NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

January 20, 2011

Time Alignment Study

Specialist's Study Report
By Christopher Babcock

1. EVENT

Location:	Philadelphia, Pennsylvania
Date:	July 7, 2010, 14:37 Eastern Daylight Time (EDT)
NTSB Number:	DCA10MM025

2. GROUP

A group was not convened.

3. SUMMARY

On Wednesday July 7, 2010, the empty 250-foot sludge barge *The Resource*, towed alongside the 78.9-foot towing vessel *M/V Caribbean Sea*, allided with the anchored 33-foot amphibious small passenger vessel *DUKW 34* in the Delaware River near Philadelphia, PA. The *DUKW 34*, operated by Ride the Ducks, carried 35 passengers and 2 crewmembers. Five crewmembers were on board the *Caribbean Sea*. As a result of the allision the *DUKW* 34 sank in approximately 55 feet of water. Two passengers aboard the *DUKW 34* were fatally injured and 26 passengers suffered minor injuries. No one aboard the *Caribbean* Sea was injured.

This time alignment study examines each time base for all sources of electronic data and attempts to place each source on the same timeline.

4. DETAILS OF INVESTIGATION

Investigators obtained several sources of electronic data during the course of the investigation including Automatic Information System (AIS) data and video and still imagery. Figure 1 identifies the locations of each image data source.

Figure 1. Locations of electronic data sources.

4.1. Electronic Data Description

4.1.1. *Caribbean Sea* AIS data

The *Caribbean Sea* was equipped with a Class A Automatic Information System (AIS)[1] transponder. This unit transmitted electronic position reports that included geographic position, true heading, speed over ground, and course over ground. These position reports were captured and recorded by the Coast Guard National AIS (NAIS) program.

Transmitted AIS position reports do not contain a full timestamp. The only timing information transmitted with the message is seconds after the minute based on the GPS time of the transmission. The local NAIS antenna system applied a GPS timestamp to the position report before sending the timestamped message to central NAIS data servers. As this timestamp was applied at the receiving station, an irregular offset was found present in the data (Figure 2). The AIS timestamp was rebuilt using the hours and minutes from the receiving station timestamp, and the seconds after the minute field from the transmitted message, producing a more consistent time history. As this data provides a reliable time synchronization to UTC and, ultimately, local EDT, it was selected as the timebase to which all other timestamped data was synchronized.

The AIS unit transmitted position reports at irregular intervals, based on speed. The recorded AIS data was interpolated to provide position each second along the vessel's track. Figure 4 depicts the track of the *Caribbean Sea* with white icons indicating actual position reporting points and blue icons indicating interpolated points. A tabular listing of AIS data for the *Caribbean Sea* can be found as an attachment to this report in the public docket for this accident.

Receiving Station Timestamp	Transmitted Message Timestamp	Offset
14:30:09	5	4
14:30:20	15	5
14:30:25	24	1
14:30:36	35	1
14:30:47	45	2
14:30:56	54	2
14:31:08	5	3
14:31:19	15	4
14:31:24	24	0
14:31:35	35	0
14:31:44	45	-1
14:31:50	54	-4

Figure 2. Comparison of timestamp between transmitted and received message.

Receiving Station Timestamp	Transmitted Message Timestamp	Rebuilt Timestamp
14:30:09	5	14:30:05
14:30:20	15	14:30:15
14:30:25	24	14:30:24
14:30:36	35	14:30:35
14:30:47	45	14:30:45
14:30:56	54	14:30:54
14:31:08	5	14:31:05
14:31:19	15	14:31:15
14:31:24	24	14:31:24
14:31:35	35	14:31:35
14:31:44	45	14:31:45
14:31:50	54	14:31:54

Figure 3. Rebuilt timestamp.

[1] AIS is a shipboard broadcast system that acts as a transponder, operating in the VHF maritime band, transmitting own ship information and receives information from nearby similarly equipped vessels to aid in collision avoidance.

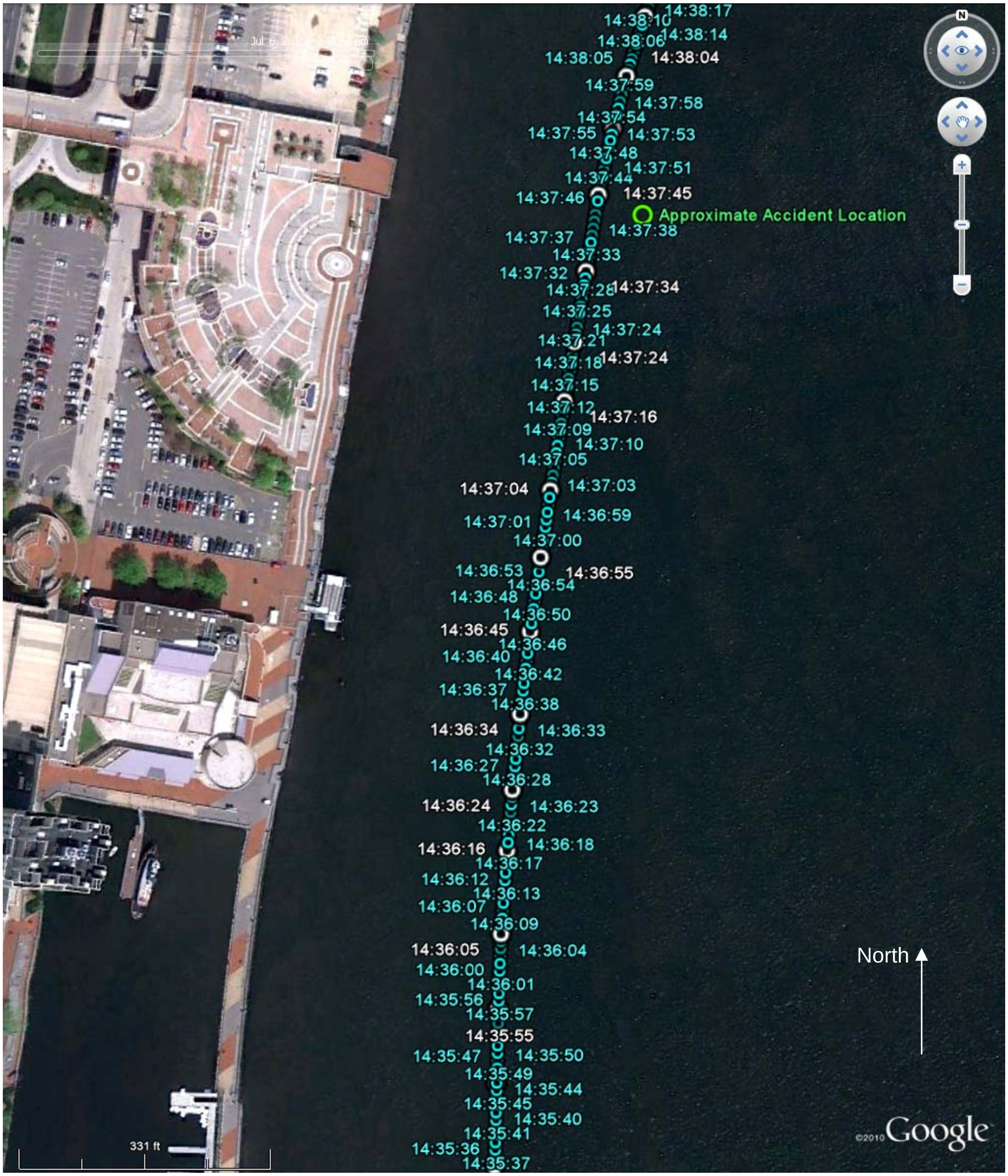

Figure 4. *Caribbean Sea* interpolated and actual AIS position reporting points.

4.1.2. Army witness video

A camera operated by a research and development lab operated by an Army contractor in Camden, New Jersey, captured the accident sequence and postaccident response. Figure 1 shows the location of the camera and the accident site. The video captured by the system was variable frame rate and contained two timestamps. The timestamp in the upper left of the frame closely approximated local EDT. The timestamp in the lower right of the frame approximated UTC, but the two timestamps did not agree with one another (Figure 5).

Figure 5. Frame capture from Army video.

In order to synchronize the timing for the video with the EDT timestamp from the AIS data, several points were selected from the video where identifiable parts of the tug/barge combination were aligned with reference points on the Philadelphia side of the river.

A scale two-dimensional planform drawing of the tug and barge consist was generated in a computer aided drafting application using video data and witness interviews to determine relative position of the tug and barge (Figure 6). The red point in Figure 6 represents the location of the GPS antenna on the *Caribbean Sea* used for the AIS position reports. The drawing was overlaid over the interpolated AIS data and satellite imagery, replicating the alignments from the video captures. Arrangement of the drawing on the imagery was based on the assumption that the barge's heading matched the transmitted course data from the *Caribbean Sea* AIS data and that the position of the barge relative to the tug was fixed throughout the accident sequence. Timing for the related video frame captures was determined by the closest interpolated AIS position to the GPS antenna. Figures 7 through 16 shows screen selected screen captures from the video and the bearing lines from the camera location to reference points on the opposite shore.

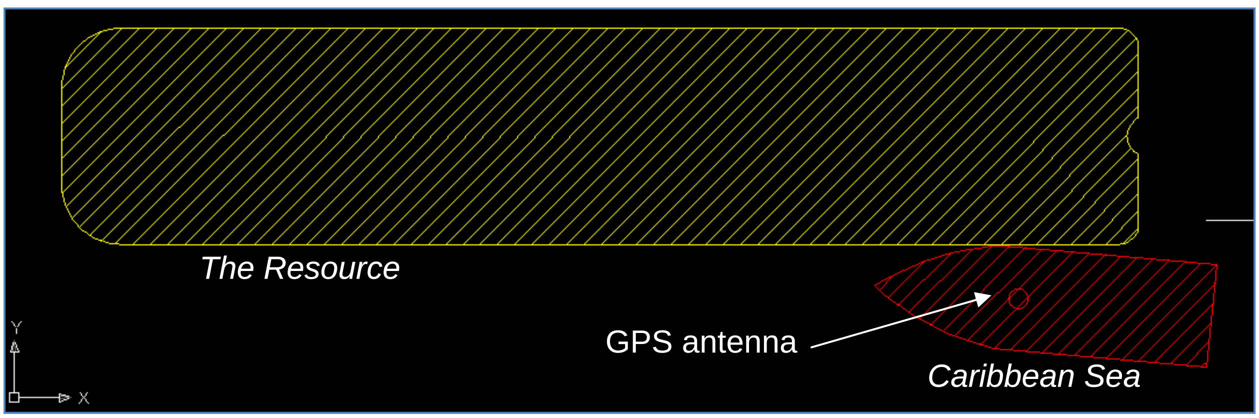

Figure 6. Scale drawing of tug/barge consist.

Figure 7. Bow alignment with southeast corner of condo tower pier.

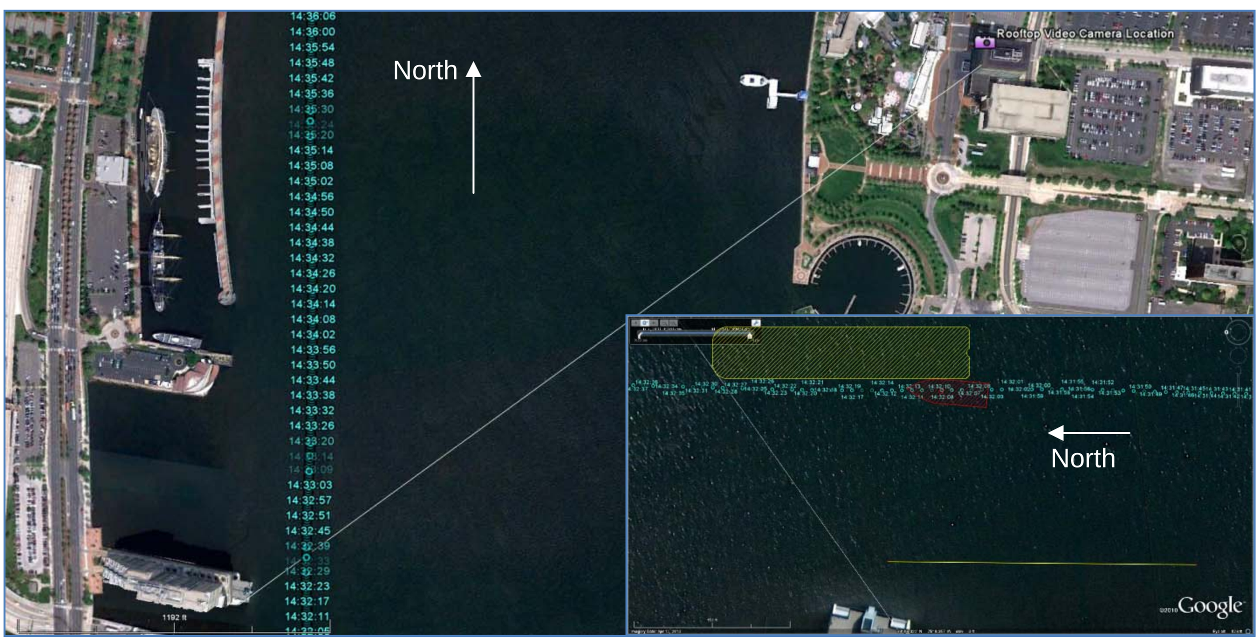

Figure 8. Diagram showing line of sight over interpolated path at time 1432:10 EDT.

Figure 9. Bow alignment with southern point of Columbus monument.

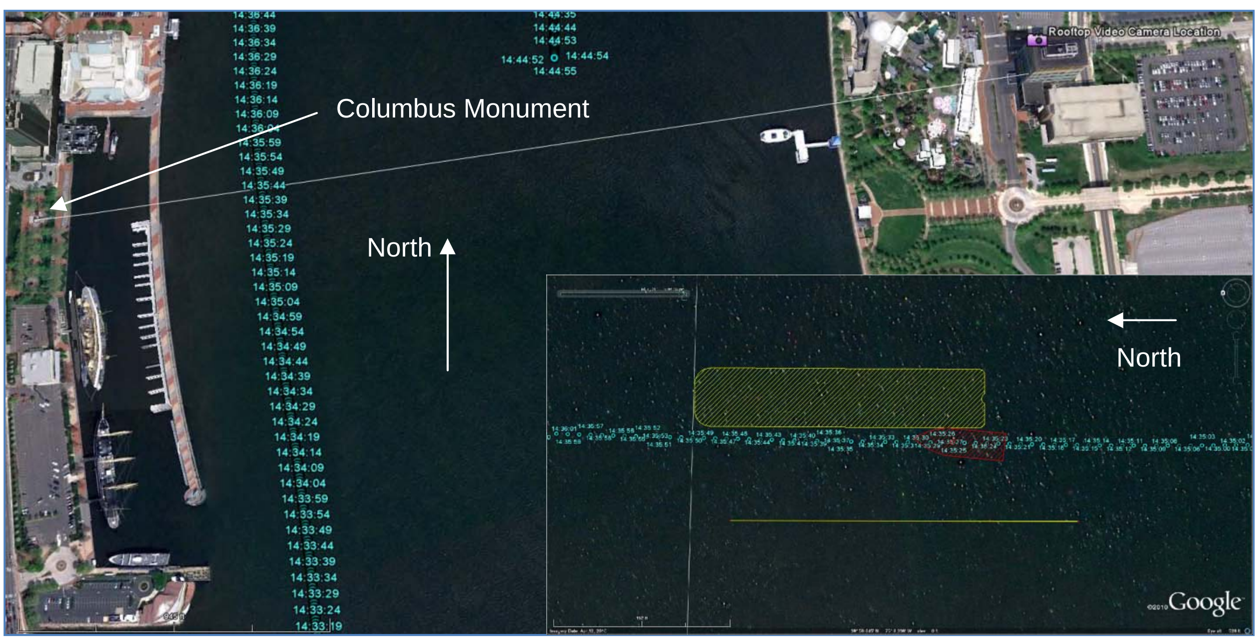

Figure 10. Diagram showing line of sight over interpolated path at time 1435:26 EDT.

Figure 11. Bow alignment with southeast support column of structure.

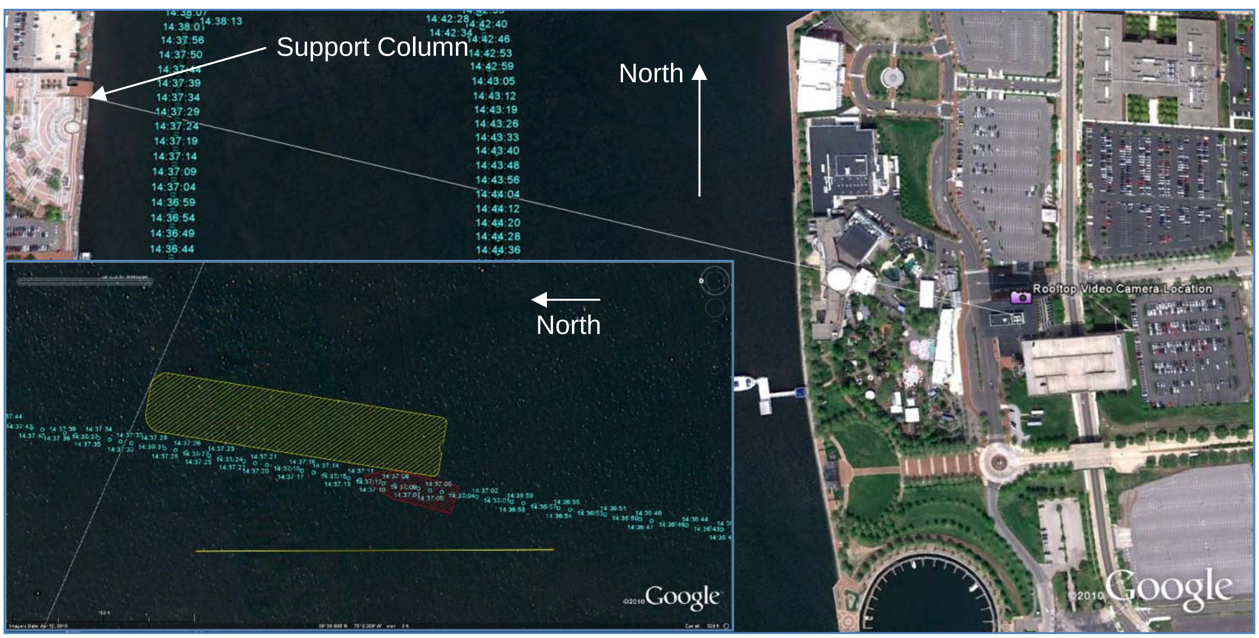

Figure 12. Diagram showing line of sight over interpolated path at time 1437:07 EDT.

Figure 13. Stern of tug aligned with southwest corner of condo building.

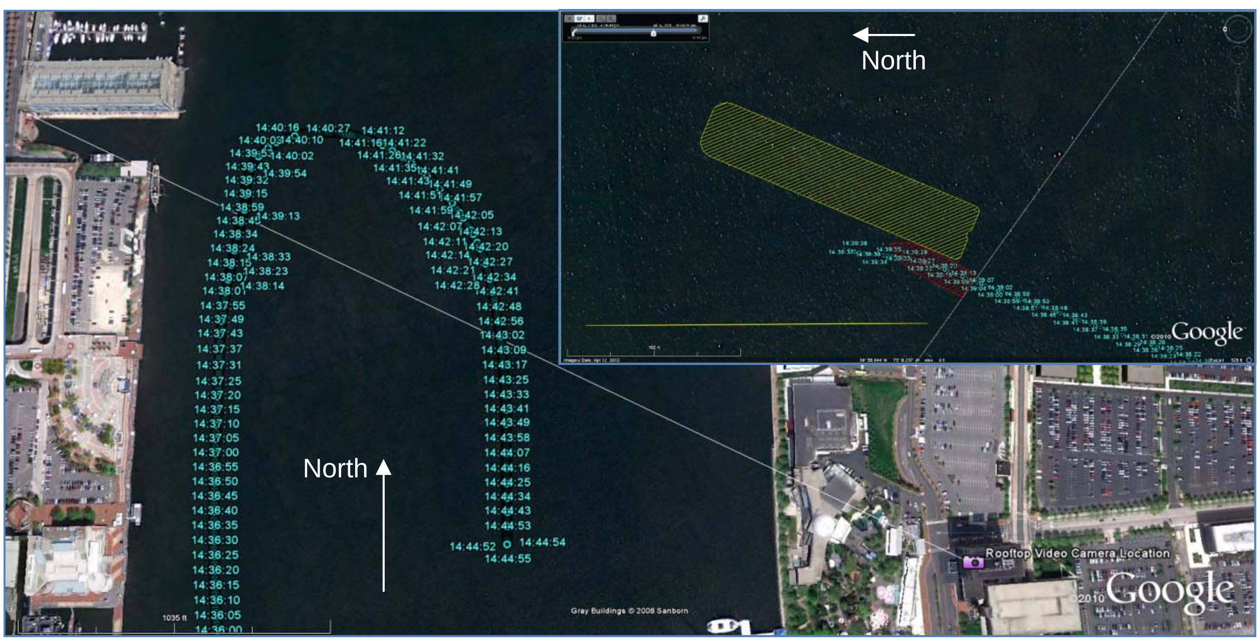

Figure 14. Diagram showing line of sight over interpolated path at time 1439:22 EDT.

Figure 15. DUKW at anchor with stern aligned with third tree from right and northeast corner of condo building in background.

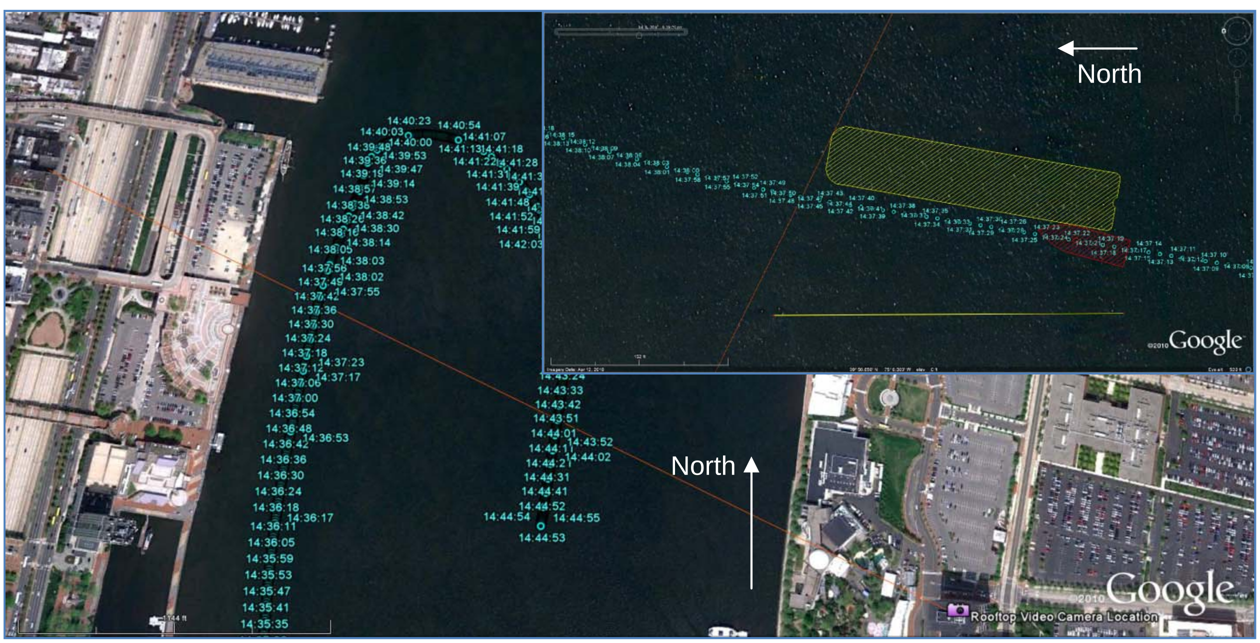

Figure 16. Diagram showing line of sight over interpolated path at accident time 1437:23 EDT.

Figure 17 shows a frame from the video at the time of the accident. The approximate local time in the upper left hand corner appears to show “14:37:20”, however the frame was captured in the process of the seconds field “:29” advancing one second to “:30”.

Figure 17. Frame capture from Army video at time of accident.

Table 1 shows the timing and offset of each frame capture in the series. To correct the time displayed in the upper left hand corner of the video to local EDT, 7 seconds should be subtracted.

Table 1. Time offsets of image series.

Event	Approximate Local Time from Video	Interpolated AIS Message Local Time	Offset
Barge bow aligned with SE corner of condo tower pier	14:32:17	14:32:10	:07
Barge bow aligned with Columbus monument	14:35:32	14:35:26	:06
Barge bow aligned with SE support column	14:37:14	14:37:07	:07
Accident	14:37:30	14:37:23	:07
Tug stern aligned with SW corner of condo building	14:39:29	14:39:22	:07

4.1.3. Witness still photography

Still digital imagery from two witnesses was recovered (see Figure 1 for locations). The metadata[2] attached to the photographs captured the time each image was taken. The timebase of each camera was not tied to a global time, but is set by the user. The cameras were later secured by Safety Board investigators and a series of photographs was taken over several months to account for drift in the camera clock and align the timebase of the camera with UTC.

4.1.3.1. Camera 1

Figure 18 shows the single image capture by camera 1, a Canon PowerShot SD1100IS Digital Elph. Table 2 shows the timing and offset for the series of images taken to identify the EDT time of the image taken prior to the accident. The series of images show the drift between 8/20/10 and 1/7/11 was both linear and predictable (Figure 19). The dataset was used to extrapolate back to the time of the accident image and determine the offset for the accident image was 2:54:26. When the offset was applied to the accident image, the extrapolation showed the image was taken at approximately 14:36:40 EDT. The AIS position of the tug at the time of the photo is also shown in Figure 20. The extrapolation indicates the image was taken 43 seconds and approximately 150 yards downriver before the accident.

Figure 18. Image captured from camera 1.

[2] Metadata is embedded within digital images that identify various camera attributes such as time, date, exposure settings, camera type, etc

Table 2. Times and offsets for camera 1 image series.

Metadata Time	Date	Offset (h:mm:ss)	EDT
11:42:14	7/7/2010	2:54:26[a]	14:36:40[a]
9:56:48	8/20/2010	2:54:01	12:50:49
7:46:55	10/25/2010	2:53:24	10:40:19
13:06:11	11/24/2010	2:53:07	15:59:18
7:25:02	1/7/2011	2:52:41	10:17:43

[a] Result of extrapolation

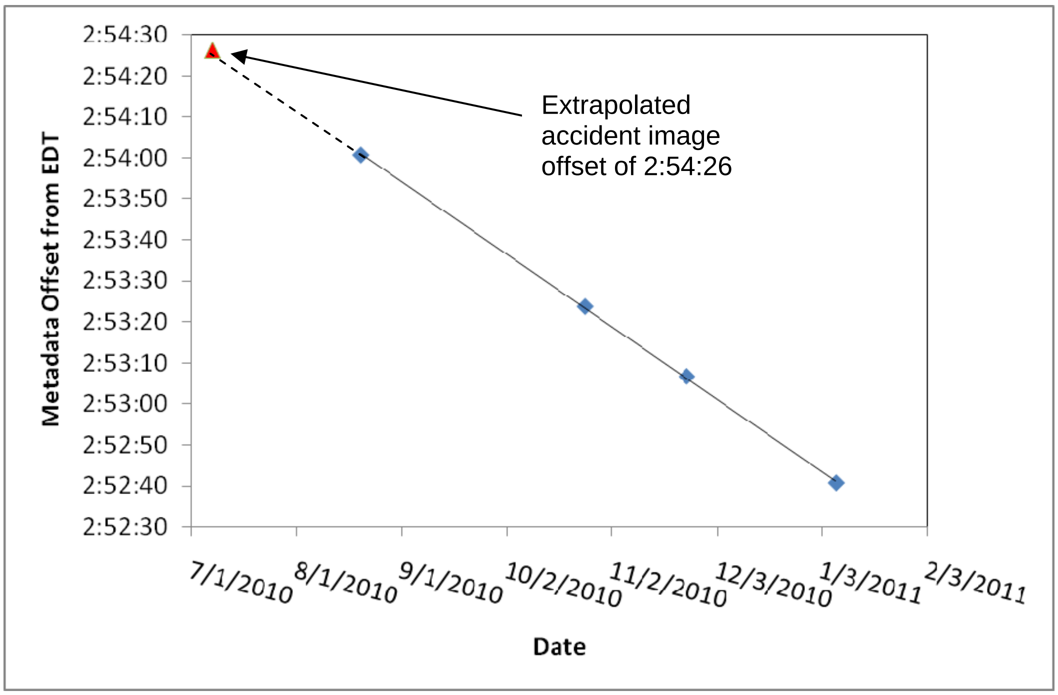

Figure 19. Extrapolated accident image offset.

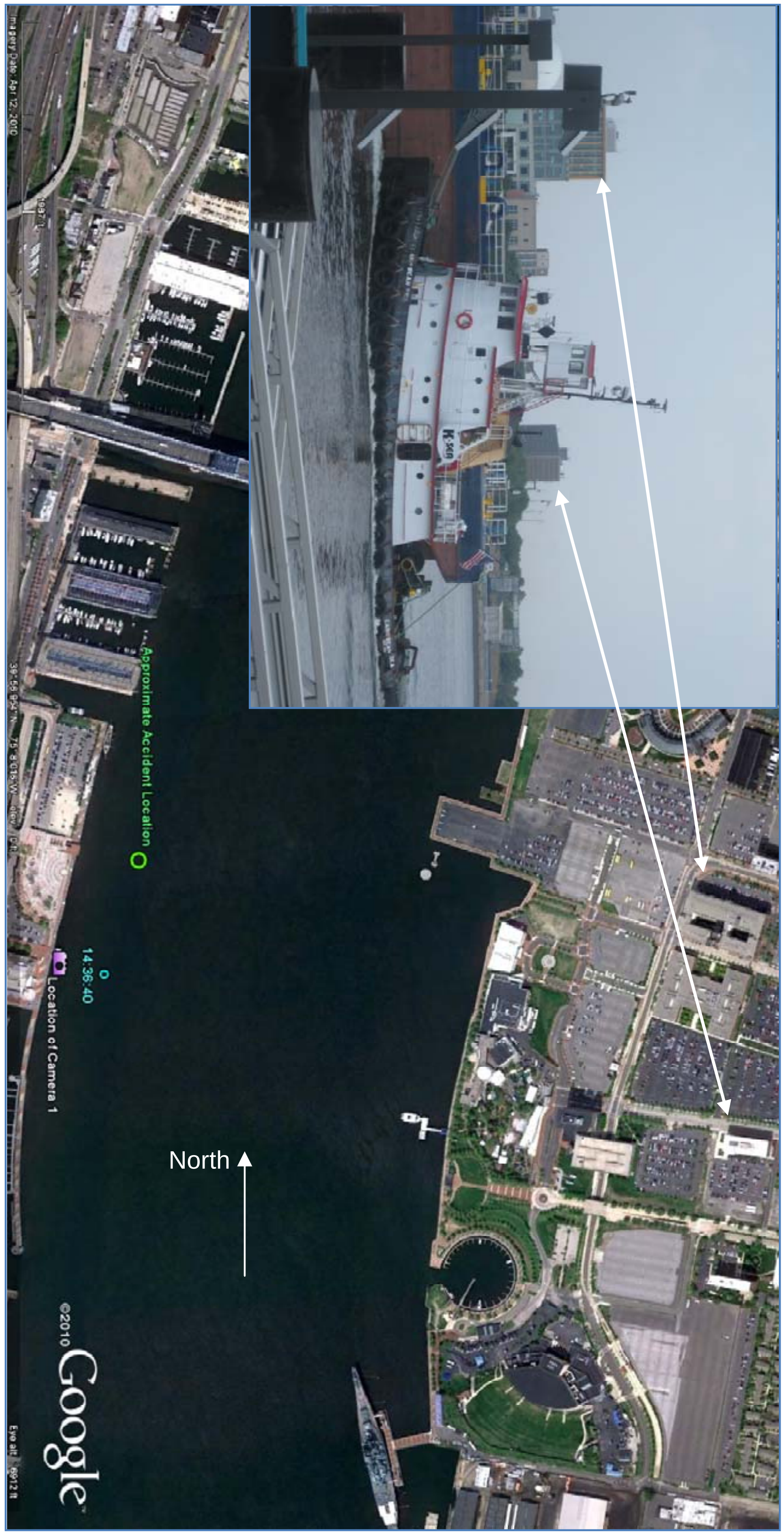

Figure 20. Image of Caribbean Sea pushing barge prior to accident identifying background building.

4.1.3.2. Camera 2

A second witness camera captured a series of images showing the events a short time prior to the accident through a short time after the accident. Evaluation of the metadata embedded in the images was not sufficient to correct to local time, however examination of the images' content was compared with AIS and video data to determine the appropriate time offset. An assumption made in this section was that, as the period of time of the images was short and power to the camera was likely uninterrupted over the series of images, the metadata time offset of each image in the series relative to another was static.

Figures 21 & 22 show an image from the witness camera at the time of the accident and a frame capture from the Army video at approximately the same time.

Figure 21. Witness camera 2 accident image.

Figure 22. Video frame capture at same time.

Metadata for the image in Figure 21 indicates the image was captured at 17:34:22. Using the time offset calculated in section 4.1.2. the video frame capture occurred approximately 2 seconds after initial impact, at 14:37:25 EDT, resulting in an offset of 2:56:57.

Table 3 shows the image content, metadata time, and offset from local time using the accident time from the video, AIS position data, and image content. The full resolution images can be found in the public docket of this accident.

Table 3. Collection of images and timing from witness camera 2.

Image content	Embedded Metadata Time	Calculated Local Time (EDT)
 100_1134.jpg	17:33:26	14:36:29
 100_1135.jpg	17:34:19	14:37:22

Image content	Embedded Metadata Time	Calculated Local Time (EDT)
 100_1136.jpg	17:34:22	14:37:25
 100_1137.jpg	17:34:26	14:37:29

Image content	Embedded Metadata Time	Calculated Local Time (EDT)
 100_1138.jpg	17:34:35	14:37:38
 100_1139.jpg	17:34:38	14:37:41

Image content	Embedded Metadata Time	Calculated Local Time (EDT)
 100_1140.jpg	17:34:57	14:38:00
 100_1141.jpg	17:35:00	14:38:03

Image content	Embedded Metadata Time	Calculated Local Time (EDT)
 100_1142.jpg	17:35:07	14:38:10

4.2. Uncertainty

The alignment of various data sources was based on several assumptions. This section attempts to quantify the worst case uncertainty that could be introduced into the study if actual conditions on the day of the accident varied from those assumptions.

4.2.1. AIS Data

The AIS dataset contains the least uncertainty. The data is likely accurate to better than one second and the interpolation provides an accurate picture of the second-by-second position of the GPS antenna as the tug is maintaining nearly constant speed and course during the period of interest. The GPS carried aboard advertises 10-meter positional accuracy when operating in the GPS mode.

4.2.2. JUMPS Video

As the timestamp from the video can be off by as much as one second, the exact time within the second of the frame capture cannot be determined.

4.2.3. Witness Camera 1

Investigators did not have immediate access to the camera so the extrapolation outlined in section 4.1.3.1 was necessary. The uncertainty of the time of the photo in Figure 18 was bounded by the necessity of the GPS antenna on the tug in the foreground being between the two buildings identified in Figure 20 in the background. The maximum uncertainty for the timing of the image in Figure 18 was 14:36:40 plus 3 seconds, minus 0 seconds.

4.2.4. Witness Camera 2

The uncertainty of the time alignment of the images from camera 2 lies in the frame capture used to reference the image in Figure 21. The video shows the bow of the barge pushing the stern of *DUKW 34* downwards and propelling it forwards in the same orientation for 3-4 seconds before the bow of the *DUKW 34* moves to the left and then under the barge. The uncertainty can be reduced to 1-2 seconds using image 100_1135.jpg in Table 3, taken only three seconds before the image in Figure 21, which shows the anchored DUKW on a direct line-of-sight from the camera to a water tower in the background behind the bridge. The image used to derive the time alignment of camera 2 (Figure 21) shows the barge just after contact with the DUKW, but before it began propelling the DUKW forward, as the DUKW is still aligned with the water tower in the background.

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