Materials and Methods

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Under the new [Supreme Court decision](https://www.supremecourt.gov/opinions/22pdf/21-454_4g15.pdf), wetlands are jurisdictional to Waters of the United States (WOTUS) if 1) a continuous surface connection is present with an existing WOTUS, and 2) the wetland is practically indistinguishable from an ocean, river, stream, or lake where the continuous surface water connection is identified. A national-scale assessment for the United States was conducted to identify potential geographically isolated wetlands (GIWs), focusing specifically on the first requirement to define those beyond a given straight-line distance from existing waterbodies. The second requirement that a wetland must be “practically indistinguishable” cannot be assessed at a national scale with existing datasets. The analysis further recognized that existing wetland protections at the state level may have precedence over federal protections. All GIWs were considered similarly across states regardless of existing protections as state rules can now be challenged under the new federal WOTUS definition.

The National Wetland Inventory (NWI, <https://www.fws.gov/program/national-wetlands-inventory>) maintained by the US Fish and Wildlife Service and the National Hydrograpy Dataset (NHD, <https://www.usgs.gov/national-hydrography/national-hydrography-dataset>) maintained by the US Geological Survey were used for the assessment. The NWI is the most comprehensive geospatial dataset (1:24,000 scale) of wetlands in the US, representing the combined mapping efforts of states, federal agencies, tribal governments, regional and local governments, and nonprofit organizations. Data are available for over 35 million wetlands classified as estuarine and marine deepwater, estuarine and marine wetland, freshwater emergent wetland, freshwater forested/shrub wetland, freshwater pond, lake, riverine, and other. The final category includes farmed wetlands, saline seeps, or other miscellaneous types (*1*). The NHD is mapped at 1:24,000 scale and includes line and area features for flow networks and waterbodies, respectively. Both the NWI and NHD are available as separate geodatabases or shapefiles for each state. A custom analysis workflow was used to quantify the amount and areal coverage of GIWs by state. Both the NWI and NHD are not without accuracy limitations, which primarily include errors of omission/commission based on constraints of the data used to create each layer (*2*, *3*). However, both datasets represent the best estimate of surface water coverage in the US and an assessment of potential GIWs is informative regardless of the limitations.

Several data preprocessing steps were required before comparing NWI and NHD features, building on similar methods as (*4*). First, NWI classes that were not considered relevant for estimating GIWs were removed. These included wetlands that were connected to existing surface waters by definition alone: estuarine and marine deepwater, estuarine and marine wetland, and riverine. Excluded wetlands totaled 11,239,007 polygons, or 31.8% of all NWI features. Second, wetland polygons that were considered part of the same wetland complex were combined based on spatial proximity. All wetland polygons that overlapped after applying a buffer distance of 0.5 meters were combined into one wetland feature, where the majority wetland class among the combined polygons was assigned to the new feature. Third, all wetlands with surface area less than 0.25 acres were excluded from analysis ( 11,875,638, or 33.6% of all NWI features). These “small” wetlands represent those that are typically already unprotected and do not require permits for activities that can degrade or eliminate their function. This size threshold varies by state or smaller regulatory jurisdictions. For example, Florida uses a threshold of 0.5 acres ([Rule 32-340 F.A.C](https://www.flrules.org/gateway/ChapterHome.asp?Chapter=62-340)), whereas Indiana uses a threshold of 0.1 acres ([Indiana Code 13-18-22](https://www.in.gov/idem/wetlands/information-about/state-regulated-wetlands-program/overview-of-idem-state-regulated-wetland-permit-types/)). As such, the 0.25 minimum acreage criteria represents a generic threshold that acknowledges most states do not protect small wetlands. For the NHD layers, only relevant feature types were retained, which included canals/ditches, streams/rivers, coastlines, and artificial paths from the flowlines layer and lakes/ponds, reservoirs, and estuaries from the waterbodies layer. We made no distinction between potentially ephemeral/intermittent and perennial streams in the NHD flowlines layer.

The analysis was conducted using the open source R statistical programming language (version 4.2.3, *5*). A custom workflow was developed to iteratively download the NWI and NHD spatial layers for each state to identify GIWs based on the Euclidean distance of wetland features to NHD features. The simple features package (sf, *6*) provided the core functions for the spatial analyses, including use of the st\_read() function for importing relevant layers from the state geodatabases and calculating distances between features using the st\_nearest() function. For the latter analysis, the pre-processed NWI layer for each state was compared separately to the pre-processed flowline and waterbody layers from the NHD, resulting in an index of NHD features that were nearest to each NWI feature. The distance between the NWI features and the nearest NHD feature were estimated using the st\_distance() function and the minimum distance to either a flowline or waterbody feature was estimated for each wetland. The final datasets included tabular information for each state, where each row was an individual wetland, with columns for the wetland attribute, acreage of the wetland, latitude and longitude (WGS 1984) of the wetland centroid, distance of the wetland in meters to the nearest NHD feature, the state abbreviation, and wetland type. All geospatial analyses were conducted using the [Albers equal area projection](https://www.fws.gov/node/264848) with a North American Datum of 1983. Code for the analysis workflow is available on GitHub at [https://github.com/tbep-tech/wetlands-eval](%5Bhttps://github.com/tbep-tech/wetlands-eval).

The state tabular data with the distance of each wetland feature to the nearest NHD feature were used to quantify the amount and extent of GIWs using a range of thresholds. In total, 35,291,995 wetlands were assessed, where the distance to NHD features ranged from 0 to 26 kilometers. A range of distances for each NWI feature to the nearest NHD feature were used to develop an expectation of the amount and extent of GIWs at risk in each state. The Supreme Court decision that wetlands must have a “continuous surface connection” to existing navigable waters does not provide specificity or quantitative guidance on how this should be defined. The range of values used to quantify potential GIWs varied from 1 to 100 meters (at 10 meter intervals) to take into account the uncertainty in the current definition, as well as the uncertainty in the mapping products used in the analysis. Based on these ranges, the amount and extent of GIWs in each state were quantified, including an assessment of GIWs by wetland type (i.e., freshwater emergent, freshwater forest/shrub, etc.). The most vulnerable wetland type by state was also identified.

Finally, all wetlands in existing protected areas were not considered in the analysis, such as those in national parks or marine conservation areas. These wetlands were considered not at risk based on the exclusion of activities in protected areas that can degrade or eliminate wetland function. These wetlands were identified by intersection of the wetland centroids with polygons in the Protected Areas Database (PAD-US) maintained by the United States Geological Survey (*7*). This database is a comprehensive inventory of protected areas, including public and voluntarily provided private lands, that are categorized by “GAP status” (Gap Analysis Program) indicating how they are being managed for conservation purposes. Each feature is assigned an integer of 1 to 4 for the GAP status, with decreasing protections for higher numbers. Only polygons with GAP status as 1 or 2 were used to exclude GIWs from the analysis, where those with GAP status 1 have permanent protections and mandated management plans and those with GAP status 2 are similar but may receive uses or management practices that degrade the quality of natural communities (e.g., suppression of natural disturbances). Conversely, wetlands in GAP status 3 and 4 were not excluded, where protected areas in GAP status 3 may be subject to extractive uses (e.g., logging, mining) and those in GAP status 4 have no protections.

# References

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