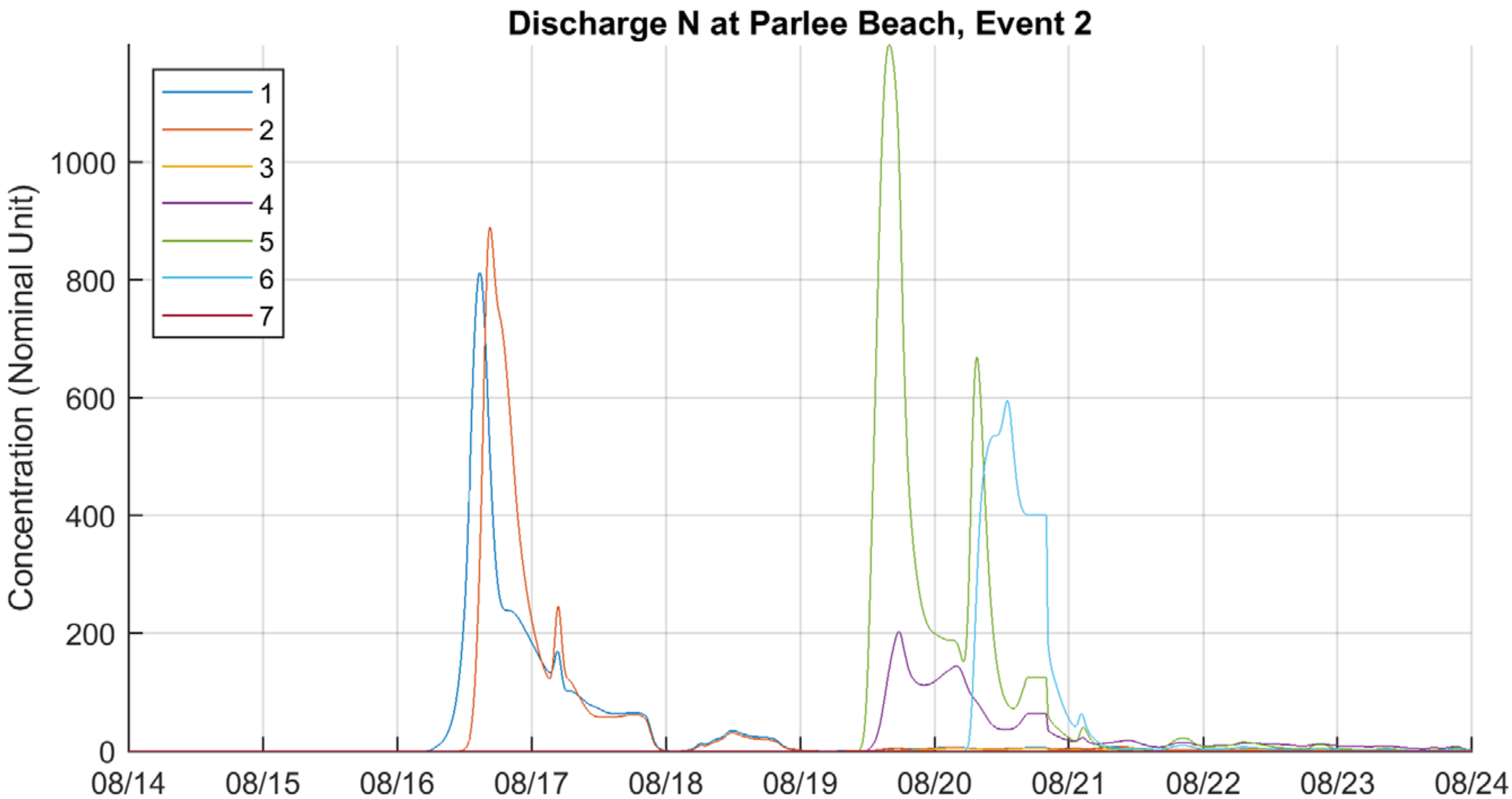

Discharge I at Parlee Beach, Event 2
Concentration (Nominal Unit)
200
180
160
140
120
100
80
60
40
20
0
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7


Discharge J at Parlee Beach, Event 2
Concentration (Nominal Unit)
350
300
250
200
150
100
50
0
1
2
3
4
5
6
7
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24

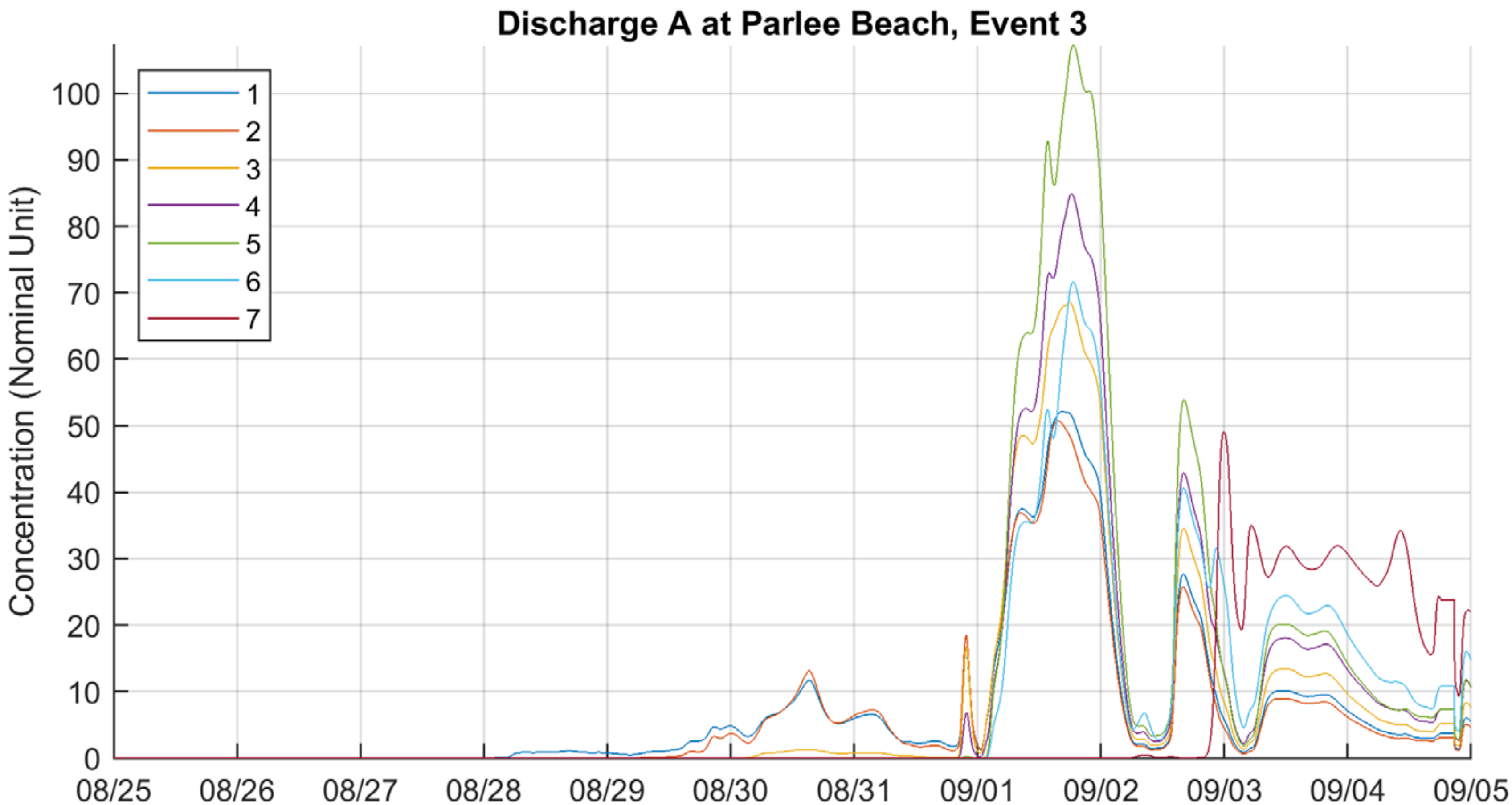

Discharge K at Parlee Beach, Event 2
Concentration (Nominal Unit)
7000
6000
5000
4000
3000
2000
1000
0
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

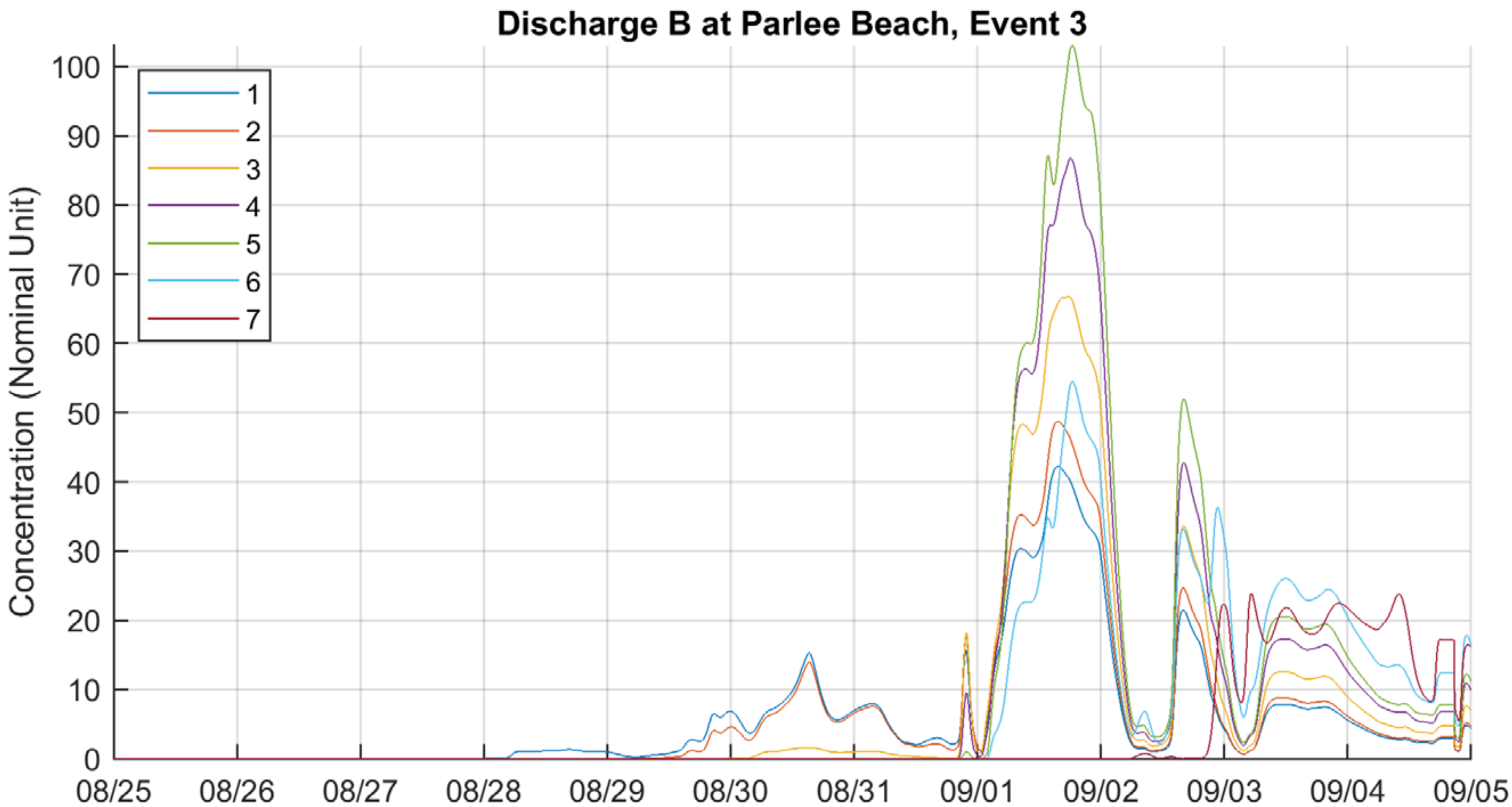

Discharge L at Parlee Beach, Event 2
Concentration (Nominal Unit)
7000
6000
5000
4000
3000
2000
1000
0
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

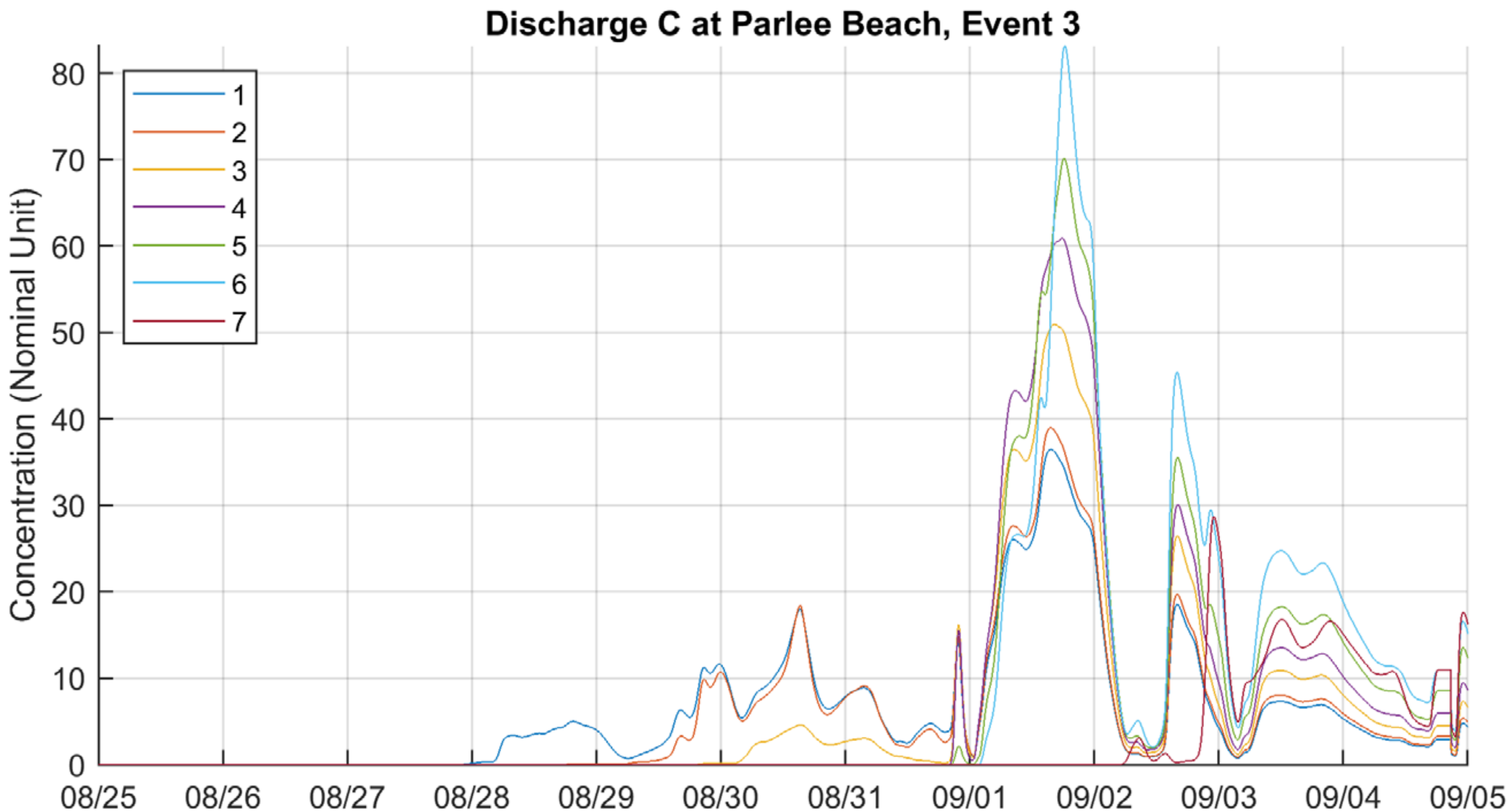

Discharge M at Parlee Beach, Event 2
Concentration (Nominal Unit)
1400
1200
1000
800
600
400
200
0
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

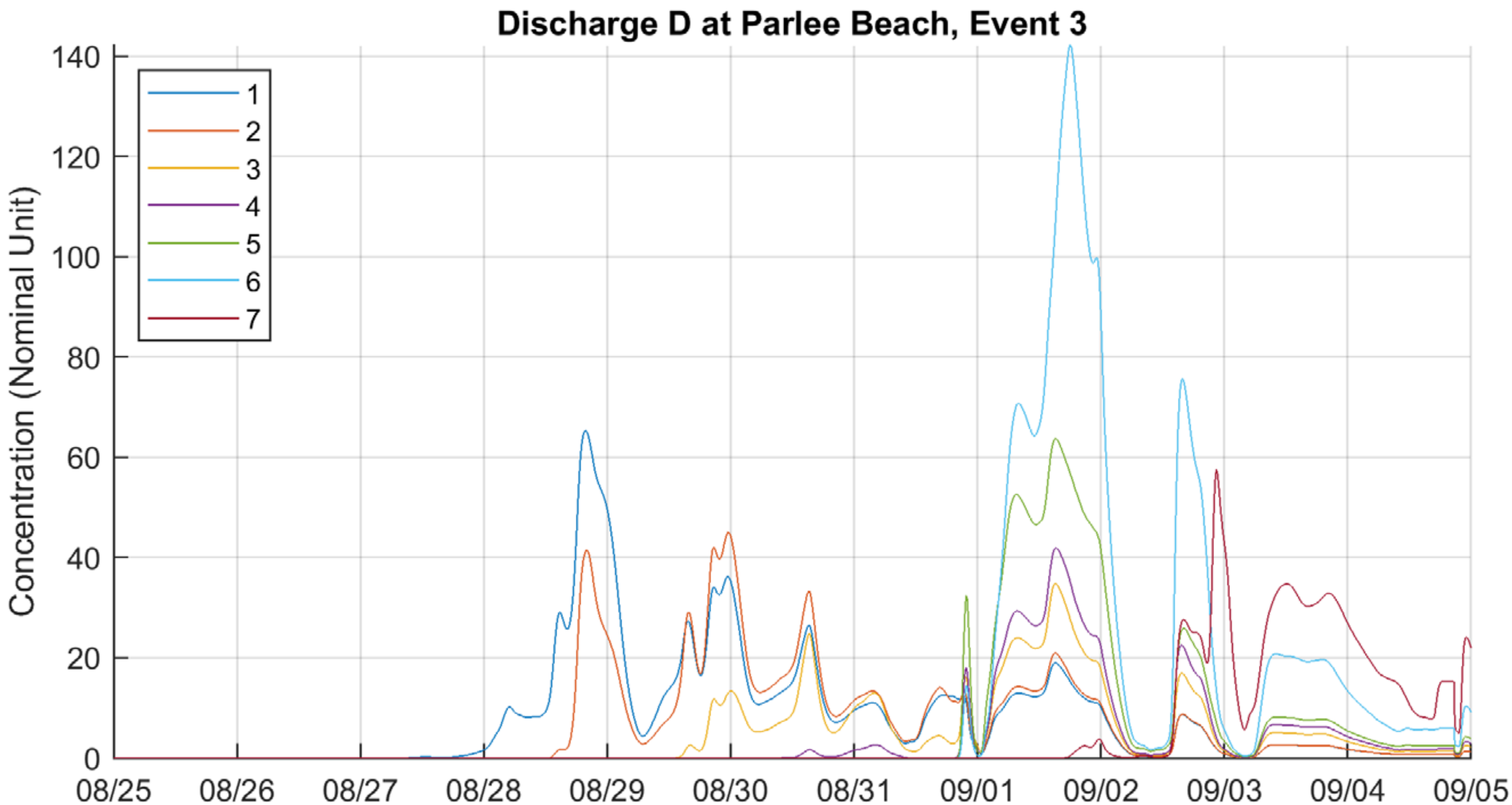

Discharge N at Parlee Beach, Event 2
Concentration (Nominal Unit)
0
200
400
600
800
1000
08/14
08/15
08/16
08/17
08/18
08/19
08/20
08/21
08/22
08/23
08/24
1
2
3
4
5
6
7

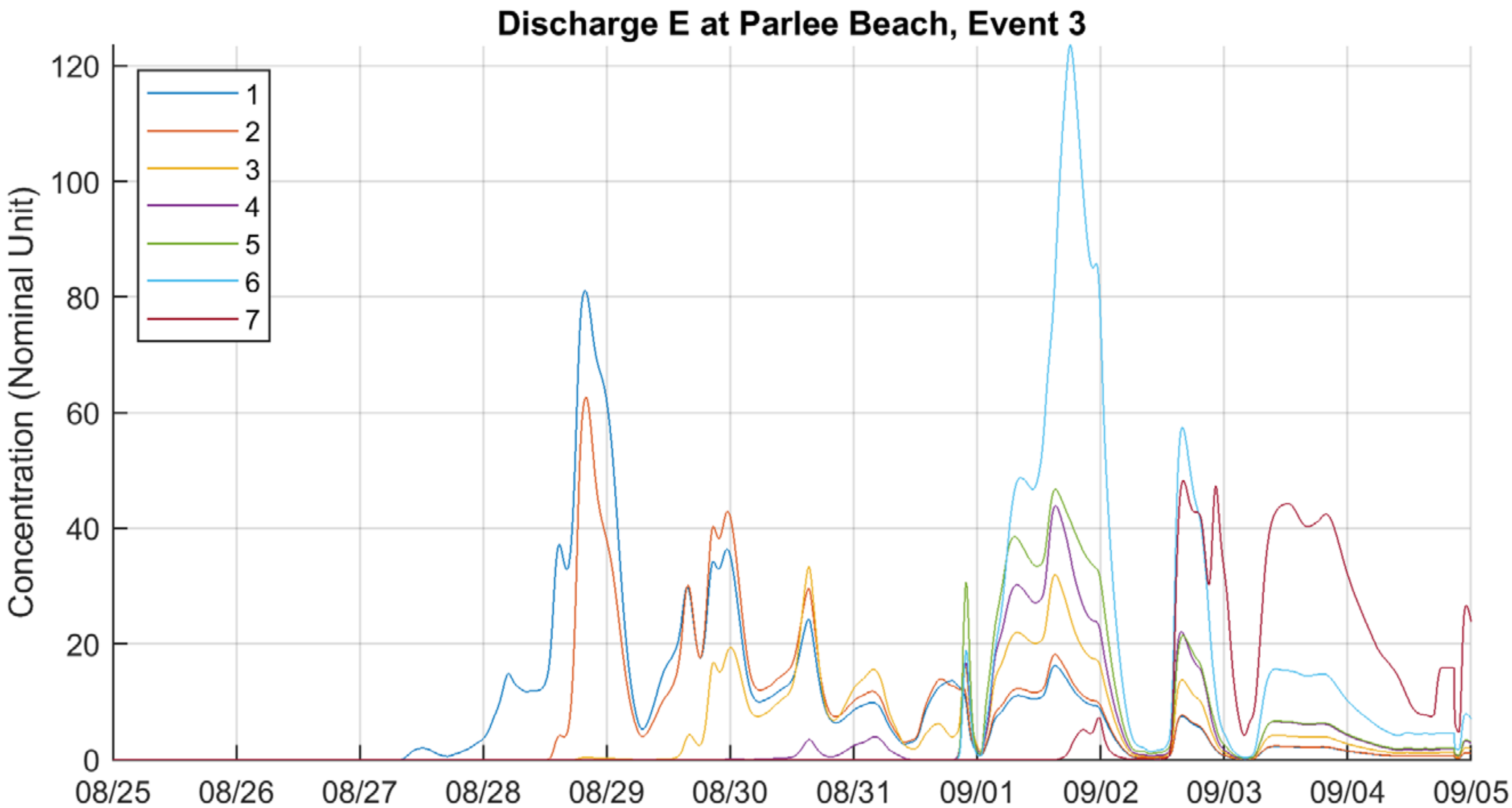
# APPENDIX C: MODELLED BACTERIAL CONCENTRATION (NOMINAL UNIT) TIME SERIES AT PARLEE BEACH FOR ALL POTENTIAL POLLUTANT SOURCES FOR EXCEEDANCE EVENT 3 (SEPTEMBER 2, 2017)

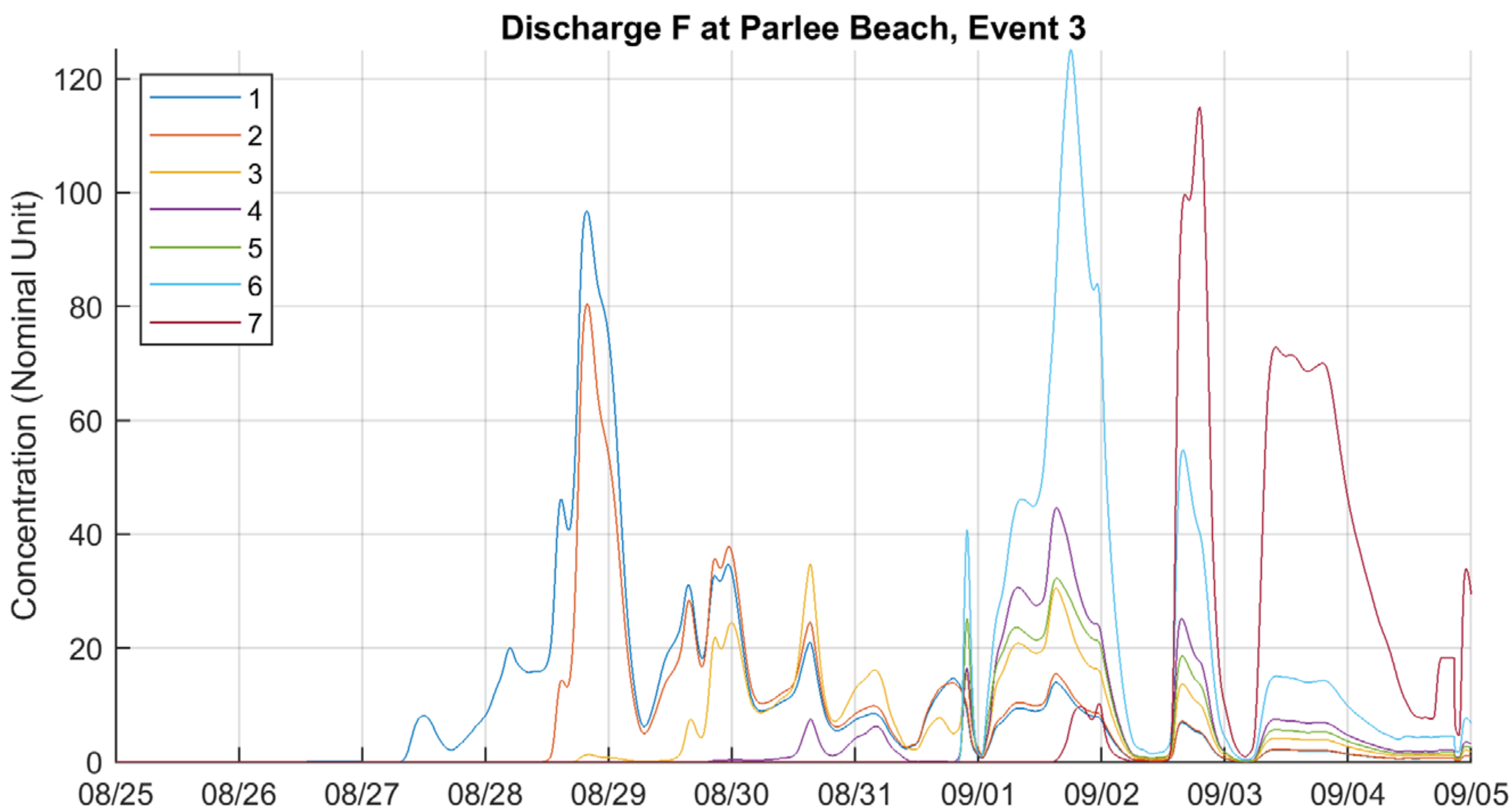

Discharge A at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05

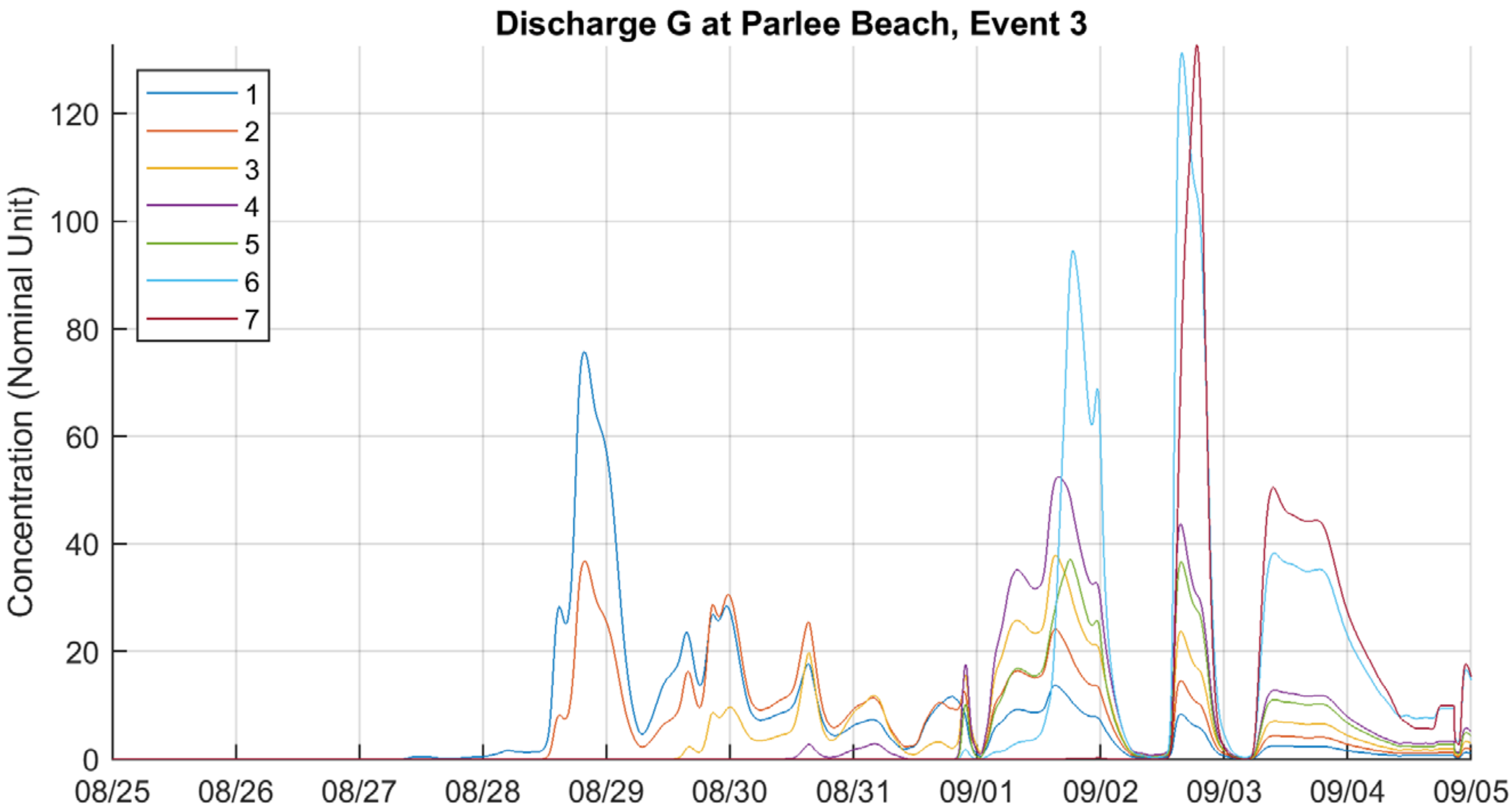

Discharge B at Parlee Beach, Event 3
Concentration (Nominal Unit)
100
90
80
70
60
50
40
30
20
10
0
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05
1
2
3
4
5
6
7

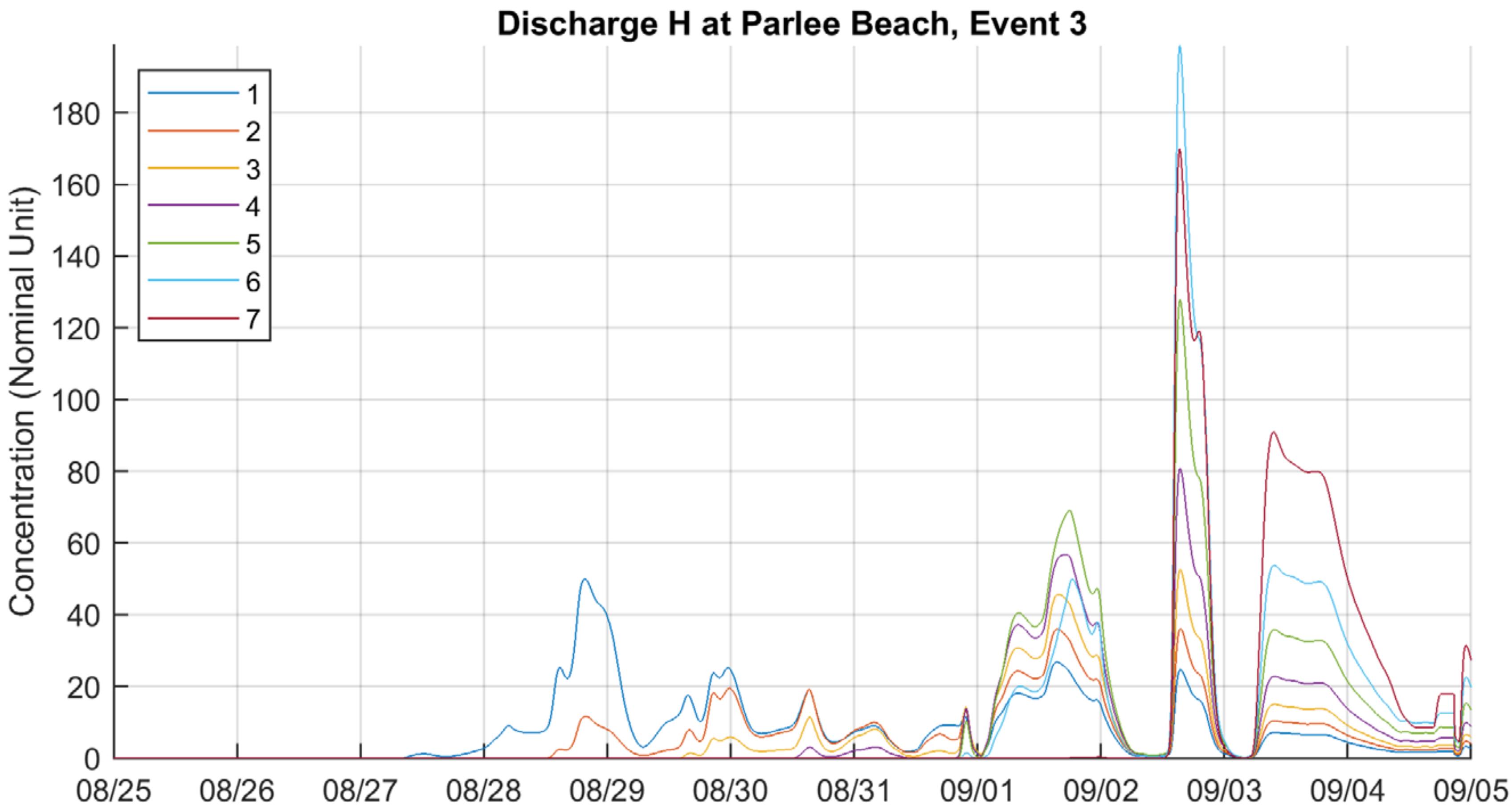

Discharge C at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05

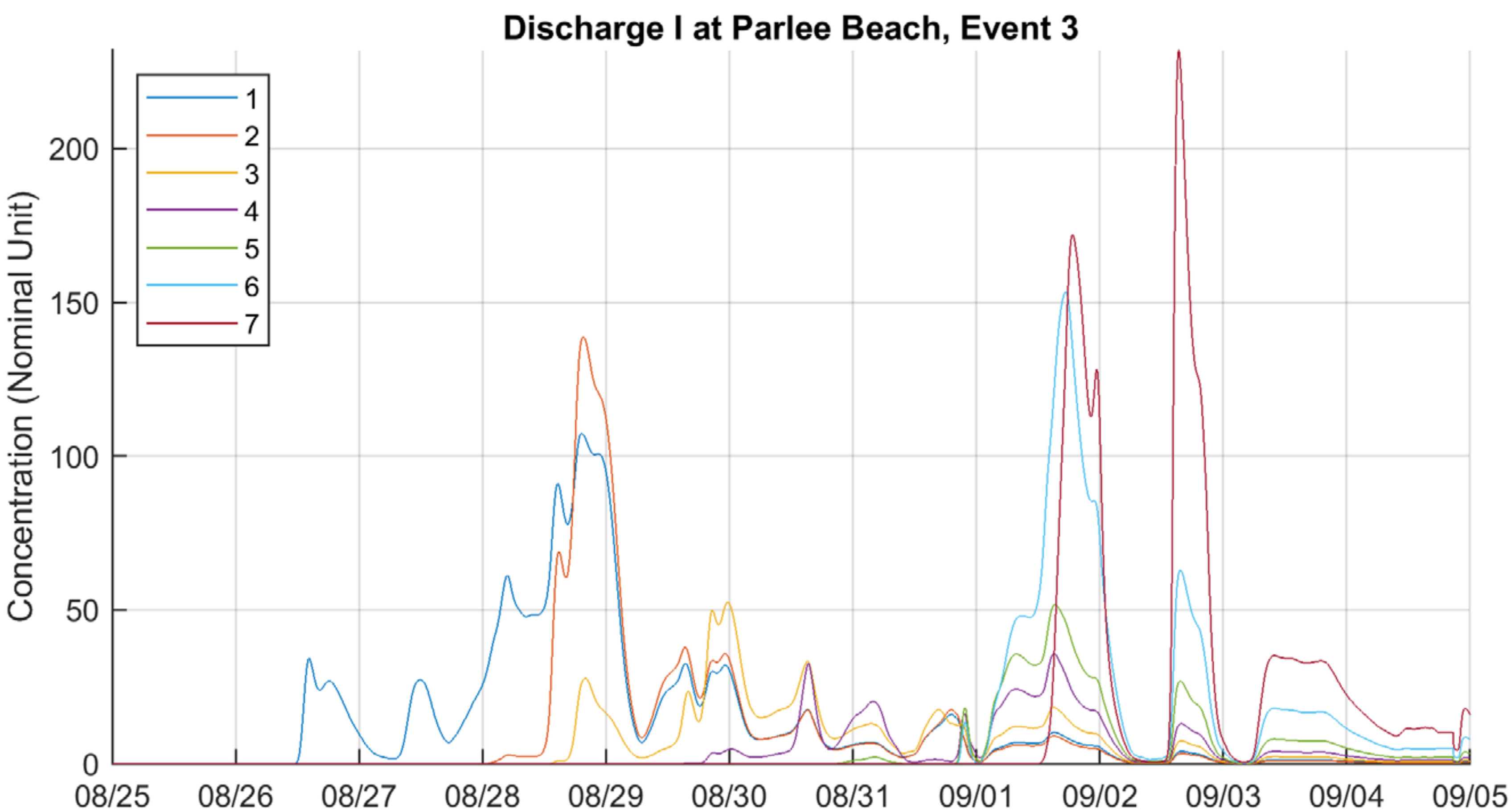

Discharge D at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
20
40
60
80
100
120
140
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05
1
2
3
4
5
6
7

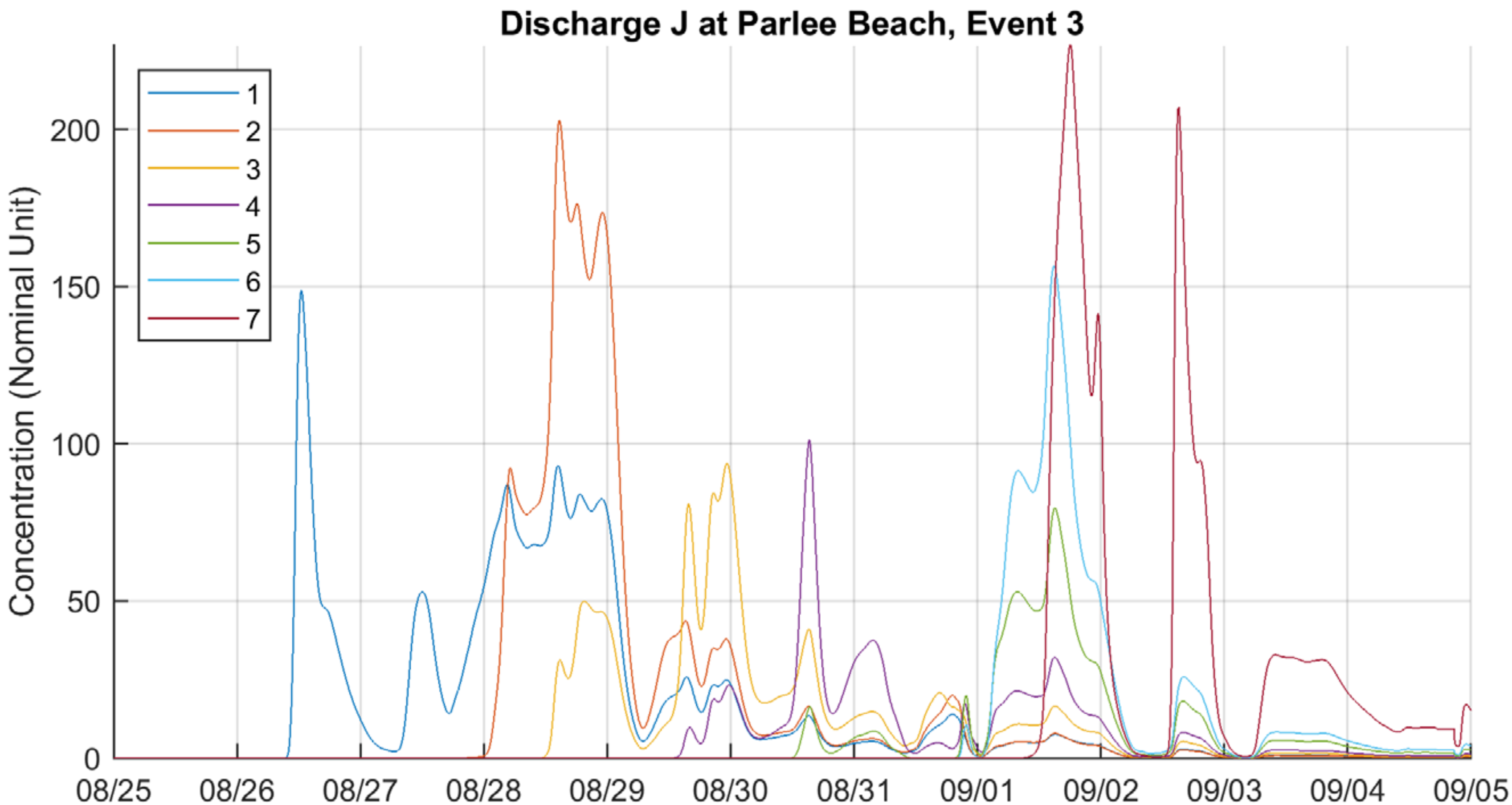

Discharge E at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
20
40
60
80
100
120
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05
1
2
3
4
5
6
7

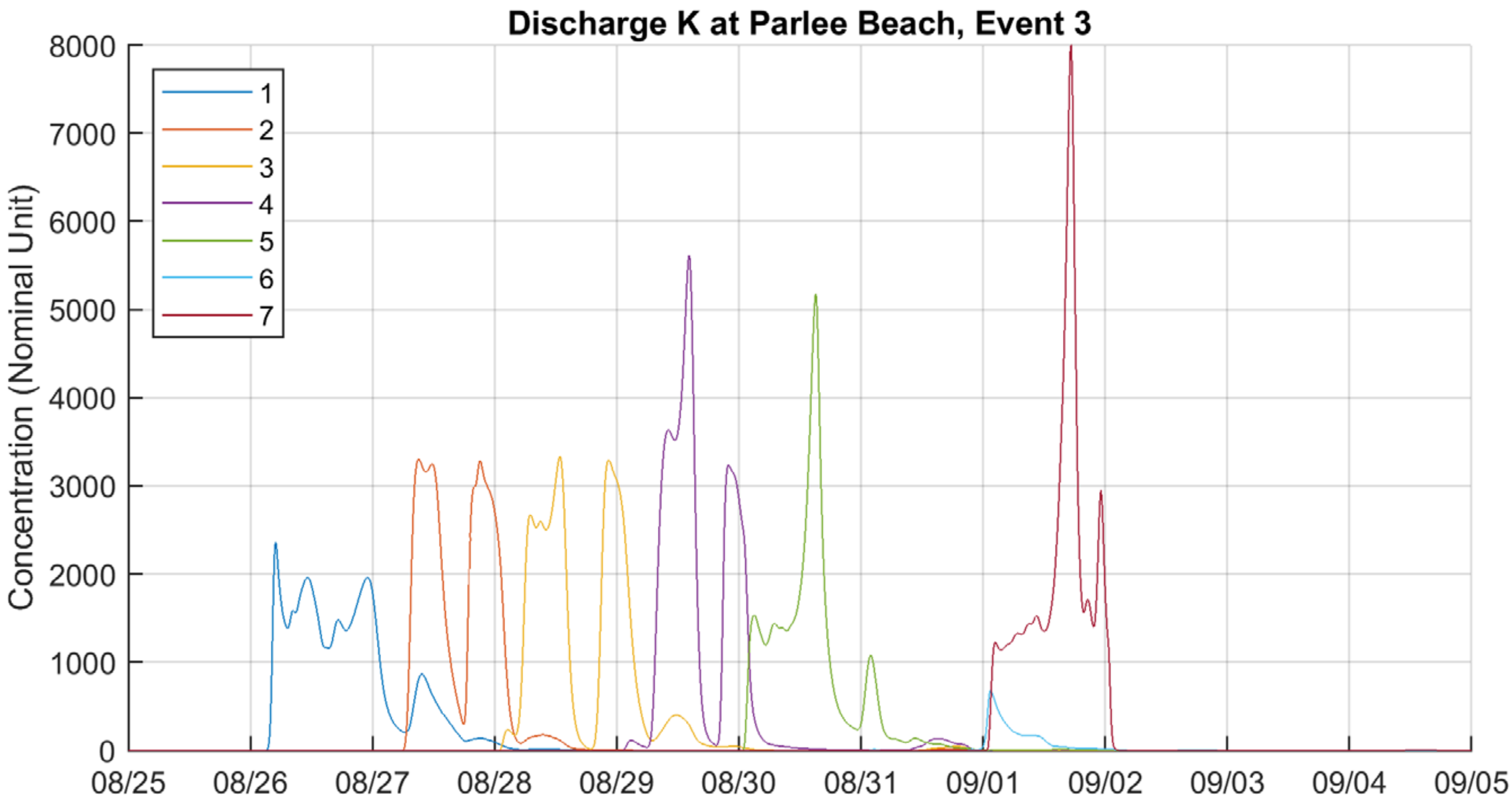

Discharge F at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
20
40
60
80
100
120
1
2
3
4
5
6
7
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05

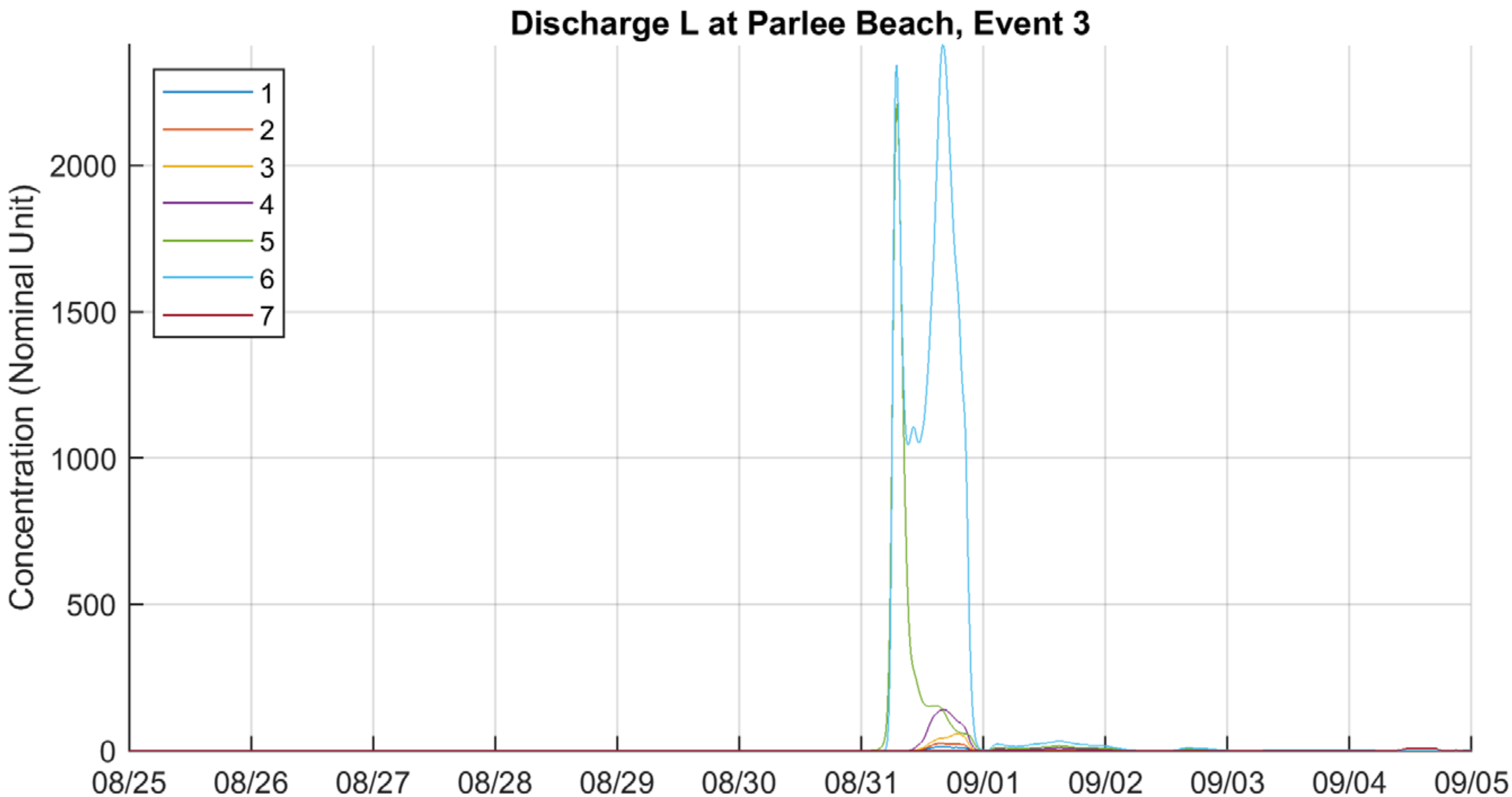

Discharge G at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
20
40
60
80
100
120
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05
1
2
3
4
5
6
7

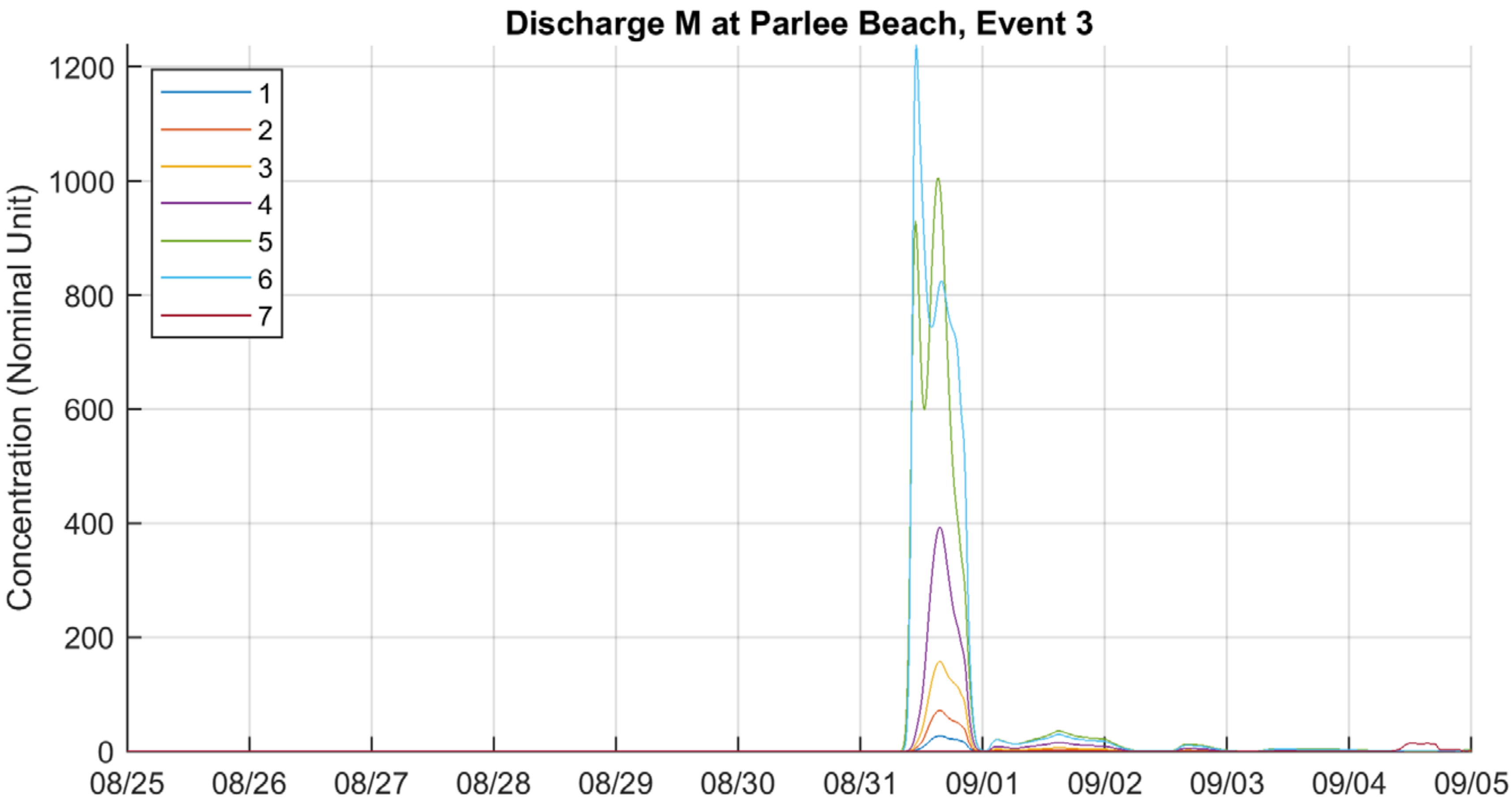

Discharge H at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
20
40
60
80
100
120
140
160
180
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05
1
2
3
4
5
6
7

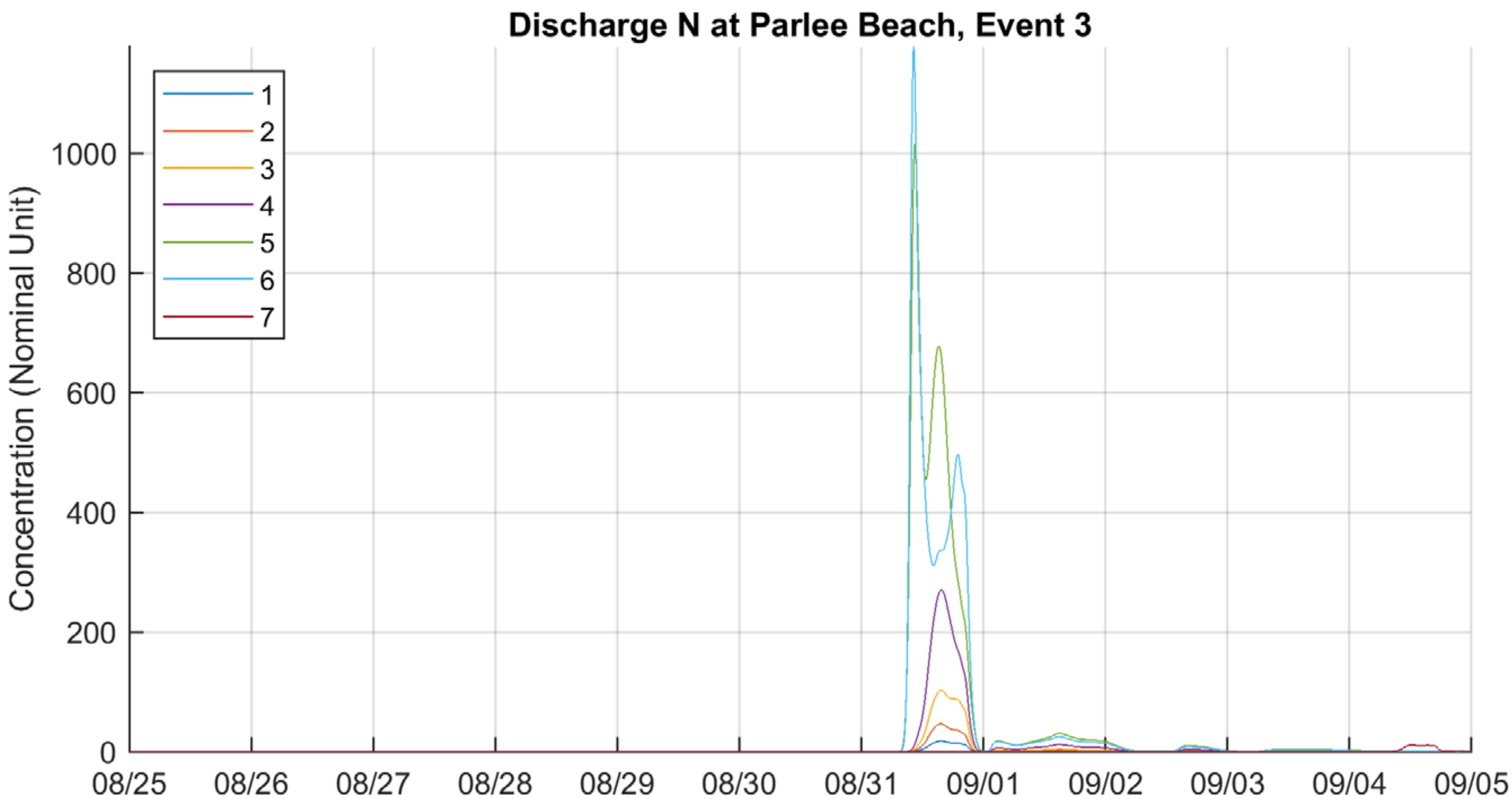

Discharge I at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
50
100
150
200
1
2
3
4
5
6
7
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05


Discharge J at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
50
100
150
200
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05
1
2
3
4
5
6
7

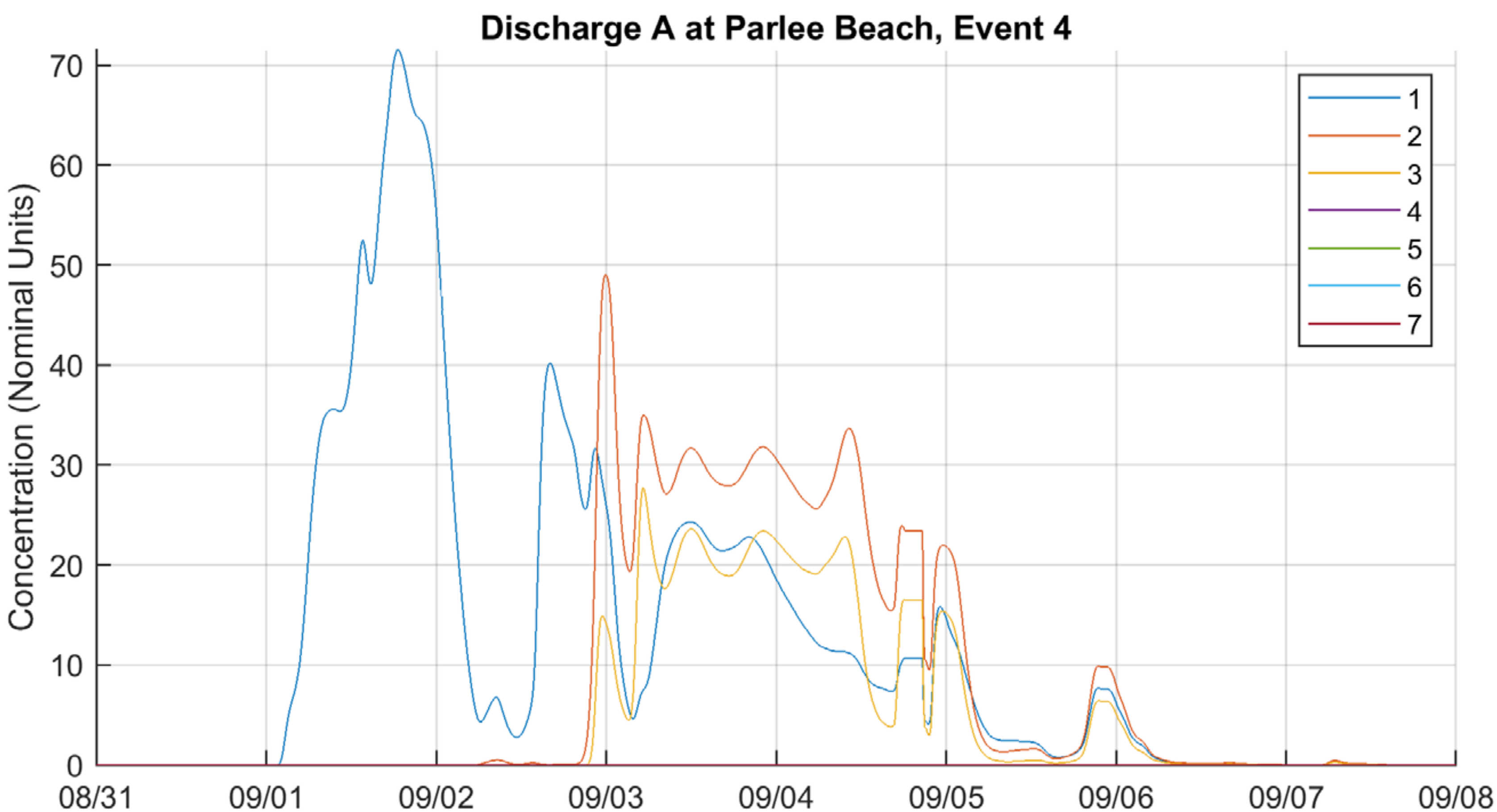

Discharge K at Parlee Beach, Event 3
Concentration (Nominal Unit)
8000
7000
6000
5000
4000
3000
2000
1000
0
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05
1
2
3
4
5
6
7

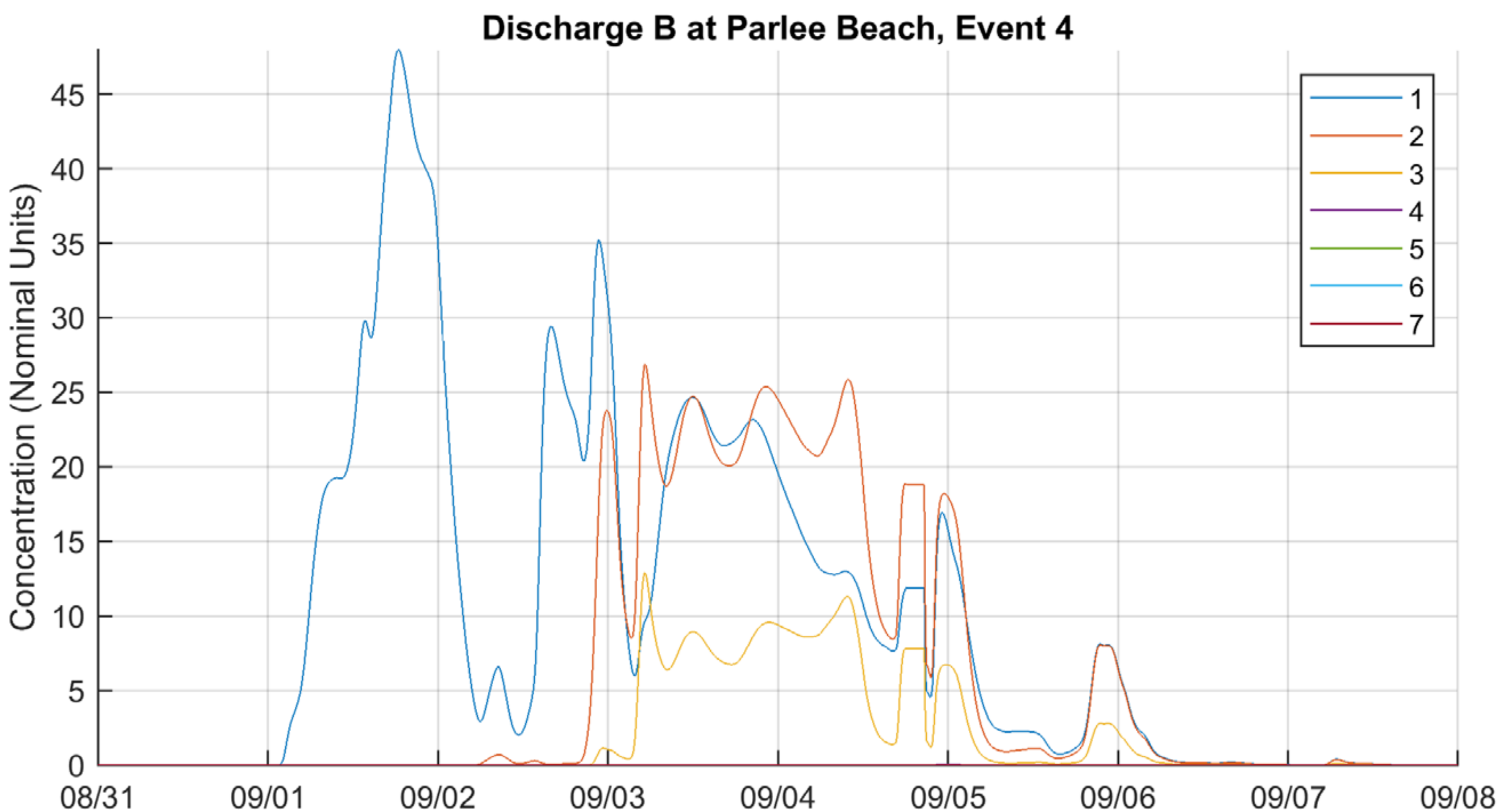

Discharge L at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
500
1000
1500
2000
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05
1
2
3
4
5
6
7

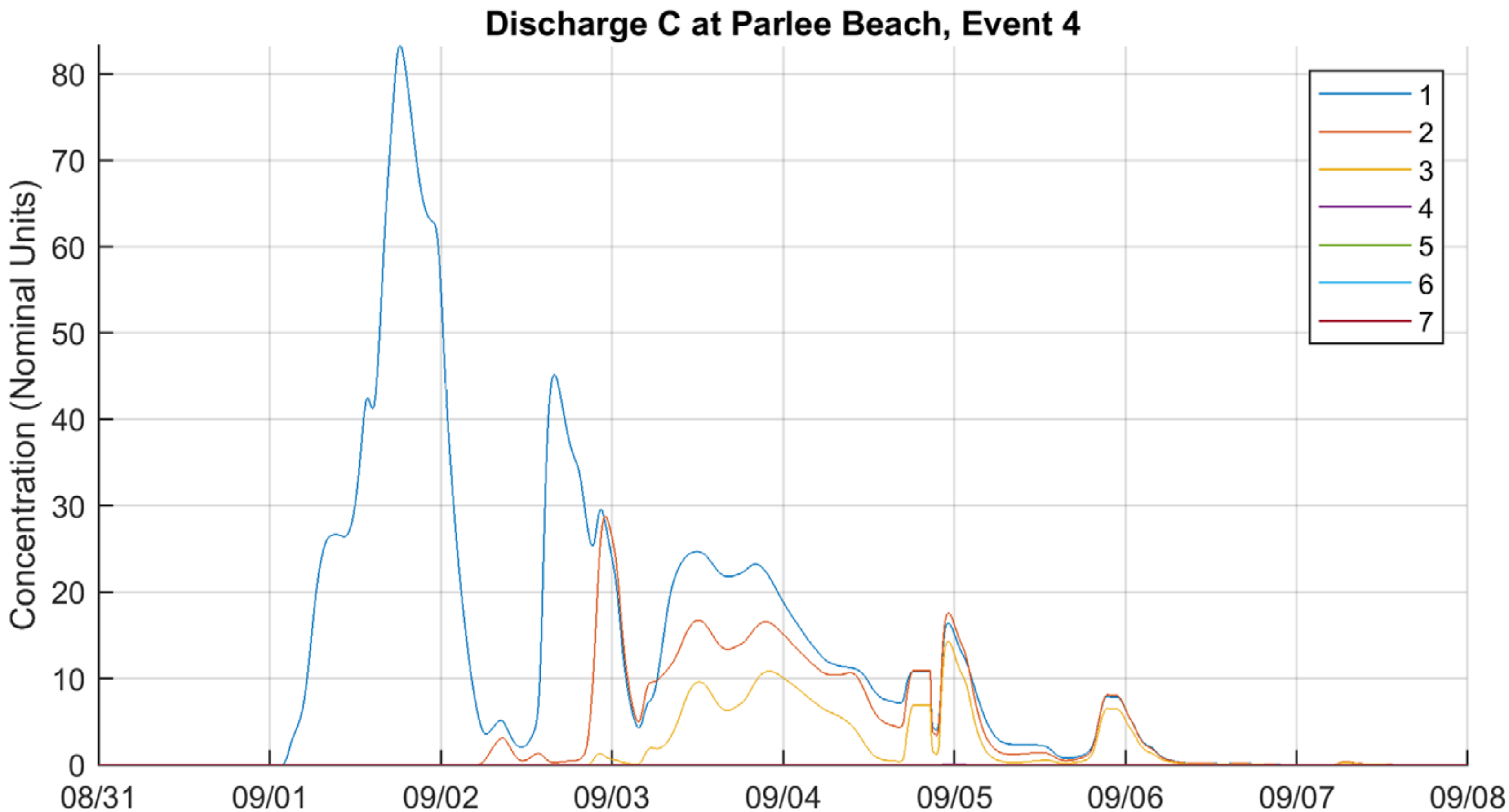

Discharge M at Parlee Beach, Event 3
Concentration (Nominal Unit)
1200
1000
800
600
400
200
0
1
2
3
4
5
6
7
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05

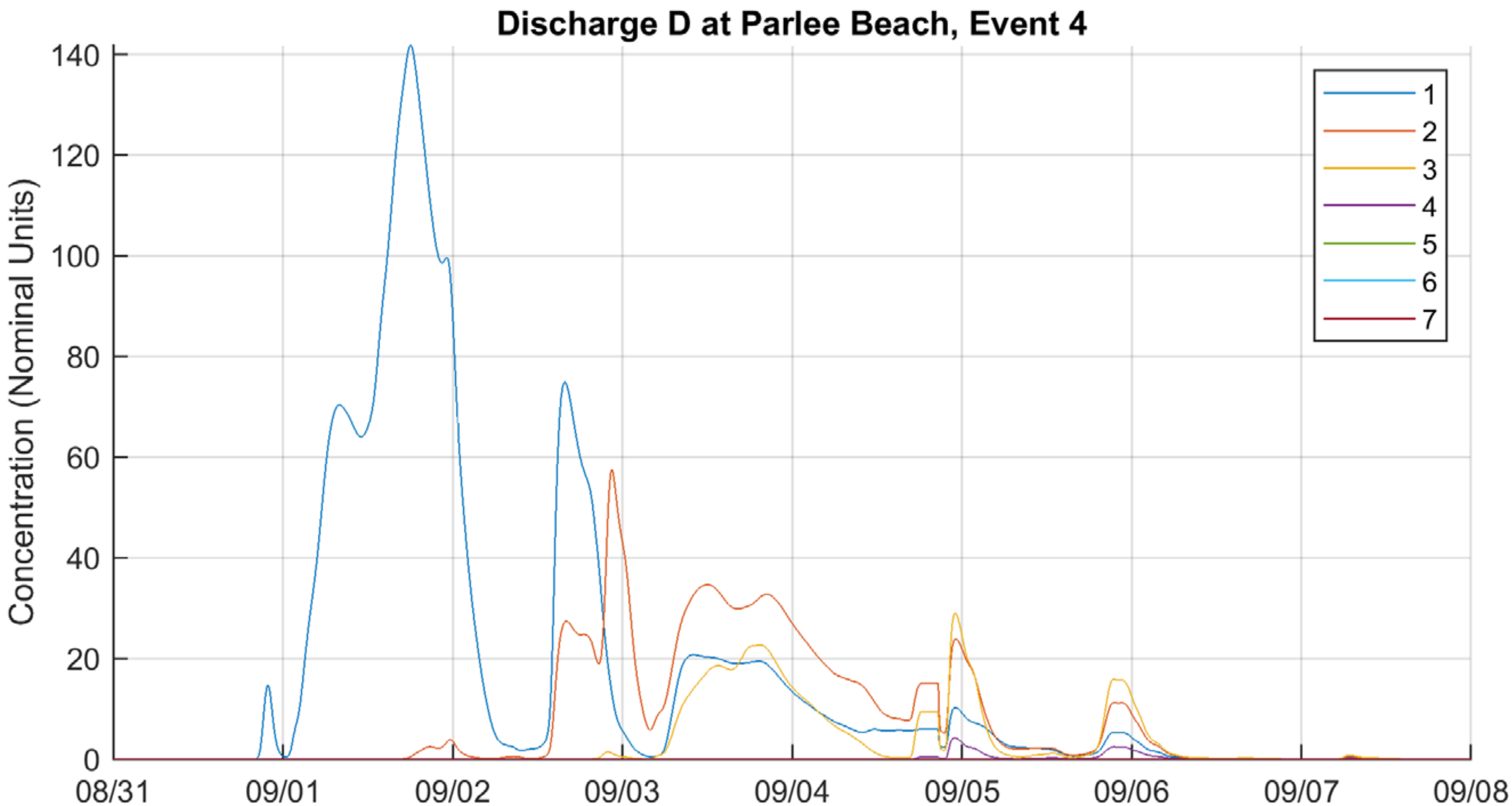

Discharge N at Parlee Beach, Event 3
Concentration (Nominal Unit)
0
200
400
600
800
1000
08/25
08/26
08/27
08/28
08/29
08/30
08/31
09/01
09/02
09/03
09/04
09/05
1
2
3
4
5
6
7

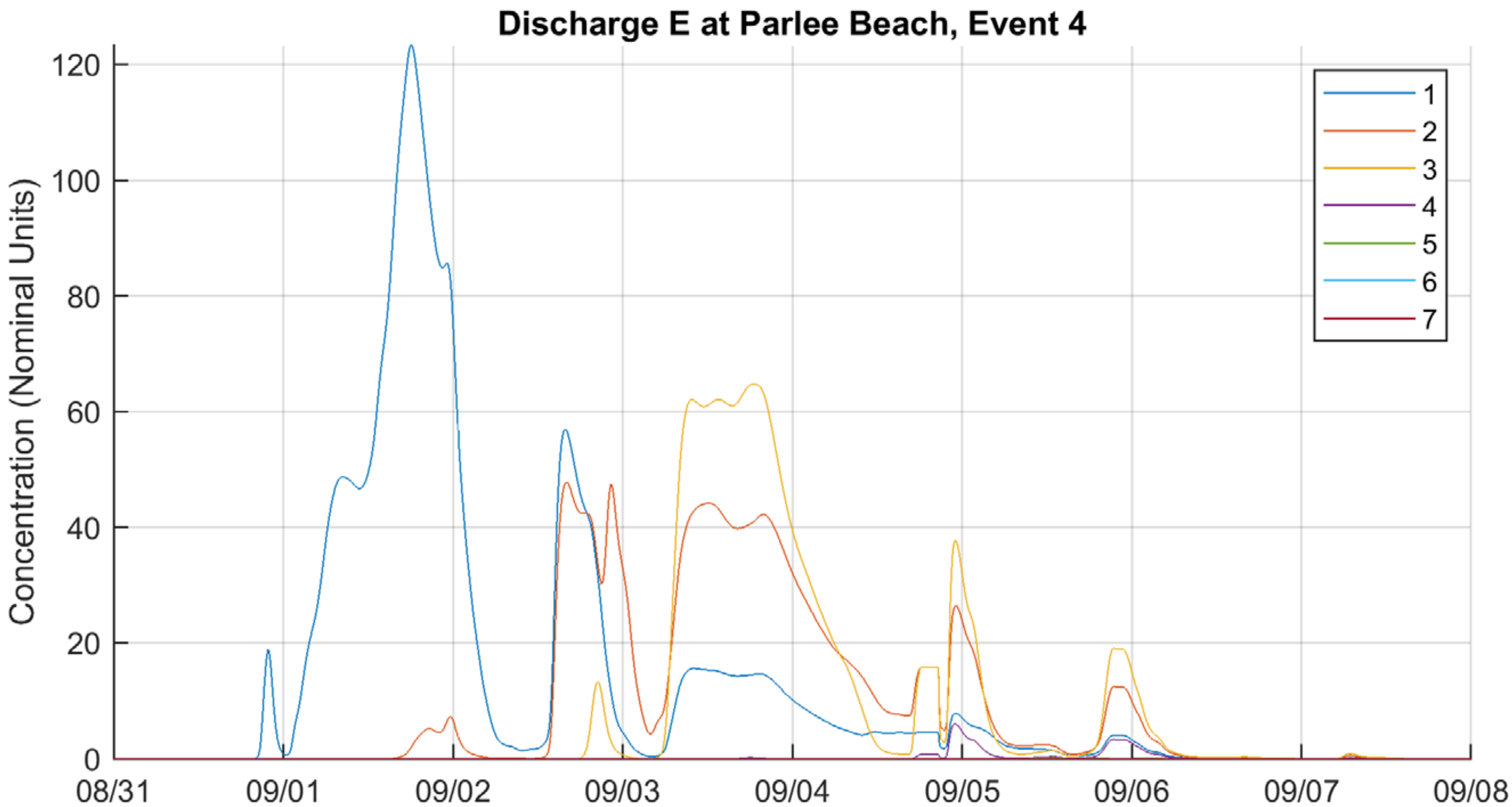
# APPENDIX D: MODELLED BACTERIAL CONCENTRATION (NOMINAL UNIT) TIME SERIES AT PARLEE BEACH FOR ALL POTENTIAL POLLUTANT SOURCES FOR THE NON-EXCEEDANCE EVENT (EVENT 4) (SEPTEMBER 7, 2017)

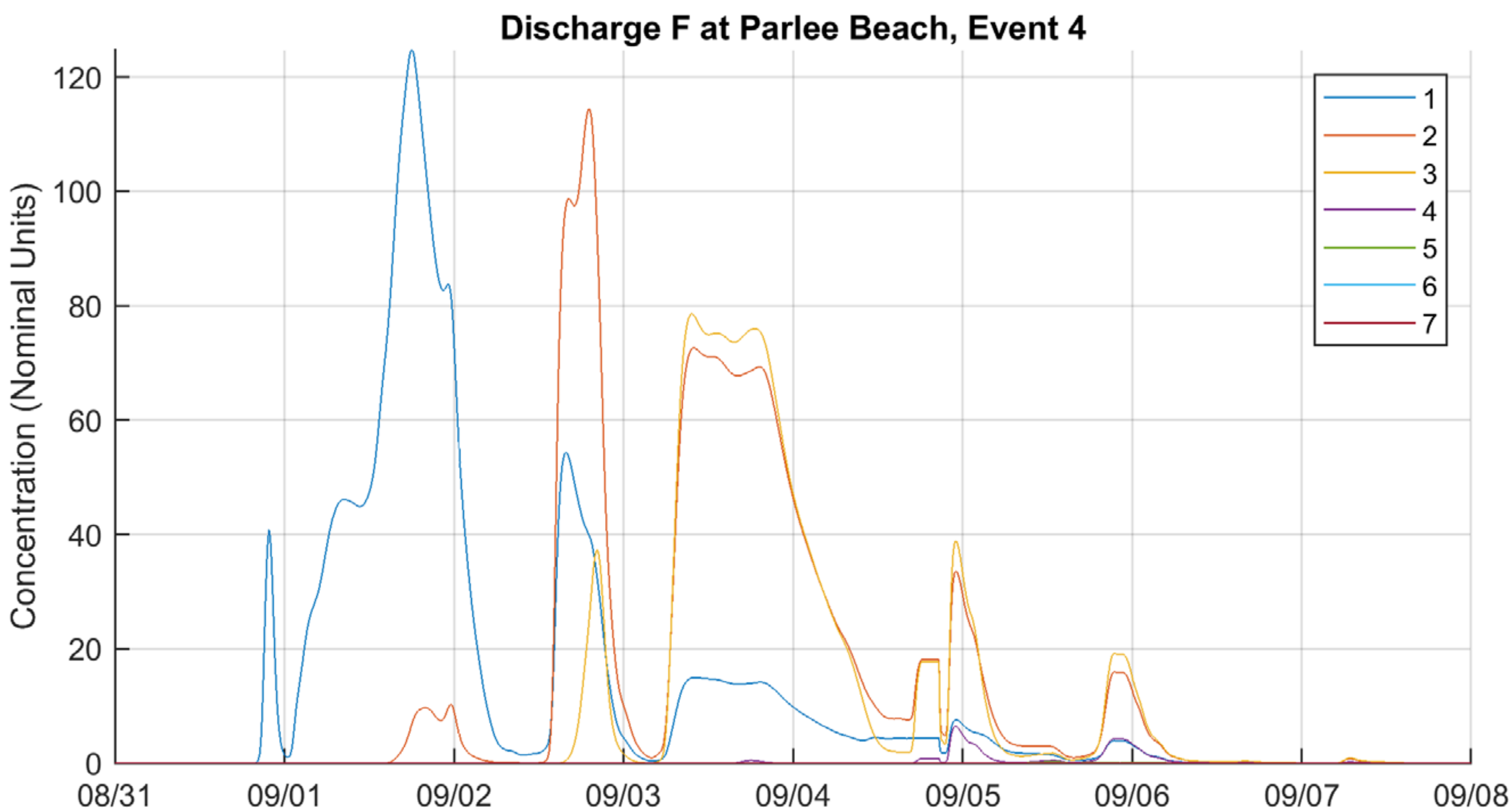

Discharge A at Parlee Beach, Event 4
Concentration (Nominal Units)
0
10
20
30
40
50
60
70
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7

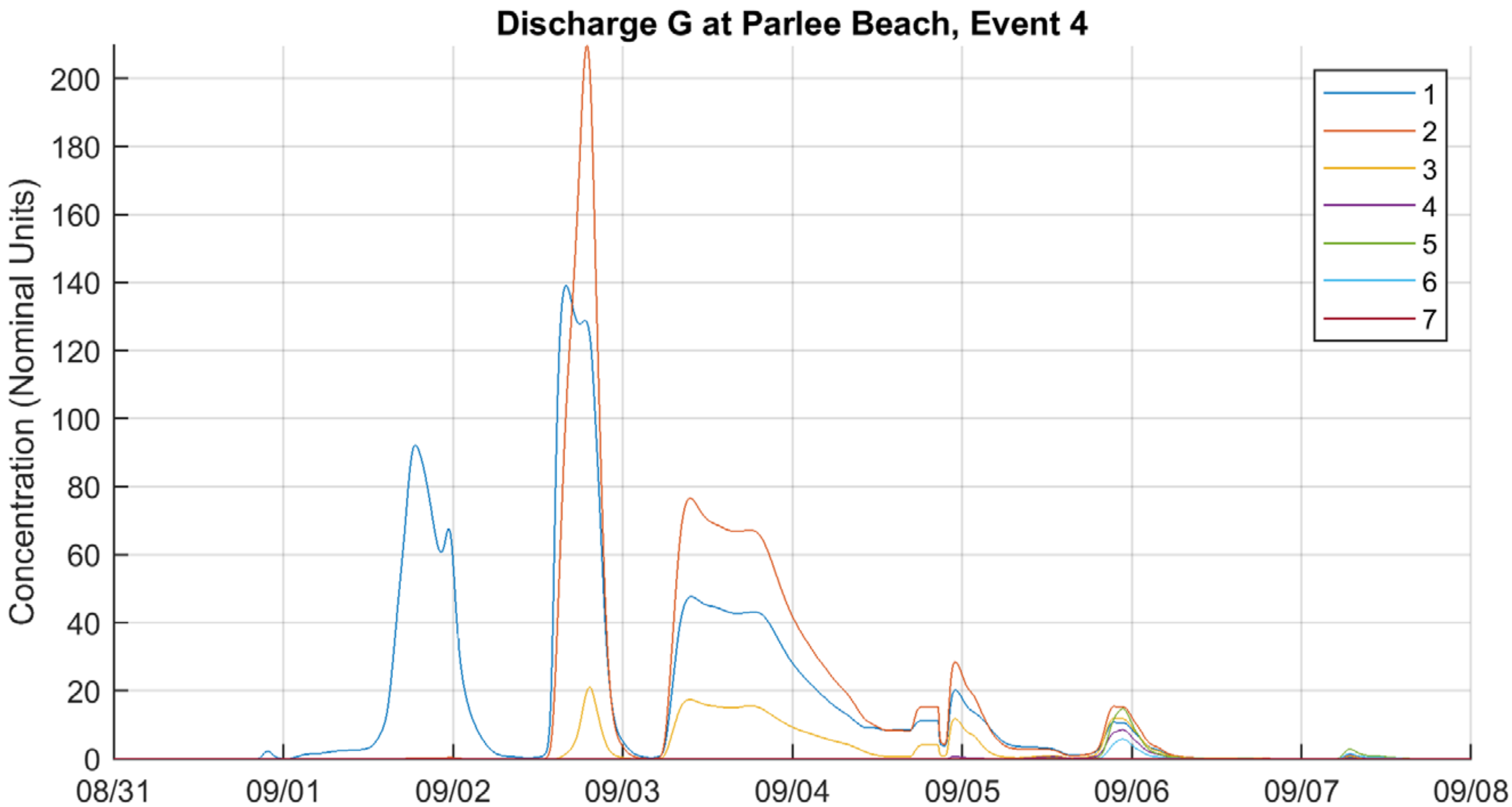

Discharge B at Parlee Beach, Event 4
Concentration (Nominal Units)
0
5
10
15
20
25
30
35
40
45
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7

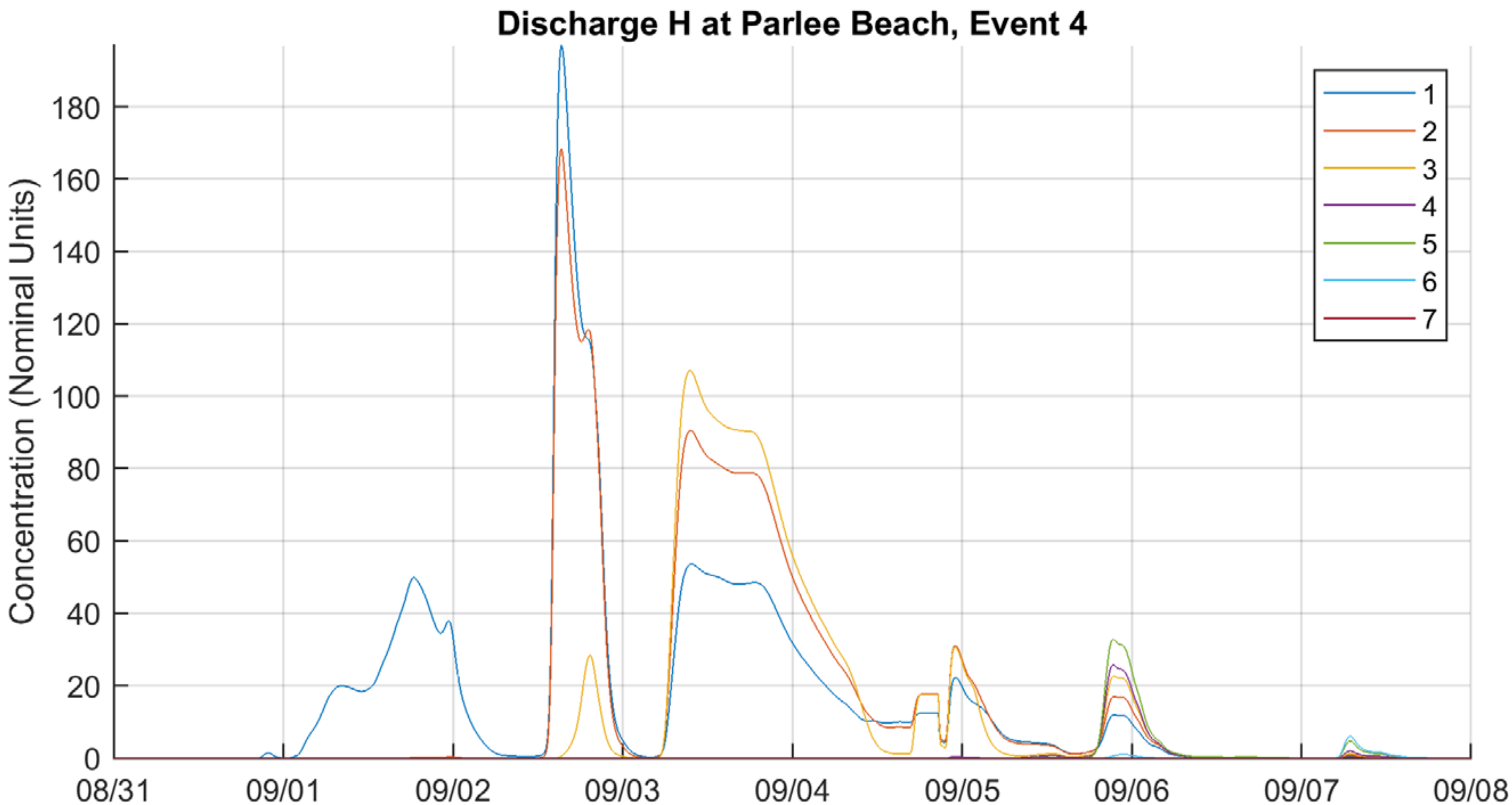

Discharge C at Parlee Beach, Event 4
Concentration (Nominal Units)
0
10
20
30
40
50
60
70
80
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7

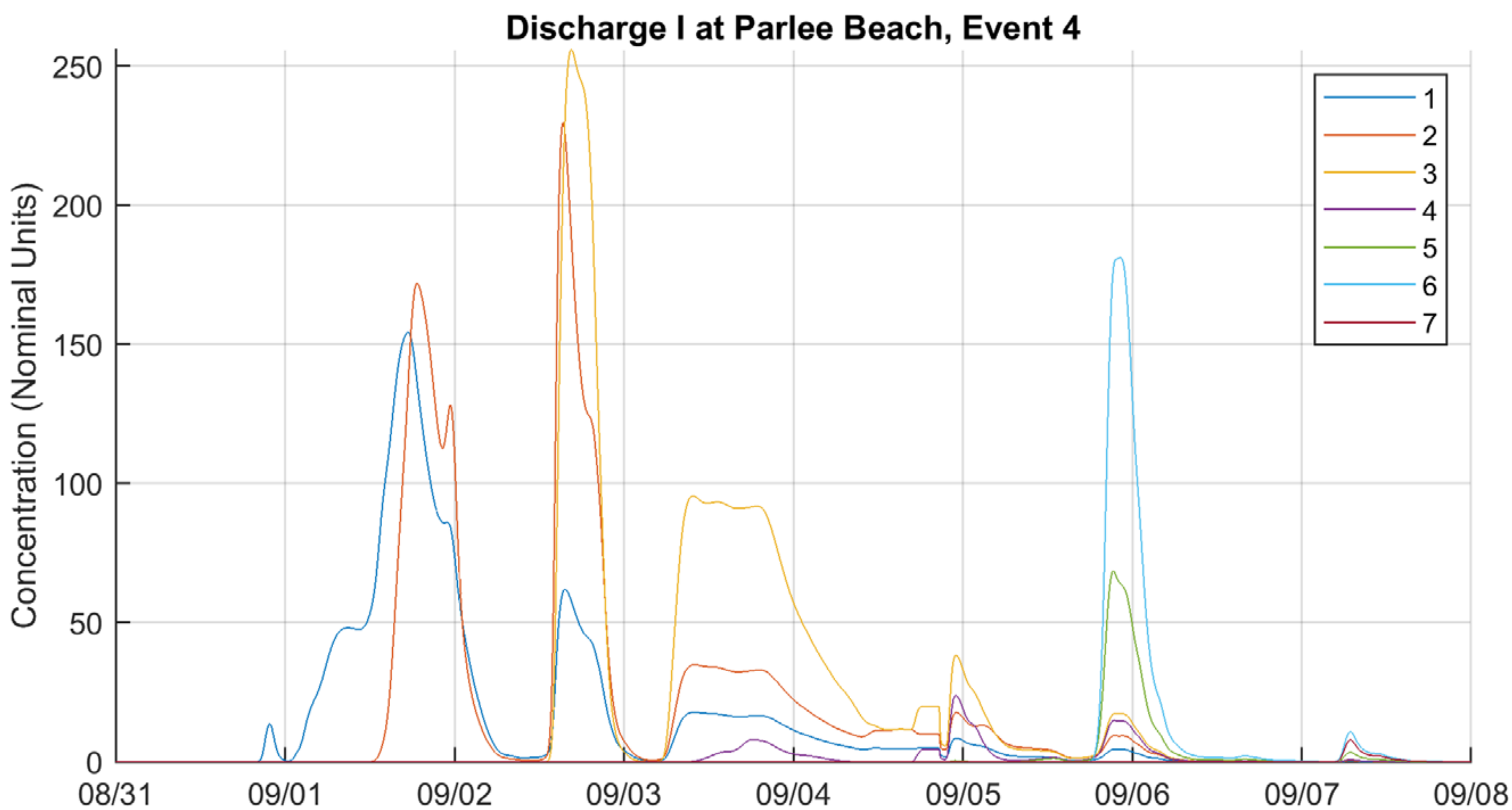

Discharge D at Parlee Beach, Event 4
Concentration (Nominal Units)
140
120
100
80
60
40
20
0
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7

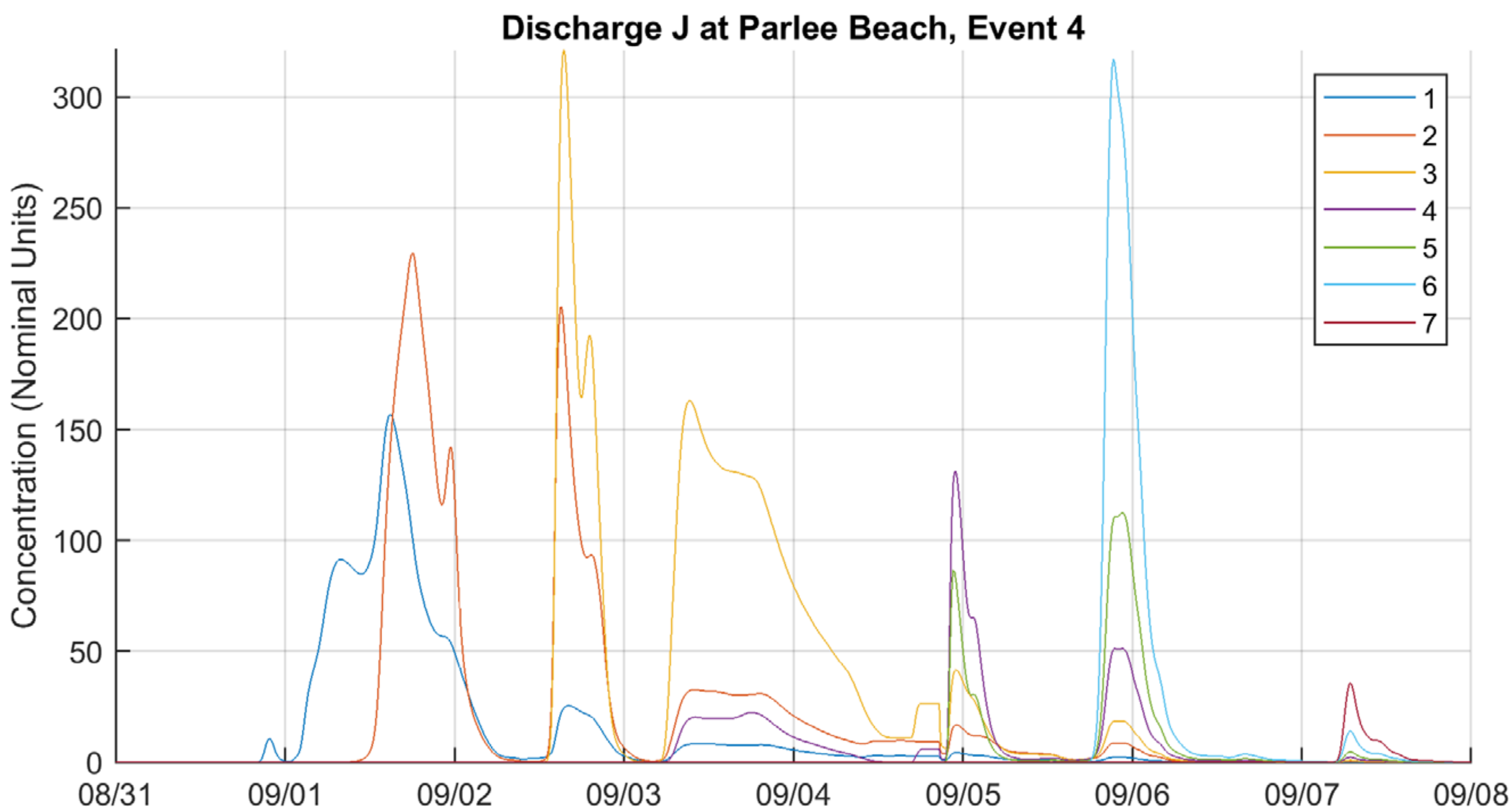

Discharge E at Parlee Beach, Event 4
Concentration (Nominal Units)
120
100
80
60
40
20
0
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7

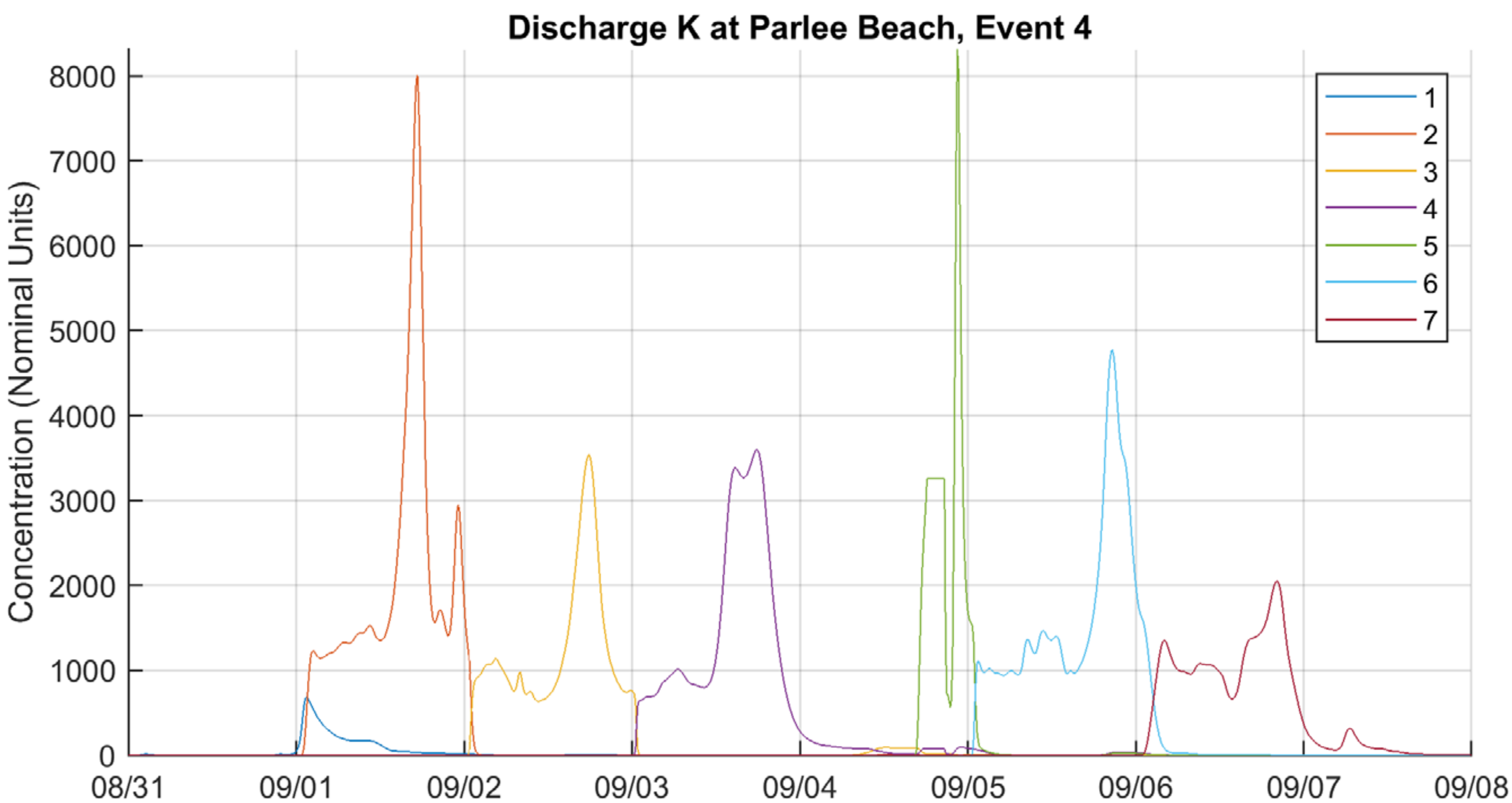

Discharge F at Parlee Beach, Event 4
Concentration (Nominal Units)
0
20
40
60
80
100
120
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7

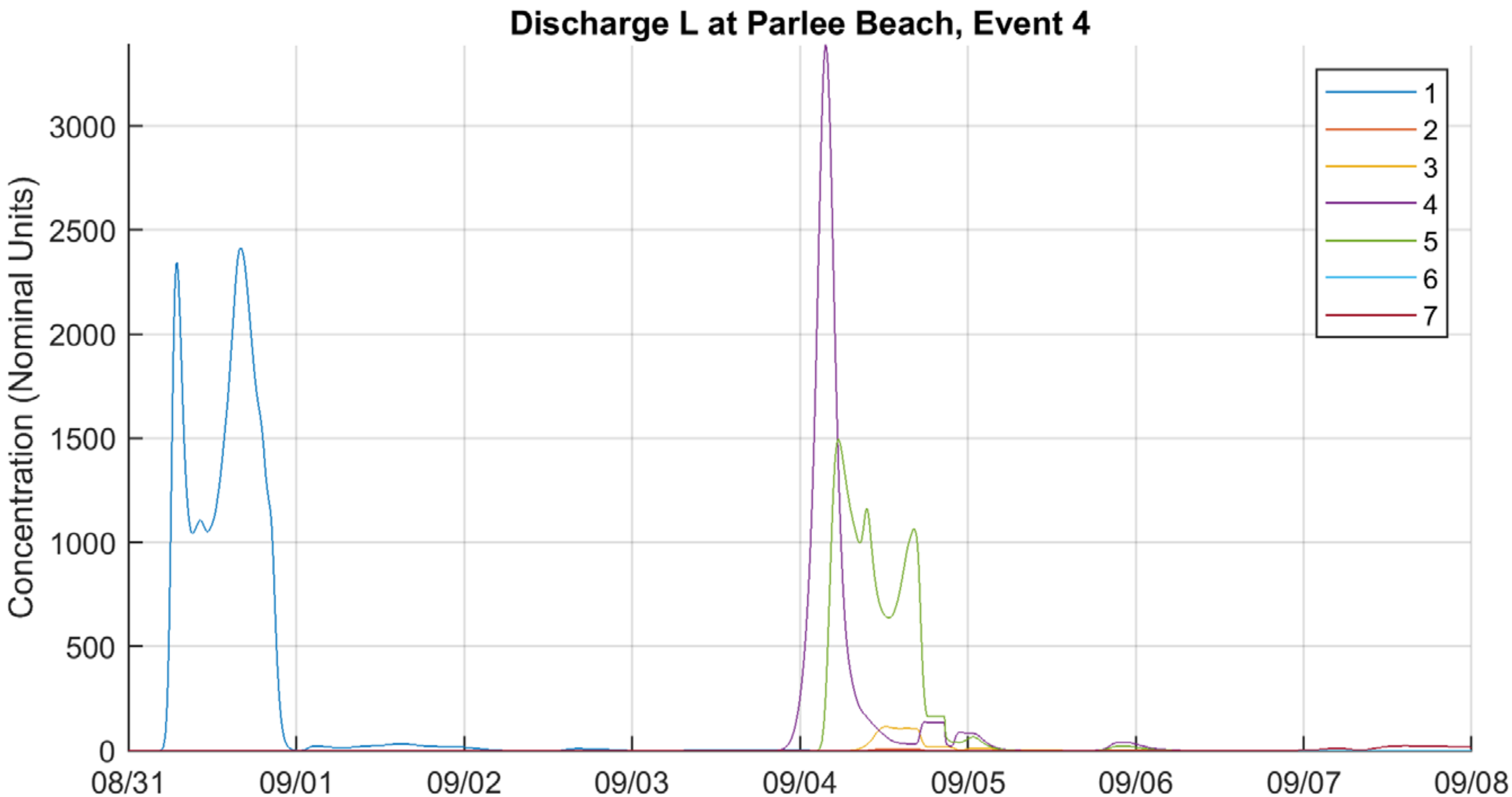

Discharge G at Parlee Beach, Event 4
Concentration (Nominal Units)
200
180
160
140
120
100
80
60
40
20
0
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7

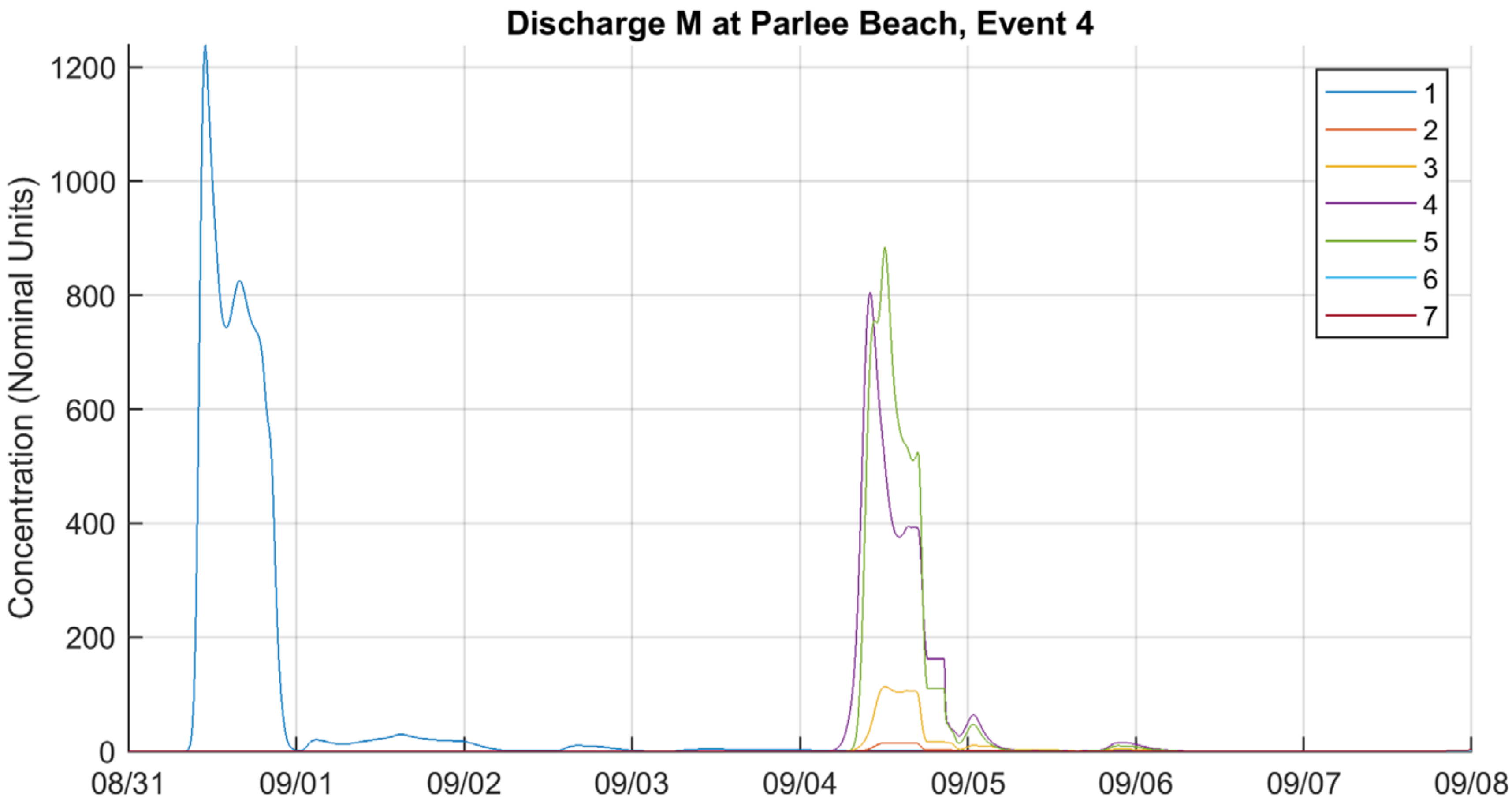

Discharge H at Parlee Beach, Event 4
Concentration (Nominal Units)
180
160
140
120
100
80
60
40
20
0
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7

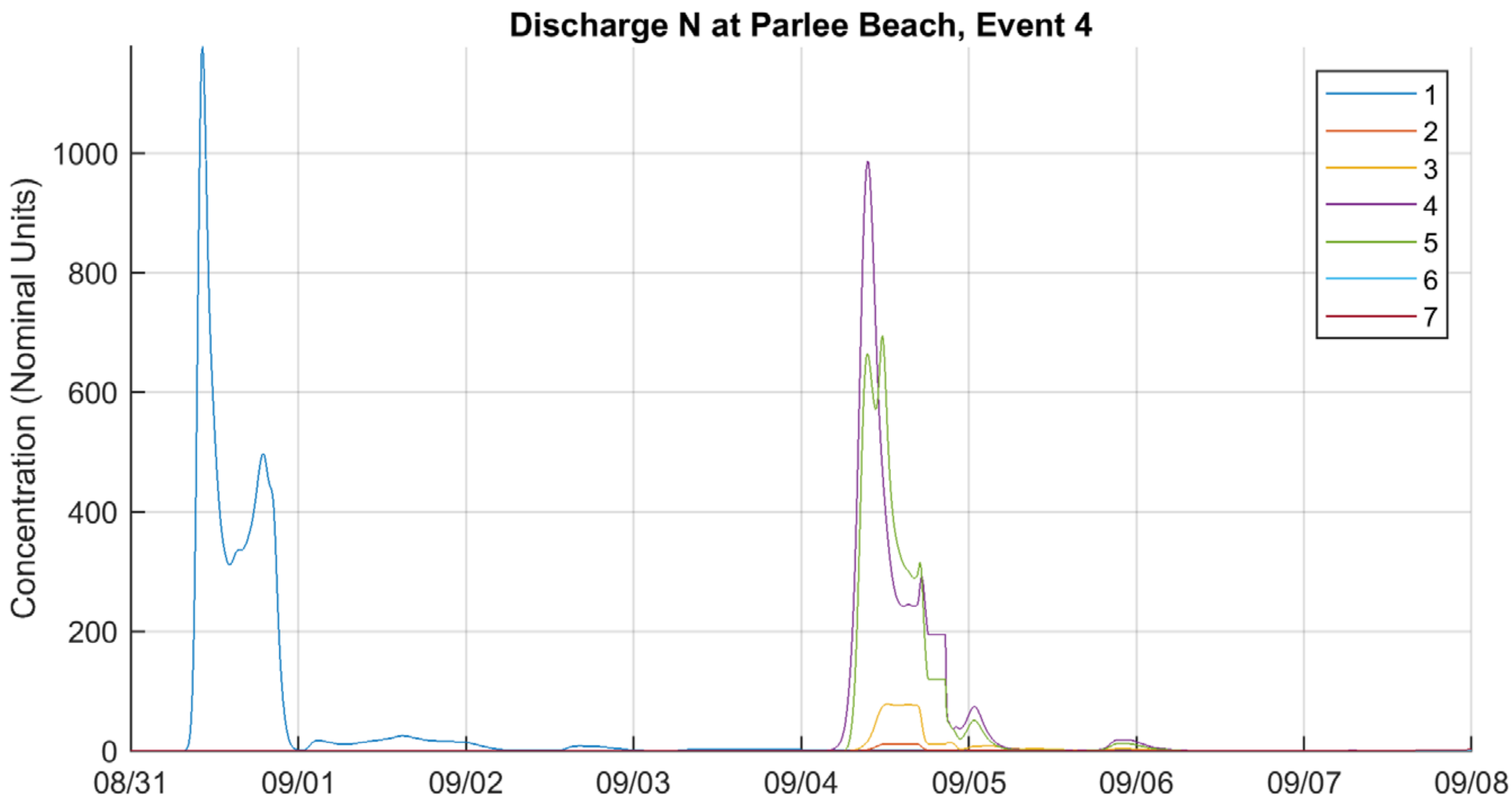

Discharge I at Parlee Beach, Event 4
Concentration (Nominal Units)
0
50
100
150
200
250
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7


Discharge J at Parlee Beach, Event 4
Concentration (Nominal Units)
300
250
200
150
100
50
0
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7


Discharge K at Parlee Beach, Event 4
Concentration (Nominal Units)
8000
7000
6000
5000
4000
3000
2000
1000
0
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7


Discharge L at Parlee Beach, Event 4
Concentration (Nominal Units)
3000
2500
2000
1500
1000
500
0
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7


Discharge M at Parlee Beach, Event 4
Concentration (Nominal Units)
1200
1000
800
600
400
200
0
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7


Discharge N at Parlee Beach, Event 4
Concentration (Nominal Units)
0
200
400
600
800
1000
08/31
09/01
09/02
09/03
09/04
09/05
09/06
09/07
09/08
1
2
3
4
5
6
7