Development of Drinking Water and Ecological Unusually Sensitive Areas (USAs): Examples Using the Water and Biological Resources of Ohio

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1.0 INTRODUCTION

The U.S. Department of Transportation's Research and Special Programs Administration (RSPA) is required to identify areas unusually sensitive to environmental damage in the event of a hazardous liquid pipeline accident. Pipeline operators that can affect "unusually sensitive areas" (USAs) must develop and follow an integrity management program to assess and evaluate the integrity of their pipelines. After extensive consultation with experts, government agencies, and other stakeholders, a process was developed to identify USAs for drinking water and ecological resources.

In general the USA identification process involves selecting a subset of USA candidates from the larger group of Environmentally Sensitive Areas (ESAs), and then applying various filter criteria to the candidates to determine final USAs. For drinking water USAs this means identifying potentially sensitive public water systems (PWS), specifically surface water intakes and ground water wells, and subjecting them to filter criteria that account for, among other factors, the type and magnitude of public usage, source aquifer susceptibility (based on a classification scheme developed by Pettyjohn et al, 1991), and the presence of adequate alternative drinking water sources. For ecological USAs the process consists of identifying various rare and protected species and ecological community occurrences (candidate USAs) and subjecting them to filter criteria that assess their level of rarity and imperilment, level of co-occurrence with other sensitive ecological resources, overall quality and importance, habitat associations, and life-history characteristics.

Development of the USA databases via two independent Geographic Information System (GIS) models is currently underway for the entire U.S. The methodology, data and results of the GIS models for the determination of both the drinking water and ecological USAs in Ohio are discussed here.

2.0 METHODOLOGY FOR DETERMINATION OF DRINKING WATER USAs

2.1 Conceptual Framework and Definitions

As noted above, the process of drinking water USA identification begins with the identification of potentially sensitive public water systems (PWS), specifically surface water intakes and ground water wells, which are then subjected to the appropriate filter criteria via a GIS program. The filter criteria used to determine which public water systems should be considered USAs are listed below:

1) The water intake for a Community Water System (CWS) or a Non-transient Non-Community Water System (NTNCWS) that obtains its water supply primarily from a surface water source and does not have an adequate alternative drinking water source (AADWS) shall be designated as a USA.
2) The Source Water Protection Area (SWPA) shall be designated as a USA for a CWS or a NTNCWS that obtains its water supply from a Class I or Class IIa aquifer and does not have an AADWS. Where a state has not yet identified the SWPA, the Wellhead Protection Area (WHPA) will be designated as a USA until the state has identified the SWPA.
3) The sole source aquifer recharge area, where the sole source aquifer is karst in nature, is designated as a USA

In order to more clearly understand the criteria and their utility in the identification of USAs in Ohio, several terms and concepts require further definition. These definitions are provided below. In addition to these definitions, the Pettyjohn classification scheme for aquifer sensitivity to spilled contaminants is also discussed in the following pages.

Definitions:

Adequate Alternative Drinking Water Source (AADWS) - *means a source of water that currently exists, can be used almost immediately with a minimal amount of effort and cost, involves no decline in water quality, and will meet the consumptive, hygiene, and fire fighting requirements of the existing population of impacted customers for at least one month for a surface water source of water and at least six months for a groundwater source.*

Community Water System (CWS) - *means a public water system that serves at least 15 service connections used by year-round residents of the area or regularly serves at least 25 year-round residents.*

Non-transient Non-community Water System (NTNCWS) - *means a public water system that regularly serves at least 25 of the same persons over six months per year. Examples of these systems include schools, factories, and hospitals that have their own water supplies.*

Public Water System (PWS) - *means a system that provides the public water for human consumption through pipes or other constructed conveyances, if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year. These systems include the sources of the water supplies - i.e., surface or ground. PWS can be community, non-transient non-community, or transient non-community systems.*

Sole Source Aquifer (SSA) - *means an area designated by the U.S. Environmental Protection Agency under the Sole Source Aquifer program as the "sole or principal" source of drinking water for an area. Such designations are made if the aquifer's ground water supplies 50% or more of the drinking water for an area, and if that aquifer were to become contaminated, it would pose a public health hazard. A sole source aquifer that is karst in nature is one composed of limestone where the porosity is derived from connected solution cavities. They are often cavernous, with high rates of flow.*

Source Water Protection Area (SWPA) - *means the area delineated by the state for a public water supply system (PWS) or including numerous PWSs, whether the source is ground water or surface water or both, as part of the state source water assessment program (SWAP) approved by EPA under section 1453 of the Safe Drinking Water Act.*

Transient Non-community Water System (TNCWS) - *means a public water system that does not regularly serve at least 25 of the same persons over six months per year. This type of water system serves a transient population found at rest stops, campgrounds, restaurants, and parks with their own source of water.*

Wellhead Protection Area (WHPA) - *means the surface and subsurface area surrounding a well or well field that supplies a public water system through which contaminants are likely to pass and eventually reach the water well or well field.*

2.2 Model Application of PWS Filter Criterion # 1

Prior to the application of any filter criteria inactive PWS and all TNCWS are removed from the provided PWS data. Filter Criterion # 1 is then applied by simply identifying active CWS and NTNCWS surface water intakes in the PWS database and removing those with a confirmed AADWS. Those remaining are USAs. All surface water features (rivers, streams, ponds, lakes, etc.) within a five mile radius of a sensitive surface water intake are buffered by one-quarter mile inland and are designated as final or interim USAs.

2.3 Model Application of PWS Filter Criterion # 2

The application of Filter Criterion #2 is the most complex portion of the drinking water model. Accurate classification of the wells requires that a geologist reviews the digital data available to the model and constructs guidelines for well classification based on this data. These guidelines are then condensed into a “rules look up table” used for automated well classification in the GIS model. A synopsis of the rules developed for Ohio is shown in Table 1. Primary literature used in the construction of these rules usually consists of a USGS Hydrologic investigations atlas, a hard copy state geologic map and any pertinent literature produced by each state’s geological survey.

The aquifer classification scheme used for the application of Filter Criterion #2 was developed in 1991 for the U.S. Environmental Protection Agency (EPA) by Pettyjohn et al. and is published in the report “Regional Assessment of Aquifer Vulnerability and Sensitivity in the Conterminous United States” (USEPA/600/2-91/043). In the Pettyjohn scheme, the principal concept is that the geology of the aquifer(s) determines the vulnerability classification. This reasoning is supported by the basic relationships observed between rock type and hydrologic factors, such as permeability. Another factor in the scheme, closely linked to geology, is well yield. High yield wells receive higher priority for protection than low yield wells. The categories within the classification scheme are listed below:

1) Class Ia: Unconsolidated Aquifers: Surficial, unconsolidated, and permeable alluvium
2) Class Ib: Soluble and Fractured Bedrock Aquifers: Potentially cavernous (karst) carbonate and evaporite lithologies such as limestone, as well as heavily fractured crystalline bedrock
3) Class Ic: Semiconsolidated Aquifers: Moderately to poorly indurated sand and gravel interbedded with clay and silt units.
4) Class Id: Covered Aquifers: A Class I aquifer that is overlain by less than 50 feet of low permeability, unconsolidated material, such as glacial till, lacustrine, and loess deposits.
5) Class I: General: Wells shallower than 50 feet, for which source information is unavailable or cannot be validated by a geologist or the GIS model, were given a general Pettyjohn class of I (surficial) and treated as preliminary USAs. This is a modification of the Pettyjohn scheme as it appears in Pettyjohn et al. (1991).
6) Class IIa: Higher Yield Bedrock Aquifers: Bedrock of any non-carbonate lithology with well yields of 50 gallons per minute (gpm) or more.
7) Class IIb: Lower Yield Bedrock Aquifers: Bedrock of any non-carbonate lithology with well yields less than 50 gallons per minute (gpm).
8) Class IIc: Covered Bedrock Aquifers: Class IIa or IIb aquifers covered by less than 50 feet of low permeability, unconsolidated material.
9) Class III: Covered Consolidated or Unconsolidated Aquifers: Aquifers overlain by more than 50 feet of low permeability material.

In cases where a source aquifer cannot be determined, four alternative classifications of vulnerability are used:

1) Vulnerable (VUN)**:** 90% or more of the surrounding wells (within a defined search radius) derive water from vulnerable aquifers (Class I or IIa).
2) Non-vulnerable (NVUN): 90% or more of the surrounding wells (within a defined search radius) derive water from non-vulnerable aquifers (Class II, IIc, or III).
3) Surficial: Unable to assign vulnerability on the basis of surrounding wells and well depth is less than 50 feet.
4) Unknown (UNK): Used in cases where information necessary to classify the well is either inadequate or incorrect and precludes a Pettyjohn classification

Using the geologist's guidelines for well classification ESRI's ArcInfo was used to automate the classification. A complete outline of the model's application of Filter Criterion #2 is beyond the scope of this paper but a brief description of the flow and the major steps of the model will be discussed here. This portion of the model has several phases:

1) Validation of source aquifer information of each well (if provided)
2) Determination of source aquifer of wells that have no source information
3) Classification of wells with validated source aquifers
4) Classification of wells without validated source aquifers
5) Determination of final USAs via application of AADWS database

Source aquifer information is validated by overlying each well with its corresponding source aquifer boundary. If the well is located inside its corresponding aquifer boundary, then the well is flagged as having validated source information. If the well falls outside its corresponding aquifer boundary and aquifer subcrop extents are incorporated into that boundary, the source information is flagged as "could not be determined". If the well falls outside its corresponding aquifer boundary and aquifer subcrop boundaries are not available, then the well is flagged as needing source information to be validated interactively by a geologist. The geologist will then validate each of these systems after studying the geological maps, cross sections and well data (location and depth). If possible, the geologist will provide source information at this stage of the model.

Wells with no source information are assigned a source using one of two methods. The first method applies in the case of a state that has source information available for the majority of the wells in the state, provided there is an adequate distribution of these wells. Wells with no source are assigned on the basis of the wells surrounding them. The automated assignment of source information in this case is conducted using a search radius defined by the longest diagonal extent of the aquifer the well in question is located within. If well depth information is available, the well in question is assigned the same source that 90% of the surrounding wells have, provided there is no greater than 20 % difference in their total depth. If well depth information is not available the well in question is given a source only if 100 % of the wells surrounding it have the same source. The second method applies in the case of a state that has source information for only a limited number of wells (typically less than 40 %). In this scenario, there is not enough data to employ the search radius method. Instead wells are assigned source information on the basis of the aquifer they are located within. To make this a little more realistic the geologists rules may incorporate some depth cut-offs (if an adequate cross section exists), allowing for the some interpretation in source aquifer.

Once source aquifer information has been validated, the Pettyjohn class of the wells is determined on the basis of the validated source aquifer. Pettyjohn classification is achieved through the application of a "rules lookup-table" that contains outcrop and subcrop rules for each aquifer, sometimes with depth cut-offs. The look-up table is used to assign the Pettyjohn class based on the intersection of the well location, aquifer, geology, source aquifer, and well depth data when applicable. As discussed above, the table is derived from the Pettyjohn classification guidelines that are devised for each state by a geologist.

After the wells with a validated source are classified, the vulnerability of those remaining wells with no source information are determined on the basis of the classification of surrounding wells (within a search radius defined as it was for the attempted source validation).

The model is stopped at this point in order for the geologist to verify or contest the Pettyjohn classifications. It should be noted that Pettyjohn classifications are entirely the result of the model and cannot be assigned on a well-by-well basis interactively by the geologist. If a classification is contested at this point, the classification guidelines are checked and/or modified, "rules lookup-table" is modified, and the model re-run.

To provide documentation of how the Pettyjohn classifications were assigned (i.e. on the basis of existing source information, source information defined by the geologist, or source information assigned automatically via the GIS model), each well is given a quality code. The quality-coding scheme is listed below:

Quality Code = 1

Source information is available and the well is located within the boundary of the associated data layer (e.g. alluvial valley; geologic formation).

Quality Code = 2

Source information is available but the well is located outside the spatial tolerance of the associated data layer. Source information validated or negated based on other geological data.

Quality Code = 3

Source information is not available but geographic position, distance to nearest aquifer, and source information of surrounding wells within a defined search radius were used to classify the well.

Quality Code = 4

No source information available, source cannot be determined from other geological information, or source information available but well classification is not possible.

Quality Code = 5

Source information unavailable, cannot be determined from other geological information, and well classification impossible just as in quality code 4. However, due to its location within a Sole-Source Aquifer, the well is classified as though it derived water from the sole source aquifer, as a precaution.

After establishing the Pettyjohn classification of the wells the final step in applying Filter Criterion #2 is to apply the AADWS information, resulting in the determination of interim and final USAs. Class I, IIa, or Vulnerable Systems with no AADWS are final

USAs where as systems with inconclusive AADWS information are interim USAs. Systems that have an AADWS reliably identified are not considered USAs.

2.4 Model Application of PWS Filter Criterion # 3

Lastly any sole-source aquifer boundaries in the state are added to the model. Of particular concern are sole-source aquifers that are karst in nature. The sole source aquifer recharge area, where the sole source aquifer is karst in nature, is designated as a USA.

3.0 METHODOLOGY FOR DETERMINATION OF ECOLOGICAL USAs

3.1 Conceptual Framework and Definitions

The conceptual framework of the ecological USA identification process is based on four major candidate resource categories and five filter criteria.

3.1.1 Candidate Ecological Resources

1) Critically imperiled and imperiled species and ecological communities
2) Threatened and endangered species
3) Depleted marine mammal species
4) Migratory waterbird concentrations

3.1.2 Ecological Filter Criteria

The following ecological filter criteria determine which candidate ecological resources become USAs:

1) Areas with critically imperiled species or ecological communities are USAs
2) Areas with multi-species assemblages of candidate resources are USAs
3) Migratory waterbird concentration areas identified as Ramsar sites or Western Hemisphere Shorebird Reserve Network (WHSRN) sites classed as hemispheric, international, or endangered species reserves are USAs
4) Areas containing candidate resource occurrences of excellent quality or good quality are USAs (see Element Occurrence Rank definition, below)
5) Areas containing candidate species or ecological communities that are aquatic or aquatic-dependent, or are terrestrial with a limited range, are USAs.

3.1.3 Definitions:

In order to more clearly understand the criteria and their utility in the identification of ecological USAs, several terms and concepts require further definition. These definitions are provided below.

Aquatic and aquatic dependent species and ecological communities - *refers to species and ecological communities primarily occurring in aquatic, marine, or wetland habitats,* *as well as species that may use terrestrial habitats during all or some portion of their life cycle, but that are still closely associated with or dependent upon aquatic, marine, or wetland habitats for some critical component or portion of their life-history (i.e., reproduction, rearing and development, feeding, etc).*

Critically imperiled (G1, T1) species and ecological communities - *refers to species or ecological communities of extreme rarity, identified using rounded Global Conservation Status Ranks (GRANKs) assigned by the Association for Biodiversity Information (ABI), The Nature Conservancy (TNC), and the Natural Heritage Programs (NHPs) and Conservation Data Centers (CDCs). Critically imperiled species and ecological communities have generally 5 or fewer occurrences, very few remaining individuals (less than 1,000), or a very small remaining area (less than 2,000 acres). These species and ecological communities are extremely vulnerable to extinction due to some natural or man-made factor. Master (1991) and Stein et al. (2000) contain additional information concerning GRANK definitions and assignments.*

Depleted marine mammal species - *refers to species that are listed as depleted under the Marine Mammal Protection Act of 1972, as amended (16 U.S.C. 1361 et seq.). This category includes species that are listed as threatened or endangered, and those determined by the National Marine Fisheries Service (NMFS) to be below their optimum sustainable populations. Species that have been proposed for depleted status are not included in this category.*

Ecological community - *refers to an interacting assemblage of plants and animals that recur under similar environmental conditions across the landscape (e.g., vernal pools; swamp blackgum floodplain seepage forests; etc.).*

Element - *refers to an element of biodiversity, generally species or ecological communities (Stein et al. 2000).*

Element Occurrence (EO) - *refers to an element at a specific location; generally a delineated species population or ecological community stand. An element occurrence indicates a geographic entity that can be mapped (Stein et al. 2000). This term may at times be shorted to "occurrence" rather than EO.*

Element occurrence rank (EORANK) - *refers to the condition or viability of a species occurrence or ecological community occurrence, based on a population's size, condition, and landscape context. An EORANK of "A" means excellent quality, and EORANK of "B" means good quality. EORANKs are assigned to individual species occurrences and community occurrences by the NHPs or CDCs operating in a state or other jurisdiction. Stein et al. (2000) contains additional information concerning EORANK definitions and assignments. EORANK is used for Filter Criteria 4, listed above.*

Imperiled (G2, T2) species and ecological communities - *refers to rare species or ecological communities, identified using rounded GRANKs assigned by ABI, TNC, and the NHPs and CDCs. Imperiled species or ecological communities have generally 6 to*

20 occurrences, few remaining individuals (1,000 to 3,000), or small remaining area (2,000 to 10,000 acres). These species and ecological communities are vulnerable to extinction due to some natural or man-made factor.

Migratory waterbird concentration areas - *locations designated as Ramsar sites or Western Hemisphere Shorebird Reserve Network (WHSRN) sites*.

Multi-species assemblage area – *an area where three or more different critically imperiled or imperiled species or ecological communities, threatened or endangered species, depleted marine mammals, or migratory waterbird concentrations co-occur.*

Ramsar sites - *areas designated under The Convention on Wetlands of International Importance Especially as Waterfowl Habitat. Ramsar sites are globally critical wetland areas that support migratory waterfowl. These include wetland areas that regularly support 20,000 waterfowl; wetland areas that regularly support substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity, or diversity; and wetland areas that regularly support 1% of the individuals in a population of one species or subspecies of waterfowl.*

Species - *refers to species, subspecies, or distinct vertebrate populations (pertains to critically imperiled, imperiled, threatened and endangered, and depleted marine mammal species). Species also refers to population stocks (primarily pertains to depleted marine mammals). Species can also refer to other subtaxa groupings, such as plant varieties (pertains to critically imperiled and imperiled species).*

Terrestrial ecological communities with limited ranges - *refers to non-aquatic and non-aquatic dependent ecological community occurrences that cover less than five acres.*

Terrestrial species with limited ranges - *refers to non-aquatic and non-aquatic dependent species with ranges of no more than five acres. For species, range typically refers to individual home range. In a few cases, range can refer to "inferred extent" of the occurrence type, as defined by TNC and ABI, rather than home range.*

Threatened and endangered species (T&E) - *refers to animal or plant species that are listed as threatened or endangered under the federal Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.). Essential and non-essential experimental populations are included in this category. Proposed and candidate species are not included in this category.*

Western Hemisphere Shorebird Reserve Network (WHSRN) sites - *areas that contain migratory shorebird concentrations that have been designated as hemispheric reserves, international reserves, regional reserves, or endangered species reserves by the WHSRN program. Hemispheric reserves host at least 500,000 shorebirds annually or 30% of a species flyway population. International reserves host 100,000 shorebirds annually or 15% of a species flyway population. Regional reserves host 20,000 shorebirds annually or 5% of a species flyway population. Endangered species reserves* *are critical to the survival of endangered species and no minimum number of birds is required.*

3.2 Ecological USA Model

A GIS model is again used to integrate candidate resource data and base layer information from various sources and to apply the filter criteria. Most of the ecological candidate data comes from Natural Heritage Program (NHP) data sets produced by state NHPs and the Association for Biodiversity Information (ABI). Environmental Sensitivity Index (ESI) data comprise the other major ecological data source, particularly for coastal states. ESI data are produced primarily by NOAA, MMS, the U.S. Coast Guard, and various states. Base layer information includes hydrography from USGS Digital Line Graph (DLG) sources, state and county boundaries, state waters, etc. The ecological USA model is outlined in the following section.

The ecological USA model has several phases:

1) Prepare data for model entry
2) Identify records meeting data quality criteria
3) Identify records meeting candidate criteria
4) Apply filter criteria
5) Generate USA boundaries
6) Final USA QA/QC, maps, and statistics

Prepare Data for Model Entry

During this phase, the original data is reviewed and any questions or inconsistencies addressed. Various standard model fields are created and updated based on: the original data fields and values, data from supporting sources, information assigned by project staff. Staff-assigned information includes habitat assignments for all point occurrences, and aquatic-dependent and limited range assignments by species or ecological community type. Habitat assignment categories are: aquatic open-water, aquatic isolated, and terrestrial. Aquatic open-water is the major distinction, and refers to species that occur in permanent open or flowing waters such as oceans, bays, lakes, rivers, etc. Ecological data from different sources, including data from adjacent portions of bordering states, are combined during this phase, prior to entry into the model.

Identify Records Meeting Data Quality Criteria

All data records are examined to determine if they meet certain data quality criteria. The first data quality criterion pertains to the precision or accuracy of the point locations or polygons representing resource occurrences. Records with imprecise or generalized locations are dropped by the model and do not become USAs. The second data quality criterion removes elements or occurrences that are extirpated (no longer present or existing in a state or at a particular location).

Identify Records Meeting Candidate Criteria

Next, the model determines which occurrences or data records meet the ecological candidate USA criteria. Critically imperiled, imperiled, threatened, endangered, and depleted (marine mammal) resource occurrences, as well as all Ramsar and WHSRM sites, are selected by the model. The model retains candidate resources for further consideration as USAs. Resources not identified as candidates are omitted.

Apply Filter Criteria

The model next applies the filter criteria to the candidate resources to identify USAs. Under Filter Criteria 1, all critically imperiled candidates are identified as USAs. The model moves to Filter Criteria 3 next, where all Ramsar sites are identified as USAs and WHSRN sites classified as hemispheric, international, and endangered species reserves are identified as USAs. Regional WHSRN sites are not considered USAs, but are retained for evaluation under Filter Criteria 2. Filter Criteria 4 evaluates the quality of candidate occurrences. Candidates originating from NHP data sources are evaluated, and records with EORANK values of A or B are identified as USAs. Records originating from ESI data or other sources are not evaluated unless items and values comparable to EORANK are available. Filter Criteria 5 selects candidates that are aquatic dependent or limited range as USAs. Filter Criteria 2 is the final filter criteria evaluated by the model. Under Filter Criteria 2, each occurrence or record that contributes to a combination of three or more overlapping resource types is identified as a USA resource in its entirety.

Generate USA Boundaries

USAs created from polygonal source data are assigned the same boundaries as the original polygons . USAs originating from point data receive boundaries based on their habitat assignments. USAs for aquatic isolated and terrestrial point occurrences are defined using 1-mile buffers around the point locations. USAs for aquatic open-water occurrences are defined by selecting all surface water features that fall within 5 miles of the point location, plus a 1/4 mile buffer distance onto land.

Final USAs: QA/QC, Maps, and Statistics

After the model run, a draft version of the final USAs and interim coverages generated by the model are reviewed by scientific and GIS staff. Once the final USAs are approved, a map is produced for each state using a standardized layout and statistics are generated. Currently, statistics include calculating the percentage of state lands and waters occupied by ecological USAs.

4.0 DATA INPUT

4.1 Drinking Water Source Data for Ohio

The PWS and SWPA data used were collected from the Ohio office of the Environmental Protection Agency (EPA) which maintains a database of public water sources. Well data included well location, top of the screened interval, production rates, and maximum well depth. Source aquifer information was not available, so well sources were assigned on the basis of well location and screen depth. A total of 10477 PWSs were obtained. Sources listed as inactive and/or TNCWS were removed from the data set (see discussion below) resulting in total model output of 5038 PWSs. Of these, 4574 were groundwater systems 464 were surface water systems and 0 were springs.

AADWS information was obtained through telephone surveys using contact information provided by the Ohio Office of Public Health. In AADWS phone surveys, individual well operators were asked if they knew of a backup source of water for their wells that met the definition of AADWS as outlined above.

Aquifer maps for the entire state were available in a digital format from the Ohio Department of Natural Resources Water Division's Statewide Aquifer Mapping Project web page (*http://www.dnr.state.oh.us/water/samp/default.htm*). The digital maps obtained covered the extent of all prominent bedrock aquifers (31 individually mapped aquifers) as well as the distribution and classifications of overlying glacial and fluvial alluvium. Digital data describing the thickness of the alluvium overlying the bedrock was also obtained from the Ohio DNR. These datasets were combined to form the aquifer map shown in Figure 1.

The state's four Sole Source Aquifers and their boundaries were obtained in a digital format from the Ohio EPA as well. The USGS Hydrologic Investigations Atlas 730-K (Lloyd and Lyke,1995) was the primary literature used in evaluating the aquifers and deriving Pettyjohn classifications.

Input to the GIS model also includes USGS 1:100,000-scale Digital Line Graph (DLG) information to represent the hydrography (or surface water features) in each state. The DLG data are digital representations of points, lines, and areas of planimetric information derived from 30- by 60-minute intermediate scale quadrangle maps. The data are considered DLG – Level 3 (DLG-3), which means the data contain a full range of attribute codes, have full topological structuring, and have passed quality-control checks described in the Federal Geographic Data Committee's (FGDC) Content Standards for Digital Geospatial Metadata.

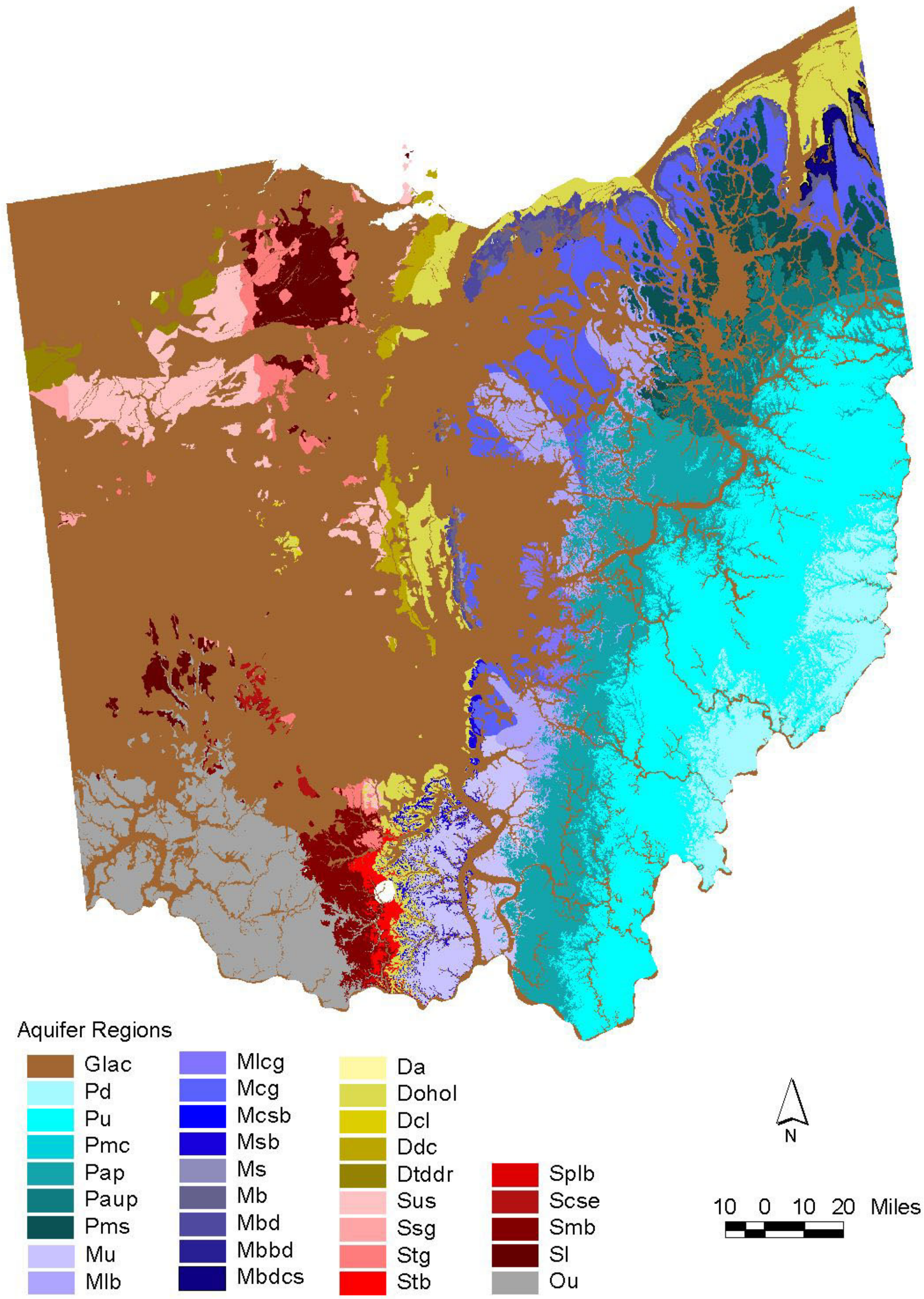

FIGURE 1 Ohio's Aquifer's as compiled from Ohio Department of Natural Resources data. See Table 1 for brief description and definition of map abbreviations.

3.1 Ecological Data Sources for Ohio

The NHP data set provided by ABI (http://www.abi.org) and the Ohio Natural Heritage Program (http://www.dnr.state.oh.us/odnr/dnap/dnap.html) was the primary data source for ecological USAs in Ohio. The NHP data set for Ohio contained 38 species and 379 element occurrence records (all point features). No ecological community occurrences for the state of Ohio were provided with the NHP data. Of the 38 species, 20 were federally listed as threatened or endangered (189 occurrences), 6 had a critically imperiled global conservation status (44 occurrences), and 26 had an imperiled global conservation status (247 occurrences). Thirty-eight data records from the Indiana Natural Heritage Data Center (http://www.ai.org/dnr/naturepr/index.htm) were also used along the western border of Ohio. Ohio had one regional WHSRN site, the Lake Erie Marshes. A GIS coverage depicting this area was developed by transferring boundary lines from a map produced by Ducks Unlimited to a 1:100,000 NOAA Nautical Chart and digitizing the boundaries. Ohio had no Ramsar sites. ESI biological resources data were not available for this state. Hydrography used in the Ohio model originated from the USGS 1:100,000 DLGs.

4.0 RESULTS

Generation of Groundwater USAs was completed in October of 2001. The Ecological USA database was completed in March of 2001 . Figure 2 (IN PREP) shows the distribution of all USAs within the state of Ohio. (IN PREP) % of the state's area is considered unusually sensitive to environmental damage in the event of a hazardous liquid pipeline accident. The USA types break down as follows:

4.1 Surface Water USAs

Of the 464 active surface water intakes input into the model, 298 became surface water USAs. The highest concentrations are found in northern Ohio the along the lake Erie shoreline and the associated drainage network. Surface water USAs also exist along the Maumeo River west of Toledo. Other notable concentrations are present along the Ohio river and it's tributaries in Scioto and Hamilton counties.

4.2 Ground Water USAs

Of the 4574 groundwater systems input in to the model 1949 (roughly 43%) of them became USAs (of either final or interim standing). As was expected the majority of the USAs, 1677 of them, were associated with the unconsolidated alluvial and glacial deposits that cover western and central Ohio (Fig. 1). The Silurian limestones of western Ohio (Fig. 1), when unglaciated or covered by thin or highly permeable glacial material, account for most of the remaining USAs with a total of 205. The unglaciated eastern portion of Ohio contained few groundwater USAs due to the presence of confining shales and an abundance of low yield sandstones. In terms of political boundaries Portage, Summit, Clark, Miami, Franklin, and Montgomery counties contained the largest concentrations of groundwater USAs.

4.3 Ecological USAs

Ecological USAs for Ohio cover roughly 7% of the state. Areas with major concentrations of ecological USAs include: the northwestern corner of the state (Williams, Defiance, and Paulding counties); shorelines and wetlands of western Lake Erie (Lucas, Ottawa, Sandusky, and Erie counties); several locations along the Ohio River and its tributaries; portions of several counties between Cincinnati and Dayton; Wyandot County (roughly half-way between Toledo and Columbus); and several counties surrounding the greater Columbus area. Most of these areas correspond with one or several liquid petroleum pipeline routes. Excluding records that did not meet the data quality criteria, ecological USAs included at least one example of all species found in the Ohio NHP database. Ecological USAs included critically imperiled and imperiled species, threatened and endangered species, and the Lake Erie Marshes WHSRN site.

5.0 REFERENCES

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TABLE 1. Aquifers of Ohio and Their Pettyjohn Classification.

Aquifer Name	Aquifer Description	Pettyjohn Classification
GLAC	Unconsolidated glacially and fluvially derived permeable sediments (alluvial valley fill, outwash, kames, eskers) as well as thick cover of impermeable ground and end moraines	Class Ia if located within modern or buried river valley alluvium, outwash, or Kame deposits. Class Id if screened at depths less than 50 ft deep and located within tills. All wells subject to Class III ranking or classification according to underlying bedrock if screened at depths greater than total unconsolidated thickness. (Rules 2-4)
Pd	Dunkard Group, low yield (0-25 gpm) sandstones w/ minor limestone Thin or no glacial cover present	Class IIb. Wells within regions covered by thin and non-aquifer glacial sediments (thin upland setting or lithcode= T) are Class IIc. (Rule 5)
Pu	Pennsylvanian undivided, a series of shales, siltstones and low yield (0-25 gpm) sandstones with minor limestones Thin or no glacial cover present	Class IIb, Wells within regions covered by thin and non-aquifer glacial sediments (thin upland setting or lithcode= T) are Class IIc, max casing depth =1500 ft (Rule 6)
Pmc	Monongahela and Conemaugh Group, shales, siltstones, and mudstones, minor limestones and coal typically low yield (0-25 gpm), Thin or no glacial cover present	Class IIb, Wells within regions covered by thin and non-aquifer glacial sediments (thin upland setting or lithcode= T) are Class IIc, max casing depth =500 ft (Rule 6)
Pap	Allegheny and Pottsville undivided, shales, siltstones, sandstones, and conglomerates, typically low yield (0-25 gpm), Thin or no glacial cover present	Class IIb, Wells within regions covered by thin and non-aquifer glacial sediments (thin upland setting or lithcode= T) are Class IIc, max casing depth =500 ft (Rule 6)
Paup	Allegheny and Upper Pottsville undivided, a series of shales, siltstones and sandstones, typically low yield (0-25 gpm)	Class IIb, Wells within regions covered by thin and non-aquifer glacial sediments (thin upland setting or lithcode= T) are Class IIc, max casing depth =500 ft (Rule 6)
Pms	Massillon through Sharon formations undivided, coarse to medium sandstones Yields up to 100 gpm	Class IIa, up to 300 ft. Wells > 300 ft depth likely source the Mississippian subcrop. Wells within regions covered by thin and non-aquifer glacial sediments (thin upland setting or lithcode= T) are Class IIc. (Rule 7)
Mu	Mississippian undivided siltstone, sandstone, and shale w/ minor limestones Typically low yield (0-5 gpm)	Class IIb up to 500 ft., Class III beyond.Wells within regions covered by thin and non-aquifer glacial sediments (thin upland setting or lithcode= T) are Class IIc. (Rule 8)
Mlb	Logan and Black Hand undivided, high yield (up to 100 gpm) sandstones w/ minor siltstones and shales	Class IIa, Wells in the southern-most region (Mlbalb #'s 25 and 28) may be up to 700 ft deep and still derive water from the Black Hand Sandstone. (Rule 9)
Mlcg	Logan and Cuyahoga Group undivided (no Black Hand Present), Interbedded shales and sandstones, Typically low yield (0-5 gpm)	Class IIb up to 500 ft., Class III beyond.Wells within regions covered by thin and non-aquifer glacial sediments (thin upland setting or lithcode= T) are Class IIc. (Rule 8)
Mcg	Cuyahoga Group, Interbedded shales and sandstones, Typically low yield (0-5 gpm)	Class IIb up to 500 ft., Class III beyond.Wells within regions covered by thin and non-aquifer glacial sediments (thin upland setting or lithcode= T) are Class IIc. (Rule 8)
Mcsb	Coldwater Shale, Sunbury-Berea-Bedford undivided, carbonaceous, silty shales	Class III due to the confining nature of the shales. Wells in these regions tap into the underlying Berea Sandstone (Rule 10)
Msb	Sunbury Shale, Berea Sandstone, and Bedford Shale undivided, shales and sandstones	Class III due to the confining nature of the shales. Wells in these regions tap into the underlying Berea Sandstone (Rule 10)
Ms	Sunbury Shale, carbonaceous shales, considered an aquifer only when underlain by Berea sandstone	Class III due to the confining nature of the shales. Wells in these regions tap into the underlying Berea Sandstone (Rule 10)
Mb	Berea Sandstone, very fine grained sandstone, in some areas non-potable, typically low yield (5-25 gpm)	Class IIb,. Wells within the outcrop deeper than 100 ft, have tapped into deeper aquifers and are Class III, Wells within regions covered by thin and non-aquifer glacial sediment (thin upland setting or lithcode= T) are Class IIc. (Rule 11)
Mbd	Bedford Shale, considered an aquifer only where not overlain by Berea Sandstone	*Class III, because of the confining nature of the shale. Typically the shale itself is not serving as the aquifer, rather, a permeable sandstone unit below the shale (as is sometimes the case with the Cussewago Sandstone).* (Rule 12)

TABLE 1. Continued *Aquifers of Ohio and Their Pettyjohn Classification.*

Mbbd	Berea Sandstone and Bedford Shale undivided, stratigraphically equivalent to the three previously listed aquifers, typically low yield (5-25 gpm)	Class IIb,. Wells within the outcrop deeper than 100 ft, have tapped into deeper aquifers and are Class III, Wells within regions covered by thin and non-aquifer glacial sediment (thin upland setting or lithcode= T) are Class IIc. (Rule 11)
Mbdcs	Bedford Shale, Cussewago Sandstone, Cussewago is a medium grained sandstone	Class III, because of the confining nature of the shale. Typically the shale itself is not serving as the aquifer, rather, a permeable sandstone unit below the shale (as is sometimes the case with the Cussewago Sandstone). (Rule 12)
Da	Antrim Shale	Class III, because of the confining nature of the shale. Typically the shale itself is not serving as the aquifer, rather, a permeable sandstone unit below the shale serves as the aquifer (Rule 13)
Dohol	Ohio and Olentangy Shales	Class III, because of the confining nature of the shale. Typically the shale itself is not serving as the aquifer, rather, a permeable sandstone unit below the shale serves as the aquifer (Rule 13)
Dcl	Columbus-Lucas undifferentiated, dolomites, Karst present in Columbus limestone	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Ddc	Delaware and Columbus Limestones, argillaceous and fossiliforous limestones and dolomites. Karst exists in Columbus limestone	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Dtddr	Traverse, Dundee, Detroit River Group, includes Holland Quarry Shale, Cherty dolomites, limestones and shales and a basal sandstone	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Sus	Undifferentiated Salina Dolomite, includes Bass Islands Group, dolomite	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Ssg	Salina Group, Thin bedded dolomite with shale partings and brecciated intervals	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Stg	Tymochtee and Greenfield Dolomites, Thin bedded dolomite with shale partings and brecciated intervals	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Stb	Tymochtee, Greenfield, and Peebles Dolomites, Lilly and Bisher Formation undivided, Dolomites with minor limestones and shales	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Splb	Peebles Dolomite, Lilly and Bisher Formation undivided, Dolomites with minor limestones and shales	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Scse	Cedarville, Springfield and Euphemia Dolomite includes Massie Shale and Laurel Dolomite where present	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Smb	Massie and Osgood Shales, Laurel Dolomite, Dayton and Brassfield Limestones Noland Formation and Estill Shale	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Sl	Lockport Dolomite/sub-Lockport undifferentiated, Massive dolomites, stratigraphcally equivalent to Scse, and Sm-b	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 14)
Ou	Ordovician undividedshales w/ interbedded dolomites and limestones, produces only from the upper fractured portion of aquifer	Class Ib when located in thin permeable cover. Class Id when located in thin and non-aquifer glacial sediment (thin upland setting or lithcode = T) (Rule 15)