CRAB and MIT Chart Project

OF THE LOWER CHARLES RIVER

Carl Zimba

Micheal Sacarny

Agenda

- Organizations and People
- Project Background and Scope
- Experimental Methods and Instrumentation
- Watersheet Level
- Uncertainty and Error
- Digital Depth Charts
- Future Work

Charles River Alliance of Boaters

- Mission is to encourage safe and accessible boating by the entire community on the Lower Basin of the Charles.
- This includes power boaters, sailors, rowers, paddlers, and others, working together to keep the Charles River a healthy resource for the enjoyment of boaters and park users alike.
- A cornerstone of our effort is the development of better avenues of communication between and among this diverse community of users.
- www.CharlesRiverAllianceofBoaters.org

MIT Sea Grant College Program

- Mission is to conduct and support research and develop technology to enable scientific investigation into problems surrounding the health and human use of the sea
- Education and outreach efforts disseminate the results of our research, encourage the stewardship and the adoption of sustainable and useful technologies, and support public policy and industry with information that is relevant, evidence-based and scientifically sound.
- Wide variety of activity including the Autonomous Underwater Vehicles (AUV) Lab, the Design Lab for naval architecture and systems, and the MIT Sea Grant Marine Advisory Services group.
- SeaGrant.mit.edu

People

- Carl Zimba
  Project Coordinator
  Charles River Alliance of Boaters

- Michael Sacarny
  Project and Survey Lead
  Research Engineer, MIT Sea Grant College Program

- Madonna Yoder
  Chart Development and Survey Crew
  Student Intern, MIT Sea Grant College Program

- Ben Bray
  Arc-GIS Website Development
  Web Developer, MIT Sea Grant College Program

- Additional Survey Crew
  - Katrina Alleyne, Hugh Dougherty, Bill Gallagher, Mark Landsberg, Paul Robinette, Cam Sacarny, and Juliet Simpson

Funding

Sea Grant
Massachusetts Institute of Technology

BOSTON DUCK TOURS

HEAD OF THE CHARLES
REGATTA

MIT SAILING

UNION BOAT CLUB

RIVERSIDE 1869

NEWTON YACHT CLUB

CRI
Community Rowing Inc.

NORTHEASTERN UNIVERSITY
LVX VERITAS VIRTVS
BOSTON, MASSACHUSETTS

CHARLES RIVER conservancy

Individual Donors

COMMUNITY BOATING INC.
BOSTON

Boston - 1775

Pelham Map
Mount Vernon Collection

Boston 1630

The diagrams were prepared by The Muriel G. and Norman B. Leventhal Family Foundation;
Cartography by MapWorks, Herb Heidt and Eliza McClemen.
Published in Karl Haglund, *Inventing the Charles River* (Cambridge: MIT Press, 2003), 460-3.

Boston 1795

The diagrams were prepared by The Muriel G. and Norman B. Leventhal Family Foundation;
Cartography by MapWorks, Herb Heidt and Eliza McClemen.
Published in Karl Haglund, *Inventing the Charles River* (Cambridge: MIT Press, 2003), 460-3.

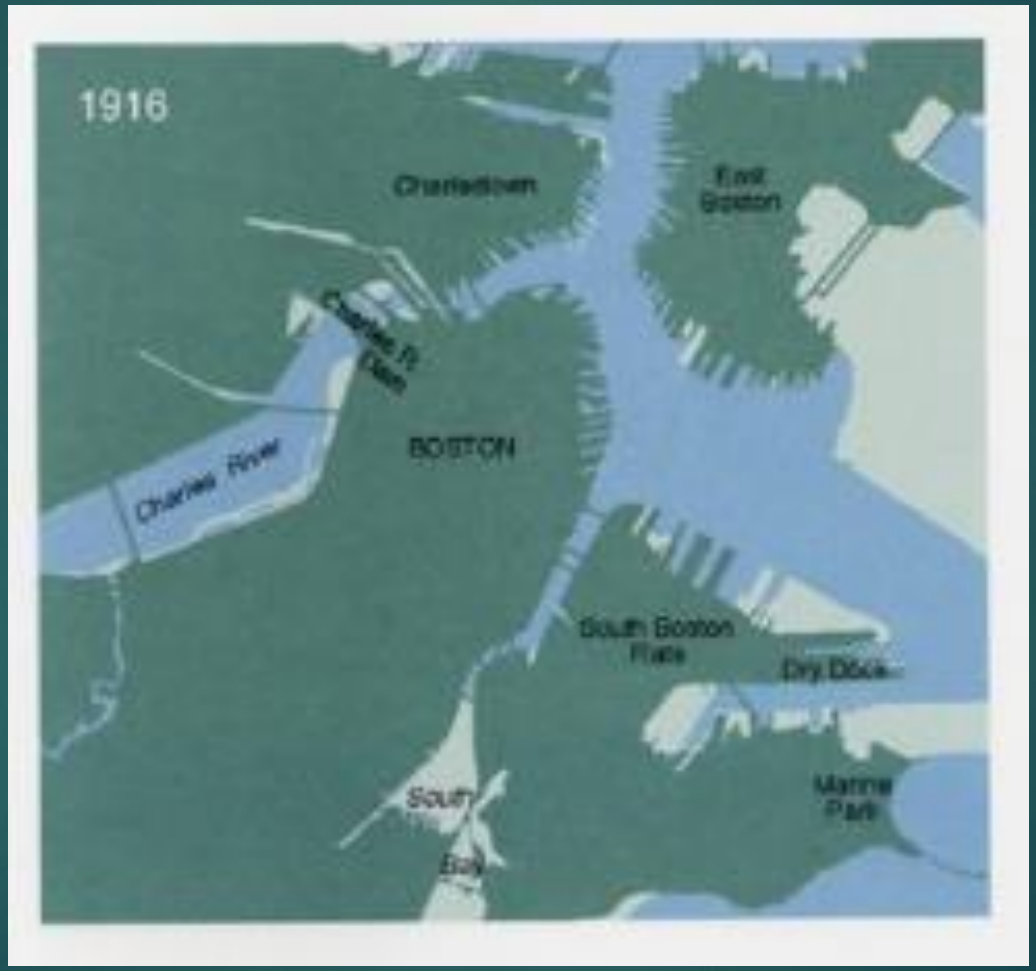
Boston 1852

The diagrams were prepared by The Muriel G. and Norman B. Leventhal Family Foundation;
Cartography by MapWorks, Herb Heidt and Eliza McClemen.
Published in Karl Haglund, *Inventing the Charles River* (Cambridge: MIT Press, 2003), 460-3.

Boston 1880

The diagrams were prepared by The Muriel G. and Norman B. Leventhal Family Foundation;
Cartography by MapWorks, Herb Heidt and Eliza McClemen.
Published in Karl Haglund, *Inventing the Charles River* (Cambridge: MIT Press, 2003), 460-3.

Boston 1916



The diagrams were prepared by The Muriel G. and Norman B. Leventhal Family Foundation;
Cartography by MapWorks, Herb Heidt and Eliza McClemen.
Published in Karl Haglund, *Inventing the Charles River* (Cambridge: MIT Press, 2003), 460-3.

Boston 1934

The diagrams were prepared by The Muriel G. and Norman B. Leventhal Family Foundation;
Cartography by MapWorks, Herb Heidt and Eliza McClemen.
Published in Karl Haglund, *Inventing the Charles River* (Cambridge: MIT Press, 2003), 460-3.

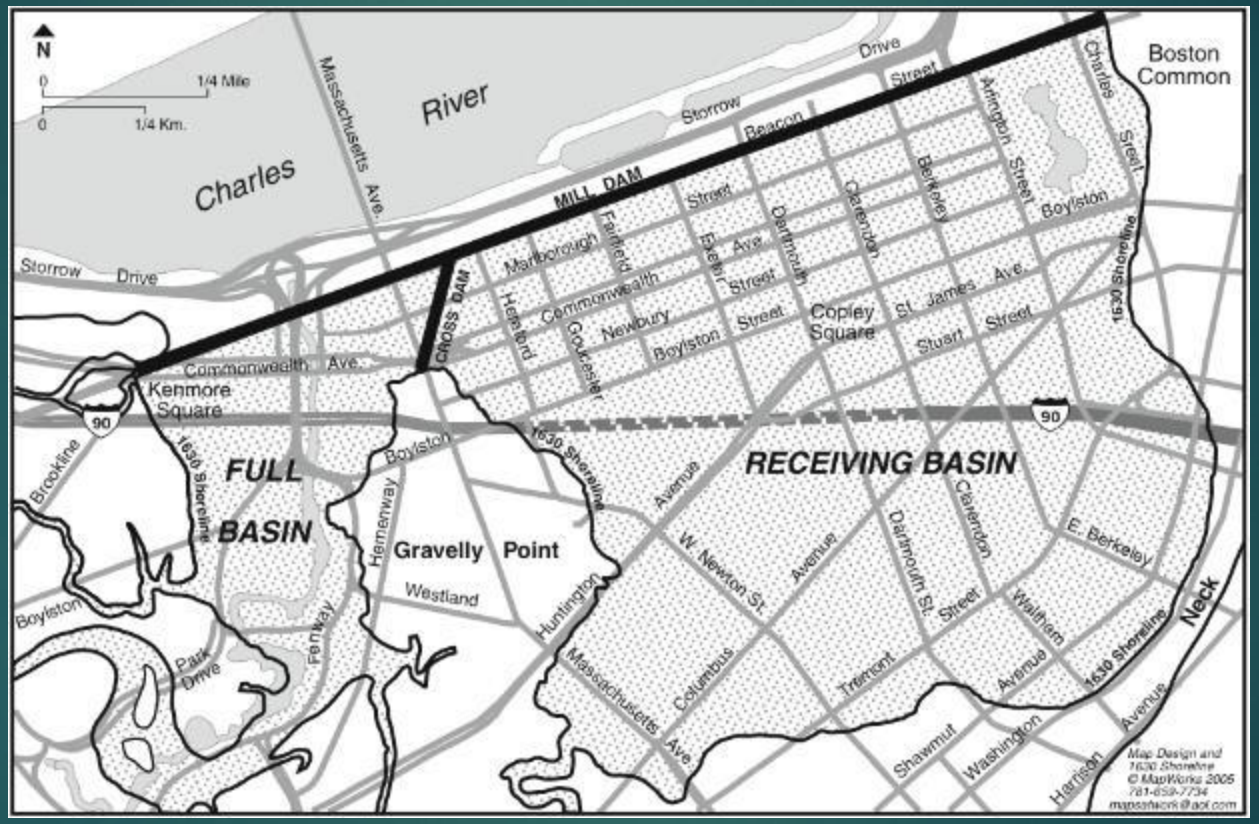
Boston 1950

The diagrams were prepared by The Muriel G. and Norman B. Leventhal Family Foundation;
Cartography by MapWorks, Herb Heidt and Eliza McClemen.
Published in Karl Haglund, *Inventing the Charles River* (Cambridge: MIT Press, 2003), 460-3.

Boston 1995

The diagrams were prepared by The Muriel G. and Norman B. Leventhal Family Foundation;
Cartography by MapWorks, Herb Heidt and Eliza McClemen.
Published in Karl Haglund, *Inventing the Charles River* (Cambridge: MIT Press, 2003), 460-3.

Back Bay Development



Timeline

1630	Boston and Cambridge founded
1636	Harvard established
1662	Great Bridge
1786	Charles River Bridge
1793	West Boston Bridge
1821	Mill Dam and Cross Dam
1881	Cambridge Esplanade
1889	Weld Boat Club
1891	Harvard Bridge
1900	Newell Boathouse
1906	Weld Boathouse
1906	Longfellow Bridge
1909	Union Boat Club
1910	Charles River Dam
1910	Boston Embankment
1912	Riverside Boat Club
1934	Charles River Yacht Club
1935	MIT Sailing Pavilion
1935	Storrow Memorial Embankment
1941	Community Boating
1941	Watertown Yacht Club
1951	Storrow Drive and Esplanade expansion
1978	New Charles River Dam
2003	Zakim Bunker Hill Bridge

Long-standing Concerns

- Shallow areas affect recreational use of the river
  - Several recent incidents resulting in damage to boats
- Sediment is reducing the channel width and depth
  - Faneuil Brook sandbar – removed in January-April 2016
  - Muddy River delta
  - Areas near some docks are getting filled with sediment
    - Newton YC, Watertown YC, Community Rowing, BB&N Rowing
- Lots of anecdotal evidence of problem areas
- Little quantitative data

CRAB and MIT Partnership

- Goal is to obtain high quality quantitative data
  - Good enough to compare with future measurements
  - Disclaimer : Not suitable as a navigational aid
- Depth data collection
  - Using fish-finder sonar units and GPS
- Characterize the influence of daily water releases
  - Use stream gauge data loggers over several months
  - Correlate magnitude and temporal variations to USGS gauge
- Deliverables
  - Web-based charts: Arc-GIS, Google Earth, Google Map
  - Printed wall poster and chart booklet
  - Chart data for navigational instruments

Depth Measurements

- Equipment
  - Lowrance HDS-7 chartplotter/fishfinder
  - Lowrance HST-WSBL 200 kHz broadband sonar transducer
  - Lowrance LSS-2 800 kHz sidescan sonar transducer
  - Lowrance Point-1 GPS
  - Onset HOBO U20L-4 Water Level (13 ft) Data Loggers
- Survey Tracks
  - Where the river was wide, survey lines were spaced between 30 and 65 feet apart and drive at speeds between 3 and 4.8 knots
  - Where the river was narrow, several passes were made up and down the river over multiple weeks
  - Broadband sonar was used in all surveys to measure depth
  - Sidescan sonar was used downriver of the BU Bridge to image the river bottom

Sonar/GPS mounting

Sonar/GPS mounting

Crew

Crew

Chartplotter underway

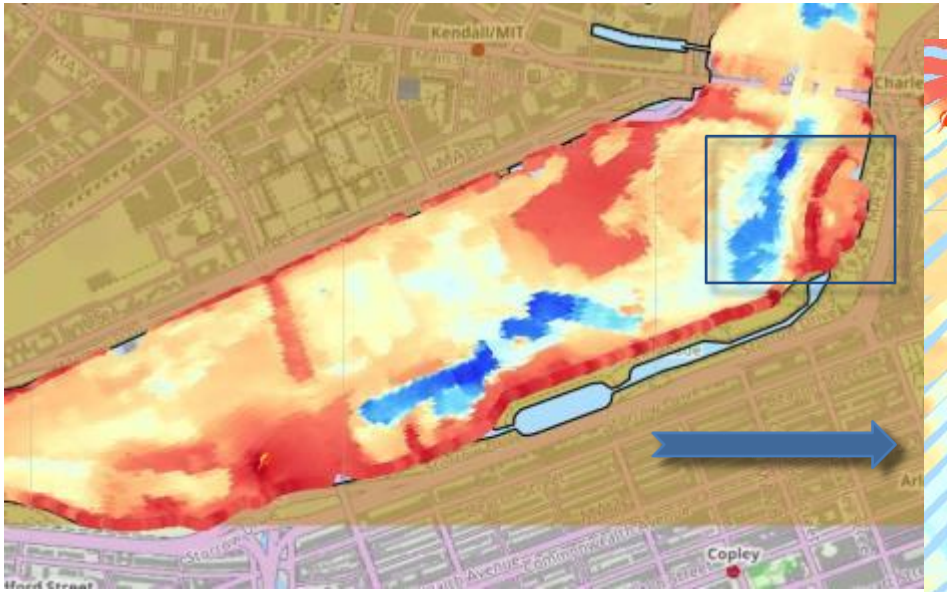
Depth spot checks

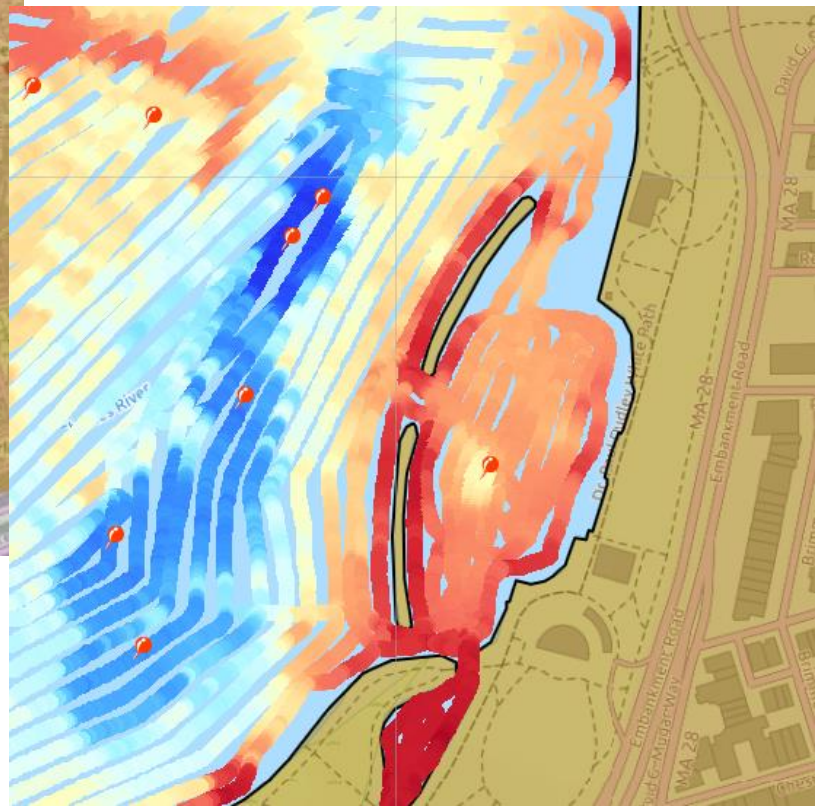
Hobo water level loggers

ReefMaster

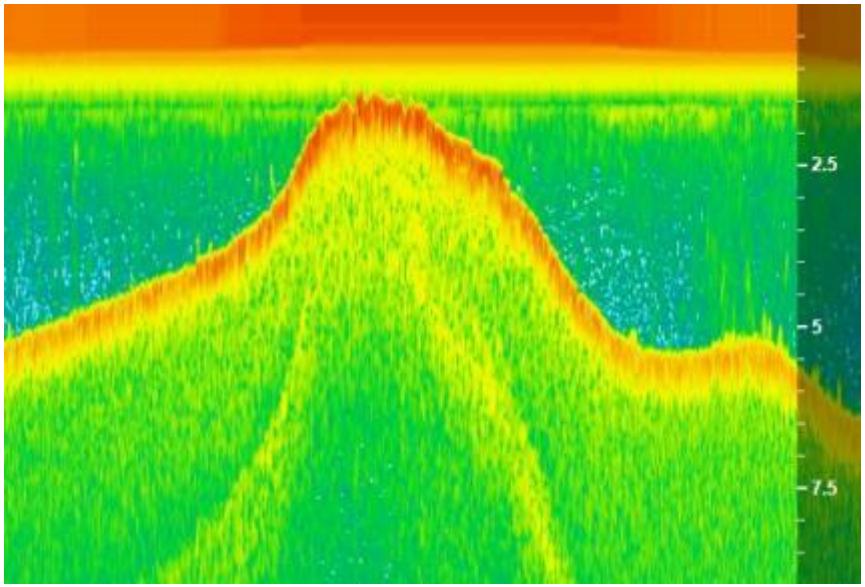

ReefMaster - lower_charles_map
Dashboard
Projects
lower_charles_map
basin
river
total
shallow
Tracks
Name
Time
2016_07_12
2016_07_13
2016_07_19
2016_07_25
2016_07_27
2016_08_01
2016_08_03
2016_08_08
2016_08_09
2016_08_30
2016_09_22
2016_09_26
2016_10_05
magazine beach
muddy_delta
newton
Waypoints
NewWaypointSet
Soundings
Sidescan Mosai
charles_sidescan
Images
Data Sets
Global View
basin
Edit
Name
basin
Project Properties
Map Settings
Colour mode
Raster
Vector
Grid smoothing
15
Max Interpolation
25m
Depth display range
Range
0
ft to
36
ft
Contour grid resolution
Auto
Manual
1
Contour intervals:
Major
3 ft
Minor
1 ft
Generate minor contour levels
Range
0
ft to
36
ft
Show minor contour levels
Map Boundaries
Overlays
Bottom Classification
Tracks
CAMBRIDGE
Harvard
Lechmere
Central
Kendall/MIT
Kenmore
Copley
Back Bay
Prudential
Saint Mary's Street
Hawes Street
Hynes Convention Center
Tufts Medical Ce
Arlington
Boylston

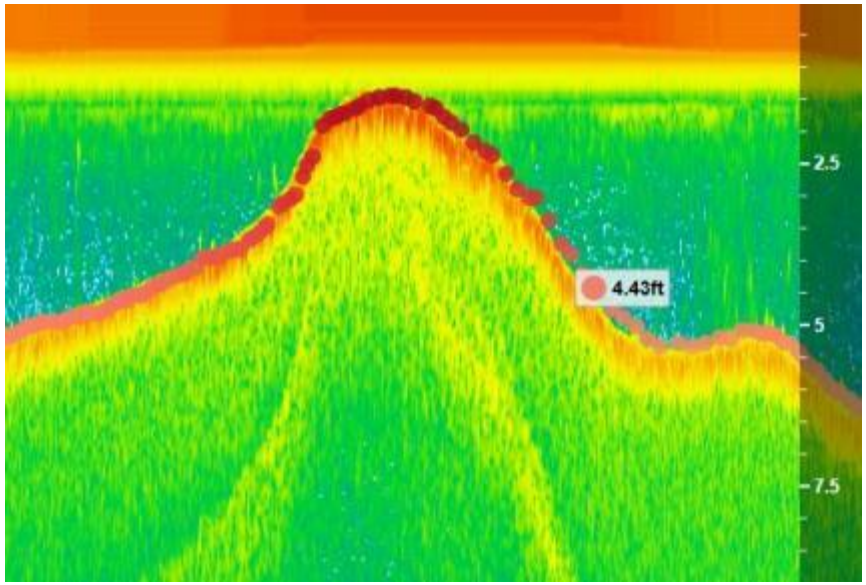
ReefMaster: Tracklines



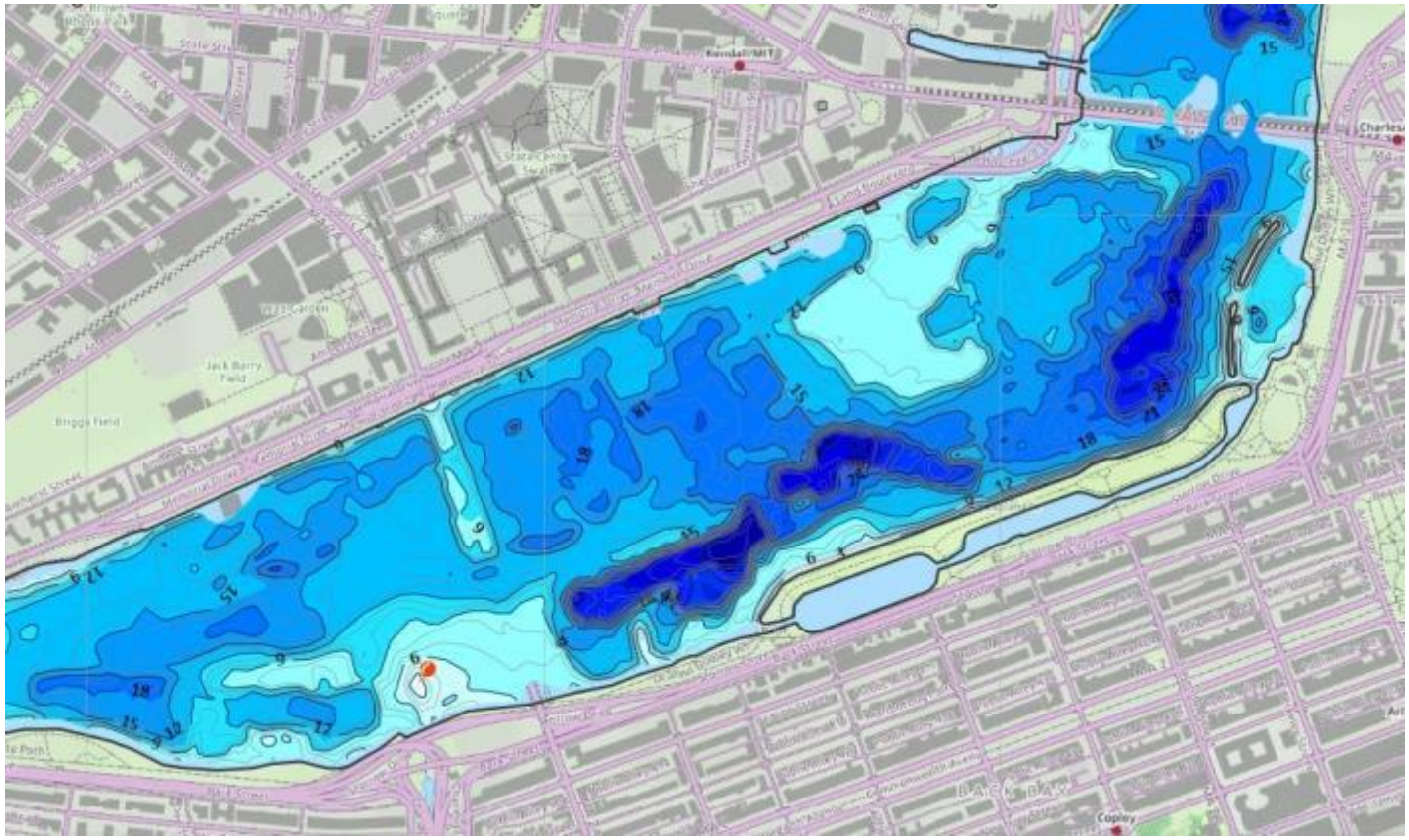


ReefMaster: Sonar

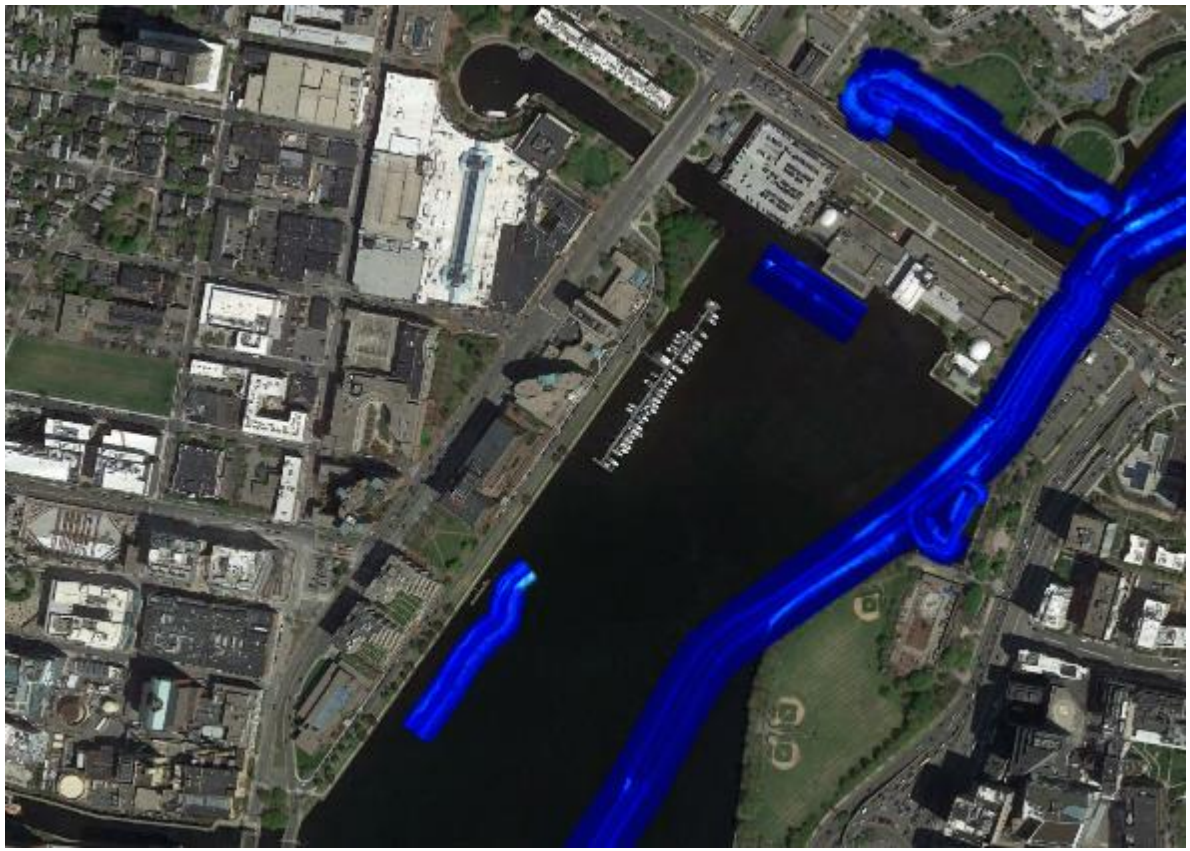


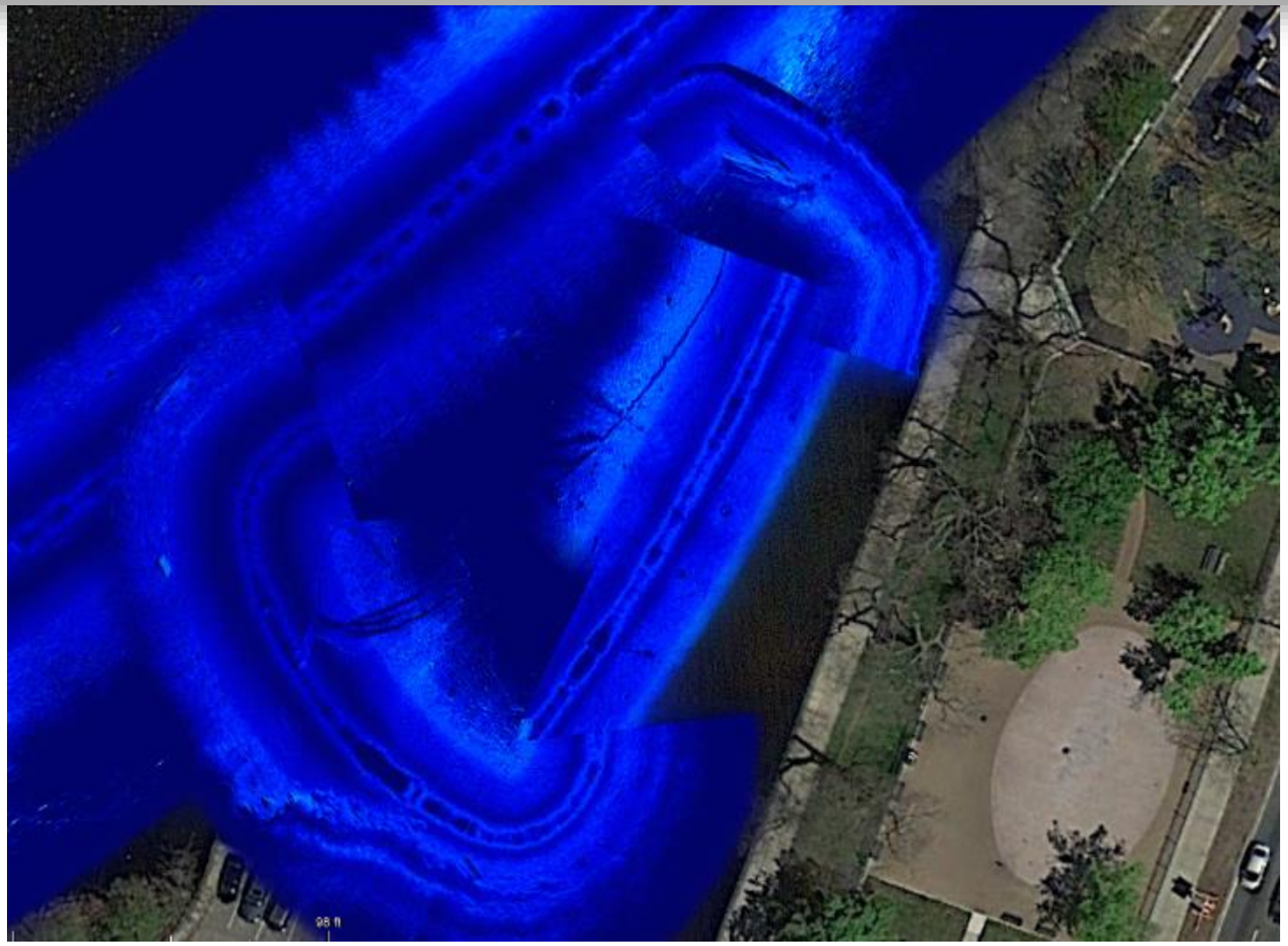


ReefMaster: Raw chart

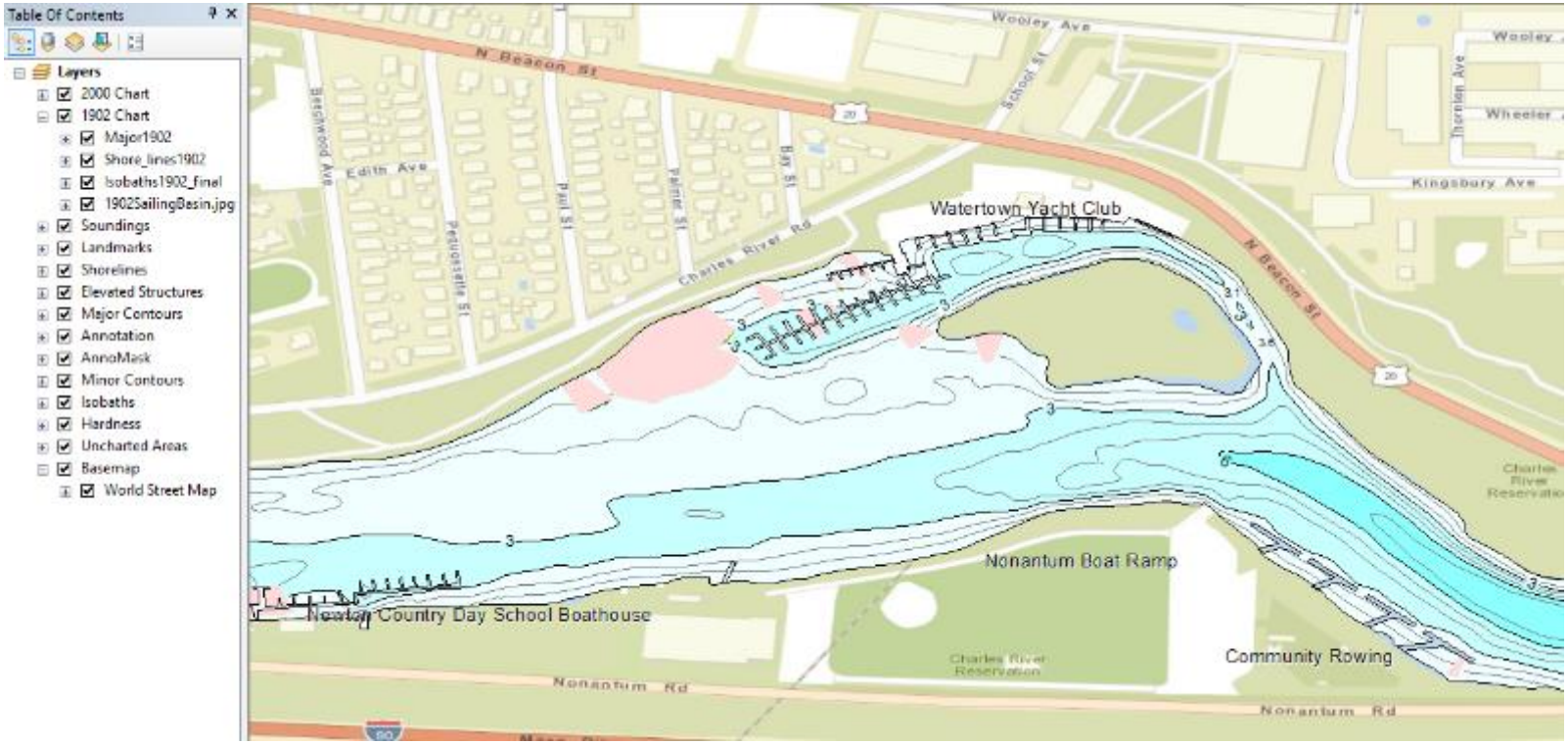


ReefMaster: Side scan mosaic

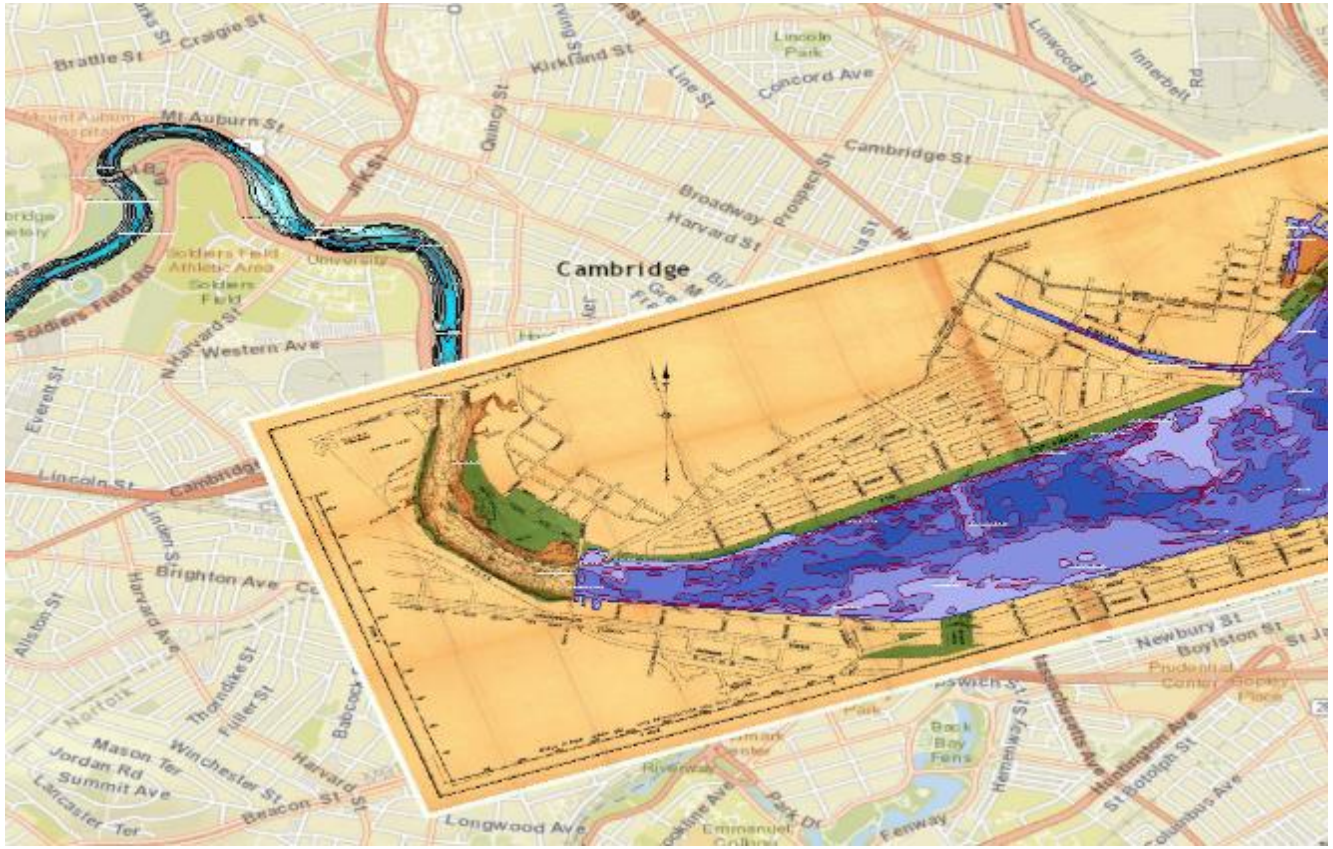


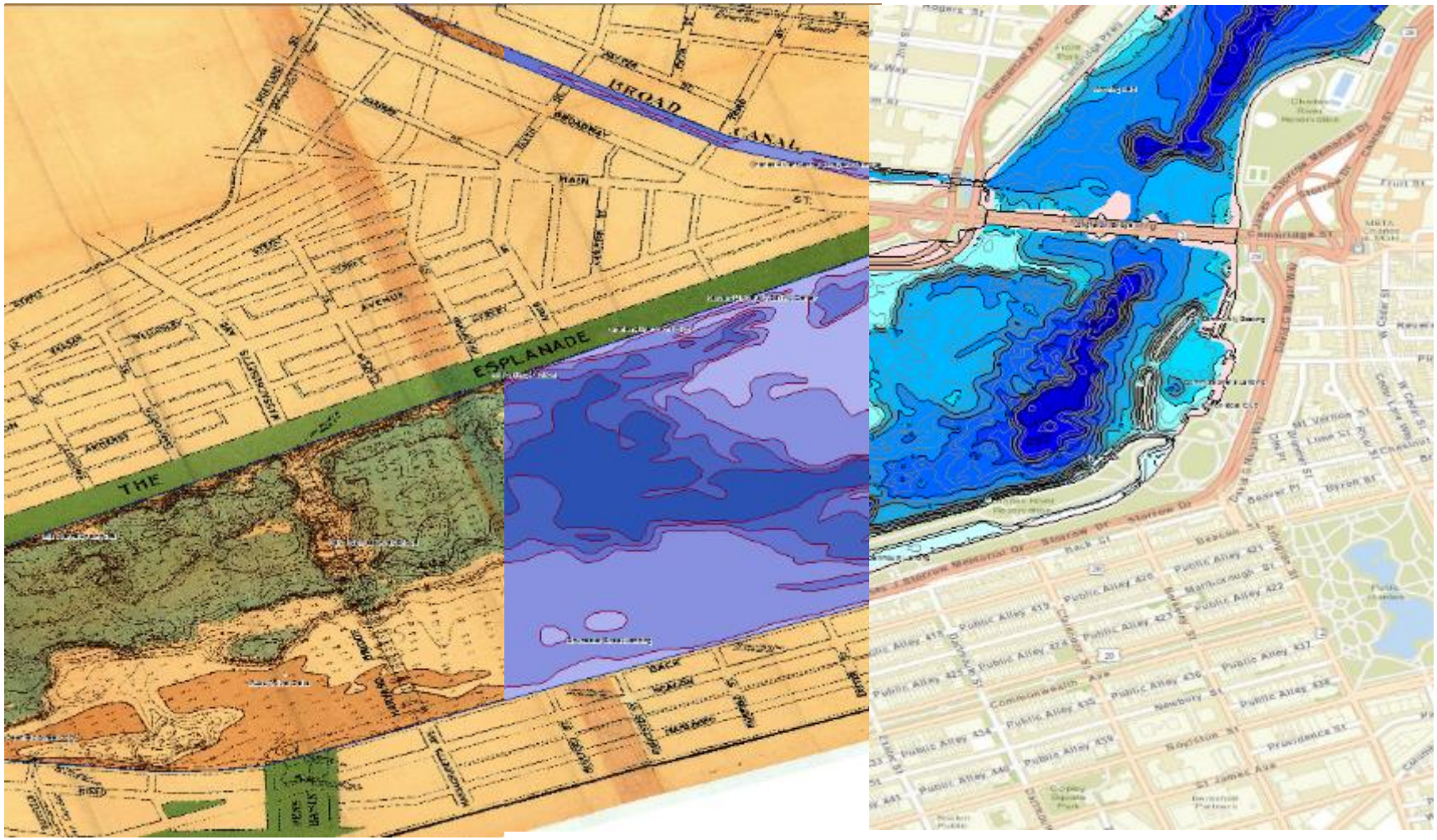

98 ft

ArcMAP component layers



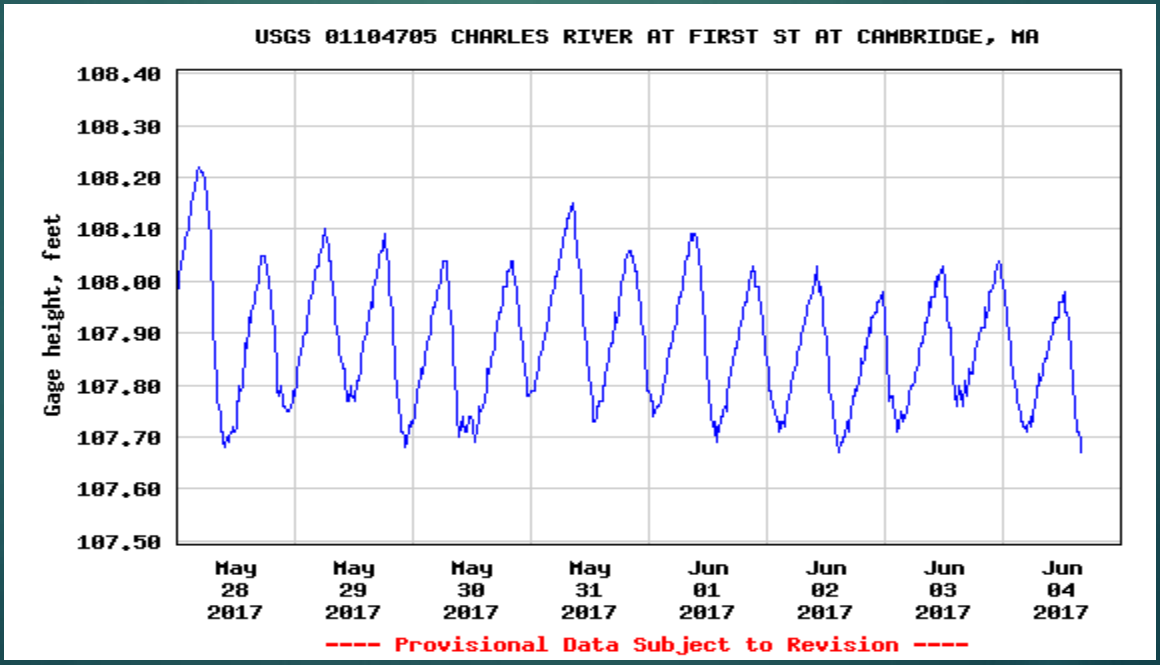
Old and new


Cambridge
Mt Auburn St
Cambridge St
Broadway
Harvard St
Western Ave
Lincoln St
Brighton Ave
Longwood Ave
Kirkland St
Concord Ave
Newbury St
Boylston St
Beacon St
Winchester St
Summit Ave
Jordan Rd
Mason Ter
Fenway

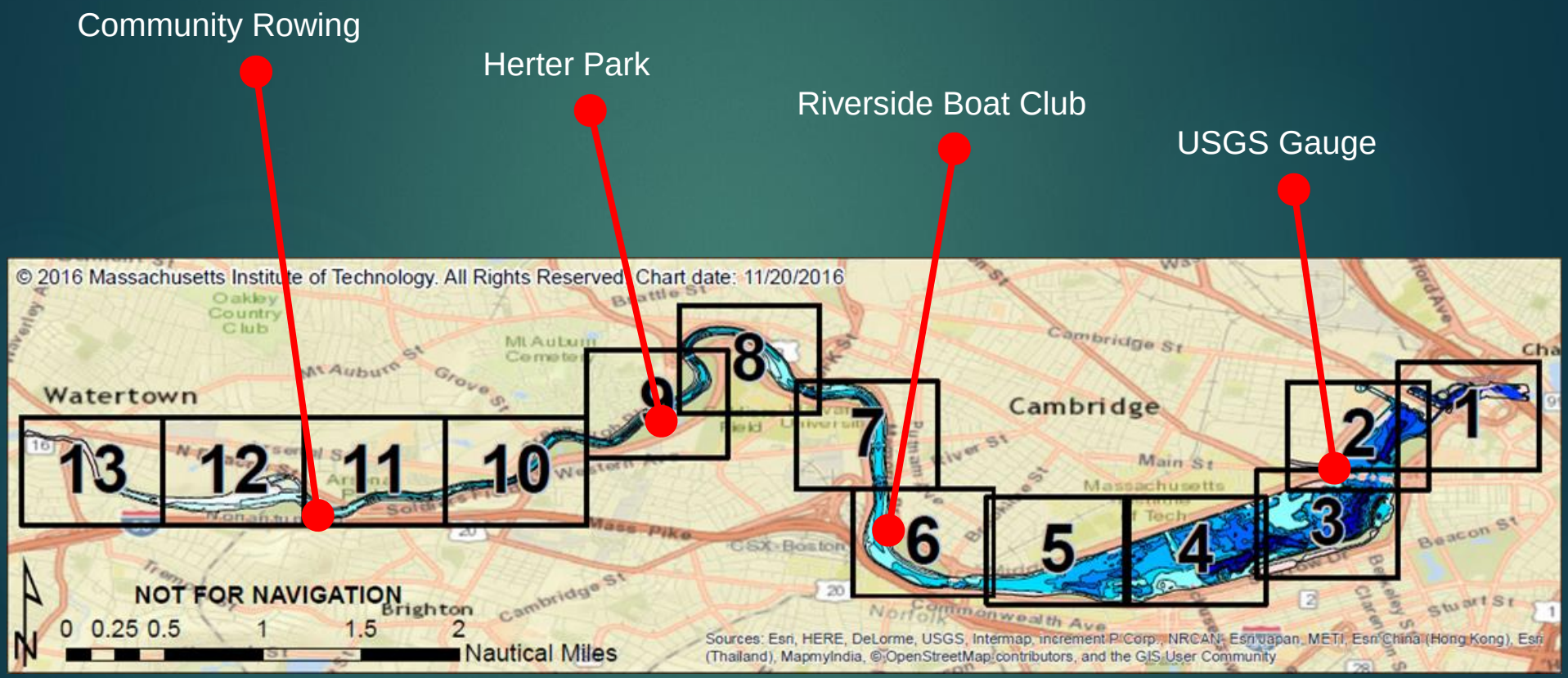

BROAD
CANAL
ESPLANADE
THE

Data Measurements

- Depth using sonar fish-finders
- Position and time using GPS
- Height of water sheet using stream gauge data loggers
  - Apply a correction to sonar depth data
  - Zero depth = 107.5 ft @ USGS First St gauge

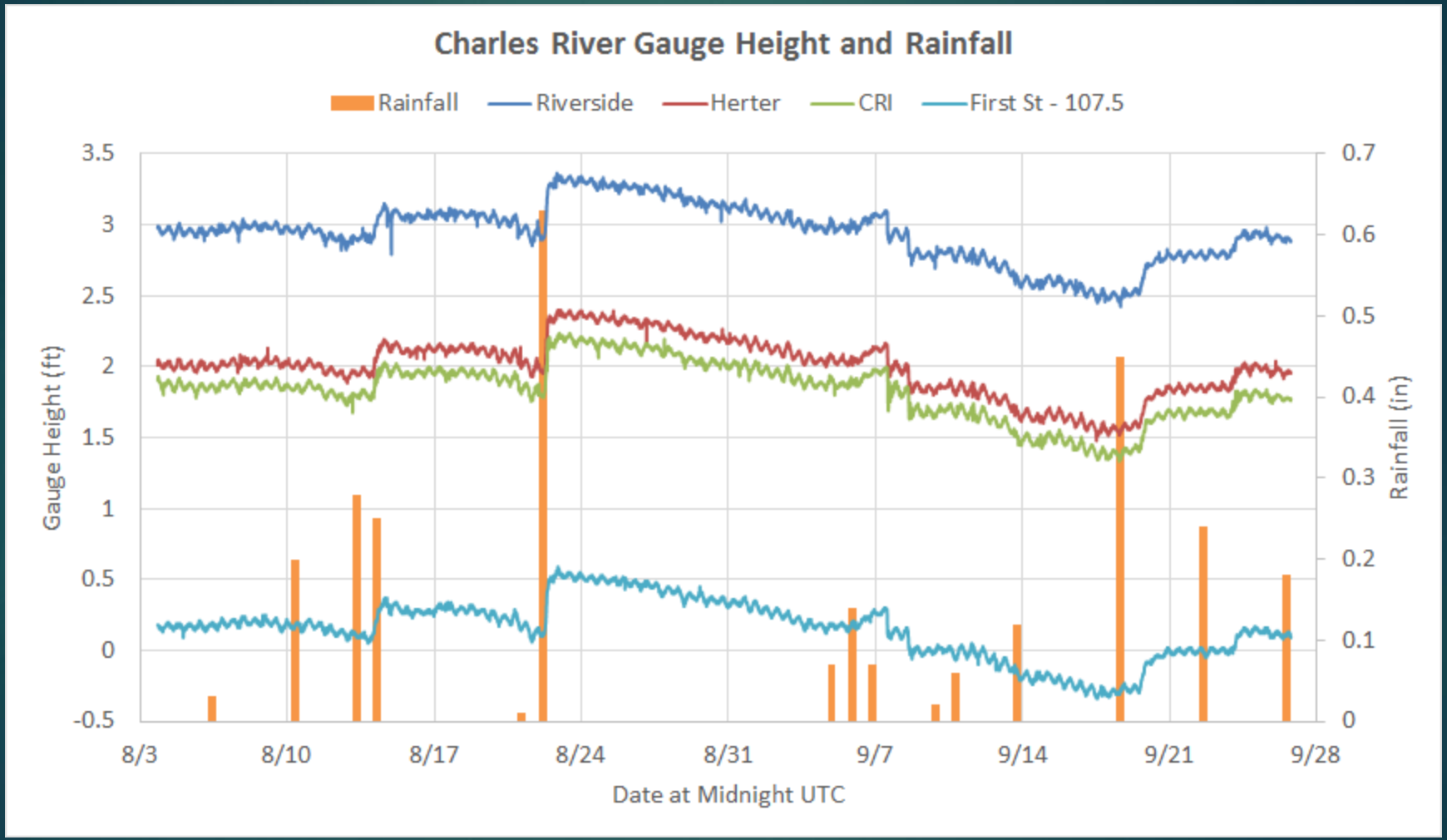


Stream Gauge Data Loggers



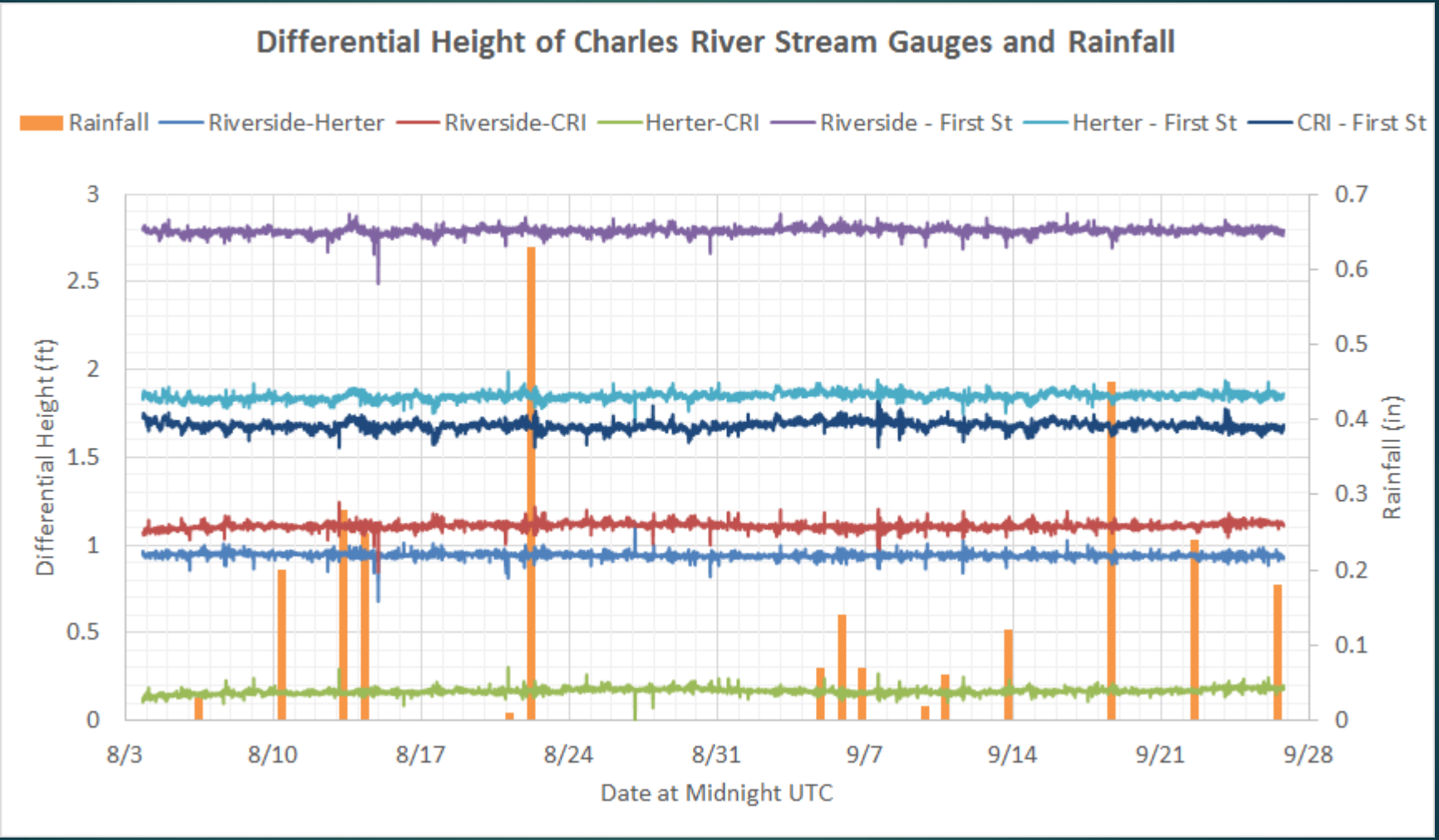
Gauge Heights and Rainfall

Water level : 5177 data points @ 15 minute intervals for each gauge

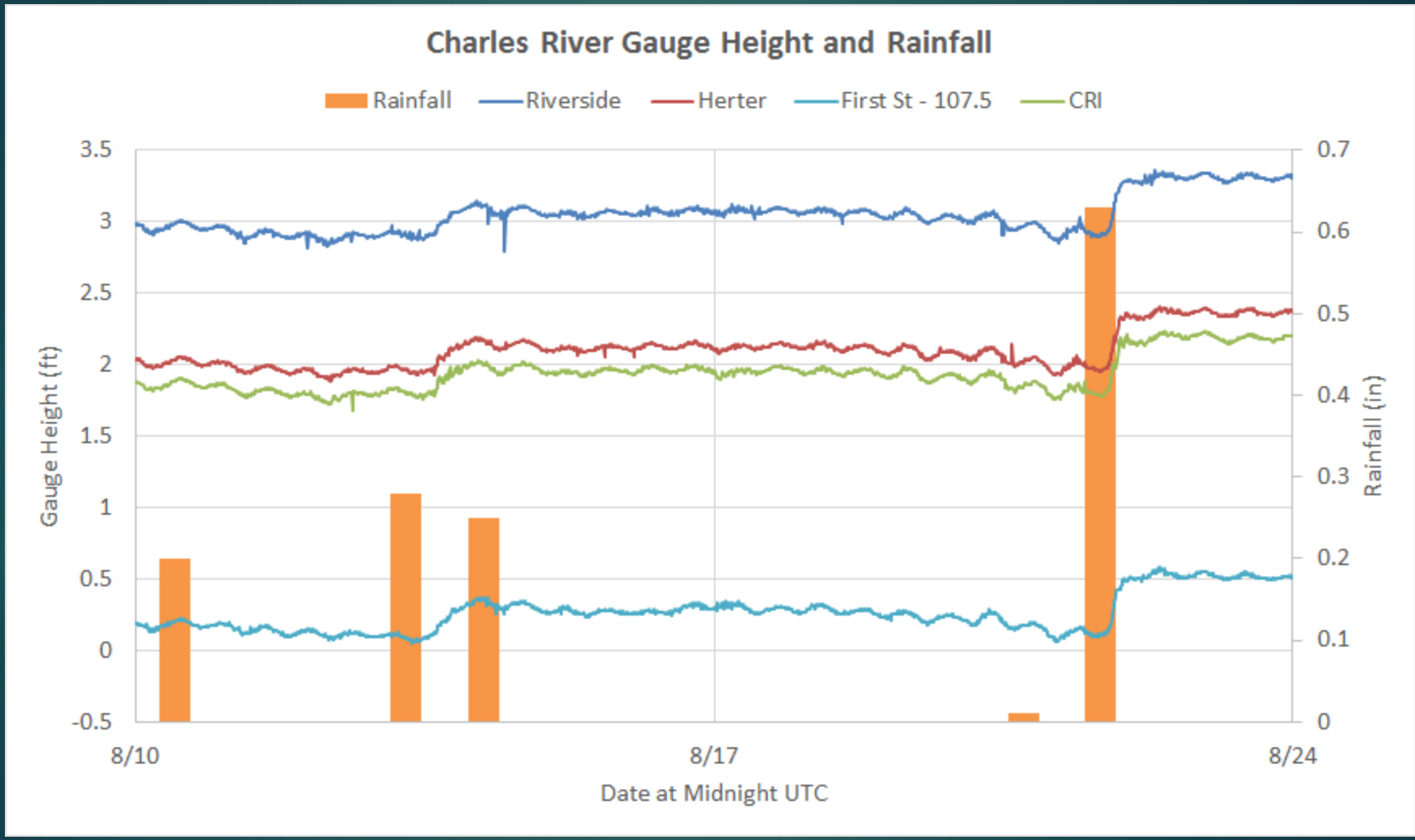


Rainfall : data from BWSC gauge in Allston

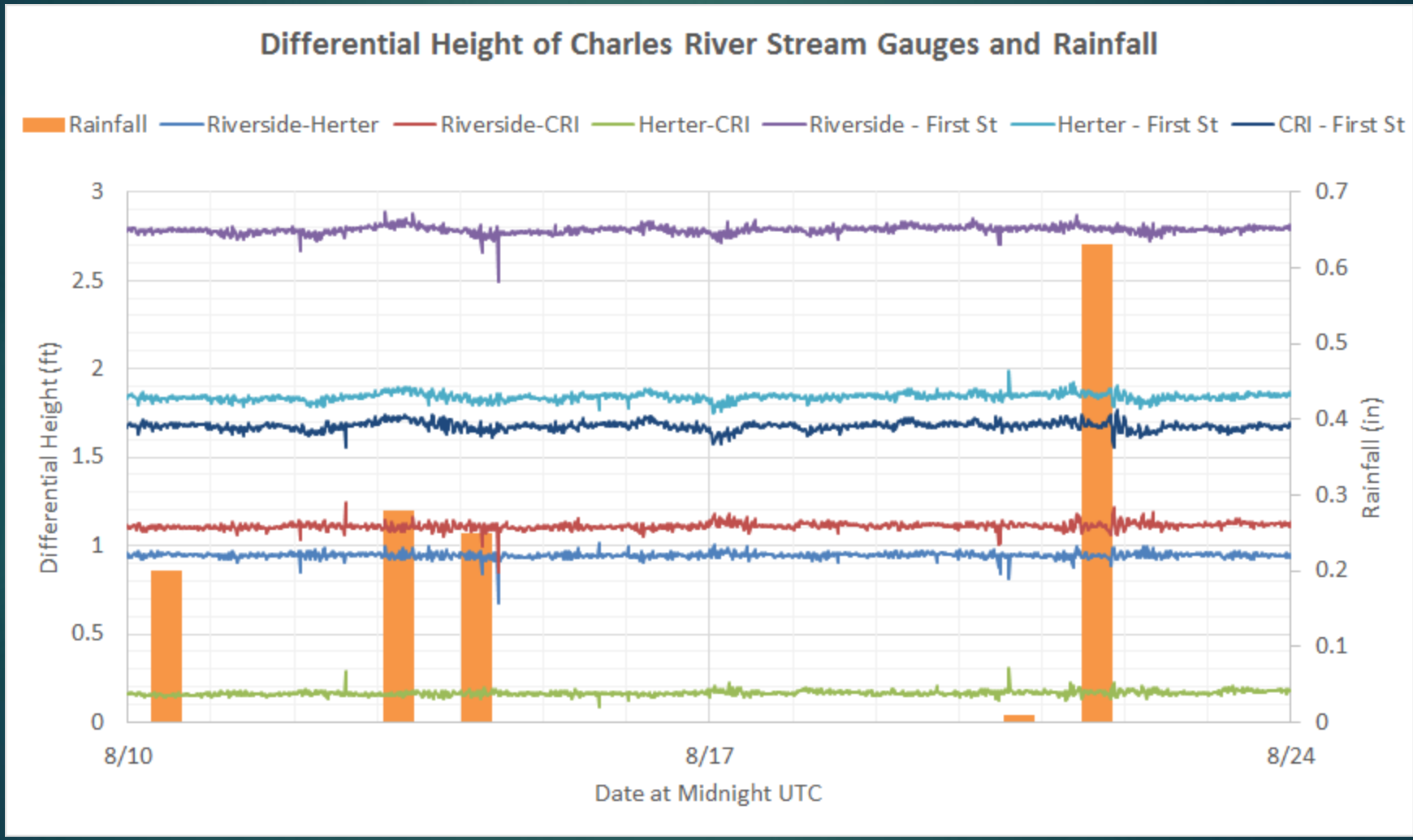
Differential Gauge Heights



Gauge Heights and Rainfall



Differential Gauge Heights



Uncertainty in Data

- Vertical Uncertainty
  - Transducer : 2% on a hard bottom, 5% on soft bottom
  - Water Sheet Height : < 0.05 foot
  - Total Depth Uncertainty : ± 5%
  - Depth is normalized to the height of the water sheet
  - Zero depth = 107.5 ft @ USGS First St gauge
- Horizontal Uncertainty
  - GPS Accuracy : ±3 meters
  - Point-to-point precision is much lower
  - GPS signal is degraded under bridge, especially the Zakim Bridge
- Difference between track path and width of track
  - Data measured at 10 Hz, every 0.85 ft at 5 knots along the track path
  - Depth perpendicular to the track (width) is extrapolated by the software
    - Non-overlapping tracks
    - Caution with over-extrapolating the width

Development of Digital Charts

- ReefMaster PRO mapping software
  - Processing of raw sonar data
  - 2-dimensional contours of depth and relative hardness
  - ESRI shapefiles for the ArcGIS ArcMap software
- ArcGIS ArcMap software
  - Generation of ArcGIS Online chart
  - Additional geospatial data
    - Contour annotation
    - Landmarks
    - Elevated structures
    - Detailed shorelines
  - Data exported for Google Earth, Google Map, chart booklet, wall chart

Digital Charts

Several formats have been developed by MIT and CRAB.
All are available to the public via CRAB website.

- Web-based
  - Arc-GIS, hosted by MIT
  - Google Earth
  - Google Map
- Printed
  - Wall Poster
  - Chart Booklet
- Data for navigational instruments
  - kmz file that can be converted by user

Exploration of on-line chart and mosaic

- Arc_GIS Online chart
  http://seagrant.mit.edu/charleschart/

Historical Perspective

- Detailed depth charts of Charles River Basin
  - Watertown dam to Boston Harbor
  - 1902 Committee on the Charles River Dam
  - 2000 US Geological Survey

- More recent surveys have been done in selected areas
  - Camp, Dresser & McKee, 1976, BU Bridge to Science Park
  - MDC / Cortell Associates, 1997, 20 transits at various locations between Newton YC and Science Park
  - Mirant-Kendall Station Outfall, 2010 ?
  - MIT Pierce Boathouse, 2013
  - Bridge Rehabilitation – Longfellow, River St, Western Ave, Anderson, 2011
  - North Point Park area by Charles River Conservancy, 2016

1902 Survey

- Done by hand with weighted line
- Elevation contours every foot of depth
- Prior to the first Charles River Dam being built

Boston Seawall - 1890

Cambridge Seawall - 1900

1902 Chart

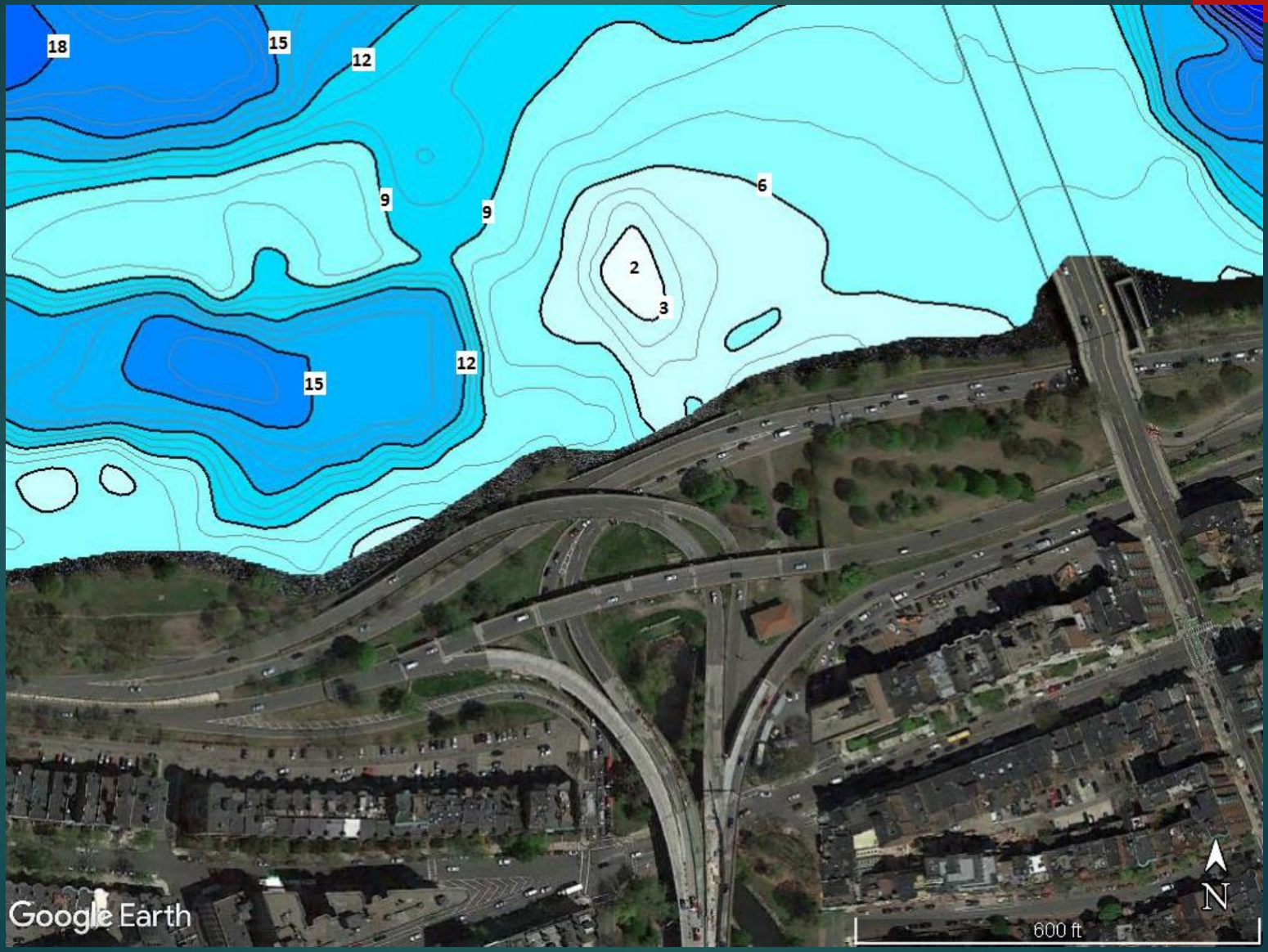

CHARLES RIVER BASIN
CONTOUR MAP OF LOWER BASIN
COMMITTEE ON CHARLES RIVER DAM

2000 USGS Survey

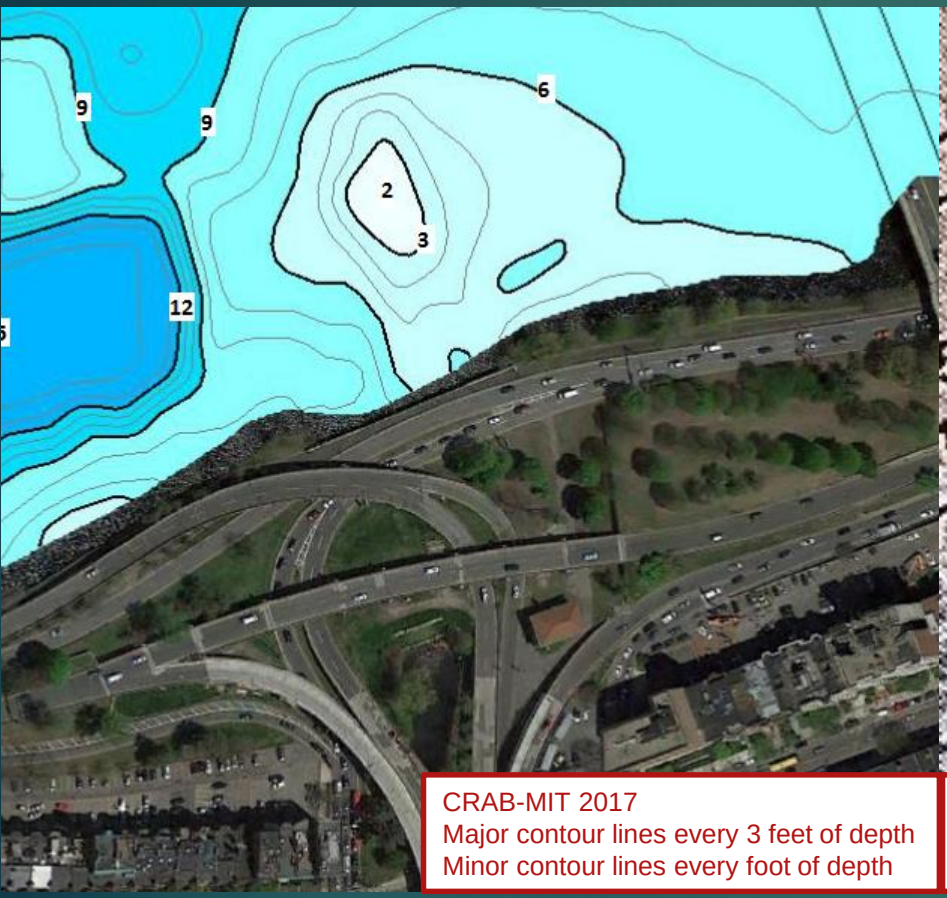
- Hydrographic survey done as part of larger studies
  - Spatial distribution, temporal variability, and chemistry of the salt wedge in the lower Charles River, USGS Report 00-4124
  - Distribution and potential for adverse biological effects of inorganic elements and organic compounds in bottom sediment, lower Charles River, USGS Report 00-4180
  - Streamflow, water quality, and contaminant loads in the lower Charles River watershed, USGS Report 02-4137
  - Potential Effects of Structural Controls and Street Sweeping on Stormwater Loads to the Lower Charles River, USGS Report 02-4220
- Charts were published with limited depth contours
  - 8000 data points - 75 times less than the 2016-17 survey
  - Contours either every 2 meters or every 5 feet of depth
  - Limited spatial resolution and detail about underwater features

2000 USGS Chart

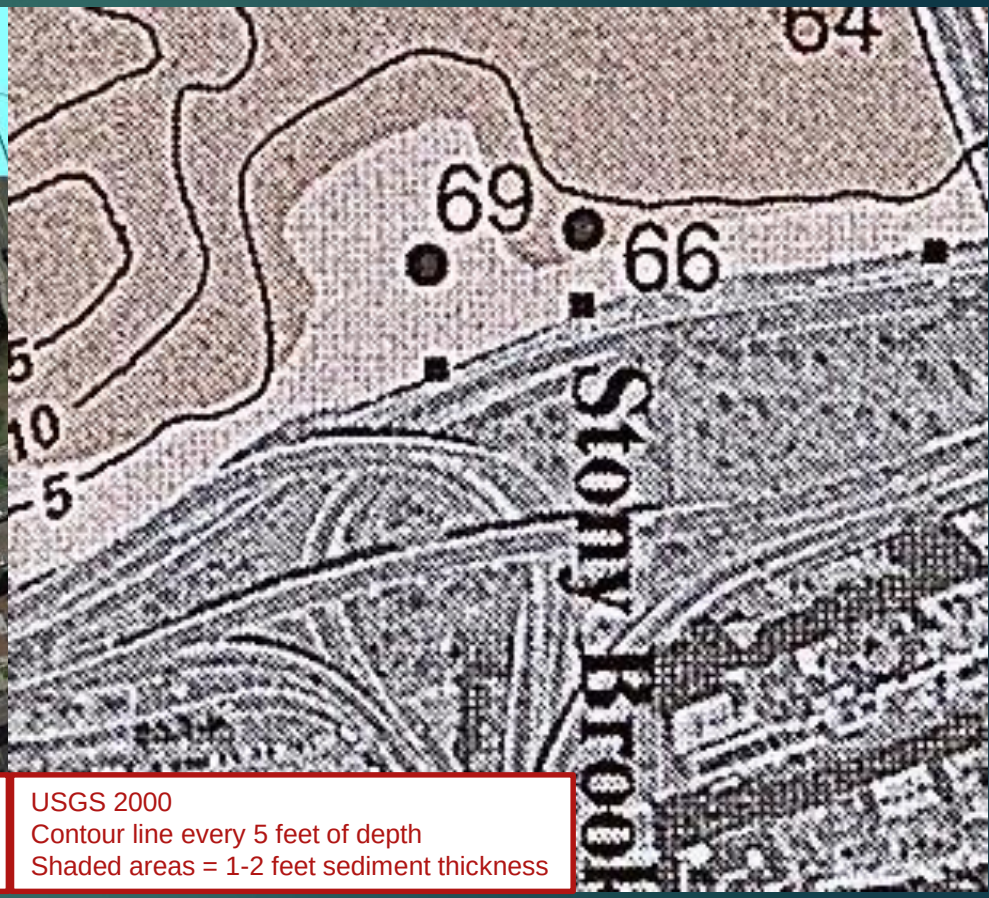
Muddy River / Stony Brook Delta



Muddy River / Stony Brook Delta

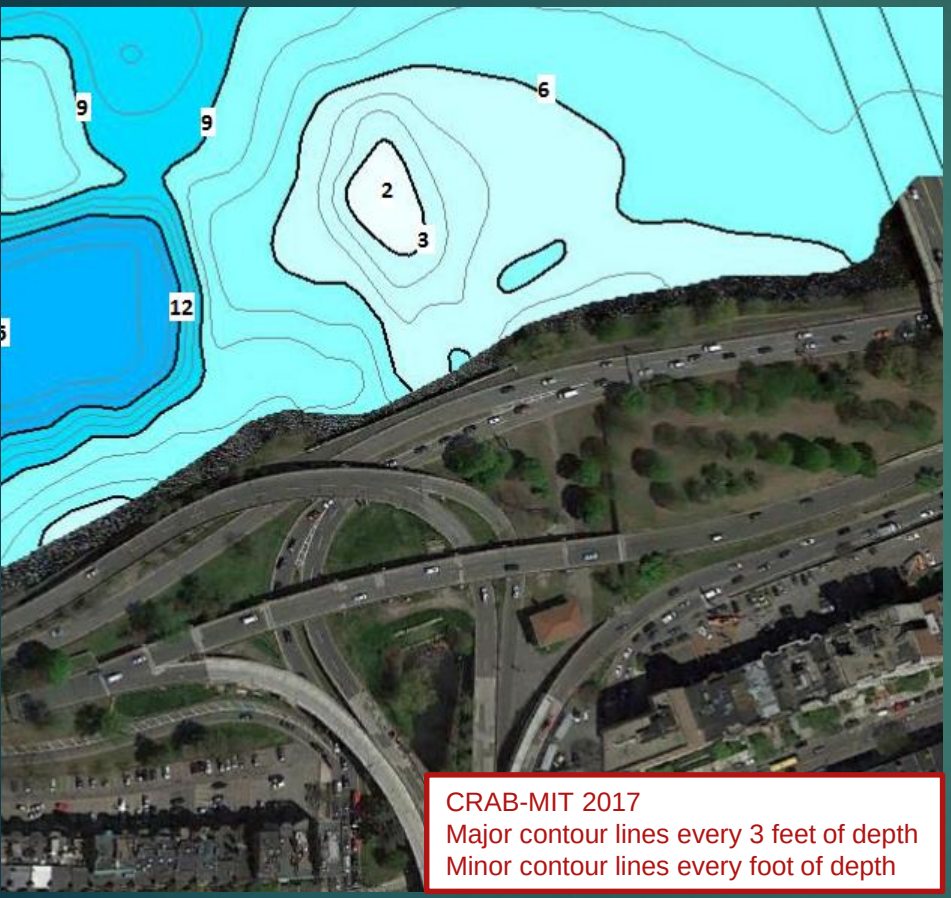


CRAB-MIT 2017
Major contour lines every 3 feet of depth
Minor contour lines every foot of depth

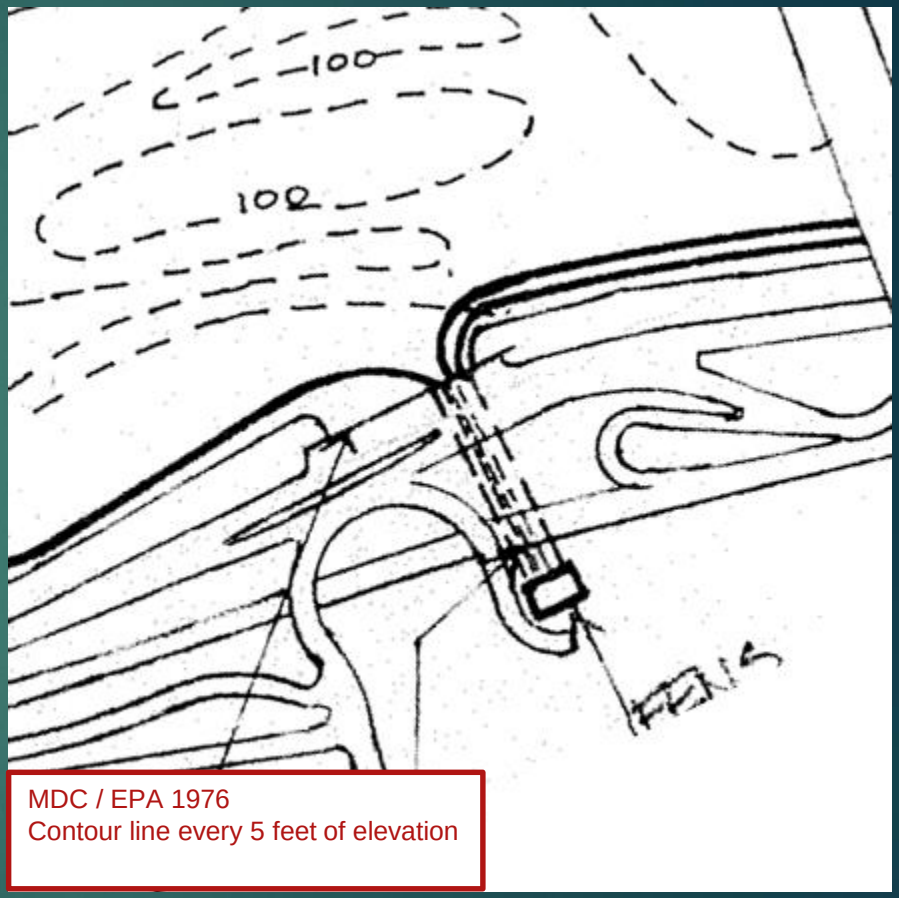


USGS 2000
Contour line every 5 feet of depth
Shaded areas = 1-2 feet sediment thickness

Muddy River / Stony Brook Delta



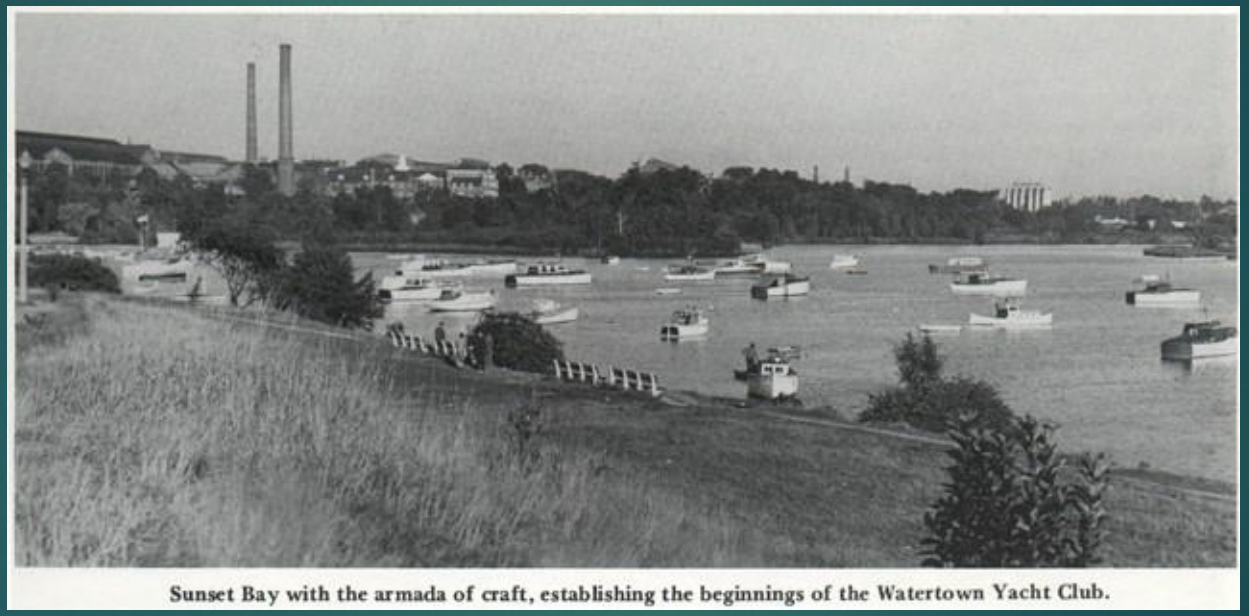
CRAB-MIT 2017
Major contour lines every 3 feet of depth
Minor contour lines every foot of depth



MDC / EPA 1976
Contour line every 5 feet of elevation

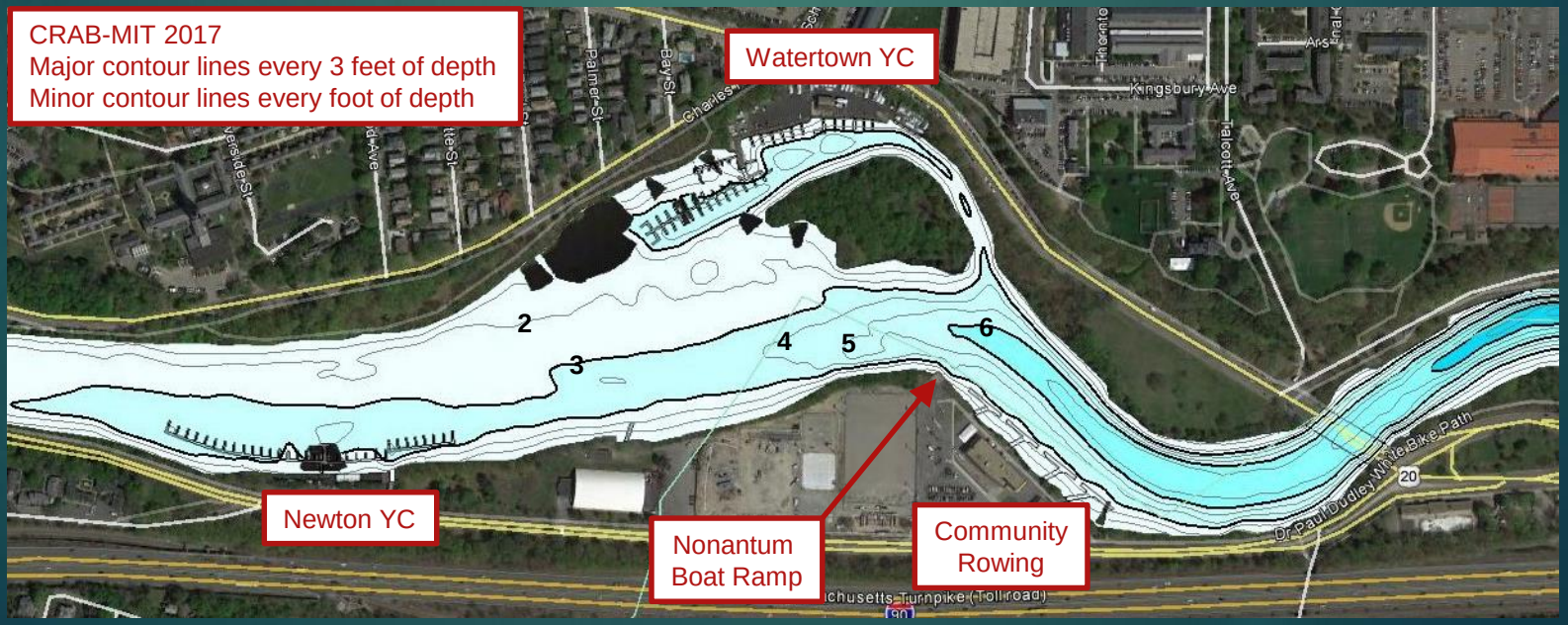
Sunset Bay, Watertown

- Lots of space for open water mooring field in 1940s
- Anecdotal recollections suggest that there was 6-10 feet of water depth

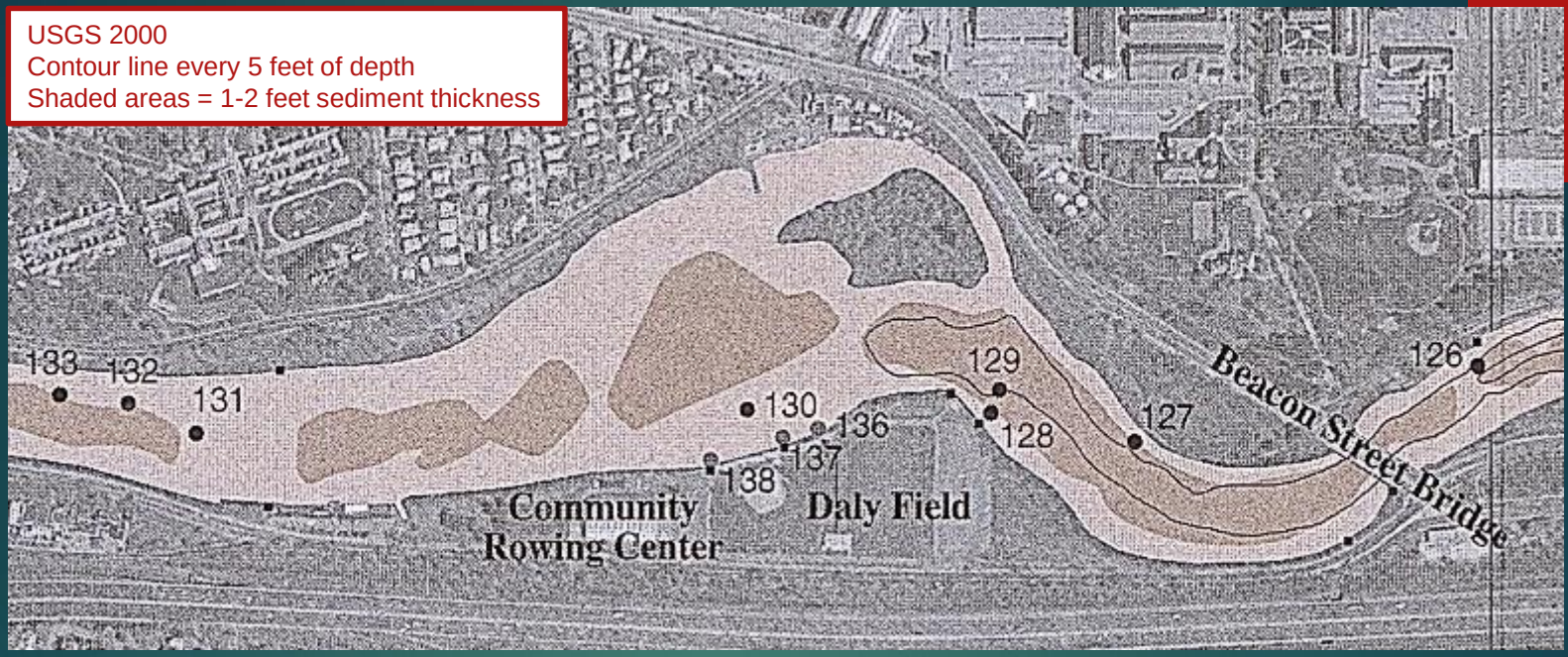


Sunset Bay with the armada of craft, establishing the beginnings of the Watertown Yacht Club.

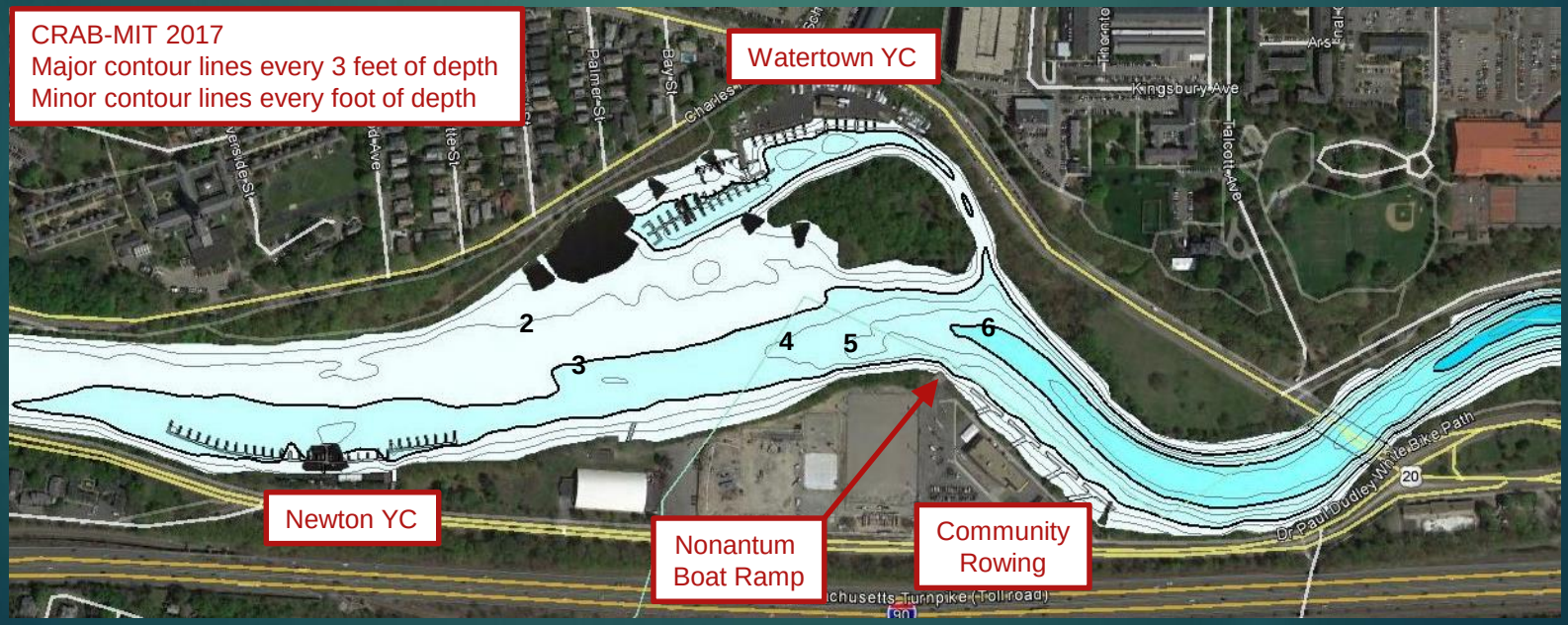

Committee on the Charles River Dam, 1902
Major contour lines every 5 feet of depth
Minor contour lines every foot of depth
U. S. GOVERNMENT
WATERTOWN
ARSENAL
BOSTON & ALBANY R. R.
N
4500
5000
5280
Faneuil Station


CRAB-MIT 2017
Major contour lines every 3 feet of depth
Minor contour lines every foot of depth
Watertown YC
Newton YC
Nonantum Boat Ramp
Community Rowing
2
3
4
5
6
Kingsbury Ave
Talcott Ave
Palmer St
Bay St
Charles
Dr. Paul Dudley White Bike Path
20

USGS 2000
Contour line every 5 feet of depth
Shaded areas = 1-2 feet sediment thickness



CRAB-MIT 2017
Major contour lines every 3 feet of depth
Minor contour lines every foot of depth



Sedimentation Rate

- Madonna Yoder Senior Thesis, 2017
- Lower basin area between Science Park and BU Bridge
- 5-10 mm per year
- 1.8 – 3.5 feet since 1908
- Undoubtedly, sedimentation rate is different in other areas

What's Next ?

- Comparison to historical surveys underway
- More detailed measurements near bridges
- Develop better understanding of bottom hardness data
- Sedimentation rate in other areas of the river
- Can we determine sediment thickness ?
- Monitor changes in future

- www.CharlesRiverAllianceofBoaters.org/chart.html
- seagrant.mit.edu/charleschart

Funding

Sea Grant
Massachusetts Institute of Technology

BOSTON DUCK TOURS

HEAD OF THE CHARLES
REGATTA

MIT SAILING

UNION BOAT CLUB

RIVERSIDE 1869

NEWTON YACHT CLUB

CRI
Community Rowing Inc.

NORTHEASTERN UNIVERSITY
LVX VERITAS VIRTVS
BOSTON, MASSACHUSETTS

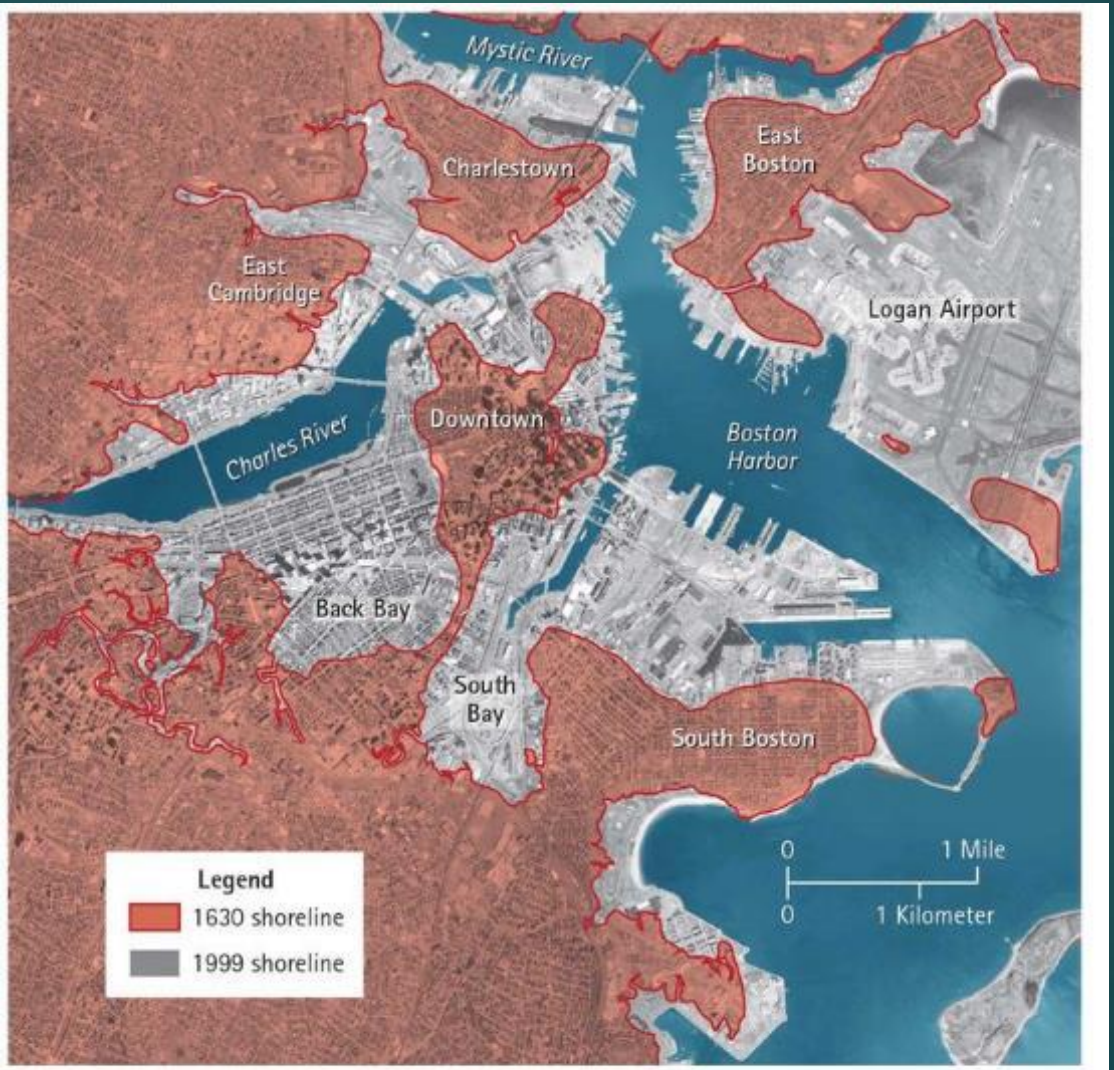
CHARLES RIVER conservancy

Individual Donors

COMMUNITY BOATING INC.
BOSTON

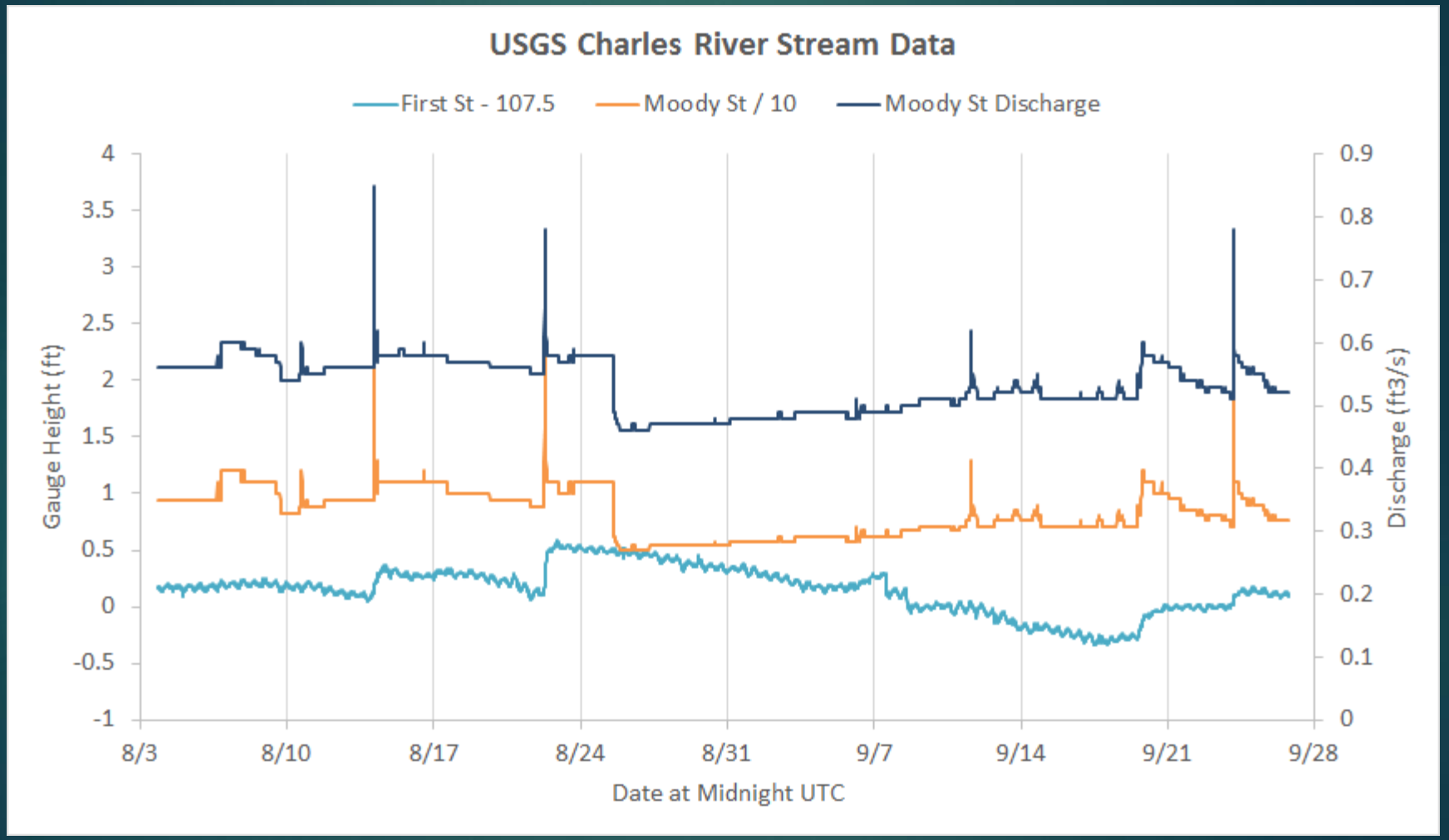
Boston - Today

Boston - Today



Source: Adapted from Weiskel, Peter K., Lora K. Barlow, and Tomas W. Smieszek. *Water Resources and the Urban Environment, Lower Charles River Watershed, Massachusetts, 1630–2005.* U.S. Department of the Interior, United States Geological Survey, in cooperation with the U.S. Environmental Protection Agency and the Massachusetts Department of Environmental Protection (2005), Circular 1280, Figure 9, p16.

USGS Gauge Height and Discharge



Gauge Height Noise Histogram