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Automatic Identification System (AIS) Data Case Study: Identifying Unofficial Mooring Areas along the Upper Mississippi River

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PURPOSE: This Dredging Operations and Technical Support (DOTS) program technical note presents the results of a study undertaken at the request of staff from the US Army Corps of Engineers (USACE) Rock Island District (MVR) as part of a larger effort examining the potential creation of seven new permanent mooring cells along the Upper Mississippi River in proximity to lock and dam (LD) locations selected by MVR. MVR staff were interested in evaluating vessel traffic and identifying unofficial mooring areas (i.e., waiting areas) in the vicinity of LD7, LD10, LD11, LD14, LD15, LD20, and LD22; they were also interested in travel times from those unofficial mooring areas to the destination lock. The search distance for unofficial mooring areas was limited to 20 miles from the lock, or the distance to the next closest lock if less than 20 miles, in the appropriate direction (i.e., upstream or downstream), as specified by MVR staff.

BACKGROUND: The Automatic Identification System (AIS) data from a transceiver onboard a vessel can provide a set of position reports, as often as every two seconds (depending on the type of maneuver), at a high temporal resolution. These position reports are time-stamped and georeferenced and provide a rich data source for understanding waterway utilization by commercial vessels (most of which are required to carry AIS when transiting US waters) and the recreational vessels that carry AIS. Details about AIS technical specifications and carriage requirements are available from multiple standard-setting bodies (IALA 2008; IEC 2001; ITU-R 2014; PIANC 2019; USCG 2018; US CFR 2019). In the United States, the USCG is responsible for setting AIS carriage requirements (US CFR 2019) and for maintaining the Nationwide AIS (NAIS) archive of historical vessel position reports received from the network of AIS stations maintained by the USCG (USCG 2018). The NAIS also receives data from a network of AIS towers operated and maintained by USACE through the Lock Operations Management Application (LOMA) program. These towers are located primarily at LD sites along inland waterways, including the Upper Mississippi River (USACE-ERDC 2017).

AIS data have been used to examine multiple elements of waterway utilization (Kress et al. 2020), potential waterway engineering applications (Tabbert et al. 2021), and the way that vessels may interact with nearby maritime structures (Scully et al. 2020; Young and Scully 2018). Table 1 presents summary information from 2020 and 2021 for commercial vessel lockages and total tonnage (in thousands of tons) handled in the main chamber of the LD locations included in this study. In general, tonnage increased further downstream. The most upstream lock in this study,

LD7, handled 10,084,000 tons in 2021, while LD22 (i.e., the furthest downstream in this study group) handled over 22,000,000 tons of commercial cargo in 2021 (USACE-IWR 2022).

Table 1. Commercial vessel lockages and tonnage totals (main chamber only), 2020 and 2021.

Lock and Dam (LD) Number, Main Chamber Only	Commercial Lockages*			Total Commercial Tonnage, Upbound and Downbound (Thousands of Tons [K])		
	2020 Up-bound	2020 Down-bound	2021 Up-bound	2021 Down-bound	2020 Total Tonnage	2021 Total Tonnage
LD7	1,307	1,037	1,158	874	12,448 K	10,084 K
LD10	1,291	1,321	1,053	1,073	16,975 K	13,043 K
LD11	1,306	1,332	1,062	1,074	17,058 K	12,994 K
LD14	2,042	1,872	1,654	1,539	21,863 K	16,694 K
LD15	1,581	1,606	1,263	1,237	21,271 K	15,666 K
LD20	2,151	2,231	1,664	1,683	26,820 K	20,034 K
LD22	2,184	2,236	1,633	1,648	30,279 K	22,780 K

Source: Data adapted from USACE-IWR 2022.
*Excludes recreational vessel lockages. Total number of tows differs from total number of lockages.

METHOD: MVR staff provided a list of potential mooring areas, which included information on whether the proposed mooring cell area was upstream or downstream from a lock. AIS position data were acquired from the USCG NAIS archive. The AIS data spanned from 1 January 2019 through 1 July 2022, and the sampling rate was 15 seconds. The AIS data were then loaded into the AIS Analysis Package (AISAP) software (USACE-ERDC 2018) for analysis. The first area of interest (AOI) geospatial filter applied to the data was a 20-mile search area upstream or downstream from the lock in the direction of the proposed mooring cell; this information was provided by MVR staff based on knowledge of the area. In other locations, a different search-area distance may be appropriate. The results of applying this filter were a series of AIS position reports from the study period. These were visualized as a signal density map (i.e., heatmap).

Figure 1 shows the LD10 search area and AIS heatmap; the large green polygon defines the search area. The hot spots of greater relative signal density within each search area appear as brighter yellow or white colors, with purple and blue tones indicating lower relative signal density. Hot spot areas were examined in greater detail to outline the boundary of the hot spot. Any hot spot that appeared next to a terminal or dock on the satellite imagery basemap was excluded because it did not represent an unofficial waiting area along the riverbank, which is what this project sought to identify.

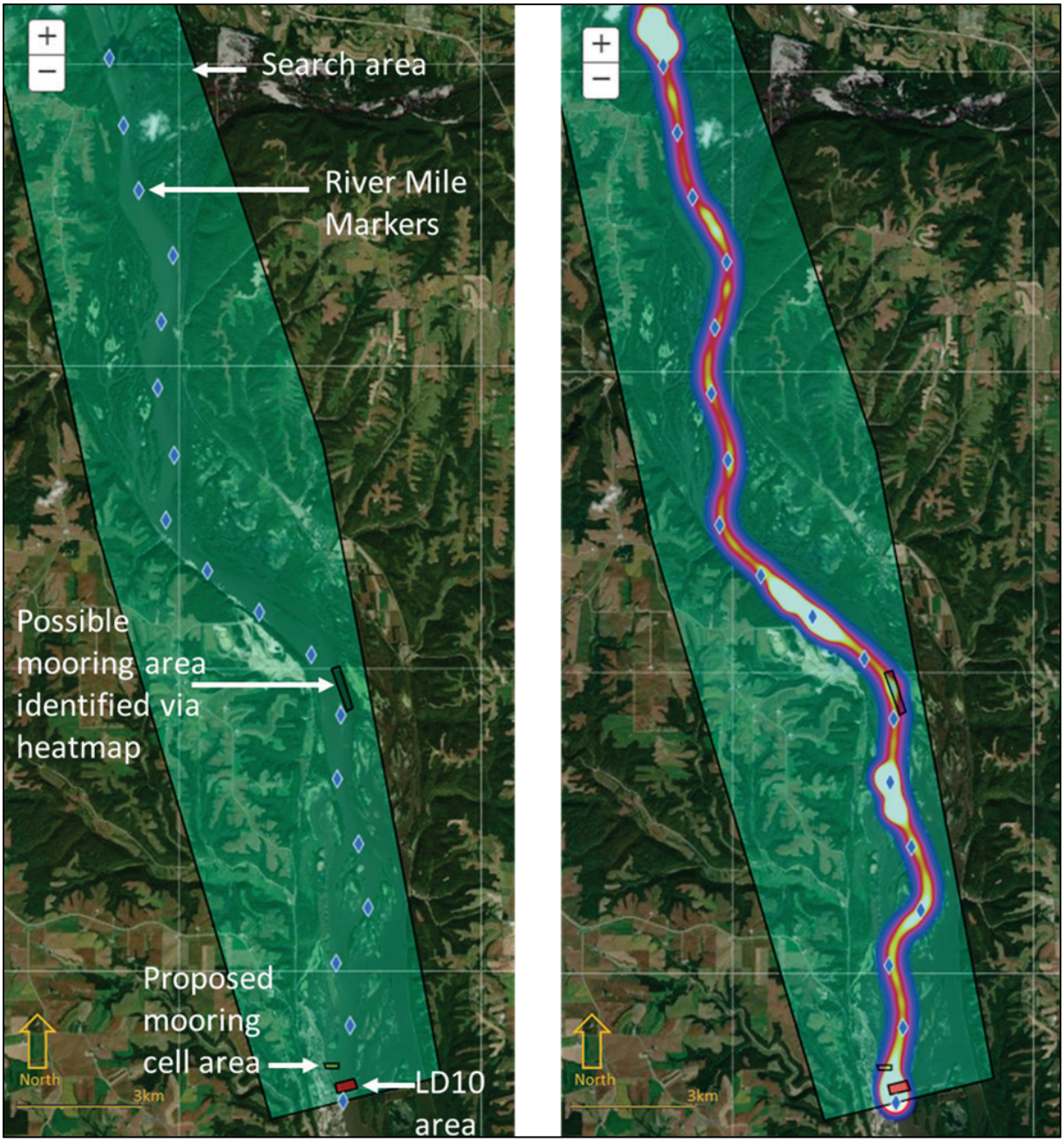

Figure 1. *Left panel*: 20-mile search area (*green-shaded polygon with black outline*) upstream of lock and dam (LD) 10, reaching from river mile (RM) 615 to RM 635. The LD10 area is a small, *red-shaded polygon* near the bottom of the figure, and the proposed mooring cell area is shown as a small *yellow polygon* upstream of the lock. *Right panel*: Automatic Identification System (AIS) signal density map (i.e., heatmap) in the 20-mile search area upstream from LD10; *bright yellow* and *white* colors indicate greater relative signal density, while *purple* and *blue* tones indicate lower relative signal density within the visible area. *Blue diamonds* are RM markers (*both panels*). Images created in the AIS Analysis Package (AISAP) software.

To be included in the study, hot spots had to be located outside of the main navigation channel, which was visible as a relatively continuous blue line on the heatmap. Unlike coastal channels,

which have defined channel footprints, the Upper Mississippi River channel shifts through time, as does the recommended sailing line within it. Figure 2 shows an AIS heatmap of vessel traffic over a short segment of river during the study period. The navigation channel is clearly identified by the continuous blue line; a separate unofficial mooring area, represented by three blue spots toward the bottom of the image, is distinctly separate from the main channel. Those three blue spots coincide with satellite imagery showing a flotilla pushed into the bank, presumably waiting in that area. Within the AISAP software, the heatmap feature color coding rescales as the user zooms in and out because the relative number of AIS position reports shown within the viewer changes. This allows an analyst to apply their judgement to draw the boundaries of a waiting area or any other polygon.

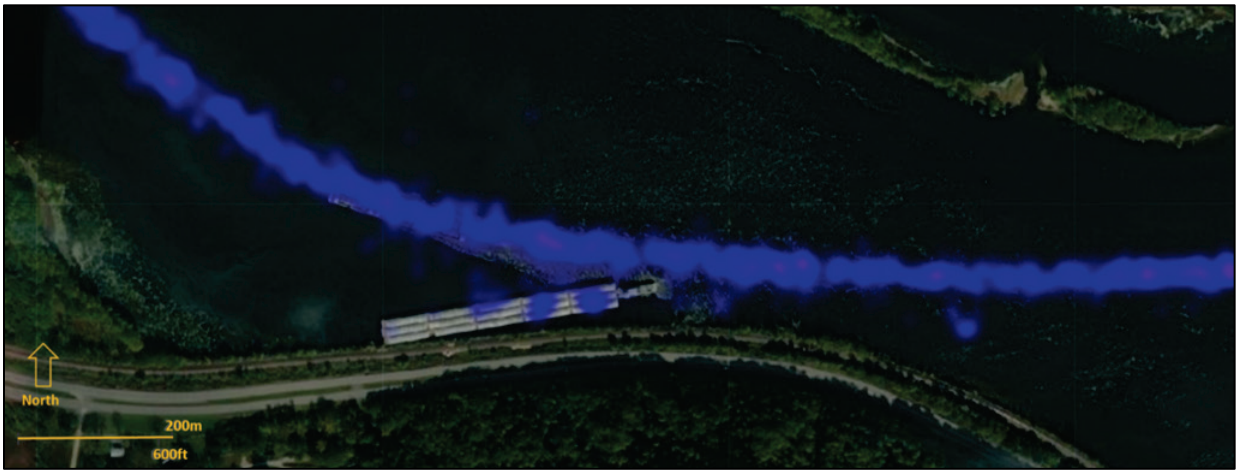

Figure 2. AIS signal density map (i.e., heatmap) with the main navigation channel shown as a continuous *blue line*. A flotilla utilizing an unofficial mooring area is shown on satellite imagery (*center bottom left*) overlain with three *blue* AIS "spots" that are spatially distinct from the main navigation channel; this indicates an unofficial mooring area. The AIS heatmap and the satellite image reinforce the finding that this is an unofficial mooring area. Images created using AISAP software.

Figure 3 shows hot spots in greater detail. The hot spots closely match the satellite imagery showing two flotillas waiting side by side along the bank. After hot spots within the 20-mile search area were identified, an AOI polygon was drawn around each hot spot. This AOI served as another geospatial filter. The number of vessels that dwelled within each hot spot and the length of each vessel's dwell time were calculated in AISAP. This was used to identify the number of times vessels utilized the unofficial mooring area during the study period and the length of their continuous dwell time within the mooring area during each dwell event. Dwell events that lasted longer than 600 minutes (10 hours) were identified as examples of possible delay events that might warrant a separate study. (The reasons for any vessel stop are not included in the AIS data itself.) Table 2 lists the number of dwell events lasting less than 600 minutes in each search area.

The two flotillas shown side by side in Figure 3 are utilizing the same unofficial mooring area at the same time. An event in which two or more vessels utilized an unofficial mooring area at the same time represented two separate dwell-time events because each motor vessel has a unique name and Maritime Mobile Service Identity (MMSI) number that are used in their AIS broadcast. Each vessel also has a unique time-stamped position report marking its entry into and exit out of the mooring area.

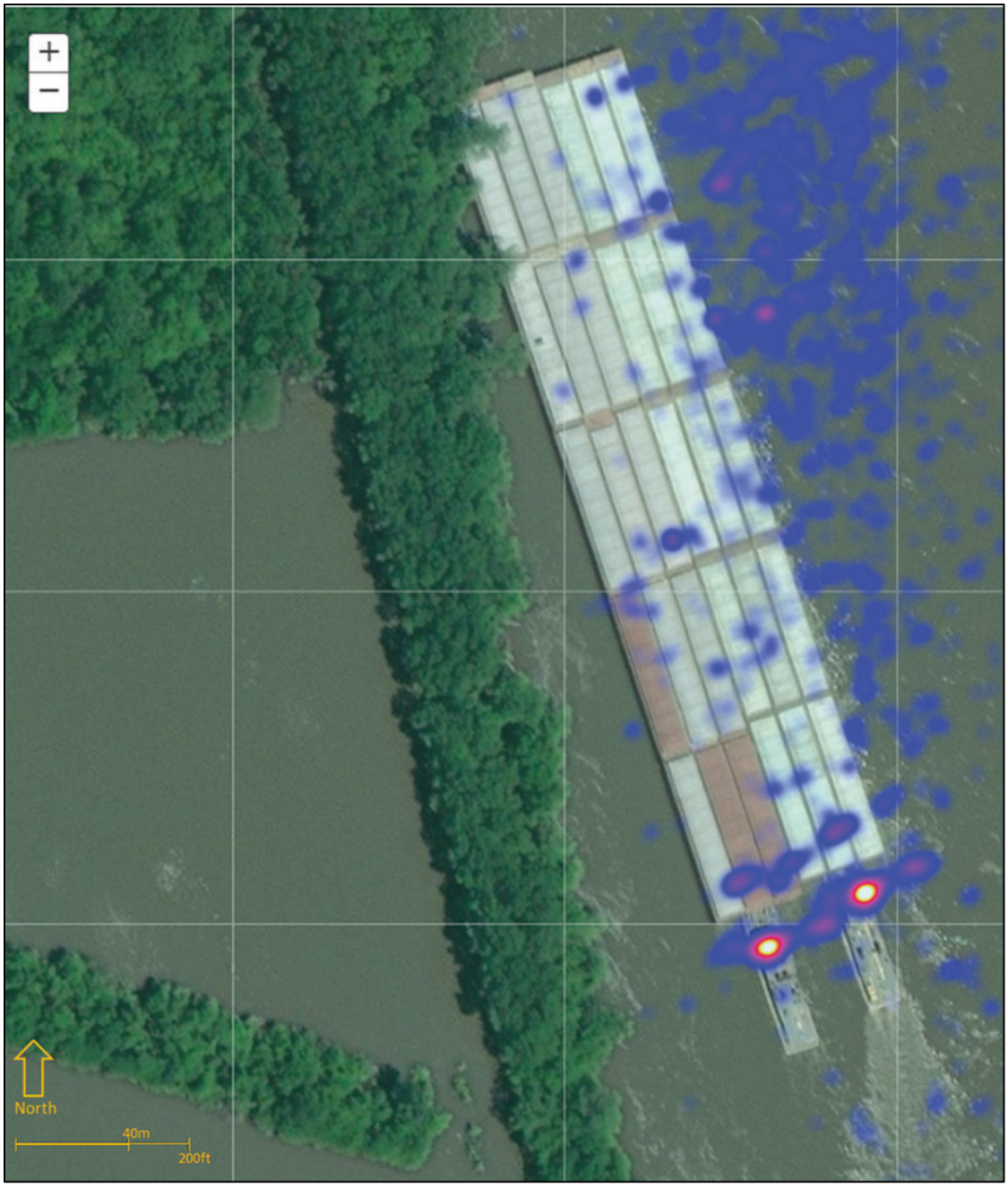

Figure 3. Two flotillas waiting along the bank in an unofficial mooring area near Upper Mississippi River RM 340.5. The AIS signal density map (i.e., heatmap) overlaid on satellite imagery was created using AISAP software. In the heatmap, *bright yellow* and *white* colors indicate greater relative signal density, while *purple* and *blue* tones indicate lower relative signal density within the visible area.

RESULTS: The unofficial mooring area polygons identified in this study varied in shape and size. Table 2 lists the number of unofficial mooring area polygons identified within each area. The number of observed unofficial dwell events was highest downstream from LD20 (at 1,794 events during the study period), but LD15, LD20, and LD22 all had over 1,000 observed events. As this was an exploratory study, there was no predefined lower bound of events that had to occur in a

space for it to be designated a hot spot. The number of hot spots in each lock area and the number of events within each hot spot varied. For example, of the five waiting areas identified near LD7, a low number of waiting events (6) was observed in Area 4 at river mile (RM) 705.5, while a much higher number of waiting events (521) was observed in the nearby Area 5 at RM 704 (Table 3).

Table 2. Summary of unofficial mooring areas identified within the search area and study period.

LD Number and Search Area Direction	Unofficial Waiting Areas Identified (Sizes Varied)	Unofficial Dwell Events Lasting Less than 600 Minutes, Counted across Identified Waiting Areas
LD7–Upstream	5	568
LD10–Upstream	6	803
LD11–Upstream	4	253
LD14–Upstream	7	580
LD15–Downstream	7	1,021
LD20–Downstream	8	1,794
LD22–Upstream	12	1,540

Note: Study period was from 1 January 2019 through 1 July 2022.

The identified waiting areas inside of the seven search areas were utilized by different numbers of vessels during the study period and for different amounts of time. The results from the LD7 search area, and the resulting five waiting areas, are shown in Table 3. LD7 is located at RM 702.5, and the search area was upstream from the lock.

Table 3. Lock and dam (LD) 7 waiting area results and travel times.

Waiting Area Name	Total Waiting Events Observed during Study Period	Minimum Travel Time from Waiting Area Polygon to Lock Area Polygon (Minutes)	Median Travel Time from Waiting Area Polygon to Lock Area Polygon (Minutes)
Area 1 at RM 712	20	70	120
Area 2 at RM 711	9	65	95
Area 3 at RM 707.5	12	15	72
Area 4 at RM 705.5	6	30	35
Area 5 at RM 704	521	5	35

Note: Results based on AIS data from the USCG, processed using AISAP.
Additional results from other locations available from the author.

Figure 4 shows the extent of the LD7 search area (blue polygon), the LD7 facility (red polygon), the five unofficial mooring areas (i.e., waiting areas) identified using AIS data (yellow polygons), and the exclusion area (gray polygon at the north end of the search area) used in the traffic direction assessment. If a vessel appeared in a waiting area and then appeared in the exclusion area, it was considered a transit that was moving away from the lock and was excluded from the travel-time analysis.

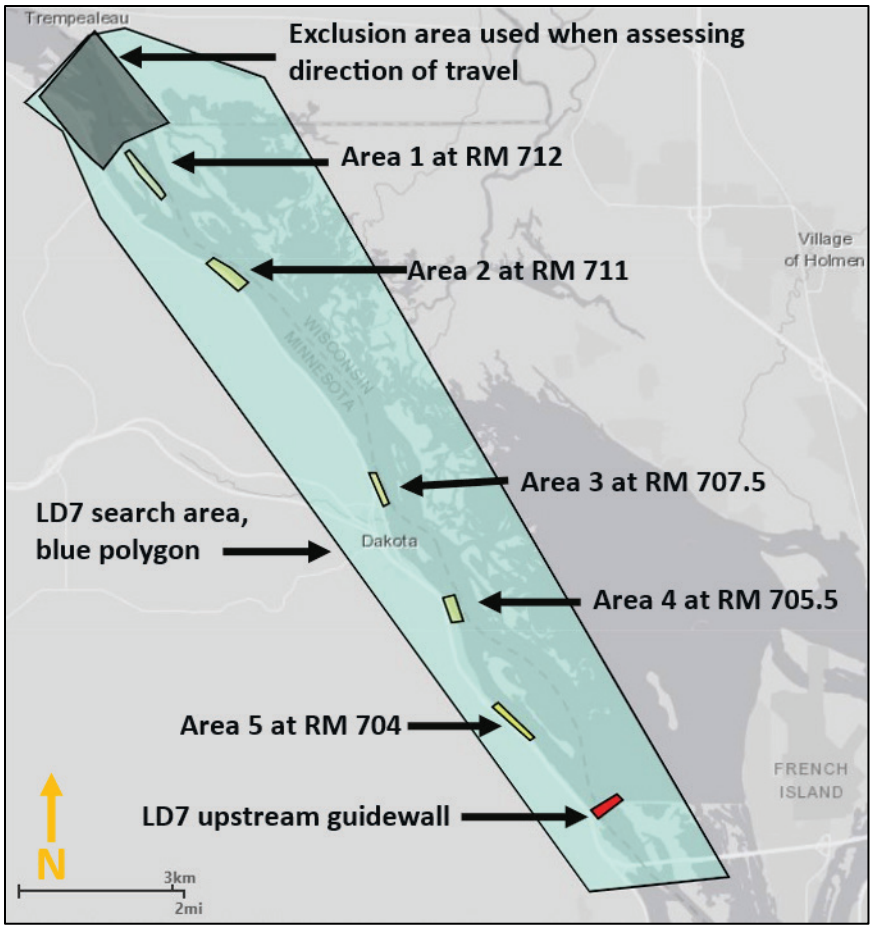

Figure 4. LD7 search area (*blue polygon*) upstream of LD7 (*red polygon*) and five unofficial waiting areas (*yellow polygons*) identified using AIS data from 1 January 2019 through 1 July 2022.

AIS data provides time-stamped and georeferenced information about vessel movements, but it does not include information about vessel operators' reasons for these movements. To put it another way, AIS data can reveal that a vessel waited in a certain location, but it does not provide information about what else was happening that caused the vessel to wait. Answering questions about lock queues, wait times before a lockage, river conditions, or other factors that may influence why and where a vessel utilizes an unofficial mooring area would require consulting additional data sources. One such potential data source is lock queue time records from the destination lock because lock queues, or lock wait times, change based on traffic. Another potential data source that could be examined in conjunction with AIS data is data on river stage (i.e., river level), which may influence how and where vessels choose to wait before receiving clearance to make a safe

approach to the lock. For questions about using AIS data in conjunction with other data sources, please contact the author.

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