Development of Community Water System Drinking Water Intake Percent Cropped Area Adjustment Factors for use in Drinking Water Exposure Assessments: 2014 Update

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Forward

The United States Environmental Protection Agency (USEPA), Office of Pesticide Programs (OPP) initiated a peer review of an earlier draft of this document (titled *Development of Community Water System Drinking Water Intake Percent Cropped Area Adjustment Factors for use in Drinking Water Exposure Assessments,* dated 10/10/2012). Internal and external experts who were familiar with the datasets used in the calculation of Percent Cropped Area (PCA) adjustment factors or with occurrence of pesticides in drinking or surface water were asked to provide comments on the document and respond to charge questions. Consistent with USEPA's Peer Review guidelines, the feedback from reviewers was carefully considered and this document was updated accordingly.

Summary

Watersheds large enough to support a drinking water facility are generally not comprised of only one land cover type, nor planted completely with a single crop. In order to account for variability in land cover, the USEPA uses percent cropped area (PCA) adjustment factors to reflect the percentage of a watershed that is covered by a particular land cover type and/or crop. Modeled concentrations of pesticides in surface waters are multiplied by a PCA to account for the areal fraction of a watershed that may be treated with a particular pesticide based on the pesticide uses and the land cover types (*i.e.,* crops) associated with those uses. The PCA-adjusted concentrations are used as the estimated drinking water concentrations (EDWCs) in human health risk assessment. Previously, PCAs were generated for Hydrologic Unit Code 8 (HUC-8)[1] regions. In this update, PCAs have been generated for watersheds delineated based on surface-source drinking water intakes (DWI) of community water system (CWS) across the United States. The new PCAs are an improvement over previously calculated PCAs in terms of relevance to human health risk assessment because the PCAs were derived for known drinking water sources. A CWS-DWI dataset, version 1.0, was used as the source of intakes and associated watersheds. Watersheds were delineated for CWS-DWIs with available tools and data. For some surface water-sourced CWS either it did not make sense to delineate a watershed for the DWIs, or watersheds were generated but subsequently failed to pass a quality assurance screen. Out of 6,550 DWI locations which both met the selection criteria for watershed delineation and passed a quality assurance screen, 74% (4,840) had unique, delineated watersheds which also passed a quality assurance screen. Of these, all but two (4,838) were located in the continental United States. For another 637 quality assured DWI locations in the continental U.S. which lacked quality assured watersheds, HUC-12 regions were taken as watershed surrogates. Maximum PCAs for the quality assured watersheds and HUC-12 surrogates in the continental U.S. (listed by HUC-2 water resource region) to use in representing various crops and two-crop combinations are shown in **Table 1** and **Table 2**, respectively. The national maximum value(s) in each case are shaded in the tables. When using PCAs to modify surface water modeling results, all of the potential pesticide use sites (*i.e.*, currently registered or proposed for registration) must be considered together, and used to select an appropriate PCA.

[1] Hydrologic units are part of a hierarchical system for classifying and mapping drainage areas in the United States (Seaber *et al.*, 1987). The largest units (regions) are designated by two digits, and hence are often called 2-digit HUCs. Subdivisions of regions are designated with additional digits. There are 2,264 8-digit HUCs in the United States.

Table 1. Maximum percent cropped area (PCA) adjustment factors for various crops, by Water Resource Region (HUC-2). Listed PCAs are specifically recommended for use in surface drinking water exposure modeling.

HUC-2	All-Ag[a]	Corn	Cotton	Orchard	Soybean	Vegetable	Wheat	Turf[b]
01	0.32	0.08	0.00	0.02	0.00	0.10	0.00	0.86
02	0.82	0.34	0.06	0.07	0.11	0.03	0.06	0.60
03	0.52	0.09	0.08	0.12	0.20	0.08	0.10	0.64
04	0.92	0.35	0.00	0.05	0.44	0.04	0.11	0.85
05	0.90	0.51	0.02	0.03	0.59	0.02	0.10	0.49
06	0.45	0.10	0.04	0.02	0.10	0.01	0.03	0.38
07	1.00	0.68	0.00	0.00	0.58	0.01	0.27	0.59
08	0.75	0.21	0.20	0.00	0.07	0.00	0.05	0.52
09	0.95	0.16	0.00	0.00	0.21	0.02	0.41	0.06
10	1.00	0.36	0.00	0.00	0.37	0.02	0.27	0.51
11	0.79	0.20	0.07	0.05	0.34	0.01	0.39	0.70
12	0.77	0.11	0.21	0.03	0.01	0.04	0.18	0.25
13	0.52	0.01	0.01	0.01	0.00	0.01	0.00	0.11
14	0.37	0.02	0.00	0.00	0.00	0.01	0.06	0.08
15	0.41	0.01	0.04	0.03	0.00	0.19	0.08	0.49
16	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
17	0.72	0.01	0.00	0.02	0.00	0.01	0.38	0.35
18	0.74	0.15	0.05	0.33	0.00	0.16	0.07	0.59

[*]Shaded cells indicate the highest value for each crop.
[a] Considers all-agriculture PCAs calculated both ways. The highest All-Ag values from Tables 3-2 and 3-4 are listed here.
[b] Represents residential turf including golf courses, but does not include sod farms. Sod farms are included in the all-agriculture land cover class PCA.

Table 2. Maximum percent cropped area (PCA) adjustment factors for various crop combinations, by Water Resource Region (HUC-2). Listed PCAs are specifically recommended for use in surface drinking water exposure modeling.

HUC-2	Corn-Wheat	Soybean-Wheat	Turf[a]-Corn	Turf[a]-Orchard	Turf[a]-Soybean	Turf[a]-Vegetable	Turf[a]-Wheat	Vegetable-Orchard	Turf[a,b]-All Ag
01	0.08	0.00	0.86	0.86	0.86	0.86	0.86	0.12	0.98
02	0.36	0.17	0.60	0.60	0.60	0.60	0.60	0.10	0.82
03	0.18	0.25	0.64	0.64	0.64	0.64	0.64	0.13	0.65
04	0.42	0.52	1.00	0.85	0.85	0.85	0.85	0.06	1.00
05	0.52	0.59	0.58	0.49	0.64	0.49	0.49	0.04	0.96
06	0.13	0.13	0.38	0.38	0.38	0.38	0.38	0.03	0.58
07	0.73	0.85	0.72	0.59	0.65	0.59	0.59	0.01	1.00
08	0.22	0.12	0.53	0.52	0.52	0.52	0.52	0.00	0.75
09	0.42	0.44	0.20	0.06	0.25	0.07	0.46	0.02	0.99
10	0.38	0.47	0.51	0.51	0.51	0.51	0.51	0.02	1.00
11	0.41	0.55	0.70	0.70	0.70	0.70	0.70	0.05	0.81
12	0.20	0.18	0.29	0.25	0.25	0.25	0.26	0.07	0.82
13	0.01	0.00	0.11	0.11	0.11	0.11	0.11	0.02	0.57
14	0.06	0.06	0.09	0.08	0.08	0.08	0.10	0.01	0.41
15	0.08	0.08	0.49	0.49	0.49	0.50	0.50	0.23	0.57
16	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.00	0.07
17	0.38	0.38	0.35	0.35	0.35	0.35	0.40	0.03	0.74
18	0.18	0.07	0.59	0.59	0.59	0.59	0.59	0.34	0.83

[*]Shaded cells indicate the highest value for each crop.
[a] Represents residential turf including golf courses, but does not include sod farms. Sod farms are included in the all-agriculture land cover class PCA.
[b] Because all-agriculture PCAs were calculated two different ways, some exceed the maximum Turf-All Ag PCAs. In such cases (*i.e.*, for HUC-2 regions 2 and 8), the maximum all-agriculture PCA is substituted in this table for the regional maximum Turf-All-Ag PCA listed in Table 3-7.

This document presents a history of the development and use of PCAs as used by the Office of Pesticide Programs (OPP), and the process used for calculating CWS-DWI specific PCAs. **Chapter 1** provides an overview of the history of PCAs, and describes DWI PCAs. **Chapter 2** documents the development of the CWS-DWI dataset and the use of HUC-12 surrogates for a subset of quality assured intakes that do not have quality assured watersheds. **Chapter 3** describes the methods used to develop the PCAs, and presents a summary of results. **Chapter 4** compares modeled drinking water concentrations, modified using DWI PCAs, to observed concentrations reported in monitoring studies for a number of pesticides. **Chapter 5** discusses uncertainties and limitations of the DWI PCA dataset, and presents suggestions on ways in which DWI PCAs may be used for risk assessment purposes.

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Nomenclature and Acronyms

Abbreviation	Definition
CDL	Cropland Data Layer
CWS-DWI	Community Water System Drinking Water Intake
EDWC	Estimated Drinking Water Concentration
EFED	Environmental Fate and Effects Division in the USEPA Office of Pesticide Programs
EXAMs	Exposure Analysis Modeling System
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FQPA	Food Quality Protection Act
GIS	Geographic Information System
HUC	Hydrologic Unit Code
NASS	National Agricultural Statistics Service (USDA)
NHD, NHDPlus	National Hydrography Dataset
NLCD	National Land Cover Database
OCSPP	Office of Chemical Safety and Pollution Prevention (USEPA)
OGWDW	Office of Ground Water and Drinking Water in the USEPA Office of Water
OPP	Office of Pesticide Programs (USEPA)
OW	Office of Water (USEPA)
PCA	Percent Cropped Area
PRZM	Pesticide Root Zone Model
PSDB	Public-Supply Database of Community Water System Intakes (developed by USGS)
SAP	Scientific Advisory Panel
SDWIS	OGWDW's Safe Drinking Water Information System (SDWIS) database
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WBD	Watershed Boundary Dataset

Chapter 1. Purpose, History, and Overview of Updates of PCA Adjustment Factors

1.1 Introduction

In response to requirements enacted by Congress under the Food Quality Protection Act of 1996 (FQPA), the United States Environmental Protection Agency (USEPA) routinely includes estimates of pesticide concentrations in drinking water as a part of its dietary exposure assessments supporting the pesticide registration process. Generation of estimated drinking water concentrations (EDWCs) typically employs computer modeling to simulate pesticide fate and transport. USEPA's Office of Pesticide Programs (OPP) uses the Pesticide Root Zone Model (PRZM) to simulate chemical behavior on, and movement (via runoff) from, a treated field to a receiving water body that is simulated using the Exposure Analysis Modeling System (EXAMS) model. For drinking water exposure assessments, OPP simulates a standard receiving water body, referred to as the "index reservoir", which has dimensions and characteristics based on those of Shipman City Lake — a small, midwestern reservoir in an agricultural setting, intended to represent vulnerable surface water sources of drinking water[2].

Prior to 2000, the USEPA employed the conservative assumptions that the entire area of a watershed was planted with the crop of interest (*i.e.*, 100% crop coverage), and thus the entire watershed could potentially be treated with a given pesticide. After a 1999 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel (SAP)[3] consultation, the USEPA began implementing the use of PCAs in generating EDWCs, to account for the fraction of a watershed potentially planted with the same crop, recognizing that the entirety of watersheds large enough to support drinking water facilities may not be used to grow single crops. This step was intended to improve the quality and accuracy of USEPA's EDWCs used for human exposure. In standard practice, to generate EDWCs, model-estimated concentrations from PRZM-EXAMS are multiplied by the appropriate PCA[4].

This document presents and describes the development of PCAs specific to community water system-drinking water intakes (CWS-DWIs) that draw from surface water sources. The CWS-DWI watershed-based PCAs are intended to update, replace, and improve upon the

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[2] See "Development and Use of the Index Reservoir in Drinking Water Exposure Assessments" on the OPP Water Models web page (http://www.epa.gov/oppefed1/models/water/index_reservoir_dwa.html) for more information on the index reservoir approach.

[3] http://www.epa.gov/scipoly/sap/index.htm

[4] PRZM/EXAMs model inputs include values for certain physical-chemical properties of the pesticide, application practices, crop agronomic information, precipitation, and soil properties. In the standard scenarios used to estimate pesticide exposure, it is assumed that 100% of the field is treated. More information on these models is available at: http://www.epa.gov/oppefed1/models/water/.

Hydrologic Unit Code level 8 (HUC-8) polygon-based PCAs used for calculating EDWCs. Previous PCA documentation[5] includes:

- *Applying a Percent Crop Area Adjustment to Tier 2 Surface Water Model Estimates for Pesticide Drinking Water Exposure Assessments*, dated December 7, 1999
- *Use of Regional Percent Crop Area Factors in Refined Drinking Water Assessments*, dated July 25, 2003
- *Development and Use of Percent Cropped Area and Percent Turf Area Adjustment Factors in Drinking Water Exposure Assessments: 2012 Update*, dated March 16, 2012

The methods used to derive the DWI PCAs are essentially the same as those described in earlier documents, but improve on previous efforts by focusing on watersheds that are specific to CWS surface water sources. The USEPA Office of Water, Office of Groundwater and Drinking Water's (OGWDW) Safe Drinking Water Information System (SDWIS) database contains a comprehensive list of CWS that report the use of surface water as a source for drinking water. From this dataset, the locations of 6,550 surface water intakes that supply water to these reported CWS have been quality-assured. Watersheds for 4,840 of these intake locations have been delineated and quality-assured. All but 2 of these are located in the continental United States, and the 4,838 that are have been used as the basis for PCA calculation.

1.2 Brief Overview of the Derivation of Percent Cropped Area Adjustment Factors

In order to derive PCAs, USEPA incorporated data on the acreage of crops of interest within a geospatial context. In keeping with methods first presented to the 1999 FIFRA SAP, USEPA employed the most current update of the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Census of Agriculture (Ag Census), which reports total acres of various agricultural crops grown in each county in the United States every five years[6,7]. USEPA also used the most current (2006) version of the National Land

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[5] Current and archived documents relevant to PCA development are available at Environmental Fate and Effects Division Water Models website (http://www.epa.gov/oppefed1/models/water/).

[6] Information on the Ag Census and data downloads are available from the USDA Census of Agriculture web site: http://www.agcensus.usda.gov/index.php. The most recently available Ag Census dataset for use in this analysis was for 2007.

[7] The Census of Agriculture, taken every five years, provides the only comprehensive source of impartial crop acreage (acres harvested) for every county and farm in the United States. There is also an Agricultural Survey Program that provides crop acreage estimates (harvested and planted acres) for counties on a quarterly and annual basis based on a subset of responders from the Census of Agriculture. Information from the Census of Agriculture is considered a more reliable source for crop acreage as it does not involve any estimates based on a subset of responders. Therefore, the Census of Agriculture is used as the source of crop acreage information. It is noted that acres harvested will be lower than acres planted, and that this introduces uncertainty into PCA estimates.

Cover Database (NLCD) geospatial data [land cover categories 82 (cultivated crops[8]) and/or 81 (pasture/hay[9])] to create a generic cropland distribution map within each county. Crop acreage within each county was apportioned to the locations within the county used for agriculture, as indicated by NLCD. DWI watersheds were then overlaid (conceptually) on the crop distribution maps, and PCAs were calculated for each watershed based on spatial overlap of the crop acreage within each watershed area.

The above-described process employs an assumption that crop acreages reported in the Ag Census are uniformly distributed across all agricultural land within a county, and that the reported cropping patterns are stable over time. While it is known that these assumptions are not technically true (*e.g*., changes in crop acreage commonly occur from year to year and many crops are not evenly distributed across all agricultural land), these assumptions are necessary to calculate and use PCAs. As noted in the **History of PCA Development** section, these assumptions have implications regarding which crops are suitable for PCA development and how PCAs may be used in drinking water assessments.

1.3 History of PCA Development

The concept of using a factor to adjust modeled estimates of pesticide concentrations in surface drinking water to account for heterogeneous land uses was first proposed to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel (SAP) in December, 1997 (Jones and Abel, 1997). In May 1999, USEPA presented to the SAP: "*Proposed Methods for Determining Watershed-derived Percent Crop Areas and Considerations for Applying Crop Area Adjustments to Surface Water Screening Models"* (Effland *et al.*, 1999). USEPA proposed PCAs for ten crops (corn, soybeans, wheat, cotton, apples, citrus, grapes, peanuts, potatoes, and strawberries), using the USDA Census of Agriculture for crop acreages by county and the United States Geological Survey's (USGS) HUC-8s as surrogates for CWS watersheds. Though not usually true watersheds (Omernik, 2003), hydrologic units are a hierarchical system developed by USGS to classify contiguous drainage areas within the U.S. (**Figure 1-1**) (Seaber *et al.*, 1987). In this system, hydrologic units are arranged within each other, such that each unit is identified by a unique code (HUC) consisting of two or more digits based on the level of classification in the hydrologic unit system[10]. At the time of the original

[8] 2006 NLCD Land Cover Category 82 is labeled as cultivated crops. It is defined as, "areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of the total vegetation. This class also includes all land being actively tilled" (USGS, 2011).
[9] 2006 NLCD Land Cover Category 81 is labeled Pasture/Hay. It is defined as, "areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle" (USGS, 2011). Pasture/hay vegetation accounts for greater than 20% of total vegetation.
[10] http://water.usgs.gov/GIS/huc.html

PCA analysis, the HUC-8 scale was the finest resolution available nationally. Use of HUC-8s was proposed in lieu of CWS DWI watersheds, which were not available in a national spatial dataset. As a part of its submission to the SAP, USEPA compared PCA-adjusted EDWCs to relevant available monitoring data.

Figure 1-1. **Illustration of the Hierarchical Hydrologic Unit Code System Developed by USGS to Categorize Hydrologic Units**

The SAP concluded that the PCA approach "appeared to perform reasonably well with major crops in the Midwest and can be comfortably applied under those conditions" (USEPA, 1999). Based on SAP concerns about how well the assumption of uniform crop distributions held for minor crops that covered less acreage, and the degree to which HUC-8s may not represent smaller CWS watersheds, PCAs for other crops or crop combinations were not adopted. The SAP recommended moving from HUC-8 hydrologic units to CWS-specific drainage areas once such watershed delineations became available nationally. The SAP also recommended evaluating any future PCAs with pesticide monitoring data to ensure that the PCA adjustments do not result in underestimation of pesticide concentrations in drinking water.

Subsequent SAPs on the Organophosphate Cumulative Risk Assessment[11] reiterated the difficulties in deriving PCAs for minor crops due to non-uniform cropping intensities and concerns that HUC-8s may not adequately represent smaller watersheds capable of supporting drinking water supplies (USEPA, 2002).

In response to the need to refine drinking water exposure assessments over subsequent years, USEPA developed a national "default PCA" adjustment factor for crops other than the four major crops endorsed by the 1999 SAP, and regional default PCAs for the 18 HUC-2 "Water Resource Regions" shown in **Figure 1-2** (Jones *et al.*, 2010). USEPA also developed additional guidance for selecting and applying combined or multi-crop PCAs to PRZM-EXAMS model-estimated concentrations for pesticides used on multiple crops.

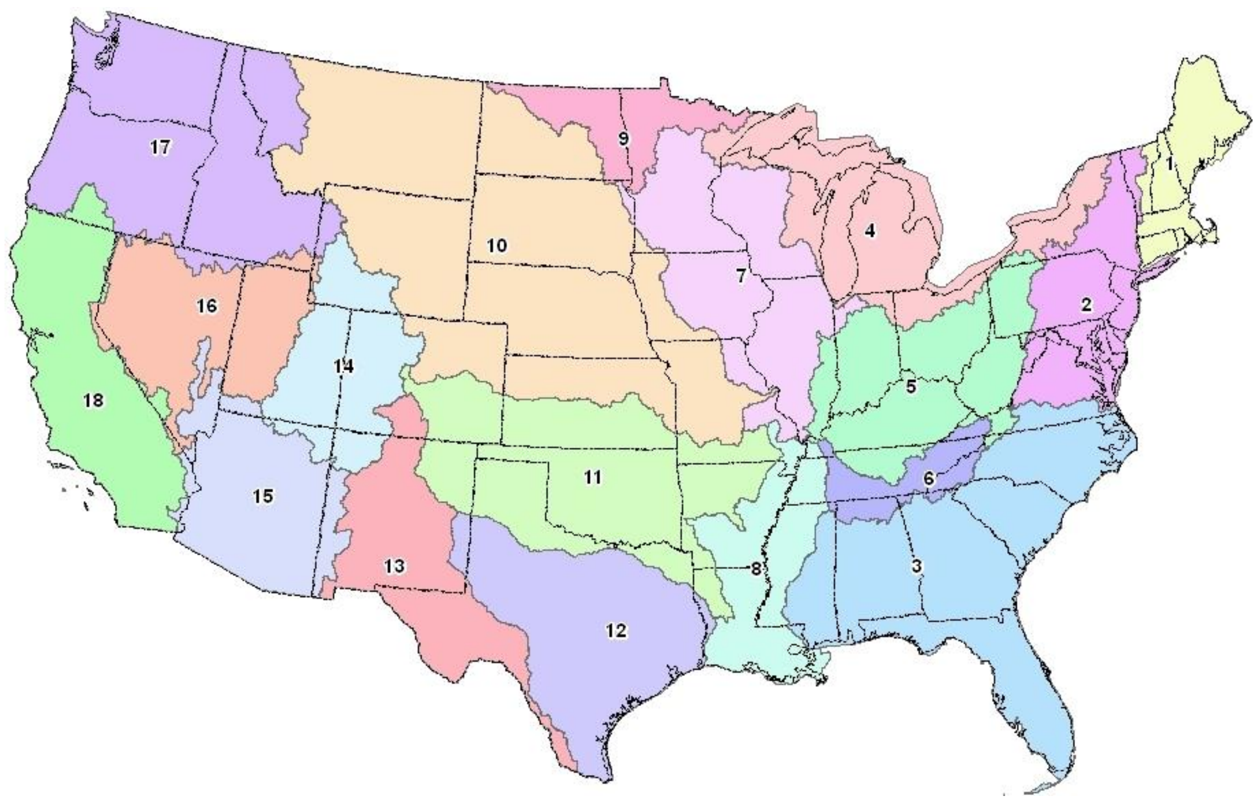

Figure 1-2. The 18 Major Hydrologic Unit "Water Resource" Regions (HUC-2) in the Continental United States, Overlain on State Boundaries

[11] http://www.epa.gov/oppsrrd1/cumulative/2006-op/op_cra_main.pdf

In 2012, PCAs were developed for additional crop groups including orchards/vineyards[12], turf[13], vegetables[14], rice, and combinations of crops or crop groups (Echeverria *et al.*, 2012). While developing these PCAs the USEPA addressed concerns raised by the 1999 SAP regarding the uniformity of minor crop distributions within watersheds. This was done by taking an aggregate approach for generating PCAs. For example, a new "aggregated vegetables" crop group PCA was derived to represent individual as well as all vegetable crops. Agricultural PCAs were derived using the 2006 NLCD (Fry *et al.*, 2011) and the 2007 Ag Census (USDA, 2009) for HUC-8s.[15] The only difference from this methodology in the current effort is that watersheds for CWS-DWI were employed. **Table 1-1** summarizes the milestones and data sources used to calculate PCAs utilized by USEPA prior to this publication.

Table 1-1. PCA Milestones and Data Sources

Year	Milestone	Data Sources	References
1997	- Water modeling SAP, proposed the use of PCAs		(Jones and Abel, 1997)
1999	- PCA SAP proposed method for deriving watershed-based PCAs	1992 Census of Agriculture HUC-8 subbasins County Boundary data	(Effland *et al.*, 1999)
2000	- Corn, soybean, wheat, cotton PCA - National all agricultural PCA	HUC-8 subbasins 1992 NLCD land cover 1992 Census of Agriculture County Boundary data	(Water Quality Tech Team, 1999)
2002	- Cumulative organophosphate SAP provided recommendations on use of PCAs for minor crops - OP-crop specific and regional PCAs used in assessment	1997 Census of Agriculture County boundary data OP-specific use data	(USEPA, 2002)
2003	- HUC-2 Regional PCAs - Crop combinations (corn, soybean, wheat, and cotton)	HUC-8 subbasins 2001 NLCD land cover 1997 Census of Agriculture County Boundary Data	(Water Quality Tech Team, 2003)
2012	- Updated data used for established HUC-8 PCAs - Orchards/vineyards, turf, vegetables - More combinations	2011 HUC-8 subbasins 2006 NLCD land cover 2007 Census of Agriculture 2008 USEPA Turf Layer[a] County Boundary Data	(Echeverria *et al.*, 2012)

[a] 2001 NLCD developed land covers (21-24) with the impervious surface layer subtracted.
[b] 2006 NLCD developed land covers (21-24) with the impervious surface layer subtracted.

[12] Orchards/vineyard PCAs are based on the "Land in Orchards" data in the Agricultural Census dataset.
[13] The turf map was derived by using all developed land cover classes in NLCD (classes 21-24) and subtracting the impervious area.
[14] Vegetables PCAs are based on the "vegetables harvested for sale" data in the Agricultural Census dataset.
[15] Previous PCAs were calculated using the 1992 NLCD land cover data and the 1997 Agricultural Census data.

1.4 Applying PCAs to Estimated Drinking Water Concentrations (EDWCs)

For drinking water assessments, model-estimated drinking water concentrations are multiplied by PCAs to reflect the fraction of the watershed covered by the crop or crops of interest. The use of PCAs to modify PRZM-EXAMS model-estimated concentrations for surface water is based on the assumption that pesticide loadings to water bodies are directly proportional to treated area. This assumption is consistent with use of the PRZM model, which is employed to estimate pesticide runoff and spray drift loadings. PRZM generates area-normalized output, and implicitly ignores factors such as landscape spatial non-uniformity, distances between treated locations and water bodies, and differential runoff from different land covers or soil types. PRZM is, in a spatial sense, essentially a one-dimensional, “lumped parameter” model. That is to say, soil and landscape properties and other governing variables are represented via numerous input parameters in PRZM, but are treated as if they were homogeneous within the simulated runoff watershed.

For national scale assessments, PCAs are selected which represent the highest fraction of the crop within any known drinking water watershed. If a pesticide is used on only one major crop, then the PCA for that particular crop is used. If the pesticide is used on a combination of crops, then the PCA for that particular combination of crops is used. Or, if pesticide uses include more or different crops than are captured in the existing PCA combinations, the default “all-agriculture” PCA is applied. Regional (*i.e.*, HUC-2) maximum PCAs may be used for refinement, but must reflect all potential pesticide use combinations for each region.

PCAs are **not** applicable to areas outside the conterminous United States (*e.g.*, Alaska, Hawaii), as data are not readily available to calculate PCAs for these areas. Therefore, drinking water exposures based on scenarios that represent these areas should not be adjusted by a PCA. PCAs are not applicable to non-agricultural uses aside from turf.

1.5 Shifting from HUC-8 Subbasins to Community Water System Watersheds

When USEPA began developing PCAs for use in drinking water assessments, a national dataset defining watersheds specific to CWS DWIs was not available. The USEPA used HUCs as surrogates for CWS DWI watersheds because they were the only nationally consistent hydrologic delineation available at the time. HUC-8s consist of more than 2,200 contiguous, non-overlapping polygons that average approximately 700 square miles in area. In general, smaller areas are more likely to have homogeneous land cover; therefore, potentially higher PCAs. USEPA noted that many drinking water supplies are fed by watersheds that are smaller than HUC-8s, and thus may have higher fractions of cropped/pesticide-treated land.

The 1999 SAP recommended that PCAs be developed specifically for drinking water intake watersheds. This report documents the development of such a dataset. **Chapter 2** provides an overview of the development of the “CWS DWI version 1.0” watershed polygon dataset that made the development of these DWI PCAs possible. **Chapter 3** describes the methodology of PCA development, and presents a summary of the results. **Chapter 4** presents a comparison between EDWCs generated using the DWI PCAs, and measured pesticide concentrations in water. **Chapter 5** provides guidance on applying the DWI PCAs to calculate pesticide EDWCs.

Chapter 2. Development of Drinking Water Intake Watershed Dataset

This chapter documents the development of the Community Water System (CWS) Drinking Water Intake (DWI) watershed dataset, version 1.0 (DWI_Basins_082013.mdb,). This dataset provides a geospatial representation of watersheds (and HUC-12 surrogates) associated with the intakes of surface water-sourced CWS across the United States. The chapter includes a summary of strengths and weaknesses of this dataset for use in applications such as the development of watershed-specific PCAs.

2.1 Background

The number of CWS in the United States which draw upon surface water as source drinking water varies over time, and changes within SDWIS as reflected in quarterly updates. Because a large portion of the population in the United States relies upon surface water as source drinking water, it is important to understand how the locations of intakes for CWS influence the vulnerability of the water supply to contamination. USEPA is particularly interested in the geospatial relationship of agricultural land and turf cover to CWS intake locations, because estimation of pesticide concentrations in surface water resulting from pesticide use is an aspect of the exposure assessment process which underlies pesticide registration and reregistration in the United States. Delineation of watersheds associated with drinking water intakes provides a mechanism for helping understand the vulnerability of different CWS to pesticide contamination. For this reason USEPA sought to develop a comprehensive geospatial dataset containing the locations of intakes for CWS in the United States, as well as watersheds associated with these intakes. Although similar datasets have been developed previously (Bhaduri, 2003), this dataset is referred to as the DWI watershed dataset, version 1.0 (DWI_Basins_082013.mdb).

Development of this dataset involved two key steps: identification of CWS surface water intake locations and delineation of catchments (watersheds) draining to these locations. The process of deriving this dataset was initiated by the Office of Pesticide Program's Environmental Fate and Effects Division (EFED) in 2007, and included collaboration with USGS and contract support. The **Database Development** section below describes steps involved.

2.2 Database Development

Surface Water Intake Locations

The surface water intakes included in the DWI watershed dataset were derived using locational data contained in the USGS's Public-Supply Database (PSDB) of CWS intake locations. PSDB was initially developed from: 1) data contained in earlier[16] versions of OGWDW's Safe Drinking Water Information System (SDWIS) database; and 2) data received

[16] 1997 to 2004

by USGS directly from states. The datasets only represent snapshots in time. For example, SDWIS is a dynamic dataset of public water supplies that changes quarterly. States provide updates that affect the number of water supplies in the dataset and the associated attributes [e.g., function (active vs. inactive) and location].

In 2007, under an Interagency Agreement[17] between USEPA OPP and USGS, PSDB was updated by USGS with surface water source data contained in a then-current download of CWS intake location data from SDWIS (12/31/2006). Updating PSDB employed the following procedure (Horn, 2007):

1. Records in a then-current version of PSDB were compared against those in the SDWIS download. This process revealed 267 DWI locations in SDWIS that were not in PSDB, and 954 intake locations that varied by more than 0.0017 decimal degrees between the two datasets. To resolve the discrepancy in the intake locations, an evaluation to determine which location was more accurate (SDWIS or PSDB) was conducted. This evaluation was conducted by mapping both locations for each intake, using DeLorme Street Atlas USA 8.0, Topozone, or Google Maps software to compare each location against other landscape features. Of the 954 intake locations that varied between the two datasets, 343 were judged to be best represented by the PSDB location and 611 to be best represented by the SDWIS location.

2. Examination of SWDIS revealed there were no surface water sources included in the download for Delaware or Ohio (which both had entries in a 12/31/2004 SDWIS download), and only one surface water source for Idaho (which had 54 entries in the 12/31/2004 SDWIS download). The Ohio sources were identified by an April 2007[18] download of SDWIS and integrated into the PSDB update. No additional information was found for the Delaware sources or the 53 missing Idaho sources. As a result, existing data for Delaware and Idaho in PSDB originating from the 12/31/2004 SDWIS download were retained under the assumption that the 2004 surface water sources were still active in 2007. This updated dataset is referred to here as the "2007 PDSB", and was the dataset used by the USGS to generate 6,550 quality-assured CWS intake locations (**Figure 2-1**) (Horn, 2007). The final deliverable to USEPA was a spreadsheet (QA.SDWIS2006.locCWSSWsource.xls), dated June 29, 2007.

   Note: The final dataset did not include intakes that were 1) outside the 50 states; 2) not associated (judging based on name attribute) with streams, rivers, lakes or reservoirs; 3)

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[17] IAG # DW-14937871-01-0
[18] Exact date not available

flagged as inactive, or; 4) lacking location information, so that the location could not be determined.

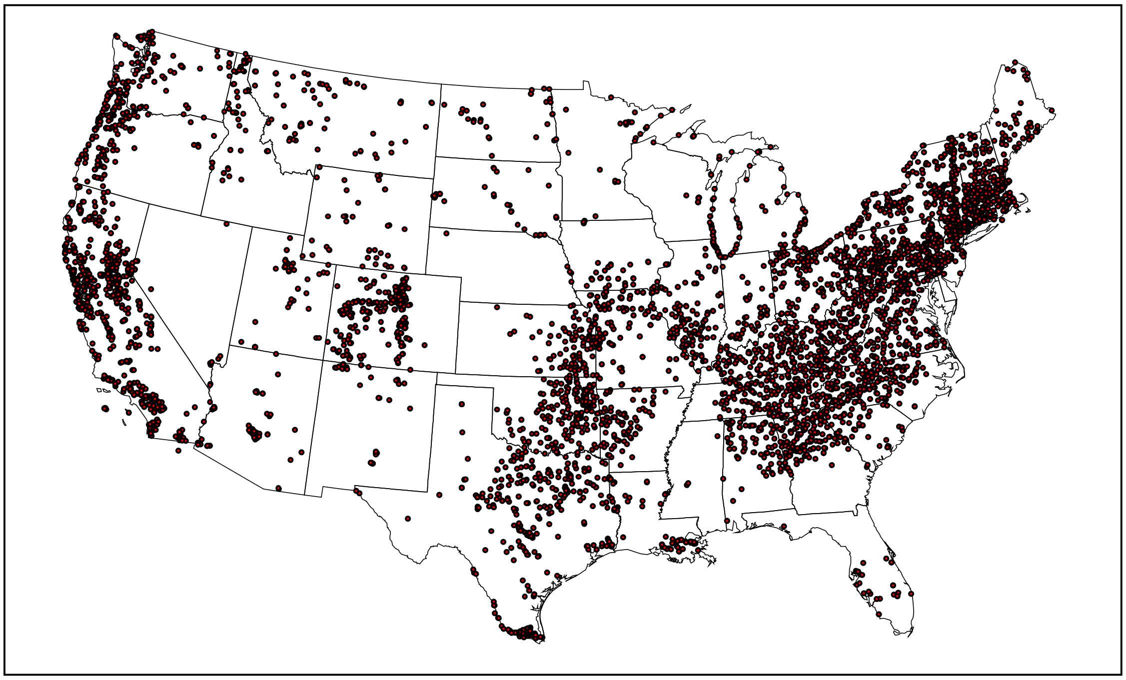

Figure 2-1. **Geographic Distribution of 6,550 Quality-assured Community Water Systems Drinking Water Intakes Locations in Public-Supply Database**

DWI Watershed Delineation

In 2010, USEPA contracted with INDUS Corporation[19] to index the 6,550 CWS DWI locations to specific surface water features in USEPA's NHDPlus[20] dataset. To accomplish this task, INDUS used a process that included proximity analysis and name matching, as follows:

1. First, INDUS identified the three nearest stream/river reach features and three nearest water body features in the NHDPlus data suite that best matched each DWI location. These features were considered potential watershed outlets ("pour points") for the watersheds defined by the DWI locations. INDUS then used an algorithm that included distance from the intake location, name matching, and feature type such as lake or stream to identify candidate NHDPlus features that best matched the intake names and locations. For each DWI site, INDUS identified up to six candidate pour points on NHDPlus features, assigned a numerical ranking based on a matching algorithm, and selected a

[19] INDUS is a non-governmental organization that specializes in providing federal information technology services.
[20] NHDPlus is an integrated suite of application-ready geospatial datasets that incorporate many of the best features of the National Hydrography Dataset (NHD), the National Elevation Dataset (NED), the National Land Cover Dataset (NLCD), and the Watershed Boundary Dataset (WBD). http://www.horizon-systems.com/nhdplus/

"winner" that is the feature judged most likely to be the correct pour point. The final product was an ArcGIS geodatabase (pending_dwigs_20100924.gdb) that included all the "winners" and candidate stream segments and water bodies.

2. Next, OPP contracted with Horizon Systems[21] in 2011, to delineate watersheds for the "winner" locations identified by INDUS. Horizon Systems found that of the 6,550 DWI locations, only 5,557 were indexed to NHDPlus features classified as streams, rivers, lakes, or reservoirs[22]; therefore, suitable for watershed delineation. The remaining DWI locations were associated with other types of water sources including infiltration galleries, canals, springs, the Great Lakes, aqueducts, off-stream reservoirs, etc., for which watershed delineation is inappropriate or not readily feasible. Horizon Systems delineated watersheds for the 5,557 NHDPlus-indexed DWI locations using the NHDPlus Basin Delineation Tool[23].

3. In 2011, USEPA requested that USGS assess the quality of the 5,557 contractor-delineated watersheds (Wieczorek, 2011). The USGS conducted an accuracy assessment by overlaying the following: the DWI site locations, the pour point locations on NHDPlus, the candidate watershed polygons delineated by Horizon Systems, digital 1:24,000 topographic maps, and aerial photography. The USGS evaluated watershed accuracy for each site through visual inspection of the geospatial data layers, and assigned a code as follows:

    a. The INDUS "winner" DWI site location was compared to the PSDB intake location. If the pour point location of the "winner" was clearly incorrect, then the "winner" pour point was discarded and the accuracies of other candidate pour point locations identified by INDUS were evaluated. If none of the pour points appeared to be accurate, then a "FAIL" rating was assigned to the DWI site.

    b. If the pour point location of the "winner" was judged to be reasonable, then the boundary of the corresponding watershed polygon was compared to the elevation contours of a topographic map. If visual inspection indicated that at least 95% of the watershed area was correctly delineated, then the INDUS

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[21] Horizon Systems is a USEPA contractor that specializes in providing federal information technology services. http://www.horizonsystems.com/

[22] NHDPlus Source Types 1, 2, 3, 6, 9, or 10

[23] http://www.horizon-systems.com/NHDPlus/NHDPlusV1_tools.php#NHDPlus Basin Delineator Tool (BasinDelineator)

"winner" was assigned a "PASS" rating value and the other candidate pour point locations were not evaluated. If visual inspection indicated that the watershed boundary was at least 85% accurate, then the INDUS "winner" was assigned a rating value of "REASONABLE".

c. If the pour point location of the "winner" was obviously incorrect, but one of the other INDUS candidate pour point locations was reasonable based on visual inspection, then the boundary of the corresponding watershed polygon was compared to the elevation contours of the topographic map. If visual inspection of the alternative watershed indicated that the area was correctly delineated, then the INDUS candidate was given a "FAIL" grade with a "PASS" option, the option being one of the other alternative candidate watersheds.

During the analysis process, USGS discovered 75 duplicate watersheds among the 5,557 delineated by Horizon Systems. Removal of the duplicate watersheds left 5,482 unique watersheds for evaluation. Using the above-detailed process, USGS determined that of the 5,482 unique watersheds, a total of 4,840 (or 88% of 5,482) fell into the "PASS", "REASONABLE", or "FAIL with PASS option" categories (**Figure 2-2**, **Figure 2-3**). These 4,840 watersheds were determined to be "reasonable and ready to use for subsequent analysis and cartographic purpose" (Wieczorek, 2011). USGS provided USEPA with an ArcGIS geodatabase (DWI_basins.mdb) containing the 4,840 delineated watersheds. **Table 2-1** details the results of this analysis by HUC-2 water resource region.[24]

[24] www.horizon-systems.com/**NHD**Plus/data/**NHD**PLUS_UserGuide.pdf

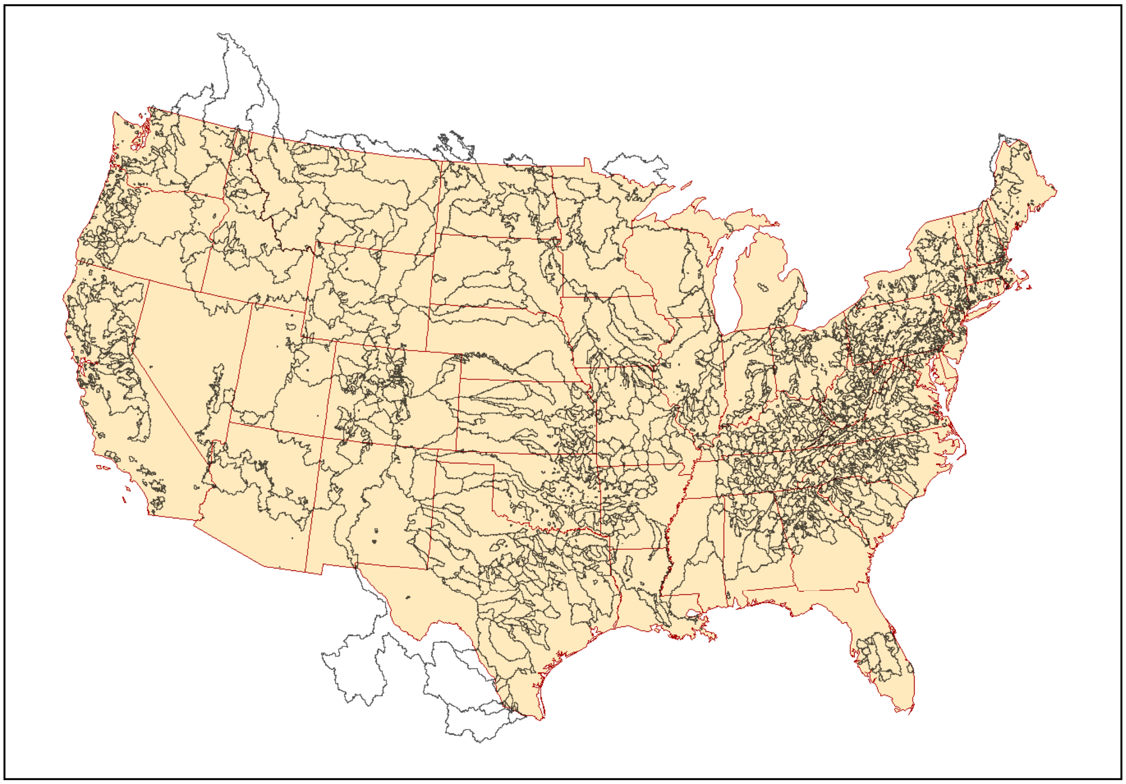

Figure 2-2. **Geographic Distribution of 4,838 Quality-assured Watersheds for Surface Water Source Drinking Water Intakes of Community Water Systems in the Continental United States**

Table 2-1. Results of USGS Pass/Fail Analysis on Drinking Water Intakes Watersheds, Listed by Water Resource Region

Water Resource Region	Assessed	Pass	Fail	Reasonable	Fail with No Pass Option	Pass, Reasonable, or Fail with Pass Option	% Pass, Reasonable, or Fail with Pass Option	%Pass
1	594	382	188	24	108	486	81.82	64.31
2	806	600	183	23	112	694	86.10	74.44
3	492	387	96	9	24	468	95.12	78.66
4	206	120	83	3	54	152	73.79	58.25
5	707	554	150	3	81	626	88.54	78.36
6	199	163	36	0	24	175	87.94	81.91
7	166	115	40	11	16	150	90.36	69.28
8	72	52	20	0	16	56	77.78	72.22
9	21	8	8	5	5	16	76.19	38.10
10L	334	238	87	9	47	287	85.93	71.26
10U	105	74	26	5	12	93	88.57	70.48
11	452	361	81	10	35	417	92.26	79.87
12	280	251	26	3	13	267	95.36	89.64
13	37	16	15	6	2	35	94.59	43.24
14	145	102	36	7	18	127	87.59	70.34
15	34	14	7	13	3	31	91.18	41.18
16	54	41	10	3	7	47	87.04	75.93
17	363	276	64	23	35	328	90.36	76.03
18	487	300	150	37	104	383	78.64	61.60
19	0	0	0	0	0	0	0.00	0.00
20	3	1	1	1	1	2	66.67	33.33
Totals	**5,557**	**4,055**	**1,307**	**195**	**717**	**4,840**	**87.10**	**63.26**

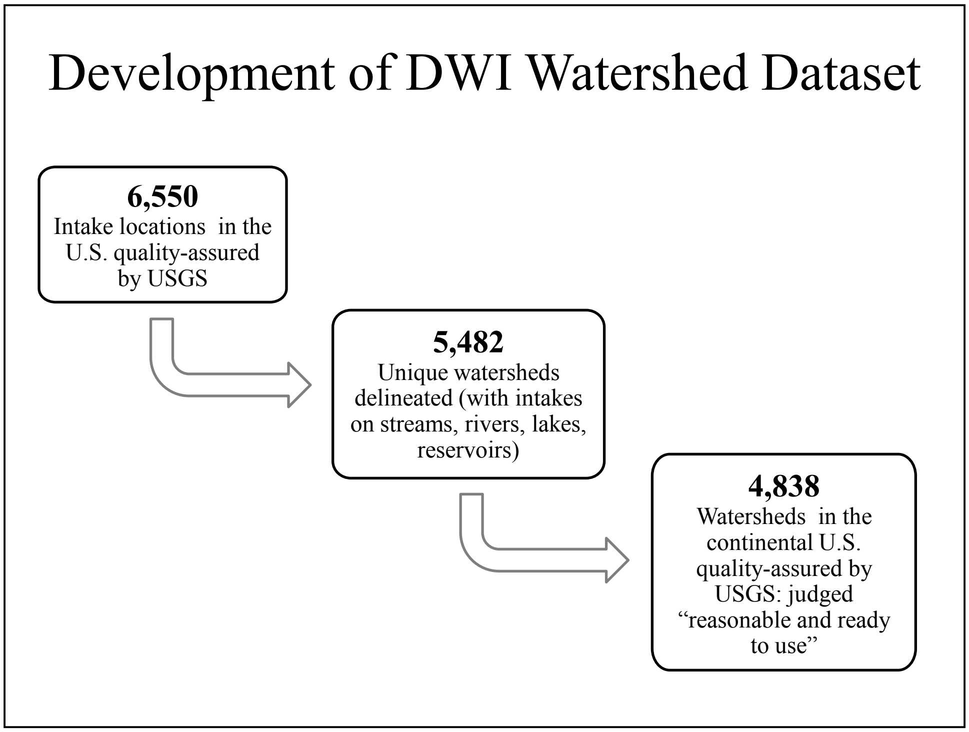

Figure 2-3. **Derivation Flowchart of the Quality-Assured Drinking Water Intakes Watershed Dataset**

Unlike HUC-8s (upon which previous PCA development exercises have focused), the distribution of areas among the 4,838 quality-assured watersheds in the continental United States is highly skewed, with a 10th percentile of 1.2 mi^2, a median of 43.5 mi^2, and a 90th percentile of 7,383 mi^2. By way of comparison, EPA's "index reservoir" scenario, based upon Shipman City Lake, Illinois, has a watershed of 0.7 mi^2, which corresponds with about the 5th percentile of the area distribution. Unlike HUCs at any given scale, which do not overlap, there is a fair degree of spatial nesting among the watersheds, such that smaller watersheds are contained inside larger ones, contained in turn inside even larger ones, and so forth.

2.3 Database Uncertainties

The degree of conservatism inherent in employing these 4,838 drainage basins to represent drinking water exposures for all surface water-sourced CWS in the United States cannot be definitively determined, in part because it cannot be determined that the existing entries are as or more vulnerable than CWS with intakes that lack quality-assured watersheds, which hypothetically could represent more vulnerable supplies. At this time EFED lacks the data and tools necessary to evaluate potential pesticide exposures for watersheds that extend beyond international boundaries, or for sources such as canals, aqueducts, off-stream reservoirs, and large, incompletely-mixed water bodies such as the Great Lakes. Nevertheless, in order to investigate this issue, EFED examined the 1,710 DWIs possessing quality-assured locations but lacking quality-assured watersheds (**Figure 2-4**). These DWIs were categorized as follows:

- **For 685 DWIs, delineated watersheds would either not be appropriate, or not applicable to this project** because (1) the intakes draw from source water types (springs or other ground water influences, sea water, Great Lakes) for which surface water watershed delineations are not applicable, (2) the intakes no longer exist, or (3) the intakes are located outside of the continental United States including Alaska, Hawaii, and U.S. territories.

- **For 637 DWIs, delineated watersheds would be appropriate** because the intakes draw from source water types (*i.e.*, streams, rivers, lakes, ponds, reservoirs) for which surface water watershed delineations are applicable. While more work could be done to determine why validated watersheds do not exist for these intakes, **OPP will use HUC-12 hydrological units as surrogates in lieu of quality assured watersheds for these DWIs**. This approach was largely supported by the recent targeted peer review on PCA documentation for DWI watersheds[25]. *Note: An additional 29 DWIs are also associated with the aforementioned source types, but are located in areas such as coasts where the calculation of HUC-12 based PCAs produces erroneous results.*

- **For 359 DWI, more information is needed to determine if delineated watersheds are appropriate** because these intakes largely draw from aqueducts and canals, and the watersheds that ultimately provide their source water are not known. In some cases, the aqueducts and canals may be hydrologically isolated from the surrounding agricultural areas; in other cases, the feeder canals seem to come from within agricultural areas. OPP is in the process of collecting more information on this set of DWIs to determine whether watersheds can be appropriately identified to represent their contributing drainage areas for PCA determination.

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[25] Initiated October 1, 2012 by Donald Brady United States Environmental Fate and Effects Division Director. Reviewers: Jonathan Becker, United States Environmental Protection Agency, Office of Pesticide Programs, Biological and Economic Analysis Division; Roger Anzzolin, United States Environmental Protection Agency Office of Water Office of Groundwater Drinking Water; Tony Selle, United States Environmental Protection Agency Region 8; Anne Neale, Environmental Protection Agency, Office of Research and Development, National Exposure Research Laboratory; Jeff Bailey, United States Department of Agriculture, National Agricultural Statistics Service; Bob Gilliom, United States Geological Service (included comments from Mike Wieczorek); Terry Councell, United States Department of Agriculture, Pesticide Data Program; Jerry Johnson, United States Department of the Interior; Ian Kennedy, Health Canada Pesticide Management Regulatory Agency

One important source of uncertainty has to do with the fact that the "universe" of DWIs is not fixed, but inherently dynamic, with existing intakes becoming inactive and new intakes being established continually over time. Because this project has taken years to complete, it is an unavoidable fact that the 2007 intake location information from which the quality assured DWI dataset was developed is several years old, and thus to some degree potentially incomplete and/or obsolete at the time of project completion in 2013. In order to investigate the potential scope of this issue, EPA obtained a more current download of SDWIS data in spring of 2013. Analysis of these data indicates the presence of about 700 DWIs that appear to be new intakes which are not part of our DWI dataset. This illustrates the importance of establishing a process for regularly updating DWI PCAs, for as long into the future as they continue to be used.

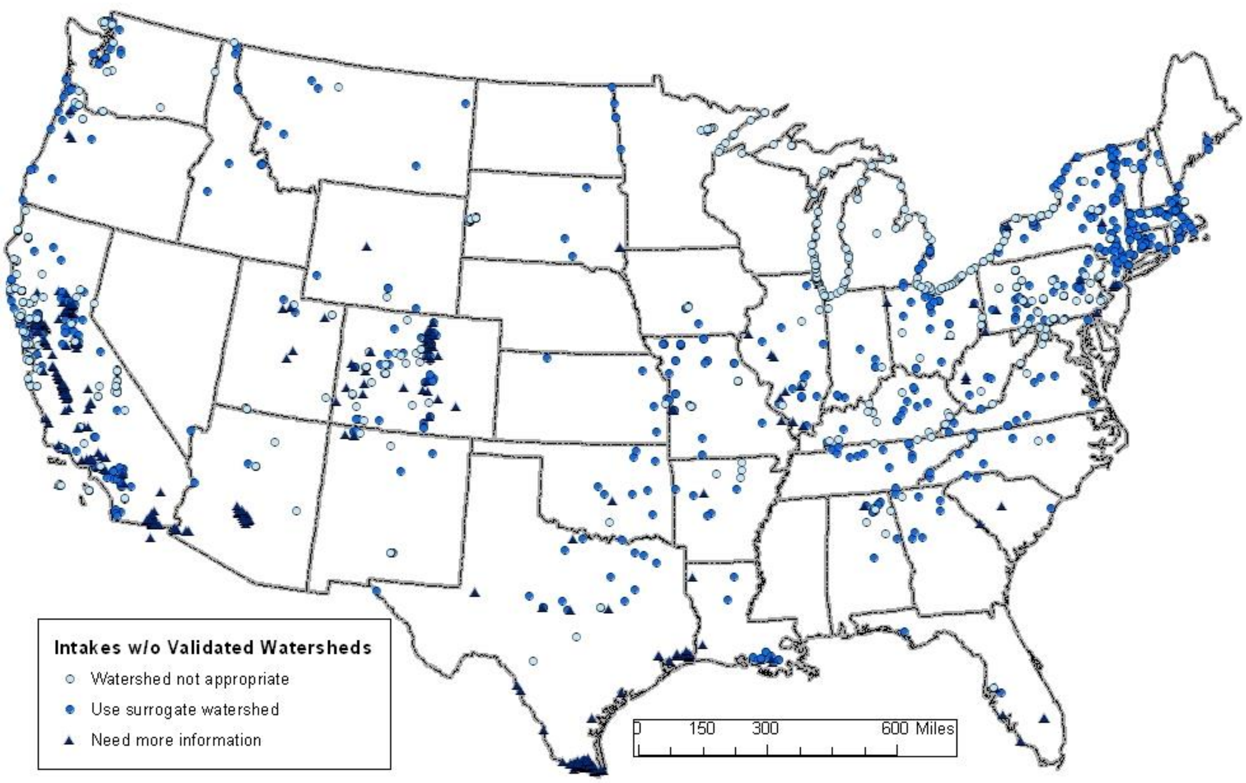

Figure 2-4. Locations of Quality-Assured DWIs in the Conterminous U.S. Lacking Quality-Assured Watersheds

Unlike HUC-8s, upon which previous PCA development focused, the area distribution among the 4,838 DWI watersheds is broad and highly skewed. The median area of HUC-8s is about 1,300 mi^2, which happens to fall at about the 79^{th} percentile of the watershed area distribution. Thus only about one fifth of DWI watersheds are larger than the scale of typical HUC-8s used in previous PCA efforts, while about four fifths of DWI watersheds are smaller.

Also, unlike HUCs, there is considerable spatial nesting among the 4,838 DWI watersheds. This occurs for example when two or more intakes are located on the same stream or river, one upstream from another, such that smaller catchments are entirely contained within larger ones. These and other unique features of this dataset, including the lack of even spatial distribution across the country and the fact that some watersheds extend beyond the United States into Canada or Mexico (**Figure 2-2**), create novel challenges for the use of this DWI watershed dataset in PCA development have not been issues in previous PCA efforts.

2.4 Conclusion

In summary, 4,438 DWI watersheds in the continental United States have been delineated and quality assured, for 6,550 quality-assured intakes that provide source surface water for community drinking water supplies throughout the country. Of the 1,710 quality-assured intakes without a quality-assured delineated watershed, 685 are either outside the continental U.S. (*i.e.*, the "lower 48" states) or not appropriate for watershed delineation, 637 are represented with HUC-12 watersheds as surrogates, and 359 require additional information to determine whether or not delineation is appropriate. There are several sources of uncertainty to be considered in determining the appropriate use of the data in a regulatory context, perhaps most importantly the fact that the set of active DWIs is not fixed over time but dynamic in nature. This is evidenced by the observation that about 700 additional DWIs were apparently brought on line between 2007 and 2013, and are therefore not represented in either the DWI watershed, or associated PCA datasets.

Chapter 3. Methods and Results

3.1 Methods

PCAs were calculated for all-agriculture, residential turf, and six individual crops (corn, soybean, cotton, orchard, wheat and vegetables) or crop groups, for each of the 4,838 drinking water watersheds and 637 HUC-12 surrogate watersheds described in **Chapter 2**. The National Land Cover Dataset (NLCD) and the National Agricultural Statistics Service (NASS) Agricultural Census data were combined to create a crop-specific land cover map for each of the specified crops, including all-agriculture. NASS provides total acres harvested by county for each individual crop[26] and the NLCD provides information on the distribution of crop acreage at the sub-county level. Data on acres harvested were selected for each crop. The crops selected and the corresponding NASS table numbers are listed in **Table 3-1**. Corn acres for grain, silage and sweet corn were added to produce a total corn PCA. Unreported counties within the NASS dataset, marked with a "D", were ignored. Of the 4,838 delineated basins, 127 include upstream areas in Canada, and 14 include upstream areas in Mexico. Both NASS and NLCD cover only the continental United States. Basins that cross international borders were clipped at the border, such that PCAs for these watersheds were calculated based solely on the distribution of land uses within the portions of the watersheds within the United States.

Table 3-1. 2007 NASS Crop Data

Crop	NASS Table
Corn for grain	25
Corn for silage or greenchop	25
Sweet Corn	30
Soybean for beans	25
Wheat for grain	25
Cotton all	25
Vegetables harvested for sale	25
Land in Orchards	25
Total Cropland	1

A detailed description of the GIS methods used in validating the PCA calculations can be found in **APPENDIX A**.

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[26] http://www.nass.usda.gov/

Single Crops

PCAs for individual crops were calculated by conceptually "blending" the NLCD agriculture pixels with the NASS county harvested data. The six individual crops all fall under the NLCD class 82: cultivated crops. Using the Spatial Analyst toolbox for ArcGIS10.0, the number of cultivated crop pixels per county was calculated. The total number of crop pixels in each county was then divided by the total harvested acres in the county according to NASS resulting in an acres-per-pixel value for each county. A crop-specific map was produced by replacing all cultivated crop pixels (class 82) with the corresponding acres-per-pixel values, removing all other land classes from the land cover map. Using the newly created crop map, watershed PCAs were calculated by summing all area-weighted crop pixels within each watershed, using the ArcGIS Spatial Analyst extension and the *zonal statistics as table* command.

The process of calculating 4,840 PCA values per crop was automated using Python scripting, which processed one catchment per shapefile per run. This was necessary due to GIS software limitations caused by the overlapping, or spatially-nested, and the nature of the DWI catchments. Nested drinking water watersheds may occur when two or more intakes are located on the same stream or river, one upstream from the other. The downstream watershed by definition includes all of the area in the upstream watershed, as well as additional area that drains to the stream or river below the location of the upstream intake.

All-agriculture

The NASS dataset provides data on acreage of "land in agriculture" that includes land in pasture. The NLCD dataset classifies land uses into 16 categories including both "cultivated crop" (class 82) and "pasture" (class 81); however, misclassifications are known to occur wherein land that is actually cultivated cropland (*e.g.,* alfalfa) is identified as pasture (*i.e.*, class 81). Until a detailed validation of the 2006 NLCD is published, it is difficult to quantify the effect of misclassification on the all-agriculture PCA results. To account for ambiguities in acreage associated with this issue, all-agriculture PCAs were calculated two different ways: 1) in the usual manner, based solely on class 82 pixels; and 2) based on the combination of classes 81 and 82. The total number of pixels per county in the latter case, thus, includes a tally of all NLCD pixels classified as either 81 or 82. The total number of such pixels is then divided by the NASS "land in agriculture" acreage values to determine the per-county acre-per-pixel weighting factors.

Residential Turf

A residential turf layer was derived from the 2006 NLCD based on an algorithm first proposed by Milesi *et al.* (2005). In summary, an impervious surface data layer is included in the NLCD 2006 data product where each pixel represents an impervious surface area. NLCD-based turf area was calculated as the non-impervious area portion of all land cover pixels classified as developed (*i.e.,* classes 21 – 24). Using this derived turf layer, turf PCAs were calculated by summing the turf area for all pixels within each watershed. HUC-12 based PCAs, used as surrogates for missing delineated watersheds, were based on 2001 NLCD turf estimates. The use of NLCD datasets from two different time points (2001 and 2006) to generate PCAs introduces a degree of uncertainty related to land cover changes during the intervening period. Specifically, developed land generally increased between 2001 and 2006, which has the effect of increasing turf acreage estimates.

HUC12 Processing and Surrogate Selection

Surface water intakes which lacked quality-assured, delineated watersheds were assigned HUC-12-based surrogate PCA values. Based on the criteria in **Section 2.3**, 637 intakes received HUC-12-based surrogate PCA values based on the intake location. HUC-12 PCAs were calculated for all-agriculture and each of the individual crops. The Watershed Boundary Dataset (Version May 16, 2011) was used for HUC12 boundary delineations.

3.2 Results

Maximum Water Resource-Regional PCAs

Each of the 4,838 watersheds was assigned to a HUC-2 water resource region based on the intake location. Maximum regional PCAs were then tabulated for each of the eighteen HUC-2 water resource regions in the conterminous United States, for each individual crop, all-agriculture and turf, and for various crop combinations. Results for specific crops and crop combinations are tabulated in **Tables 1** and **2** (in the **Summary** section of this document), and reproduced in this chapter in **Tables 3-2** and **3-3**, respectively. Maximum HUC-12-based PCAs, for the 637 quality-assured DWIs lacking quality-assured watersheds in each HUC-2, are tabulated in **Table 3-4** by crop. **Table 3-5** lists the maximum crop-specific PCA for each HUC-2, either DWI-based or HUC-12-based, whichever is greater. **Tables 3-6** and **3-7** display the analogous crop-combination results for HUC-12-based PCAs and overall maximum PCAs, respectively. Values in **Tables 3-5** and **3-7** that are HUC-12 based, and therefore greater than the corresponding DWI watershed-based values, are indicated in italics. As **Tables 3-5** and **3-7** demonstrate, inclusion of HUC-12-based PCAs for the 637 DWIs which hypothetically warrant (currently lacking) watershed delineations, results in a number of increased regional maximum PCAs, for both individual crops and crop combinations.

Table 3-2. Maximum DWI-PCAs for Various Crops, by Water Resource Region (HUC-2)

HUC-2	All Ag[a]	All Ag[b]	Corn	Cotton	Orchard	Soybean	Vegetable	Wheat	Turf[c]
01	0.30	0.24	0.08	0.00	0.02	0.00	0.10	0.00	0.45
02	0.82	0.72	0.34	0.06	0.05	0.11	0.03	0.06	0.58
03	0.52	0.44	0.09	0.08	0.12	0.20	0.08	0.10	0.64
04	0.92	0.91	0.35	0.00	0.05	0.44	0.04	0.11	0.32
05	0.88	0.89	0.51	0.20	0.03	0.59	0.02	0.10	0.49
06	0.20	0.45	0.10	0.04	0.02	0.10	0.01	0.03	0.38
07	0.95	1.00	0.68	0.00	0.00	0.58	0.01	0.27	0.59
08	0.75	0.51	0.21	0.20	0.00	0.07	0.00	0.05	0.08
09	0.88	0.95	0.16	0.00	0.00	0.21	0.02	0.41	0.06
10	0.80	0.85	0.36	0.00	0.00	0.37	0.01	0.20	0.51
11	0.69	0.79	0.20	0.07	0.05	0.34	0.01	0.39	0.70
12	0.67	0.77	0.11	0.21	0.02	0.01	0.01	0.18	0.25
13	0.36	0.52	0.01	0.01	0.01	0.00	0.01	0.00	0.05
14	0.01	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.07
15	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.10
16	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
17	0.61	0.72	0.01	0.00	0.02	0.00	0.01	0.38	0.28
18	0.28	0.27	0.03	0.02	0.21	0.00	0.07	0.01	0.59

[*]Shaded cells indicate the highest value for each crop.
[a] All Ag PCAs based on NLCD land use 82 and Ag Census data.
[b] All Ag PCAs based on NLCD land uses 81 and 82, and Ag Census data.
[c] Represents residential turf including golf courses, but does not include sod farms. Sod farms are included in the all-agriculture land cover class.

Table 3-3. Maximum DWI-PCAs for Various Crop Combinations, by Water Resource Region (HUC-2)

HUC-2	Corn-Wheat	Soybean-Wheat	Turf[a]-Corn	Turf[a]-Orchard	Turf[a]-Soybean	Turf[a]-Vegetable	Turf[a]-Wheat	Vegetable-Orchard	Turf[a]-All Ag[b]
01	0.08	0.00	0.45	0.45	0.45	0.45	0.45	0.12	0.46
02	0.36	0.17	0.58	0.58	0.58	0.58	0.58	0.06	0.79
03	0.18	0.25	0.64	0.64	0.64	0.64	0.64	0.13	0.65
04	0.42	0.52	0.47	0.32	0.51	0.32	0.32	0.06	0.98
05	0.52	0.59	0.58	0.49	0.65	0.49	0.49	0.04	0.96
06	0.13	0.13	0.38	0.38	0.38	0.38	0.38	0.03	0.58
07	0.73	0.85	0.72	0.59	0.65	0.59	0.59	0.01	1.00
08	0.22	0.12	0.28	0.08	0.12	0.08	0.09	0.00	0.58
09	0.42	0.44	0.20	0.06	0.25	0.07	0.46	0.02	0.99
10	0.38	0.47	0.51	0.51	0.51	0.51	0.51	0.01	0.88
11	0.41	0.55	0.70	0.70	0.70	0.70	0.70	0.05	0.81
12	0.20	0.18	0.29	0.25	0.25	0.25	0.26	0.02	0.82
13	0.01	0.00	0.06	0.06	0.05	0.07	0.05	0.02	0.57
14	0.00	0.00	0.07	0.07	0.07	0.07	0.07	0.00	0.18
15	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.00	0.39
16	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.00	0.07
17	0.38	0.38	0.28	0.28	0.28	0.28	0.40	0.02	0.74
18	0.03	0.01	0.59	0.59	0.59	0.59	0.59	0.21	0.59

[*]Shaded cells indicate the highest value for each crop.
[a] Represents residential turf including golf courses, but does not include sod farms. Sod farms are included in the all-agriculture land cover class.
[b] All Ag PCAs based on NLCD land uses 81 and 82, and Ag Census data.

Table 3-4. Maximum Crop-specific HUC-12-based PCAs, Listed by Water Resource Region (HUC-2), for the 637 Quality-Assured DWIs Lacking Quality-Assured Watersheds

HUC-2	All Ag[a]	Corn	Cotton	Orchard	Soybean	Vegetable	Wheat	Turf[b]
01	0.32	0.05	0.00	0.01	0.00	0.02	0.00	0.86
02	0.65	0.25	0.05	0.07	0.08	0.03	0.04	0.60
03	0.15	0.00	0.00	0.02	0.00	0.02	0.00	0.41
04	0.82	0.31	0.00	0.05	0.34	0.03	0.10	0.85
05	0.90	0.50	0.00	0.00	0.35	0.00	0.06	0.38
06	0.20	0.03	0.01	0.00	0.03	0.00	0.00	0.22
07	0.59	0.32	0.00	0.00	0.22	0.00	0.03	0.45
08	0.24	0.01	0.00	0.00	0.00	0.00	0.00	0.52
09	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
10	1.00	0.23	0.00	0.00	0.26	0.02	0.27	0.47
11	0.63	0.04	0.00	0.01	0.01	0.01	0.17	0.39
12	0.66	0.04	0.07	0.03	0.00	0.04	0.02	0.19
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
14	0.37	0.02	0.00	0.00	0.00	0.01	0.06	0.08
15	0.41	0.01	0.04	0.03	0.00	0.19	0.08	0.49
16	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03
17	0.40	0.01	0.00	0.02	0.00	0.01	0.01	0.35
18	0.74	0.15	0.05	0.33	0.00	0.16	0.07	0.47

[*]Shaded cells indicate the highest value for each crop.
[a] All Ag PCAs based on NLCD land use 82 and Ag Census data.
[b] Represents residential turf including golf courses, but does not include sod farms. Sod farms are included in the all-agriculture land cover class. HUC12 turf results are derived from the 2001 NLCD.

Table 3-5. Maximum Crop-specific PCAs, Listed by Water Resource Region (HUC-2), Including Both 4,840 DWI PCAs for Quality-assured Watersheds, and the 637 HUC-12-based PCAs for Quality-Assured DWIs that Lacking Quality-Assured Watersheds

HUC-2	All-Ag[a]	Corn	Cotton	Orchard	Soybean	Vegetable	Wheat	Turf[b]
01	0.32	0.08	0.00	0.02	0.00	0.10	0.00	*0.86*
02	0.82	0.34	0.06	*0.07*	0.11	0.03	0.06	*0.60*
03	0.52	0.09	0.08	0.12	0.20	0.08	0.10	0.64
04	0.92	0.35	0.00	0.05	0.44	0.04	0.11	*0.85*
05	*0.90*	0.51	0.02	0.03	0.59	0.02	0.10	0.49
06	0.45	0.10	0.04	0.02	0.10	0.01	0.03	0.38
07	1.00	0.68	0.00	0.00	0.58	0.01	0.27	0.59
08	0.75	0.21	0.20	0.00	0.07	0.00	0.05	*0.52*
09	0.95	0.16	0.00	0.00	0.21	0.02	0.41	0.06
10	1.00	0.36	0.00	0.00	0.37	*0.02*	*0.27*	0.51
11	0.79	0.20	0.07	0.05	0.34	0.01	0.39	0.70
12	0.77	0.11	0.21	*0.03*	0.01	*0.04*	0.18	0.25
13	0.52	0.01	0.01	0.01	0.00	0.01	0.00	*0.11*
14	*0.37*	*0.02*	0.00	0.00	0.00	*0.01*	0.06	*0.08*
15	*0.41*	*0.01*	0.04	0.03	0.00	*0.19*	0.08	*0.49*
16	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
17	0.72	0.01	0.00	0.02	0.00	0.01	0.38	*0.35*
18	*0.74*	0.15	*0.05*	*0.33*	0.00	*0.16*	0.07	0.59

[*]Shaded cells indicate the highest value for each crop.
[a] Considers all-agriculture PCAs calculated both ways. The highest All-Ag values from Tables 3-2 and 3-4 are listed here.
[b] Represents residential turf including golf courses, but does not include sod farms. Sod farms are included in the all-agriculture land cover class PCA.

Table 3-6. Maximum HUC-12-based PCAs for Various Crop Combinations, by Water Resource Region (HUC-2), for the 637 Quality-Assured DWIs Lacking Quality-Assured Watersheds

HUC-2	Corn-Wheat	Soybean-Wheat	Turf[a]-Corn	Turf[a]-Orchard	Turf[a]-Soybean	Turf[a]-Vegetable	Turf[a]-Wheat	Vegetable-Orchard	Turf[a]-All Ag[b]
01	0.05	0.00	0.86	0.86	0.86	0.86	0.86	0.02	0.98
02	0.29	0.11	0.60	0.60	0.60	0.60	0.60	0.10	0.72
03	0.00	0.00	0.41	0.41	0.41	0.41	0.41	0.03	0.41
04	0.40	0.44	1.00	0.85	0.85	0.85	0.85	0.05	1.00
05	0.52	0.37	0.55	0.38	0.41	0.38	0.38	0.00	0.95
06	0.04	0.03	0.22	0.22	0.22	0.22	0.22	0.00	0.31
07	0.33	0.23	0.51	0.45	0.47	0.45	0.45	0.00	0.64
08	0.01	0.00	0.53	0.52	0.52	0.52	0.52	0.00	0.55
09	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
10	0.27	0.28	0.47	0.47	0.47	0.47	0.47	0.02	1.00
11	0.17	0.17	0.39	0.39	0.39	0.39	0.41	0.01	0.67
12	0.05	0.02	0.22	0.23	0.19	0.23	0.19	0.07	0.78
13	0.00	0.00	0.11	0.11	0.11	0.11	0.11	0.00	0.11
14	0.06	0.06	0.09	0.08	0.08	0.08	0.10	0.01	0.41
15	0.08	0.08	0.49	0.49	0.49	0.50	0.50	0.23	0.57
16	0.00	0.00	0.03	0.03	0.03	0.03	0.03	0.00	0.04
17	0.01	0.01	0.35	0.35	0.35	0.35	0.35	0.03	0.49
18	0.18	0.07	0.47	0.47	0.47	0.47	0.47	0.34	0.83

[*]Shaded cells indicate the highest value for each crop.
[a] Represents residential turf including golf courses, but does not include sod farms. Sod farms are included in the all-agriculture land cover class. HUC12 turf values are derived from the 2001 NLCD.
[b] All Ag PCAs based on NLCD land use 82, and Ag Census data.

Table 3-7. Maximum Crop-combination PCAs, Listed by Water Resource Region (HUC-2), Including both the 4,840 DWI PCAs for Quality-Assured Watersheds, and the 637 HUC-12-based PCAs for Quality-Assured DWIs Lacking Quality-Assured Watersheds

HUC-2	Corn-Wheat	Soybean-Wheat	Turf[a]-Corn	Turf[a]-Orchard	Turf[a]-Soybean	Turf[a]-Vegetable	Turf[a]-Wheat	Vegetable-Orchard	Turf[a]-All Ag
01	0.08	0.00	*0.86*	*0.86*	*0.86*	*0.86*	0.86	0.12	*0.98*
02	0.36	0.17	*0.60*	*0.60*	*0.60*	*0.60*	0.60	0.10	0.79
03	0.18	0.25	0.64	0.64	0.64	0.64	0.64	0.13	0.65
04	0.42	0.52	*1.00*	*0.85*	*0.85*	*0.85*	*0.85*	0.06	*1.00*
05	0.52	0.59	0.58	0.49	0.64	0.49	0.49	0.04	0.96
06	0.13	0.13	0.38	0.38	0.38	0.38	0.38	0.03	0.58
07	0.73	0.85	0.72	0.59	0.65	0.59	0.59	0.01	1.00
08	0.22	0.12	*0.53*	*0.52*	*0.52*	*0.52*	*0.52*	0.00	0.58
09	0.42	0.44	0.20	0.06	0.25	0.07	0.46	0.02	0.99
10	0.38	0.47	0.51	0.51	0.51	0.51	0.51	*0.02*	*1.00*
11	0.41	0.55	0.70	0.70	0.70	0.70	0.70	0.05	0.81
12	0.20	0.18	0.29	0.25	0.25	0.25	0.26	*0.07*	0.82
13	0.01	0.00	*0.11*	*0.11*	*0.11*	*0.11*	*0.11*	0.02	0.57
14	*0.06*	0.06	*0.09*	*0.08*	*0.08*	*0.08*	*0.10*	*0.01*	*0.41*
15	*0.08*	0.08	*0.49*	*0.49*	*0.49*	*0.50*	*0.50*	*0.23*	*0.57*
16	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.00	0.07
17	0.38	0.38	*0.35*	*0.35*	*0.35*	*0.35*	*0.40*	*0.03*	0.74
18	*0.18*	0.07	0.59	0.59	0.59	0.59	0.59	0.34	*0.83*

[*]Shaded cells indicate the highest value for each crop.
[a] Represents residential turf including golf courses, but does not include sod farms. Sod farms are included in the all-agriculture land cover class PCA.

Appendix B comprises figures that display comparisons of national-scale PCA cumulative distribution functions (CDFs), between DWI-watersheds, HUC-12 surrogates, and the two combined. For a number of crops or crop combinations (orchard, vegetable, turf, turf-corn, turf-orchard, turf-soybean, turf-vegetable, turf-wheat, turf-all-agriculture, and vegetable-orchard), the distribution of PCAs for HUC-12 surrogates is shifted to the right as compared with PCAs for DWI watersheds, meaning that the HUC-12 PCAs are generally more conservative. For soy and soy-wheat the opposite is true. However in most cases, the figures show that little change is caused by including the HUC-12 based PCAs in the overall distributions.

Figure 3-1 shows a comparison of national maximum DWI PCAs (with and without inclusion of the HUC-12 based subset), against the existing HUC-8 based PCAs. **Figure 3-2** similarly displays a comparison of maximum all-agriculture PCAs per HUC-2 region, between the new DWI PCAs (calculated with and without pasture/hay) and the existing HUC-8 PCAs. In most cases, both figures show that the new maximum DWI PCAs are slightly greater than the HUC-8 based values.

3.3 Validation of PCAs

An independent validation of the PCAs was conducted using an alternate set of GIS procedures to derive PCAs for a random selection of DWI watersheds (**APPENDIX A**). The purpose of the validation was to identify any data processing errors or data anomalies (the accuracies of the intake locations and basin delineations were not evaluated by EFED, but were evaluated by USGS as described in **Chapter 2**). A team of EFED reviewers selected a variety of watersheds for each of the crops, and applied the alternate PCA calculation methodology. The resulting PCAs for these watersheds were compared with the original PCAs for verification. The list of verified catchment PCAs is provided in **Table A-2**.

The validation process revealed some watersheds that were incorrectly identified as having PCAs of zero. Further analysis revealed that the automated (Python script-based) process occasionally skipped watersheds, for reasons that have not yet been identified. The watersheds that were skipped in this manner varied from one crop to another. An independent analysis identified approximately 20 – 40 watersheds per crop, for which the automated process failed to correctly calculate a PCA. Once identified, PCAs for these watersheds were calculated manually.

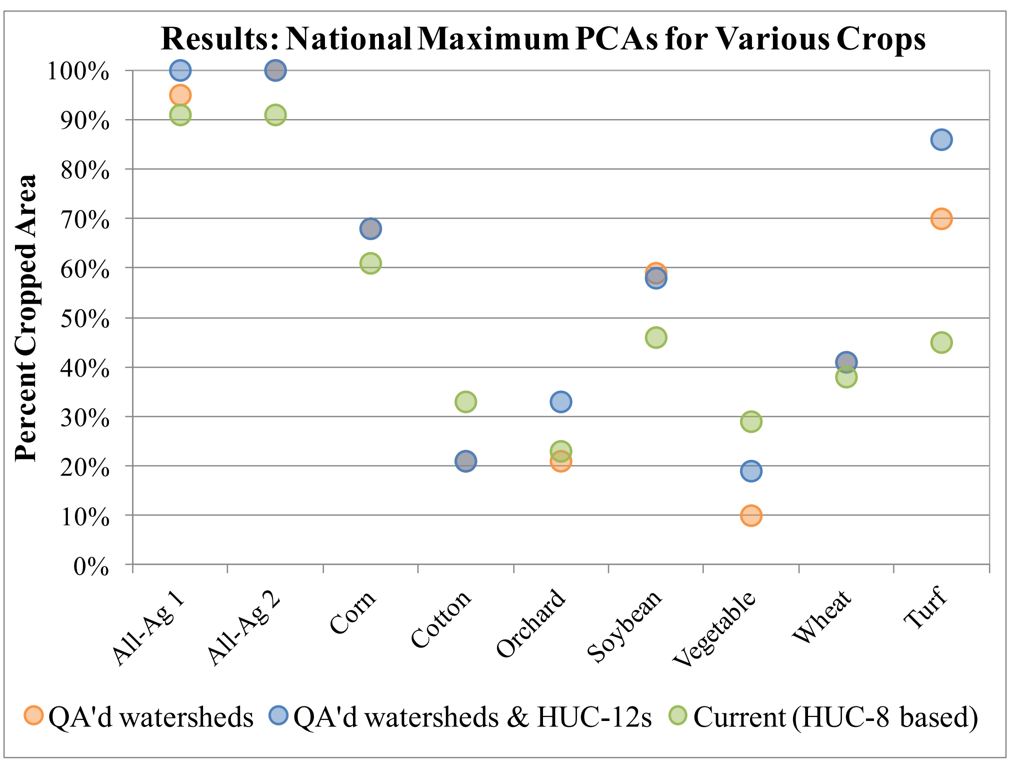

Figure 3-1. Comparison of existing HUC-8 based PCAs against DWI PCAs with and without inclusion of the HUC-12 based subset.

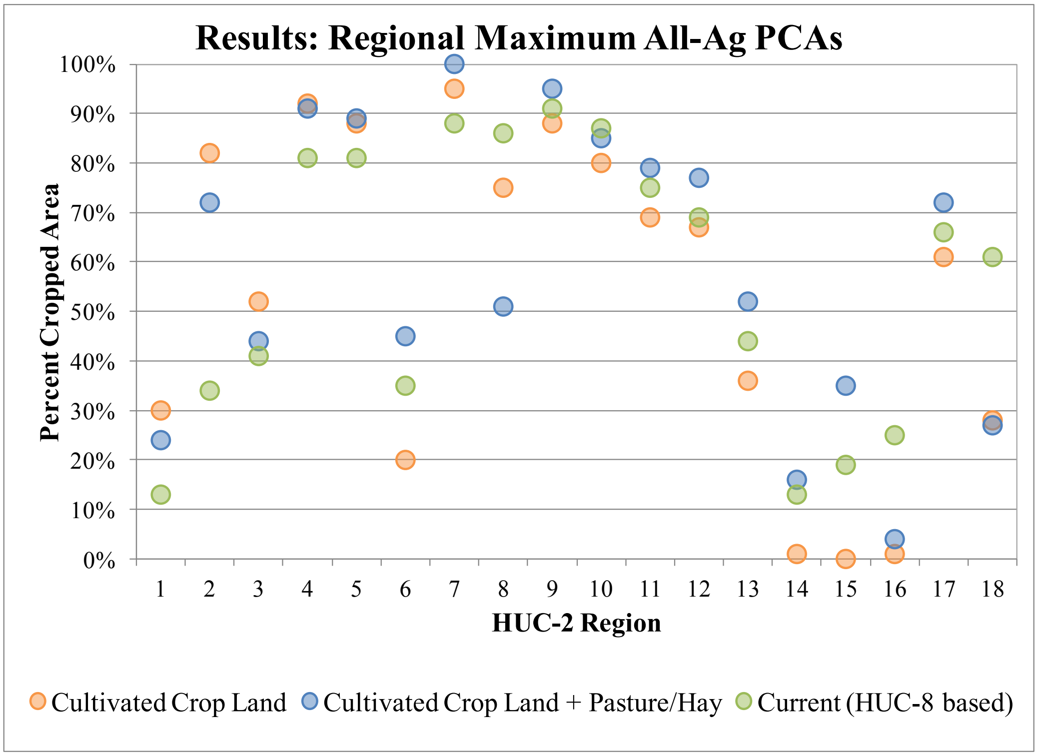

Figure 3-2. Comparison of maximum all-agriculture PCAs by HUC-2 region. Shown are DWI PCAs based on NLCD land use 82 (cultivated crop land) and based on land uses 81 and 82 (crop land plus pasture/hay), and current HUC-8 based PCAs.

3.4 Data Limitations

There are several potential sources of error in the spatial data and methodology used. The magnitudes of these errors and limitations are not known. Limitations include:

- Rates of misclassification between NLCD classes 81 and 82, and between 81, 82 and other classes appear to be significant, but have not yet been quantified. Such misclassifications could either increase or decrease PCAs.
- A necessary assumption under the current PCA calculation methodology is that the NASS acres for a given crop are evenly distributed across all agricultural land within each county. This is unlikely to be true, and may mask significant regional clustering of crop types at a sub-county scale.
- PCA values for basins that cross into Canada and Mexico have a particularly high degree of uncertainty associated with them, as data on land uses and pesticide applications outside the U.S. are not available.

- The remote sensing data used to generate the 2006 NLCD land cover map were collected during the early 2000's, whereas the NASS data are from 2007. Any land use changes during the interim, *e.g.,* conversion of marginal land to agriculture, would result in errors due to the mismatch between datasets.
- It is possible that two separate crops were reported for the same acreage in places where the land was double-cropped, thus resulting in double-counting of total cropland in the agricultural census for such areas. This could result in PCAs greater than 100%.

3.5 Future Improvements

- Use of the USDA cropland data layer (CDL) in place of NLCD data will be considered for future analysis. This would presumably allow for more accurate sub-county designations of the locations of specific crops. Since a new CDL product is now released annually, it should be easier to select data from a time frame that matches NASS data.

Chapter 4. Monitoring Data Comparisons

An aspect of the evaluation process for the DWI PCAs was a comparison between monitored pesticide concentrations and model-estimated concentrations when DWI PCAs are applied. The objective of the evaluation was to ensure that the use of DWI PCAs, in conjunction with USEPA's screening modeling approach for estimating pesticide concentrations in surface water, results in concentrations that are protective of vulnerable drinking water supplies. This section describes the methodology and the results of the evaluation.

4.1 Methodology

In the modeling part of the evaluation effort, for each of seven "crops" (corn, cotton, soybeans, wheat, turf, vegetables, and orchards) as well as all-agriculture, for which DWI PCAs were developed, EFED identified up to three pesticides (*i.e.*, active ingredients) used primarily on that crop. EFED utilized data supplied by OPP's Biological and Economic Analysis Division (BEAD) to define the extent to which each pesticide was used on each particular crop. EFED then collected physical-chemical properties, fate data, and application information (*e.g.,* application method and maximum single rates, minimum retreatment interval, date of first application, and maximum number of applications/year) for each pesticide from its most recent drinking water or endangered species assessment. Using these data, EFED ran the PRZM and EXAMS models with the PE5 shell (PRZM-EXAMS Model Shell)[27], using standard scenarios for each crop and the index reservoir, to estimate 1-in-10 year return frequency daily concentrations. EFED then multiplied these concentrations by the appropriate DWI PCAs to develop EDWCs.

The ideal monitoring site for evaluating PCA-adjusted modeling data would reflect an area of high pesticide use on a specific, individual crop or crop group, in an area considered particularly vulnerable to runoff due to rainfall, hydrology, soil conditions, etc., and from water actually used as a source water supply for a CWS. Ideally, such a site would also be sampled frequently enough during the pesticide use season to either capture peak pesticide concentrations, or allow for calculation of reasonable statistical bounds on measured concentrations[28]. Unfortunately, monitoring data meeting all these criteria particularly runoff-vulnerability and crop-specificity are not usually available. All of the CWS data employed in this analysis were collected at monthly sampling intervals, with the exception of atrazine and iprodione, which were sampled at weekly intervals. For each of the three identified chemicals used on each crop, EFED sought to compare EDWCs against monitored concentrations in two fundamental

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[27] The PE5 shell is a graphical user interface for running the PRZM and EXAMS models.
[28] In recent FIFRA Scientific Advisory Panel consultations on the pesticide atrazine, the USEPA reviewed methods for designing monitoring studies to capture exposures of concern and approaches for analyzing and interpreting existing monitoring data and characterizing the uncertainties in those estimates for use in risk assessments (USEPA, 2010a, 2010b, 2011, and 2012).

categories: (1) maximum detections in surface water used specifically as (or supplying water to reservoirs used as), source drinking water by CWSs, and (2) maximum detections in surface water of any kind.

For the former category, EFED employed data primarily from a USGS study on CWS source water: *Concentration Data for Anthropogenic Organic Compounds in Ground Water, Surface Water, and Finished Water of Selected Community Water Systems in the United States, 2002–05*.[29] The USGS CWS dataset was selected because this study focused on a number of rivers across the country that are used as source drinking water, with monitoring consisting of several years of monthly sampling. EFED considered CWS data from the Pesticide Data Program (PDP) as well, however, these concentrations were lower than the maximum detections from the USGS study; therefore, not used in present evaluation. EFED supplemented the CWS data with data on two specific chemicals (atrazine and iprodione) also measured in surface water used either directly as source drinking water by CWS (or, in the case of atrazine, measured in a creek that drains into reservoirs used directly as CWS source water), from registrant-conducted monitoring studies submitted to USEPA. Although most of these data represent drinking water supplies, they are primarily situated on fairly large river systems (**Table 4-1**) with large drainage areas, thus, are inherently heterogeneous and unlikely to be representative of water supplies most vulnerable to pesticide contamination. Additionally, given that the sampled systems were all lotic (flowing) rather than lentic (*i.e.,* lakes, reservoirs), the monthly sampling interval employed by USGS is unlikely to have resulted in sample collection coinciding with peak pesticide concentrations. The registrant-sponsored sampling for atrazine and iprodione was conducted approximately weekly.

To address some of these weaknesses, for the second category of comparisons against modeling results, EFED obtained the maximum measured concentration of each chemical in surface water of any kind (*i.e.,* not limited to community water supplies) throughout the United States measured by the USGS as part of the NAWQA program. Though EFED has no information to suggest that any of the monitored water bodies (**Table 4-2**) in this case are used as drinking water supplies, the concentrations generally exceed concentrations reported in the CWS studies.

For each crop and pesticide combination and each type of measured concentration (*i.e.,* CWS supply and miscellaneous surface water), EFED used two different kinds of DWI PCAs to modify the PRZM-EXAMS results: the national maximum crop-specific PCA, and a regional maximum, crop-specific PCA, for the water resource region corresponding with the location where the reported concentration was measured. Using each of these sets of PCAs, EFED

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[29] http://pubs.usgs.gov/ds/2007/268/

compared the national and regional PCA-adjusted EDWCs with measured drinking water supply (**Table 4-1** and **Figure 4-1**) and miscellaneous surface water (**Table 4-2** and **Figure 4-3**) concentrations. This was done to evaluate the level of protectiveness implicit in utilizing these PCAs in drinking water assessments. For comparison against the NAWQA dataset, EFED also developed EDWCs using regional PCAs that reflect all labeled pesticide uses (**Table 4-3** and **Figure 4-4**); similar to what might be done as part of a drinking water assessment.

Monitoring in many surface water bodies, particularly lotic systems or others with short residence times, is unlikely to capture true maximum concentrations because hydrologic conditions and the concentrations these conditions influence typically exhibit fluctuations on shorter time scales than the intervals between samples. In general, as sampling frequency increases, maximum concentrations measured in such samples increase (SAP 2010). In the absence of continuous monitoring, true maximum concentrations are unknown. While PCA-adjusted modeled pesticide concentrations that exceed measured pesticide concentrations provide some assurance that EFED's assessment process using PCAs has not underestimated pesticide concentrations in drinking water supplies, actual peak pesticide concentrations in surface water may exceed maximum measured concentrations by an order of magnitude or more (USEPA, 2010b, 2011, and 2012). To evaluate the possible degree of under-representing true peak concentrations inherent in sampling water bodies at less often than daily frequencies, EFED is exploring the use of concentration-adjustment "bias factors".[30] Based upon an analysis of daily atrazine monitoring data, estimated mean bias factors for weekly and monthly sampling intervals are 5.46 and 44.48, respectively.[31] These values were empirically derived from a limited monitoring dataset. In addition to sampling frequency, factors that may influence measured concentrations include water body hydrology, pesticide fate properties, and pesticide application patterns and practices. Bias factors based upon atrazine data may thus not be appropriate for use with chemicals that have very different fate properties or application patterns, for example. The use in this exercise is therefore included for illustrative purposes only. To use the bias factor, the maximum monitored concentration from a weekly interval sampling methodology is multiplied by the bias factor of 5.46 to estimate an upper bound concentration to account for the limited monitoring data. **Figure 4-2** shows the same modeling-monitoring comparison as in **Figure 4-1**, but with the measured concentrations adjusted using sampling interval-appropriate bias factors. Unlike the CWS data, the NAWQA data were not collected at regular intervals over extended durations at a given location, thus, it was not possible to develop bias factors to use in this analysis.

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[30] U.S. EPA 2012. FIFRA Science Advisory Panel– Problem Formulation for the Reassessment of Ecological Risks from the Use of Atrizine. Available at http://www.epa.gov/scipoly/sap/meetings/2012/061212meeting.html
[31] Personal Communication: Jim Hetrick, United States Environmental Protection Agency, Office of Pesticide Programs, Environmental Fate and Effects Division.

4.2 Results

Tables 4-1 and **4-2** provide comparisons between measured and modeled estimated pesticide concentrations that have been adjusted using national and regional maximum DWI watershed (plus HUC-12 surrogate) PCAs. **Tables 4-1** and **4-2** include DWI PCA-adjusted 1-in-10 year peak EDWCs, along with the crop-specific maximum measured concentration of each chemical in CWS-supply surface water, and miscellaneous surface water respectively. All of the sample concentrations listed in both tables are actual detections, *i.e.,* concentrations measured above method detection limits, and not bias factor-adjusted concentrations. National-maximum crop-specific PCAs (for DWI watersheds plus HUC-12 surrogates), and region-specific PCAs for the HUC-2 regions corresponding to the sampling locations are tabulated. **Figure 4-1** displays scatterplots of the PCA-adjusted EDWCs against the maximum detected concentrations of each pesticide in surface drinking water supplies. **Figure 4-2** displays the same PCA-adjusted EDWCs plotted against the estimated maximum bias factor-adjusted concentrations in the same water bodies. **Figure 4-3** displays scatterplots of the PCA-adjusted EDWCs against maximum detected concentrations of each chemical in miscellaneous surface water bodies (*i.e.,* NAWQA monitoring). Modeled concentrations in each case are compared only against the peak measured concentrations because monitoring data of sufficient frequency, duration and regularity to permit calculation of chronic or longer-term concentrations does not exist for the majority of pesticides. **Figure 4-4** displays a scatterplot of EDWCs adjusted using regional specific, all-use-inclusive PCAs against the same NAWQA monitoring data. The all-use-inclusive PCA values are consistent with the EDWCs that would be presented in a drinking water exposure assessment for use in dietary risk assessment. This is consistent with EFED standard methodologies (described in **Chapter 5**). The results of these comparisons are as follows:

1. Using national maximum DWI PCAs (based on DWI watersheds plus HUC-12 surrogates), adjusted EDWCs are greater than maximum monitored concentrations in CWS source water, for all chemicals except atrazine. In the case of atrazine, a single monitored sample (which, as mentioned previously, was collected from a creek that drains into source water reservoirs) had a concentration of 227 μg/L, which is 56% higher than the EDWC of 145.6 μg/L. Using regional maximum DWI PCAs, EDWCs are also greater than monitored concentrations for all chemicals except atrazine.

2. When bias factors are used to estimate maximum pesticide concentrations in CWS source surface waters; DWI PCA-adjusted EDWCs are greater than these concentrations for all but four chemicals when either national or regional maximum PCAs are used.

3. Adjusted EDWCs are greater than maximum measured concentrations for 13 out of 20 pesticides in miscellaneous (*i.e.*, NAWQA) surface waters when national maximum DWI PCAs are used. Using regional maximum DWI PCAs, adjusted EDWCs are greater than

maximum measured concentrations for less than half (9 out of 20) of the evaluated pesticides. Using regional maximum all-use-inclusive DWI PCAs, adjusted EDWCs (*i.e.*, EDWC that would be used in EFED drinking water exposure assessments) are greater than maximum measured concentrations for 14 out of 20 pesticides in miscellaneous (NAWQA) surface waters.

Table 4-1. Comparison Between Maximum Monitored Pesticide Concentrations in Drinking (surface) Water Sources (USGS study), and Acute EDWCs Adjusted using DWI PCAs

Crop	Pesticide	DW Measured Conc. (µg/L)	State where measured	Water body	National Max PCA	Regional Max PCA[a]	PE5 Conc. (µg/L)	National EDWC (µg/L)	Regional EDWC (µg/L)	Ratio National EDWC /Meas. DW Conc.	Ratio Regional EDWC / Meas. DW Conc.
All Ag	diazinon	0.0855	GA	Chattahoochee River	1.00	0.52	150	150	78	1754	912
All Ag	chlorothalonil (TTR)[b]	0.71[c]	IN	White River	1.00	0.89	363	363	323	511	455
All Ag	chlorothalonil (parent)[b]	0.71[c]	IN	White River	1.00	0.89	83.9	79	75	118	105
All Ag	carbofuran	0.0141	IN	White River	1.00	0.89	27.9	28	25	1860	1761
Corn	acetochlor	4.77	IN	White River	0.68	0.51	82.3	56	42	12	8.8
Corn	atrazine	227	OH[d]	Sterling Run Creek	0.68	0.51	214	146	109	0.64	0.48
Corn	fipronil	0.0375	NC	Neuse River	0.68	0.09	0.813	0.55	0.07	15	2.0
Cotton	fluometuron	0.0065	NC	Neuse River	0.21	0.08	89.6	19	7.2	2895	1103
Orchard	bromacil	0.0927	GA	Chattahoochee River	0.33	0.12	268	88	32	954	347
Orchard	oryzalin	0.065	MD	Potomac River	0.33	0.05	261	86	13	1325	201
Orchard	phosmet	0.0074	MD	Potomac River	0.33	0.05	11.1	3.7	0.56	495	75
Soybean	imazaquin	0.16	IN	White River	0.59	0.59	19.3	11	11	71	71
Soybean	acifluorfen	0.011	IN	White River	0.59	0.59	86.8	51	51	4656	4656
Soybean	bentazon	0.11	IN	White River	0.59	0.59	20.5	12	12	110	110
Turf	picloram	0.17	IN	White River	0.86	0.49	19	16	9	96	55
Turf	triclopyr	0.45	IN	White River	0.86	0.49	1143	983	560	2184	1254
Turf	iprodione	0.564	NJ[2]	Rahway River	0.86	0.60	361	310	217	550	384
Vegetable	dcpa	0.0049	OR	Clackamas River	0.19	0.01	1427	143	14	29122	2912
Wheat	bromoxynil	0.0046	IN	White River	0.41	0.10	5.16	2.1	0.5	460	112

Wheat	mcpa	0.47	GA	Chattahoochee River	0.41	0.10	40.2	16	4.0	35	8.6

Concentration (Conc.)
Measured Drinking Water Concentration (Meas. DW Conc.)
[a] Region based on location where listed concentration was measured.
[b] Chlorothalonil was run twice, once using the fate data for all of the residues of concern, then again using just the fate data for the parent.
[c] Monitoring value obtained from turf drinking water study (MRID 47881501).
[d] Monitoring value obtained from Syngenta's atrazine monitoring program (AMP) dataset collected between 2004 and 2010.

Table 4-2. Comparison Between Maximum Monitored Pesticide Concentrations in Surface Water (USGS NAWQA), and Acute EDWCs Adjusted Using DWI PCAs

Crop	Pesticide	Max. NAWQA conc. (µg/L)	State where measured	Water body	National Max PCA	Regional Max PCA[a]	PE5 conc. (µg/L)	National EDWC (µg/L)	Regional EDWC (µg/L)	Ratio National EDWC /Meas. DW Conc.	Ratio Regional EDWC / Meas. DW Conc.
All Ag	diazinon	3.8	CA	Orestimba Creek	1.00	0.74	150	150	111	39	29
All Ag	chlorothalonil (TTR)[b,c]	0.71[b]	NJ	Great Egg Harbor River	1.00	0.82	363	363	261	511	410
All Ag	chlorothalonil (parent)[b,c]	0.71[b]	NJ	Great Egg Harbor River	1.00	0.82	83.9	84	69	118	97
All Ag	carbofuran	32.2	OR	Zollner Creek	1.00	0.72	27.9	27.9	20	0.87	0.62
Corn	acetochlor	215	NE	tributary to South Fork Dry Creek	0.68	0.36	82.3	56	30	0.26	0.14
Corn	atrazine	201	AL	Bogue Chitto Creek	0.68	0.09	214	146	19	0.72	0.10
Corn	fipronil	6.41	LA	Bayou Blue	0.68	0.21	0.813	0.6	0.2	0.09	0.03
Cotton	fluometuron	37.8	LA	Bayou Macon	0.21	0.20	89.6	19	17.9	0.50	0.47
Orchard	bromacil	5	GA	Peachtree Creek	0.33	0.12	268	88	32	18	6.4
Orchard	oryzalin	1.9	VA	Accotink Creek	0.33	0.12	261	86	31	45	16.5
Orchard	phosmet	0.063	MS	Yazoo River	0.33	0.00	11.1	3.7	0.0	58	0.0
Soybean	imazaquin	5.9	AL	Three Mile Creek	0.59	0.20	19.3	11	4	1.9	0.7
Soybean	acifluorfen	2.2	IN	Kessinger Ditch	0.59	0.59	86.8	51	51	23	23
Soybean	bentazon	8.6	TX	White's Bayou	0.59	0.01	20.5	12	0	1.4	0.0
Turf	picloram	2.7	TX	East Fork Trinity River	0.86	0.25	19	16	5	6.1	1.8
Turf	triclopyr	16	TX	White's Bayou	0.86	0.25	1143	983	286	61	18
Turf	iprodione	141	CA	culvert discharging to Mustang Creek	0.86	0.59	361	310	213	2.2	1.5
Vegetable	dcpa	100	CO	Lonetree Creek	0.19	0.02	1427	271	29	2.7	0.29

Wheat	bromoxynil	6.1	CO	Lonetree Creek	0.41	0.27	5.16	2.1	1.4	0.35	0.23
Wheat	mcpa	18.6	MI	Clinton River	0.41	0.11	40.2	16	4.4	0.89	0.24

Concentration (Conc.)
Measured Drinking Water Concentration (Meas. DW Conc.)
[a] Region based on location where listed concentration was measured.
[b] Chlorothalonil was run twice, once using the fate data for all of the residues of concern, then again using just the fate data for the parent.
[c] Monitoring value obtained from turf drinking water study (MRID 47881501).

Table 4-3. Comparison Between Maximum Monitored Pesticide Concentrations in Drinking (Surface) Water Sources (USGS study), and Acute EDWCs Adjusted Using Crop and Regionally-Appropriate DWI PCAs

Pesticide	Uses	Max. NAWQA Conc. (µg/L)	Name of water body where measured	State where measured	Region where measured	Use-appropriate PCA	PCA type	PE5 conc. (µg/L)	Regional EDWC (µg/L)	Regional Ratio EDWC /max.
Diazinon	almonds, apples, apricots, bananas, beets (red, table), blackberries, blueberries, cabbage, carrots, cauliflower, celery, cherries, collards, sweet corn, cranberries, cucumbers, endive (escarole), figs, filberts, ginseng, grapes, hops, kale, lettuce, loganberries, melons, mushrooms, nectarines, onions, parsley, parsnips, peaches, pears, peas, peppers, pineapples, plums, Irish potatoes, prunes, radishes, radishes (Chinese), raspberries, rutabagas, squash (winter and summer), spinach, strawberries, sugar beets, sweet potatoes, Swiss chard, tomatoes, turnips (roots and tops), vegetables (Brassica leafy group), walnuts, and watercress	3.8	Orestimba Creek	CA	18	0.74	All Ag	150	111	29
chlorothalonil (TTR)[a]	apricot, berries, cabbage, cantaloupes, carrots, celery, cherries, cotton, cucumber, melons, nectarines, onions, peanuts, potatoes, tomatoes, watermelons, container-grown nursery crops, flowers, greens, golf courses, sod farms, lawns, greenhouse crops	0.71[b]	Great Egg Harbor River	NJ	2	0.82	All Ag	363	261	368
chlorothalonil (parent)[s]	apricot, berries, cabbage, cantaloupes, carrots, celery, cherries, cotton, cucumber, melons, nectarines, onions, peanuts, potatoes, tomatoes, watermelons, container-grown nursery crops, flowers, greens, golf courses, sod farms, lawns, greenhouse crops	0.71[b]	Great Egg Harbor River	NJ	2	0.82	All Ag	83.9	60	85

carbofuran	alfalfa, artichoke, banana, barley, coffee, corn (field, pop, and sweet), cotton, cucurbits (cucumber, melons, and squash), grapes, oats, pepper, plantain, potato, sorghum, soybean, sugar beet, sugarcane, sunflower, wheat, agricultural fallow land, cotton, ornamental and/or shade trees, ornamental herbaceous plants, ornamental non-flowering plants, ornamental woody shrubs and vines, pine, spinach grown for seed, tobacco	32.2	Zollner Creek	OR	17	0.74	All Ag	27.9	20	0.62
acetochlor	corn and "rotational crops"	215	Tributary to South Fork Dry Creek	NE	10	0.38	Corn-wheat	82.3	31	0.15
atrazine	corn (field & sweet), sorghum, suragcane, turf, range grasses, wheat stubble on fallow land	201	Bogue Chitto Creek	AL	3	0.65	Turf-All Ag	214	139	0.69
fipronil	rice, turf, other residential uses (fire ant mounds), potatoes, turnips, rutubagas	6.41	Bayou Blue	LA	8	0.58	Turf-All Ag	0.813	0.5	0.07
fluometuron	cotton	37.8	Bayou Macon	LA	8	0.20	Cotton	89.6	17.9	0.47
bromacil	grapefruit, lemons, oranges, limes, tangerines, rights-of-way	5	Peachtree Creek	GA	3	0.64	Turf-orchard	268	169	33.8
oryzalin	orchards, berries, and vine crops, Christmas tree plantations, field-grown roses, nursery stock, ornamentals, golf courses, non-crop areas, and parks and greenhouse drainage areas, turf	1.9	Accotink Creek	VA	2	0.79	Turf-All Ag	261	206	108.5
phosmet	corn (sweet), citrus; homeowner uses (trees, shrubs, ornamental plants, gardens, fire ant mounds); fruit & nut trees, grapes, kiwi, blueberries, cranberries, cotton, peas, potatoes, sweet potatoes	0.063	Yazoo River	MS	8	0.75	All Ag	11.1	10.5	167.4
imazaquin	soybeans, turf, ornamentals	5.9	Three Mile Creek	AL	3	0.64	Turf-soybeans	19.3	12	2.1

acifluorfen	soybeans, rice, peanuts, mulch, ornamental shrubs, lawns, herbaceous plants and shade trees, private roads, sidewalks, patios, paths	2.2	Kessinger Ditch	IN	5	0.96	Turf-All Ag	86.8	83	38
bentazon	soybeans, alfalfa, corn, sorghum, turf	8.6	White's Bayou	TX	12	0.82	Turf-All Ag	20.5	17	2.0
picloram	pasture, wheat, barley, oats, rangeland, forest trees, roadsides	2.7	East Fork Trinity River	TX	12	0.82	Turf-All Ag	19	16	5.8
triclopyr	rice, pasture and rangeland, rights-of-way, forestry, turf	16	White's Bayou	TX	12	0.82	Turf-All Ag	1143	286	18
iprodione	almonds, apricots, cherries, nectarines, peaches, pecans, plums, prunes, beans (dried, lima, and snap), blackberries, blueberries, broccoli, bushberries, caneberries, carrots, garlic, grapes, ginseng, gooseberries, huckleberries, lettuce (head and leaf), loganberries, mustard, cabbage, Chinese cabbage, dry bulb onions, peanuts, potatoes, raspberries, strawberries, ornamentals, turf, ornamentals	141	culvert discharging to Mustang Creek	CA	18	0.83	Turf-All Ag	361	300	2.1
dcpa	beans, beets, broccoli, Brussels sprouts, cabbage, cauliflower, cole crops, collards, cress, cucumber, eggplant, garlic, kale, melons, mustards, onion, peas (southern), pepper, radish, squash, strawberry, sweet potato, tomato, turnip, yam	100	Lonetree Creek	CO	10	1.00	All-Ag	1427	1427	14.27
bromoxynil	wheat, garlic/onions, mint, flax, spearmint, peppermint, barley, oats, rye, triticale, sorghum, cotton, corn (field, sweet, and pop), fodder/hay, grass, millet (proso), alfalfa, sudangrass, fallow land, turf, ornamentals	6.1	Lonetree Creek	CO	10	1.00	Turf-All Ag	5.16	5.16	0.85
mcpa	wheat, alfalfa, barley, clover, flax, lespedeza, oats, pasture and rangeland grass, peas, rice, rye, sorghum, trefoil, triticale, turf, rights-of-way, forestry	18.6	Clinton River	MI	4	1.00	Turf-All Ag	40.2	40.2	2.16

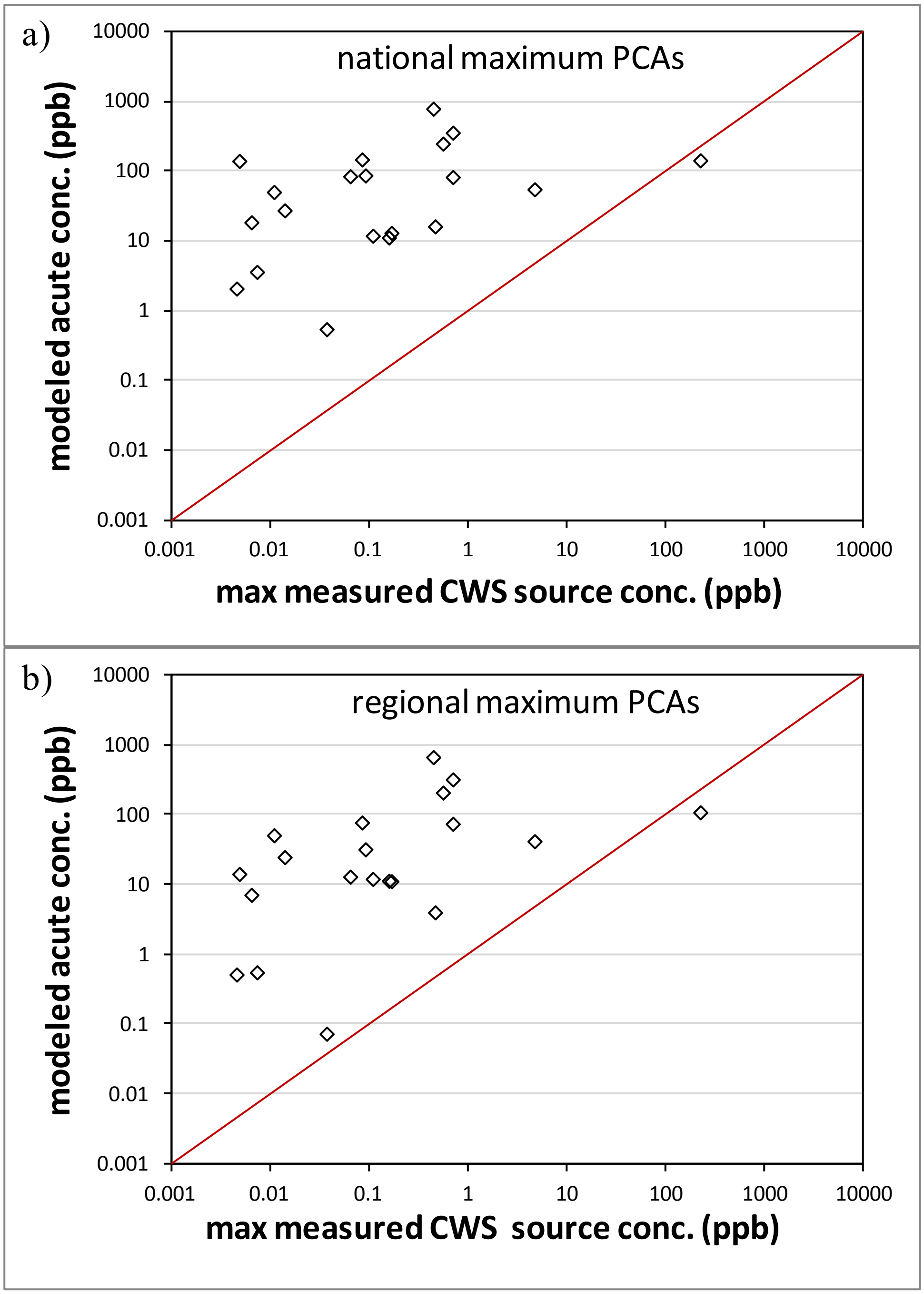

Figure 4-1. **Comparison of Modeled 1-in-10 Year Maximum EDWCs Against Maximum Single Sample Concentrations of the Same Chemicals Measured in Studies of Rivers and One Creek that Serve as Source Water for Community Water Supplies, Using: a) National Maximum DWI PCAs, and b) Regional Maximum DWI PCAs, with Region DWI PCA Selected to Match Locations of Monitored Concentrations**

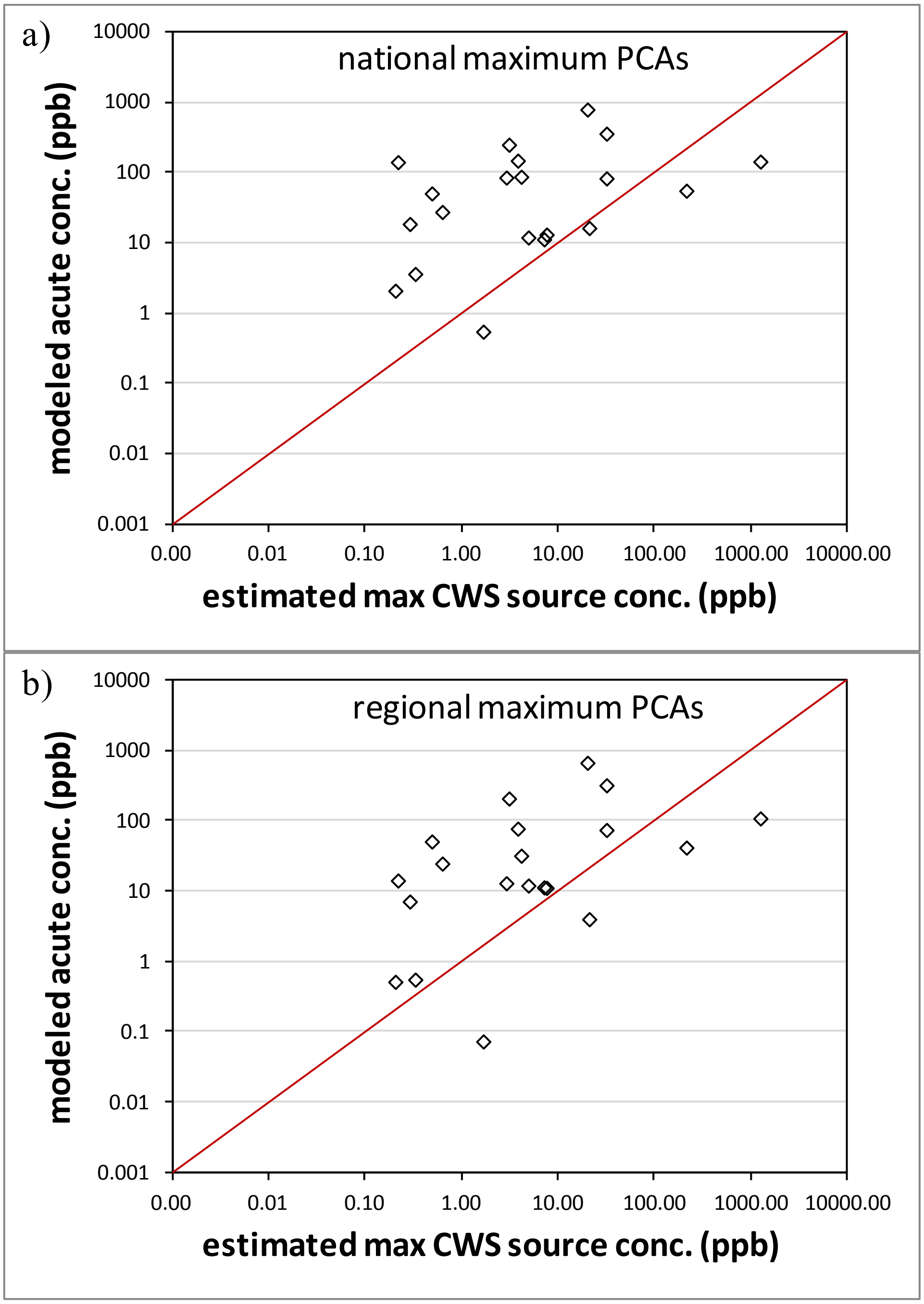

Figure 4-2. Comparison of Modeled 1-in-10 Year Maximum EDWCs Against Bias Factor-adjusted Maximum Single Sample Concentrations of the Same Chemicals Measured in Studies of Rivers and One Creek that Serve as Source Water for Community Water Supplies, using: a) National Maximum DWI PCAs, and b) Regional Maximum DWI PCAs, with Region Selected to Match Locations of Monitored Concentrations

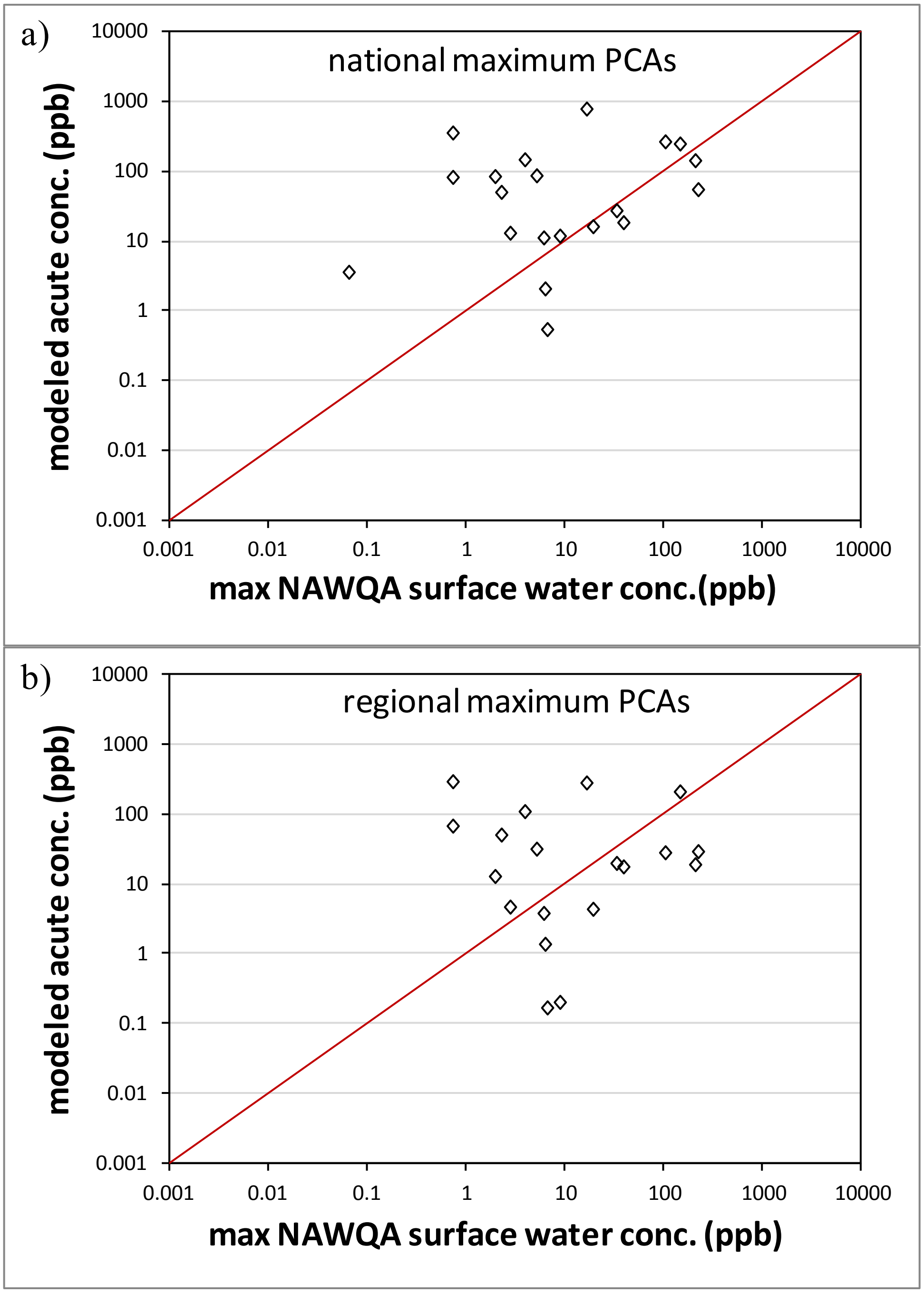

Figure 4-3. **Comparison of Modeled 1-in-10 Year Maximum EDWCs Against Maximum Single Sample Concentrations of the Same Chemicals Measured in Surface Waters by the USGS NAWQA Program, Using: a) National Maximum DWI PCAs, and b) Regional Maximum DWI PCAs, with Region Selected to Match Locations of Monitored Concentrations.** [Note that PCAs in this comparison largely reflect only single crops, and may not correspond with PCAs that would be used in a regional drinking water assessment]

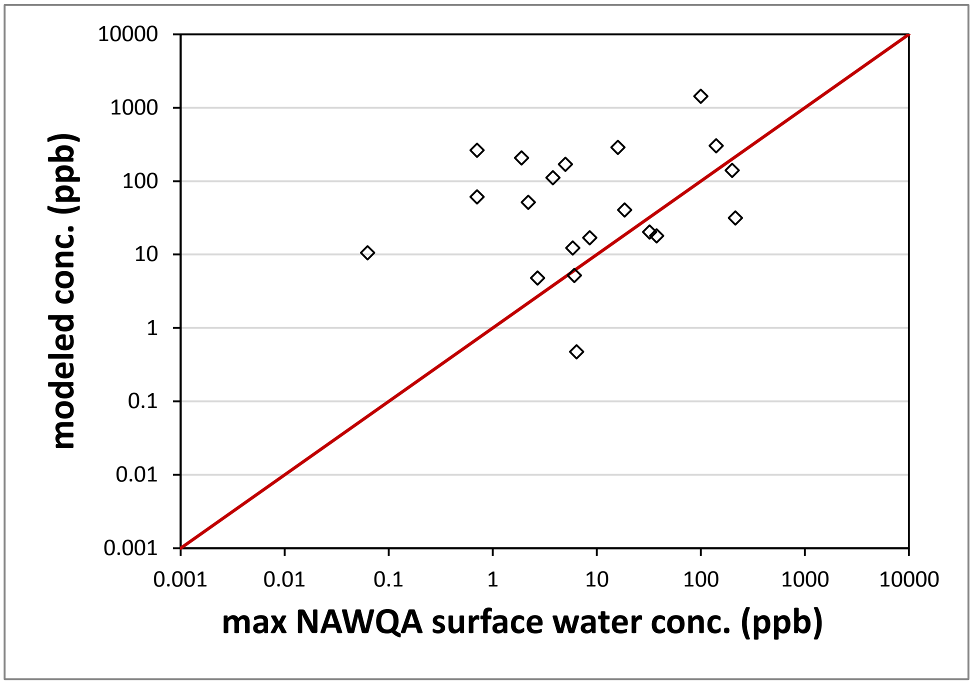

Figure 4-4. **Comparison of Modeled 1-in-10 Year Maximum EDWCs Against Maximum Single Sample Concentrations of the Same Chemicals Measured in Surface Waters by the USGS NAWQA Program, Using PCAs reflective of all labeled uses of the pesticide, as indicated in Table 4-3**

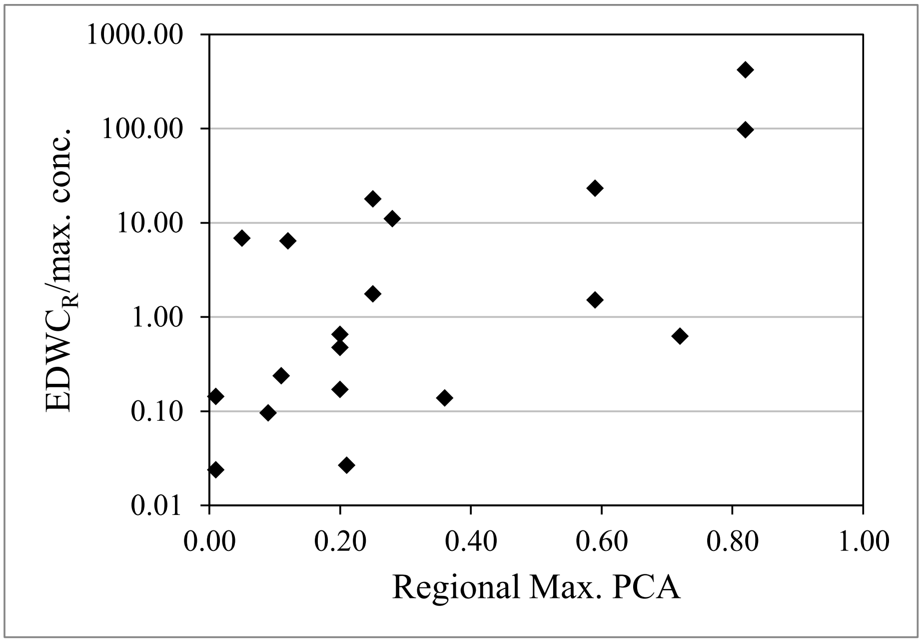

Figure 4-5. Ratio of Regional PCA Adjusted Modeled Pesticide Concentrations (EDWCs) to Maximum Measured (NAWQA) Pesticide Concentrations, *vs.* Regional Crop-specific PCA Employed in Calculating the Modeled Concentrations

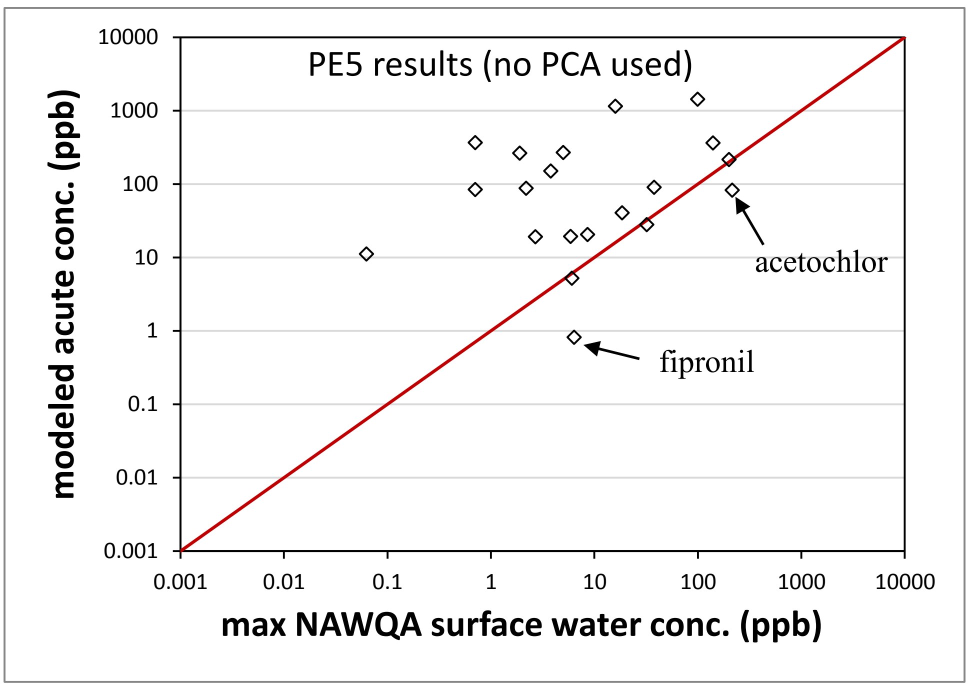

Figure 4-6. Comparison of Modeled 1-in-10 Year Maximum EDWCs (calculated using no PCA adjustment) Against Maximum Single Sample Concentrations of the Same Chemicals Measured in Surface Waters by the USGS NAWQA Program

4.3 Discussion

For all but one pesticide, atrazine, results of aforementioned analyses demonstrate that PRZM-EXAMS modeling coupled with the use of both national and regional-maximum DWI PCAs adjustments, generates concentration estimates that exceed maximum observed pesticide concentrations in lotic surface waters used for (or lentic waters draining directly to lotic waters used for) CWS supply. The fact that the atrazine data, which were collected at a higher frequency than most of the other data used in this analysis, are the lone exception to this observation is noteworthy. In addition, atrazine uses include use on rights-of-ways and ornamentals; thus, a PCA of 1.0 would be used in drinking water exposure assessment. When standard methodologies are used, the modeled concentration exceeds the measured value. In flowing water bodies, less often than daily sampling is unlikely to capture peak pesticide concentrations generated by stormflow runoff events, which may transport pesticides into water bodies over much shorter time scales. The use of bias factors, as in **Figure 4-2**, is an attempt to adjust monitoring data to account for limitations in sampling frequency. Many of the CWS supply sampling locations from which data used in this analysis were collected are unlikely to represent the kind of highly vulnerable sites that USEPA's PRZM-EXAMS modeling is intended to represent, thus, modeled estimated concentrations are expected to generally exceed maximum concentrations observed in actual waters. **Figure 4-2** supports this assumption.

Results of the second phase of this analysis, in which modeled concentrations are compared against national maximum pesticide concentrations measured in surface water by the USGS NAWQA sampling program, demonstrate that PCA-adjusted PRZM-EXAMS concentrations can underestimate real pesticide concentrations, at least sometimes in some water bodies. The implications of this for pesticides in drinking water supplies are not clear. The degree to which conditions in these water bodies resemble conditions in vulnerable CWS supplies is not known. **Figure 4-5** demonstrates an apparent (though weak) relationship between the regional PCAs used in the NAWQA data comparison of **Figure 4-3**, and the degree to which modeled concentrations are higher or lower than observed concentrations. Such a relationship suggests that the degree of under or overestimation for any pesticide may be dominated by the PCA rather than by the PRZM-EXAMS results, which suggests that underestimates may be a consequence of use of a "wrong" PCA, *i.e.,* one that underestimates real crop coverage or pesticide use. Additionally, **Figure 4-5** shows that when low PCAs are used (those less than 0.4), PCA adjusted EDWC are commonly lower than monitored concentrations. While it is unknown whether the NAWQA sampling sites occurred in water bodies near DWIs, it is possible that some of the sampling sites are near DWIs or are representative sites where DWI may be found.

Figure 4-6 displays a comparison between the same NAWQA data, and unadjusted (*i.e.,* no PCA) PRZM-EXAMS concentration results. As the figure illustrates, in this case modeled concentrations exceed measured concentrations for all but four pesticides. Modeled concentrations underestimate measured concentrations by more than 20% for only two pesticides: fipronil and acetochlor. The largest degree of underestimation, which is by less than an order of magnitude, is seen for fipronil. The fipronil detection in question occurred in a Louisiana bayou, and may be influenced by use of the chemical on rice cultivation in the area. A PCA for rice is not reported in this document. The results displayed in **Figure 4-6** illustrate that modeled pesticide concentrations even without PCA adjustment do not always exceed real world concentrations, and serve to emphasize the apparent importance of selecting PCAs appropriately.

USEPA will continue to evaluate PCA-adjusted EDWCs against available monitoring data to ensure that estimated exposures do not underestimate measured concentrations in drinking water sources. Additionally, USEPA will continue to work on developing reliable methods of quantifying confidence bounds on measured concentrations to account for uncertainties related to sampling frequency, and providing spatial context to monitoring data.

Chapter 5. Guidance on Applying PCAs to Estimate Drinking Water Concentrations

5.1 National Screening Level Assessments

OPP uses the coupled PRZM and EXAMS models[32] to generate EDWCs for pesticides applied to a crop at an expected high-end exposure scenario for that crop use. The resulting EDWCs are multiplied by the PCA (expressed as a fraction) to adjust for the maximum potential percent of the watershed that is covered by the crop of interest; thus, could potentially be treated by the pesticide of interest.

For an initial, national screening level assessment of a pesticide used on a single crop, the PCA used represents the highest value for the given crop in any CWS-DWI watershed (plus HUC-12 surrogates) nationally (*i.e.,* the highlighted crop-specific value in **Table 1**). If the pesticide is only used on one of the crop combinations listed in **Table 2**, then the national-maximum PCA for that crop combination (*i.e.,* the highlighted value in **Table 2**) is used. If the pesticide is used on other crops or crop combinations than those listed in **Tables 1** and **2**, then the default "all-agriculture" PCA should be applied. PCAs can be applied to the 1-in-10-year peak, annual, or other time-weighted average duration, or to the full time-series generated by PRZM-EXAMS in a Tier 2 drinking water assessment.

Figure 5-1 provides a decision tree for selecting PCAs for national-level drinking water assessments. Estimates may be developed for the following situations: (A) a single crop with a crop specific PCA; (B) multiple crops that all have crop-specific PCAs; or (C) a single crop without a crop specific PCA, or multiple crops besides those with specific crop combination PCAs. A discussion of these three situations follows.

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[32] See http://www.epa.gov/oppefed1/models/water/ to learn more about how these models generate EDWCs based on the physical-chemical properties of a pesticide, application parameters, agronomic information on a crop, precipitation, and other soil, hydrologic, and landscape properties.

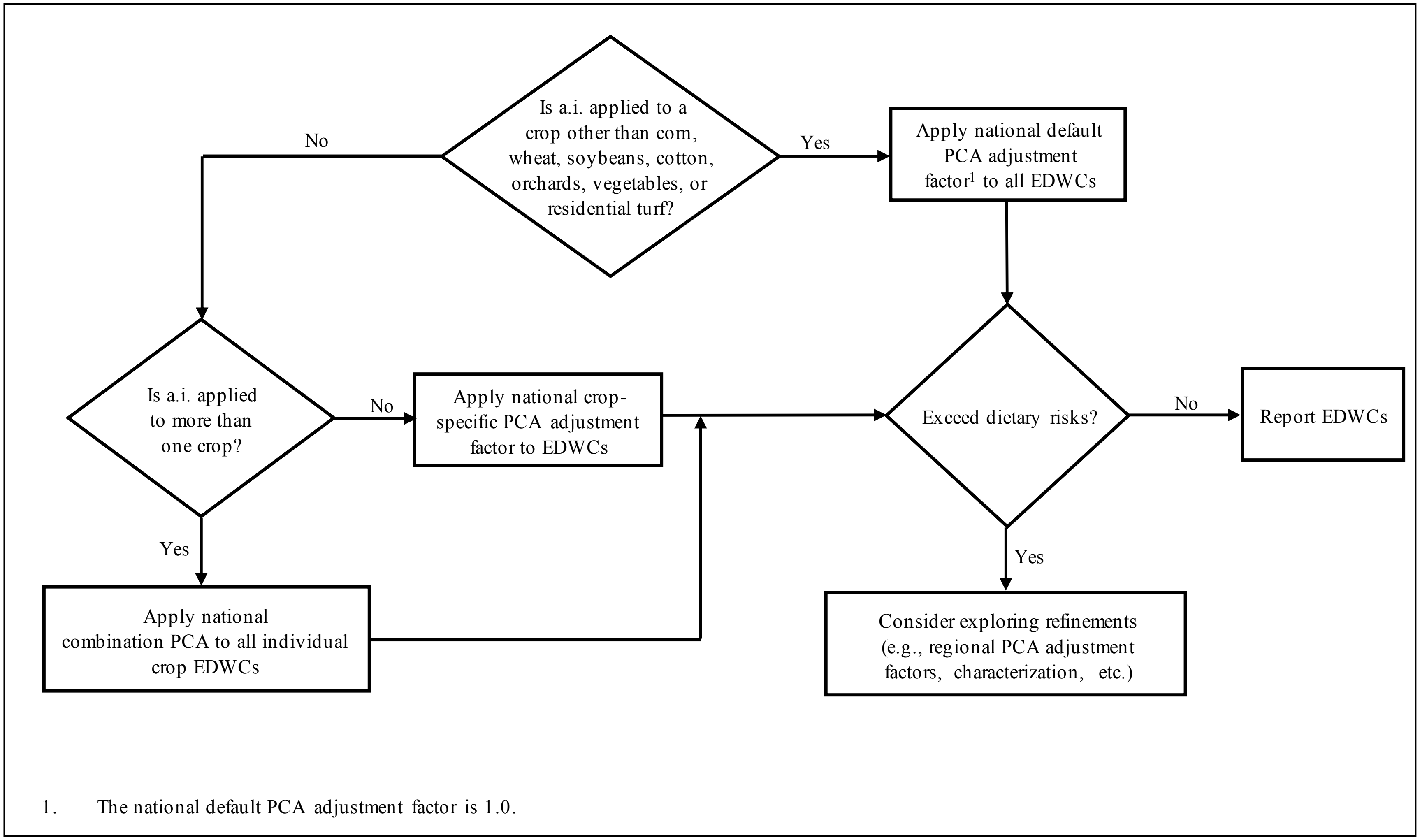

Figure 5-1. Decision Tree for National PCA Adjustment Factor Determination.

A) If a pesticide is only registered for use on a single crop for which a crop-specific PCA exists (corn, soybeans, wheat, cotton, vegetable, orchard, or turf), multiply the unadjusted EDWC by the appropriate national PCA for that crop (**Table 1**) to obtain the final EDWC. For Tier 2 screening modeling, apply the maximum national PCA regardless of the modeled scenario location. If an individual crop is in an established crop group (such as tomatoes, which would be included in the vegetable group), or if all of the uses fall within the same crop group, apply the PCA for that crop group.

B) If a pesticide is registered for use only on multiple crops for which specific crop-combination PCA have been developed (Table 2), then multiply the unadjusted EDWC by the PCA for the crop combination to obtain the final EDWC. The PCA that should be used represents the maximum potential percentage of the watershed that could be planted with these crops.

C) If a pesticide is applied to a single crop that lacks a crop-specific PCA, multiply the unadjusted estimated drinking water concentration (EDWC) for the crop by the national default PCA (1.0 for all-agriculture) to obtain the final EDWC. If the pesticide is applied to multiple crops not limited to corn, soybeans, wheat, cotton, vegetable, orchard, and turf, multiply EDWCs by the national default PCA to obtain the final EDWCs. If the pesticide is used for non-agricultural purposes other than residential turf (*e.g.,* ornamental plants, non-cropland areas, pasture and rangeland, forestry, or rights-of-way), multiply EDWCs by the national default PCA to obtain the final EDWCs. In such cases, if any of the crops (including turf) or crop combinations to which the pesticide is applied include crops for which PCAs have been developed, the reviewer should note this circumstance, as it has potential relevance for regional refinements that may be possible.

5.2 Regional Refinements

If dietary risks are exceeded in a national screening level assessment, the risk manager may ask EFED to refine the pesticide exposure assessment. The risk assessor can either refine the assessment qualitatively by providing additional characterization of potential exposure, or refine it quantitatively by simulating additional sites for each crop and/or by using regional PCAs in place of national PCAs.

Regional PCAs can be used to determine whether potential screening level EDWCs exceed dietary risks nationwide or only in certain regions of the country. The most appropriate use of regional PCAs can be best determined in discussions between risk assessors and risk managers. Possible options that may be considered include the following:

- Use of regional default PCAs to refine EDWCs for uses with limited regional extent, such as Section 18 emergency exemptions, Section 24(c) Special Local Need requests, or crops with limited, well-defined growing regions (*e.g.*, citrus).
- Use of regional PCAs to better distinguish which crop-pesticide scenarios in a pesticide use area may result in the highest surface water EDWCs. For instance, a crop with a small percentage of total usage of the pesticide grown in the South Atlantic-Gulf region may have a maximum use rate much higher than the predominant usage on corn in the Midwest. However, after application of the regional PCA to the minor use scenario, the EDWC from the Midwest corn scenario might be higher and, therefore, the driver of the drinking water exposure assessment.
- Use of regional PCAs in association with a pesticide usage map to distinguish between magnitudes of possible exposure for the same crop in different regions of the country, and to focus spatial modeling refinements.
- Use of regional PCAs to populate a matrix of regional peak or chronic EDWCs for each labeled use of a pesticide that is expected to result in dietary risk exceedances, in order to refine a drinking water exposure assessment. This begins with tabulating states by water resource (HUC-2) region where labeled crops are grown and allowed for use. Then PRZM-EXAMS scenarios or surrogates for each relevant HUC-2 are derived. These scenarios incorporate the maximum labeled use pattern (which may be geographically-specific) for each use. Regional PCA-adjusted EDWCs are then tabulated for comparative purposes. The risk assessor may request from HED a back-calculated drinking water level of concern for reference (*e.g.*, highlight on the table regions with EDWCs that exceed the level of concern).

As an additional refinement, for uses with regional PCA-adjusted EDWCs greater than the level of concern, the risk assessor in consultation with the risk manager may request reported use information from areas of the United States with similar geography and/or crop management practices from the BEAD. This information can be used to model and characterize "reported" use patterns, based on the average number of applications and high-ends of the application rate distributions reported. Characterization of these reported use patterns may help risk managers to determine whether use pattern reductions to levels that appear to remain efficacious, may constitute worthwhile label mitigation.

5.3 Summary

The DWI, DWI watershed, and DWI watershed PCA datasets provide USEPA with new tools that open the possibility of exploring geographically specific drinking water assessments beyond standard regional refinements, in ways that have not previously been available using existing tools. The geospatial nature of these datasets means that locations with greater risk (*i.e.*, hot-spots) and more vulnerable communities can be identified. That information can be coupled with geographically specific soil, hydrology, weather, and landscape property data, so that targeted mitigation measures can potentially be developed. Methodologies and procedures for conducting such analyses need further development, and policy and resource implications for USEPA to adopt such approaches into risk assessment practice need further investigation. However, under the assumption that these datasets will prove to be as useful as anticipated, it is USEPA's current plan to update the DWI, DWI watershed, and DWI watershed PCA datasets on an ongoing five year basis for the foreseeable future.

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Appendix A

QA/QC of Drinking Water PCAs for Various Crops and Crop Groups

(1) Objectives

A process was devised to verify the validity of the drinking water PCA values obtained for corn, cotton, orchards, rice, soybean, total cropland, vegetables and wheat. The process consisted of two main components, namely:

(a) Verify that county NASS agricultural statistics data were correctly retrieved from the source, and
(b) Verify that GIS processing of the source data is correct and reproducible.

(2) Methodology

A. Validation of NASS Data

The following steps were executed to check that NASS data were correctly retrieved from the source:

(a) "County NASS Agricultural Statistics data" used in deriving PCA values were entered into the attached verification spreadsheet (**Table A-1**). For each crop or crop group, data included the total county acreage in counties associated with the HUC-8, plus additional counties selected at random. For example, the total number of counties checked was 6 each for soybean/ orchards/vegetables, 7 each for corn/rice/wheat, and 8 each for cotton/total cropland. In addition, the total US acreage for these crops/crop groups was recorded; and

(b) Data used in deriving PCAs (**Table A-1**, highlighted in yellow) were compared with that obtained by the above stated QA/QC step (**Table A-1**, highlighted in green).

Table A-1 NASS Validation Sheet

Associated With:	Thawley (Data Used to derive PCAs)			Ruhman (QA/AC)		
	Total	From Original	NASS Table #	Total	QA/QC	NASS Table #
Corn for grain PCA	593.0684	217,106	25	593.0684	217,106	1
Corn for grain PCA	567.9952	215,502	25	567.9952	215,502	1
Corn for grain PCA	592.4867	233,657	25	592.4867	233,657	1
Corn for grain PCA	570.4783	219,435	25	570.4783	219,435	1
Corn for grain: Random Selection	565.9654	203,297	25	565.9654	203,297	1
Corn for grain: Random Selection	471.9035	124,421	25	471.9035	124,421	1
Corn for grain: Random Selection	566.6673	161,542	25	566.6673	161,542	1
Total for USA		86,248,542	25		86,248,542	1
Corn for silage PCA	593.0684	1,172	25	593.0684	1,172	1
Corn for silage PCA	567.9952	561	25	567.9952	561	1
Corn for silage PCA	592.4867	1,358	25	592.4867	1,358	1
Corn for silage PCA	570.4783	1,033	25	570.4783	1,033	1
Corn for silage: Random Selection	565.9654	539	25	565.9654	539	1
Corn for silage: Random Selection	471.9035	4,639	25	471.9035	4,639	1
Corn for silage: Random Selection	566.6673	2,031	25	566.6673	2,031	1
Total for USA		5,979,661	25		5,979,661	1
Corn, sweet PCA	593.0684	0	30	593.0684	0	30
Corn, sweet PCA	567.9952	0	30	567.9952	0	30
Corn, sweet PCA	592.4867	0	30	592.4867	0	30
Corn, sweet PCA	570.4783	0	30	570.4783	0	30
Corn, sweet: Random Selection	565.9654	0	30	565.9654	0	30
Corn, sweet: Random Selection	471.9035	0	30	471.9035	0	30
Corn, sweet: Random Selection	566.6673	4	30	566.6673	4	30

Associated With:	Thawley (Data Used to derive PCAs)			Ruhman (QA/AC)		
	Total	From Original	NASS Table #	Total	QA/QC	NASS Table #
Total for USA		**662,946**	**30**		**662,946**	**30**
Total All corn USA		**92,891,149**			**92,891,149**	
Cotton: Random Selection	**887.9326**	**23,240**	**25**	**887.9326**	**23,240**	**1**
Cotton PCA	**913.2301**	**171,616**	**25**	**913.2301**	**171,616**	**1**
Cotton: Random Selection	**895.2175**	**58,223**	**25**	**895.2175**	**58,223**	**1**
Cotton PCA	**904.0704**	**44,952**	**25**	**904.0704**	**44,952**	**1**
Cotton PCA	**980.0022**	**164,297**	**25**	**980.0022**	**164,297**	**1**
Cotton PCA	**920.3648**	**218,069**	**25**	**920.3648**	**218,069**	**1**
Cotton: Random Selection	**987.5633**	**121,319**	**25**	**987.5633**	**121,319**	**1**
Cotton PCA	**908.9309**	**242,656**	**25**	**908.9309**	**242,656**	**1**
Total for USA		**10,493,238**	**25**		**10,493,238**	**1**
Rice: Random Selection	**1,663.6851**	**97,845**	**25**	**1,663.6851**	**97,845**	**1**
Rice PCA	**1,164.6440**	**147,817**	**25**	**1,164.6440**	**147,817**	**1**
Rice PCA	**1,317.6992**	**93,817**	**25**	**1,317.6992**	**93,817**	**1**
Rice: Random Selection	**1,497.0533**	**9,313**	**25**	**1,497.0533**	**9,313**	**1**
Rice: Random Selection	**964.4799**	**0**	**25**	**964.4799**	**0**	**1**
Rice PCA	**607.9575**	**99,284**	**25**	**607.9575**	**99,284**	**1**
Rice PCA	**1,029.1834**	**29,675**	**25**	**1,029.1834**	**29,675**	**1**
Total for USA		**2,758,792**	**25**		**2,758,792**	**1**
Orchards PCA	**5,939.5449**	**4,008**	**25**	**5,939.5449**	**4,008**	**1**
Orchards: Random Selection	**8,186.6423**	**836**	**25**	**8,186.6423**	**836**	**1**
Orchards PCA	**1,381.1756**	**434**	**25**	**1,381.1756**	**434**	**1**
Orchards: Random Selection	**3,138.0985**	**1**	**25**	**3,138.0985**	**1**	**1**
Orchards PCA	**1,383.6187**	**218**	**25**	**1,383.6187**	**218**	**1**

Associated With:	Thawley (Data Used to derive PCAs)			Ruhman (QA/AC)		
	Total	From Original	NASS Table #	Total	QA/QC	NASS Table #
Orchards: Random Selection	4,754.1505	3,671	25	4,754.1505	3,671	1
Total for USA		115,935	25		115,935	1
Soybean for beans: Random Selection	701.8973	101,713	25	701.8973	101,713	1
Soybean for beans: Random Selection	589.6797	65,993	25	589.6797	65,993	1
Soybean for beans: PCA	445.2008	143,739	25	445.2008	143,739	1
Soybean for beans: PCA	696.9727	144,817	25	696.9727	144,817	1
Soybean for beans: PCA	429.9780	89,173	25	429.9780	89,173	1
Soybean for beans: Random Selection	555.6067	90,448	25	555.6067	90,448	1
Total for USA		63,915,821	25		63,915,821	1
Vegetables harvested for sale: Random Selection	5,939.5449	195,401	25	5,939.5449	195,401	1
Vegetables harvested for sale: Random Selection	1,954.2251	59,533	25	1,954.2251	59,533	1
Vegetables harvested for sale: PCA	3,323.2549	253,704	25	3,323.2549	253,704	1
Vegetables harvested for sale: PCA	1,383.6187	26,878	25	1,383.6187	26,878	1
Vegetables harvested for sale: Random Selection	443.3458	1,808	25	443.3458	1,808	1
Vegetables harvested for sale: PCA	?	0?	25	?	0?	1
Total for USA		4,682,588	25		4,682,588	1
Wheat for grain PCA	535.1650	114,175	25	535.1650	114,175	1
Wheat for grain : Random Selection	901.0108	212,115	25	901.0108	212,115	1
Wheat for grain: Random Selection	747.8055	135,502	25	747.8055	135,502	1

Associated With:	Thawley (Data Used to derive PCAs)			Ruhman (QA/AC)		
	Total	From Original	NASS Table #	Total	QA/QC	NASS Table #
Wheat for grain PCA	1,280.3259	232,736	25	1,280.3259	232,736	1
Wheat for grain PCA	725.5505	161,148	25	725.5505	161,148	1
Wheat for grain PCA	1,017.5079	159,192	25	1,017.5079	159,192	1
Wheat for grain PCA	793.6035	155,734	25	793.6035	155,734	1
Wheat for grain: Random Selection	1,188.1477	182,524	25	1,188.1477	182,524	1
Total for USA		50,932,969	25		50,932,969	1

B. Validation of GIS Data Processing

Using GIS data generated in the process of calculating PCAs, a stepwise verification procedure was devised to check the accuracy of the calculations (**Attachment 1**). Results obtained are included in **Table A-2** for total cropland and **Table A-3** for all other crops/crop groups. GIS-Processed PCAs (columns highlighted in yellow) were compared with those obtained by the QA/QC step (column highlighted in green).

Table A-2 Total Cropland (See Abbreviations below)

Basin ID	*A*	*B*	*C*	*D*	*E*	*Checked by*
2864984-4	21,015,232	15,690	14,121,000	0.672	0.672	Nelson
2465311-4	6,093,064,572	2,758,944	2,483,049,600	0.408	0.408	Nelson
5558420-4	14,805,585	7,272	6,544,800	0.443	0.442	Nelson
2465225-1	1,192,544,133	393,351	354,015,900	0.297	0.297	Nelson
2465228-4	6,047,787	3,152	2,836,800	0.469	0.469	Nelson
5307907-1	444,046,508,554	244,400,740	219,960,666,000	0.495	0.495	Nelson
2475894-1	1,340,158,995,240	366,799,272	330,119,344,800	0.246	0.246	Nelson

Basin ID	A	B	C	D	E	Checked by
2865475-1	1,824,376,444,050	625,065,457	562,558,911,300	0.308	0.308	Nelson
2110236-4	3,201,355,326,230	945,584,945	851,026,450,500	0.266	0.266	Nelson
2518031-4	92,573,313	285	256,500	0.003	0.003	Carleton
1803354-4	171,491,820	1,216	1,094,400	0.006	0.006	Carleton
1824462-1	5,340,517,534	739,312	665,380,800	0.125	0.125	Carleton
5165295-1	2,466,515,941	25	22,500	0.000	0.000	Bohaty
3546663-1	6,066,516,584	16,436	14,792,400	0.002	0.002	Bohaty
5619627-2	21,442,384,816	1,770,705	1,593,634,500	0.074	0.074	Bohaty
4456096-1	13,756,943,650	1,055,683	950,114,700	0.069	0.069	Bohaty
1313266-4	3,917,970		0		0.000	white
4789703-1	327,978,347	36,286	32,657,400	0.099	0.100	Crk
2699520-1	551,272,695	42,220	37,998,000	0.069	0.069	Crk
2656247-4	45,207,026	929	836,100	0.018	0.018	Crk
8994820-1	123,348,488	0	0	0.000	0.000	Ruhman
5097721-1	52,695,985,932	6,329,296	5,696,366,400	0.108	0.108	Ruhman
2162560-3	7,538,527,565	123,585	111,226,500	0.015	0.015	Ruhman
2170726-4	410,098,449	161,701	145,530,900	0.355	0.355	Ruhman
2171471-4	60,492,273,360	21,970,846	19,773,761,400	0.327	0.327	Ruhman
2172683-4	397,390,615	20,038	18,034,200	0.045	0.045	Ruhman
2175072-1	10,877,194,565	43,876	39,488,400	0.004	0.004	Ruhman
2183398-1	524,227,547,489	2,641,165	2,377,048,500	0.005	0.005	Ruhman
2185119-4	94,791,486,928	11,848,042	10,663,237,800	0.112	0.112	Ruhman
2238412-4	615,434,824	13,718	12,346,200	0.020	0.020	Ruhman
2675257-4	816,014,418	374	336,600	0.000	0.000	Ruhman
4947011-4	165,126,368	0	0	0.000	0.000	Ruhman

Basin ID	A	B	C	D	E	Checked by
4964080-2	36,345,999,013	9,188,639	8,269,775,100	0.228	0.228	Ruhman
5093574-2	6,094,228,382	11,681	10,512,900	0.002	0.002	Ruhman
5102087-1	308,631,027	0	0	0.000	0.000	Ruhman
2464830-4	3,391,030	744	669,600	0.197	0.197	white
2307903-1	9771300	0	0	0.000	0.000	white
2441299-4	2799415.415	0	0	0.000	0.000	white
5557005-4	13285940.07	3543	3,188,700	0.241	0.240	white
2354497-2	2700	0	0	0.000	0.000	white
4828820-4	1106177.317	0	0	0.000	0.000	white
5320907-4	2352489.05	1382	1,243,800	0.529	0.529	white
4830079-4	1527636.091	16	14,400	0.009	0.009	white
5556951-1	42561000	3090	2,781,000	0.065	0.065	white
5163403-1	330109284.3	0	0	0.000	0.000	white
3820202-1	1993500	0	0	0.000	0.000	white
2717511-1	339300	0	0	0.000	0.000	white

Abbreviations:

Title	Description	Source
A	Basin Area (m2)	From map
B	Total Cropland (Pixels)	QA/QC process
C	Total Cropland (m^2)	Conversion of acres to m^2 (C= B* 900) (Single pixel area= 900 m^2)
D	PCA To be checked	Data obtained by the procedure used for calculating PCAs.
E	PCA calculated by the QA/QC process	E= C/A

Table A-3: Other Crops/Crop Group (See Abbreviations below)

Basin ID	*Crop*	*A*	*B*	*C*	*D*	*E*	*Checked by*
2864984-4	Corn	21	1,357	5	0.2615	0.2614	Nelson
2465311-4	Corn	6,093	197,930	801	0.1315	0.1315	Nelson
5558420-4	Corn	15	952	4	0.258	0.2603	Nelson
2460190-1	Corn	2,291	78,903	319	0.1393	0.1394	Nelson
2465225-1	Corn	1,193	23,782	96	0	0.0807	Nelson
5307907-1	Corn	444,047	31,094,211	125,838	0.2835	0.2834	Nelson
9999969-4	Cotton	3,945	202,039	817.65	0.2074	0.2073	Ruhman
2156379-4	Cotton	7,857	378,714	1,532.66	0.1952	0.1951	Ruhman
8994588-1	Cotton	38,201	1,225,212	4,958.43	0.1298	0.1298	Ruhman
2465311-4	Orchard	6,093	185	1	0.0001	0.0001	Nelson
5558420-4	Orchard	15		0	0.0003	0	Nelson
5307907-1	Orchard	444,047	12,218	49	0.0001	0.0001	Nelson
2518031-4	Orchard	93	0	0	7.07E-06	7.07E-06	Carleton
2210000-4	Rice	780	81,604	330.25	0.4237	0.4235	Ruhman
2229033-4	Rice	5	316	1.28	0.2568	0.2564	Ruhman
2673430-4	Rice	4,804	128,089	518.38	0.1079	0.1079	Ruhman
2864984-4	Soybeans	21	1,647	7	0.3173	0.3172	Nelson
2465311-4	Soybeans	6,093	328,012	1,327	0.2179	0.2179	Nelson
5558420-4	Soybeans	15		0	0.2626	0	Nelson
2460190-1	Soybeans	2,291	74,728	302	0.1319	0.132	Nelson
2465225-1	Soybeans	1,193	50,648	205	0	0.1719	Nelson
5307907-1	Soybeans	444,047	17,321,311	70,099	0.1579	0.1579	Nelson
2465311-4	Vegetables	6,093	37	0	0	0	Nelson
5307907-1	Vegetables	444,047	432,485	1,750	0.0039	0.0039	Nelson
2170726-4	Vegetables	410	1,395	5.65	0.0138	0.0138	Ruhman

Basin ID	Crop	A	B	C	D	E	Checked by
2171471-4	Vegetables	60,492	12,005	48.59	0.0008	0.0008	Ruhman
2172683-4	Vegetables	397	100	0.41	0.0001	0.001	Ruhman
2183398-1	Vegetables	301,672	44,525	180.19	0.0006	0.0006	Ruhman
2185119-4	Vegetables	94,791	8,722	35.3	0.0004	0.0004	Ruhman
2675257-4	Vegetables	816	60	0.24	0.0003	0.0003	Ruhman
5097721-1	Vegetables	52,696	50,454	204.19	0.0039	0.0039	Ruhman
5102087-1	Vegetables	309	0	0	0	0	Ruhman
2864984-4	Wheat	21	355	1	0.0683	0.0683	Nelson
2465311-4	Wheat	6,093	51,874	210	0.0345	0.0345	Nelson
5558420-4	Wheat	15		0	0.0551	0	Nelson
2465225-1	Wheat	1,193	5,073	21	0	0.0172	Nelson
5307907-1	Wheat	444,047	851,872	3,448	0.0078	0.0078	Nelson
2423671-1	Wheat	10,612	433,995	1,756	0.166	0.166	Carleton

Title	Description	Source
A	Basin Area (km^2)	From map
B	Total Crop Acres	QA/QC process
C	Total Crop (km^2)	Conversion of acres to km^2 (C= B* 0.004047)
D	PCA To be checked	Data obtained by the procedure used for calculating PCAs
E	PCA calculated by the QA/QC process	E= C/A

For this process a total of 47 drinking water watersheds were examined for the total-agriculture PCAs, and 38 for other crops/crop groups. All watersheds were randomly chosen and were distributed as follows: Corn (6), Cotton (3), Orchards (4), Rice (3), Soybeans (6), Vegetables (10), and Wheat (6). A map of the locations of the QA/QC drinking water intake watersheds is included in **Figure A-1**.

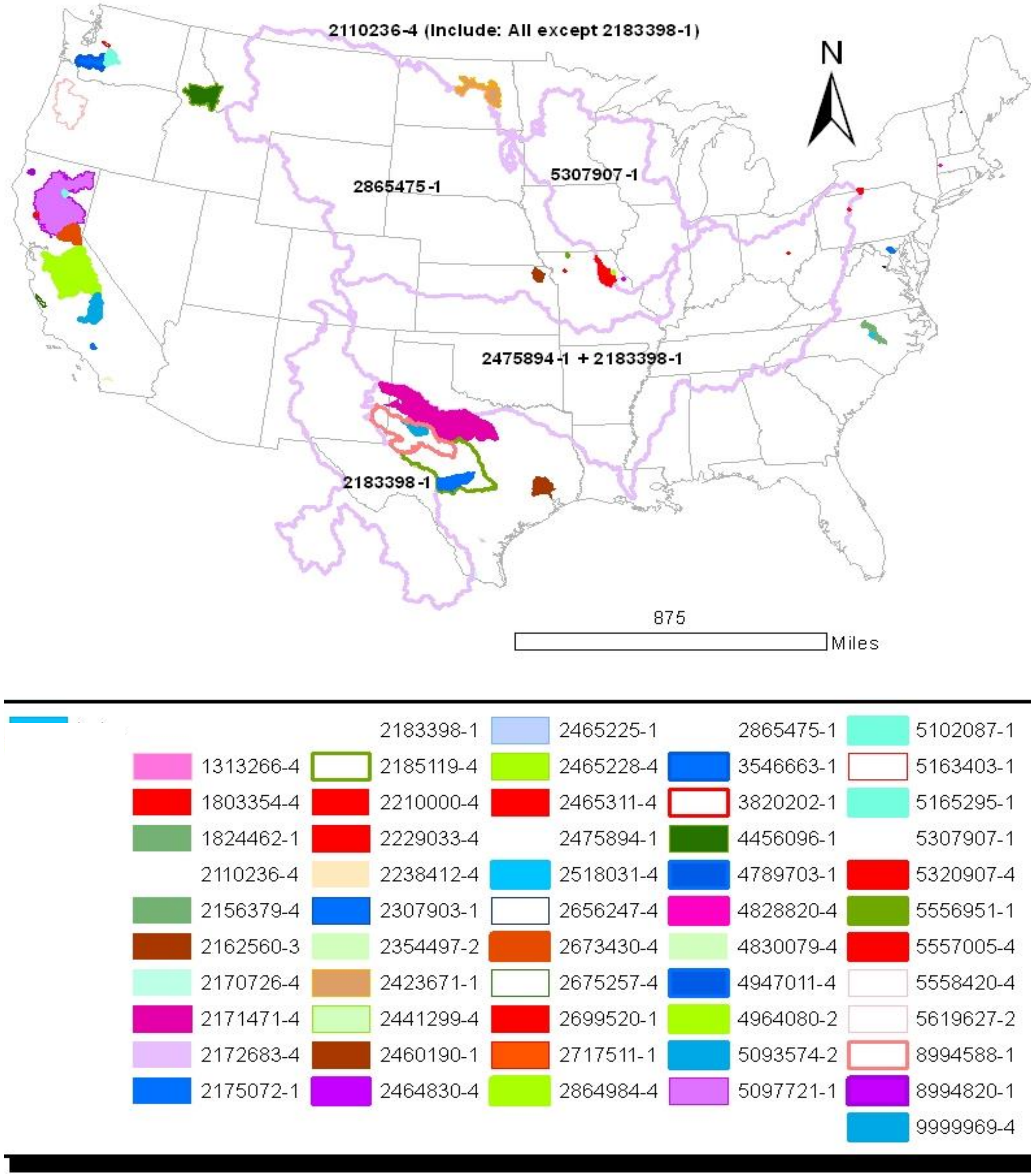


Figure A-1. Locations of the DWI watersheds examined in the QA/QC process (note some of the watersheds are too small to see in this map, and some are masked by larger watersheds; the borders for the five large watersheds (>1,000 km2) are shown in light pink).

(3) Results

NASS data used in calculating PCAs were found to be accurate for all crops/crop groups. Data were found to be accurate even when different NASS Tables were used (**Table A-1**). Additionally, the PCA verification process produced the same results (within two decimal places) as the original processed PCAs. The exceptions are included in the Table, below:

Basin ID	***Crop***	***A***	***B***	***C***	***D***	***E***	***Checked by***
2465225-1	Corn	1,193	23,782	96	0	0.0807	Nelson
5558420-4	Soybeans	15		0	0.2626	0	Nelson
2465225-1	Soybeans	1,193	50,648	205	0	0.1719	Nelson
2465225-1	Wheat	1,193	5,073	21	0	0.0172	Nelson

For reference, an example containing all processing data is included in the following directory: P:\CWS_PCA_Data\QA-QC Example. This main folder contains data in the following folders:

Acre pixels Data (APD)

Chosen DWI watersheds (CDWIW)

Exported DWI watersheds (EDWIW)

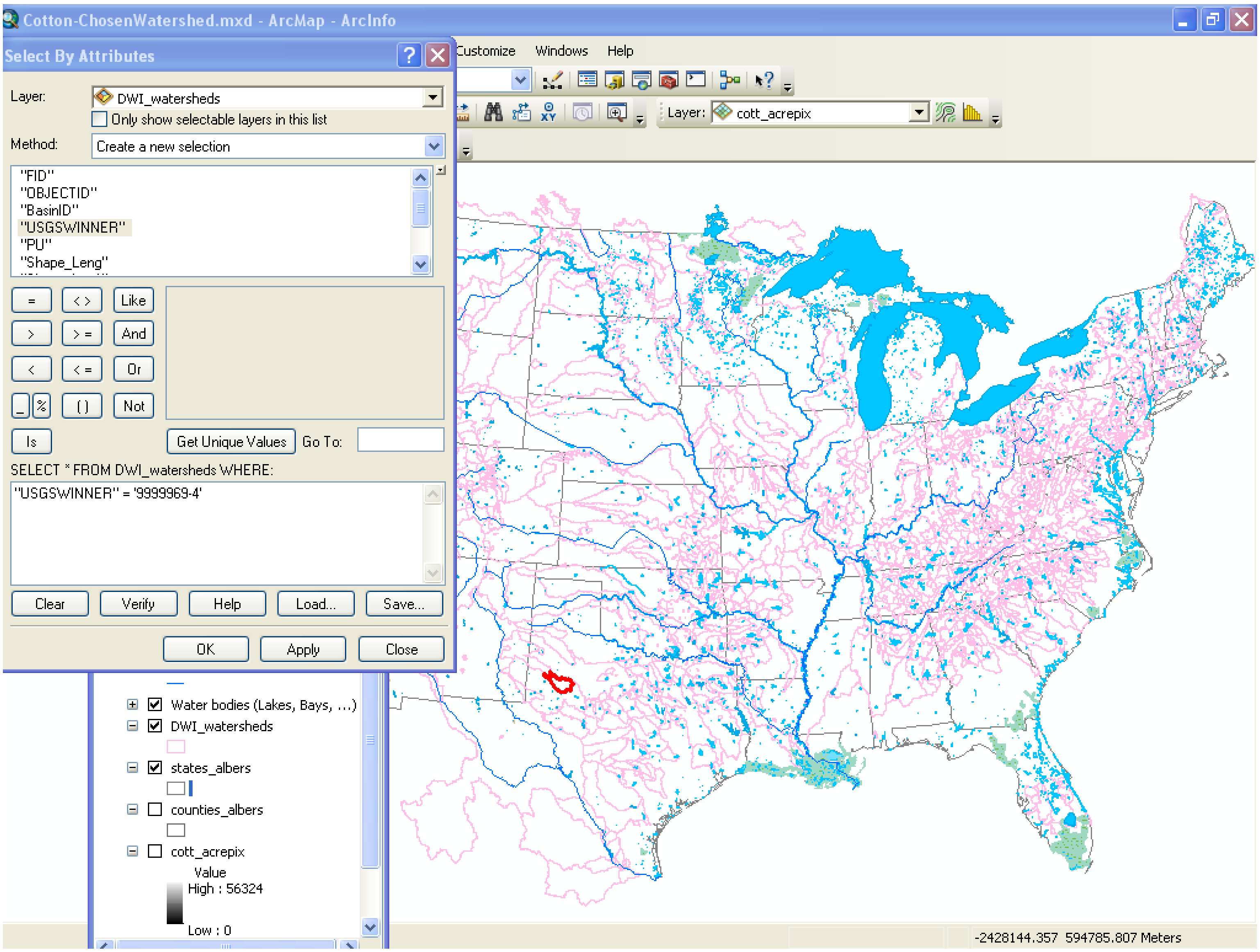
Extraction Results (ER)

PCA Maps-Verification Spreadsheet (PCAM-VS)

<u>**Attachment 1:** Step by Step Process for PCA Verification</u>

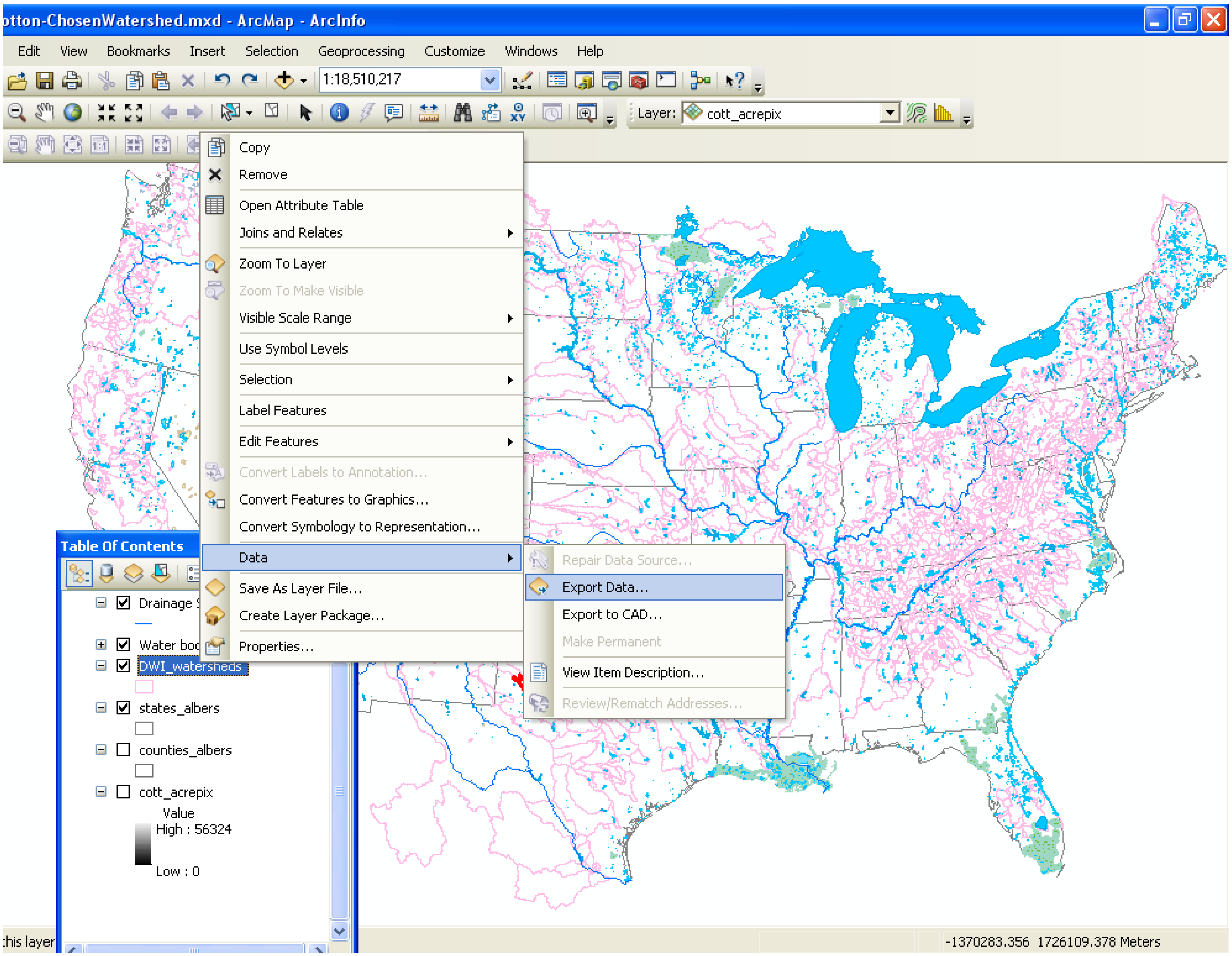
Step 1: Selection of the drinking water intakes watershed for cotton: ID 9999969-4

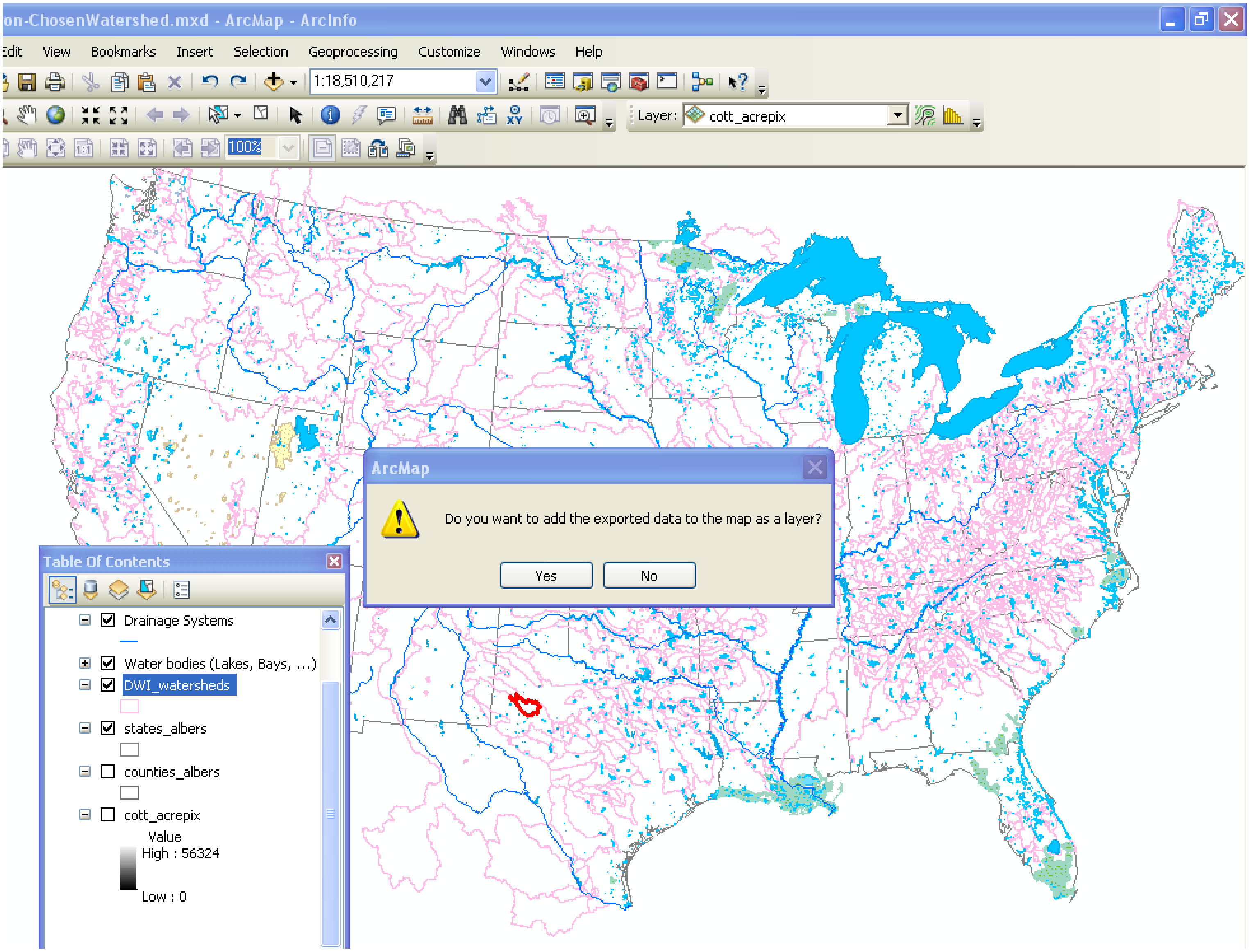
(Select by attribute: "USGSWINNER" = '9999969-4')



Step 2: Export data for the selected watershed into the folder: Exported DWI watersheds (EDWIW)

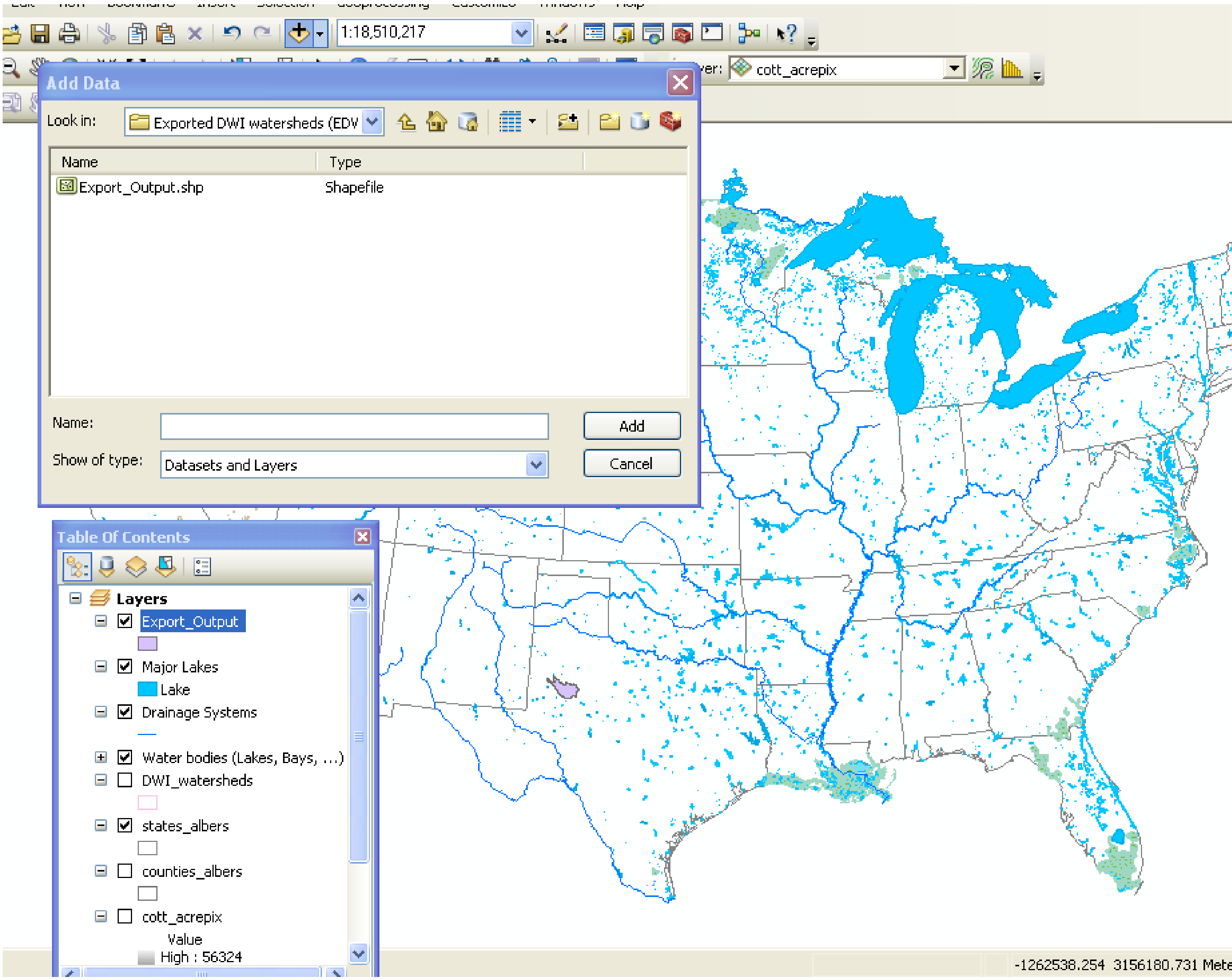
Export Data into the folder specified above: P:\CWS_PCA_Data\QA-QC Example\Exported DWI watersheds (EDWIW)\Export_Output.sh

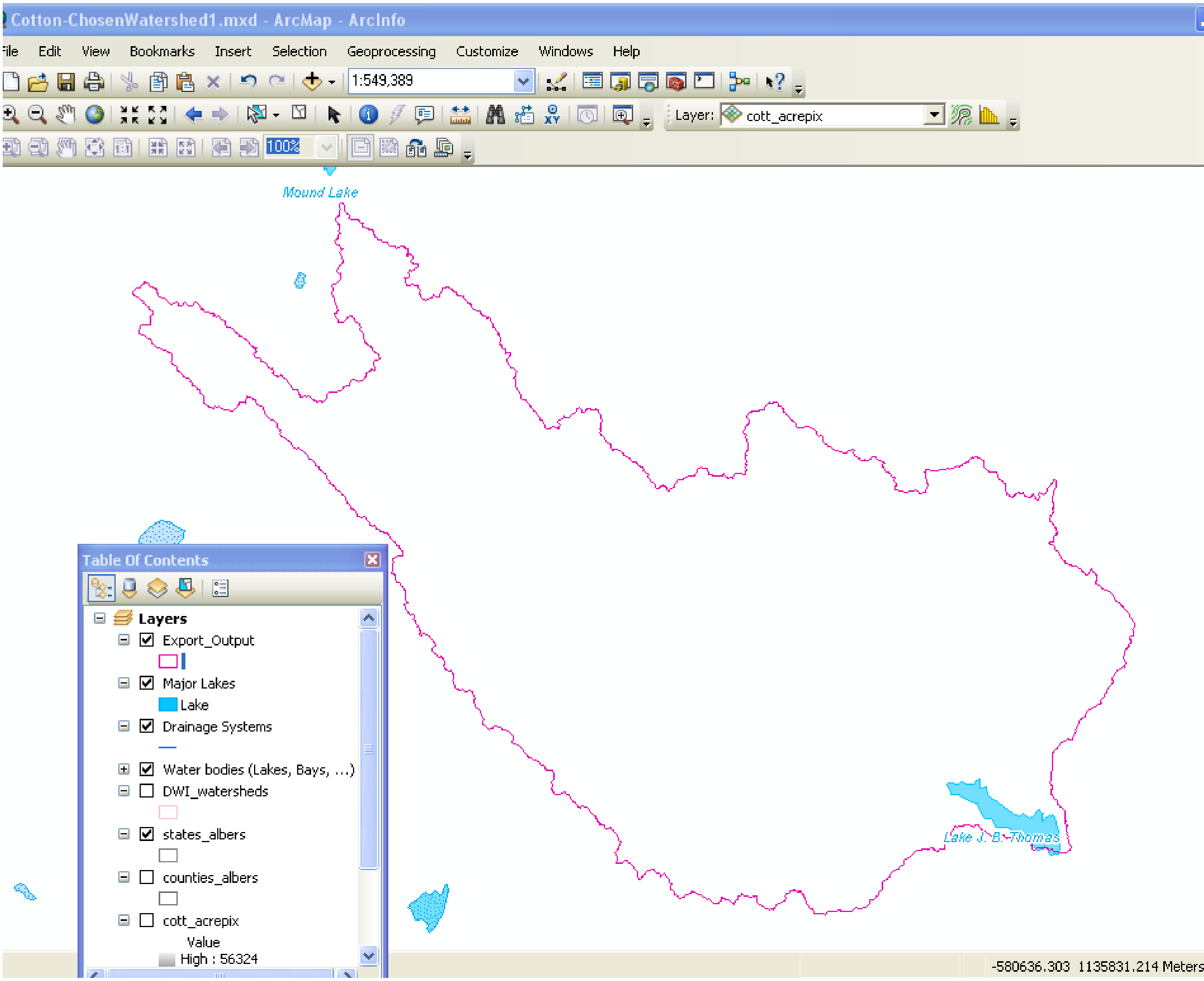



on-ChosenWatershed.mxd - ArcMap - ArcInfo
Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
1:18,510,217
Layer: cott_acrepix
100%
ArcMap
Do you want to add the exported data to the map as a layer?
Yes
No
Table Of Contents
Drainage Systems
Water bodies (Lakes, Bays, ...)
DWI_watersheds
states_albers
counties_albers
cott_acrepix
Value
High : 56324
Low : 0

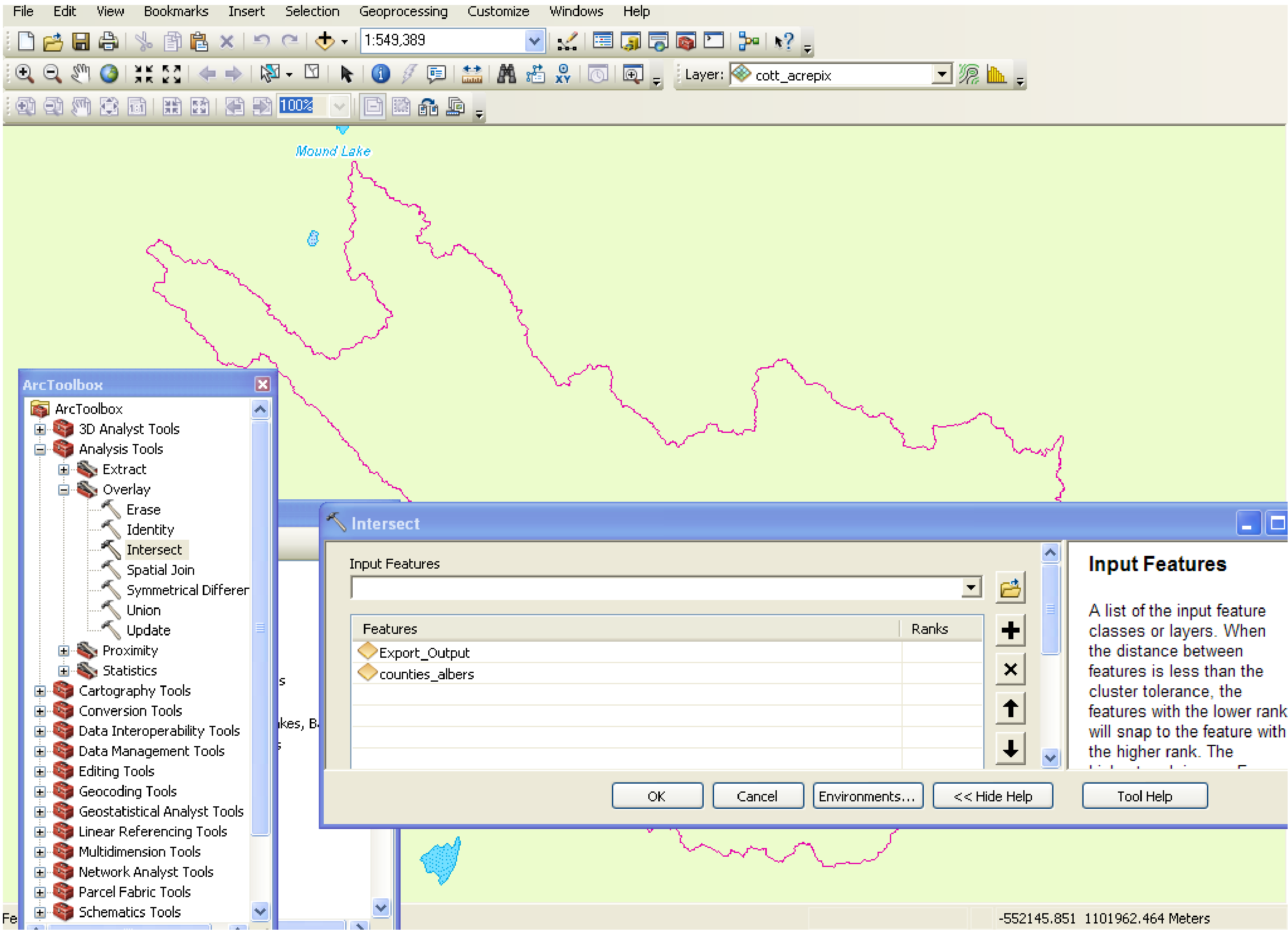
Answer NO

Step 3: Add the exported watershed data into a new map and zoom to the selected watershed (show only the outline of the selected watershed).

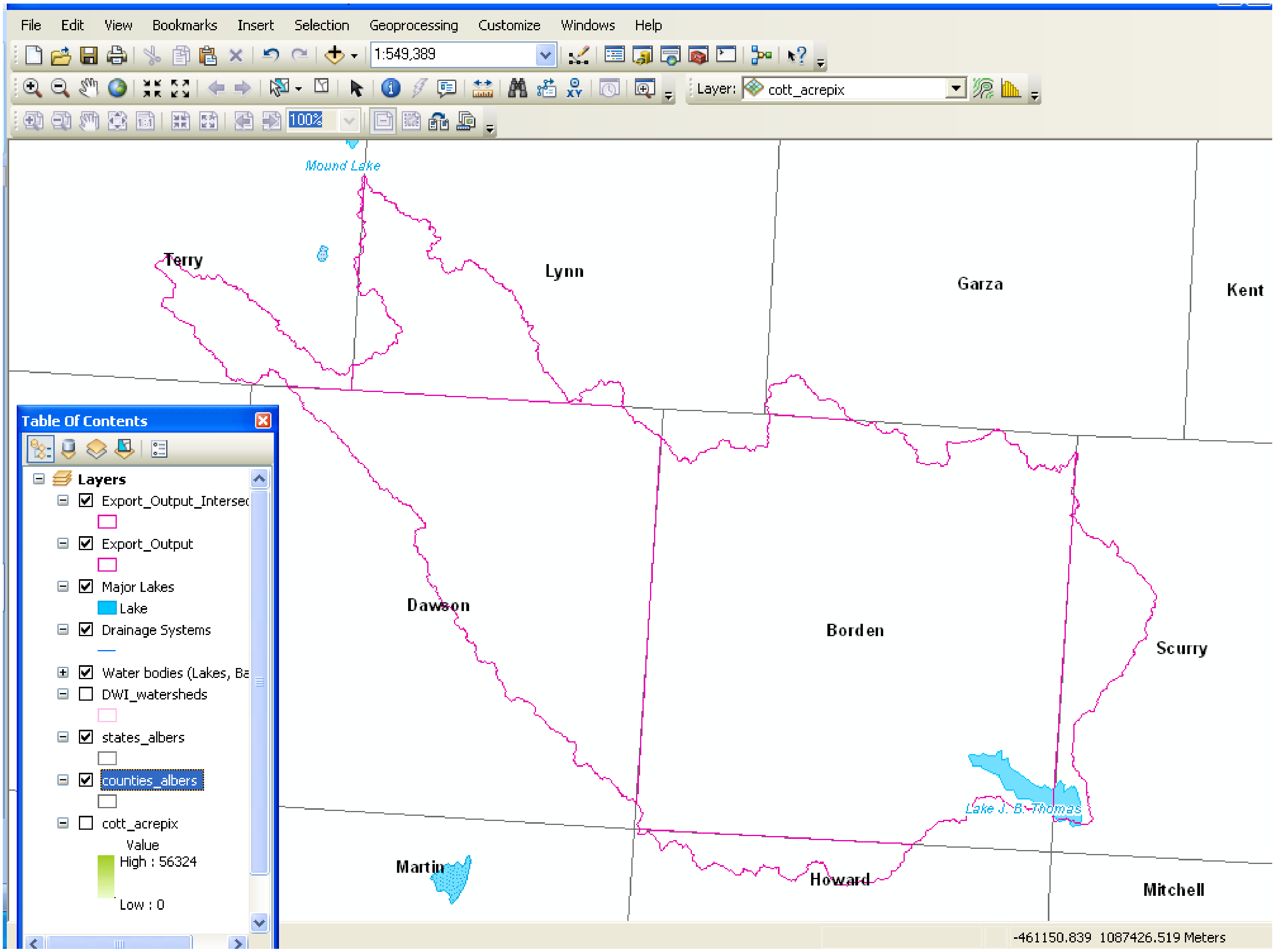



Cotton-ChosenWatershed1.mxd - ArcMap - ArcInfo
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
1:549,389
Layer: cott_acrepix
100%
Mound Lake
Lake J. B. Thomas
Table Of Contents
Layers
Export_Output
Major Lakes
Lake
Drainage Systems
Water bodies (Lakes, Bays, ...)
DWI_watersheds
states_albers
counties_albers
cott_acrepix
Value
High : 56324
-580636.303 1135831.214 Meters

Step 4: Intersect the exported shapefile with the county shapefile using the intersect tool from the toolbox (Analysis tools/Overlay/Intersect). Note the input features chosen (export-output and counties).

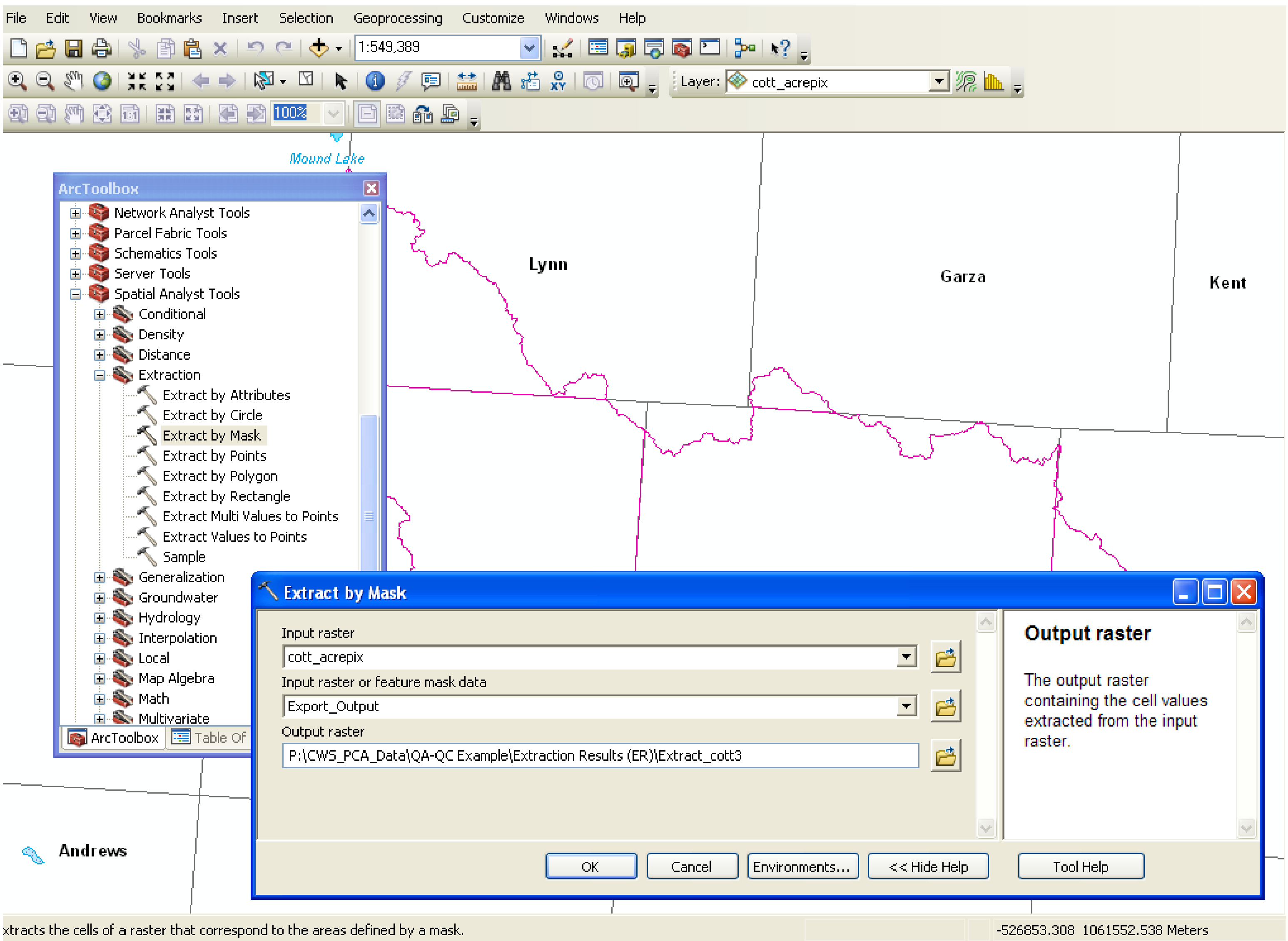


Hereunder, the resultant map (the watershed areas in various counties will appear):

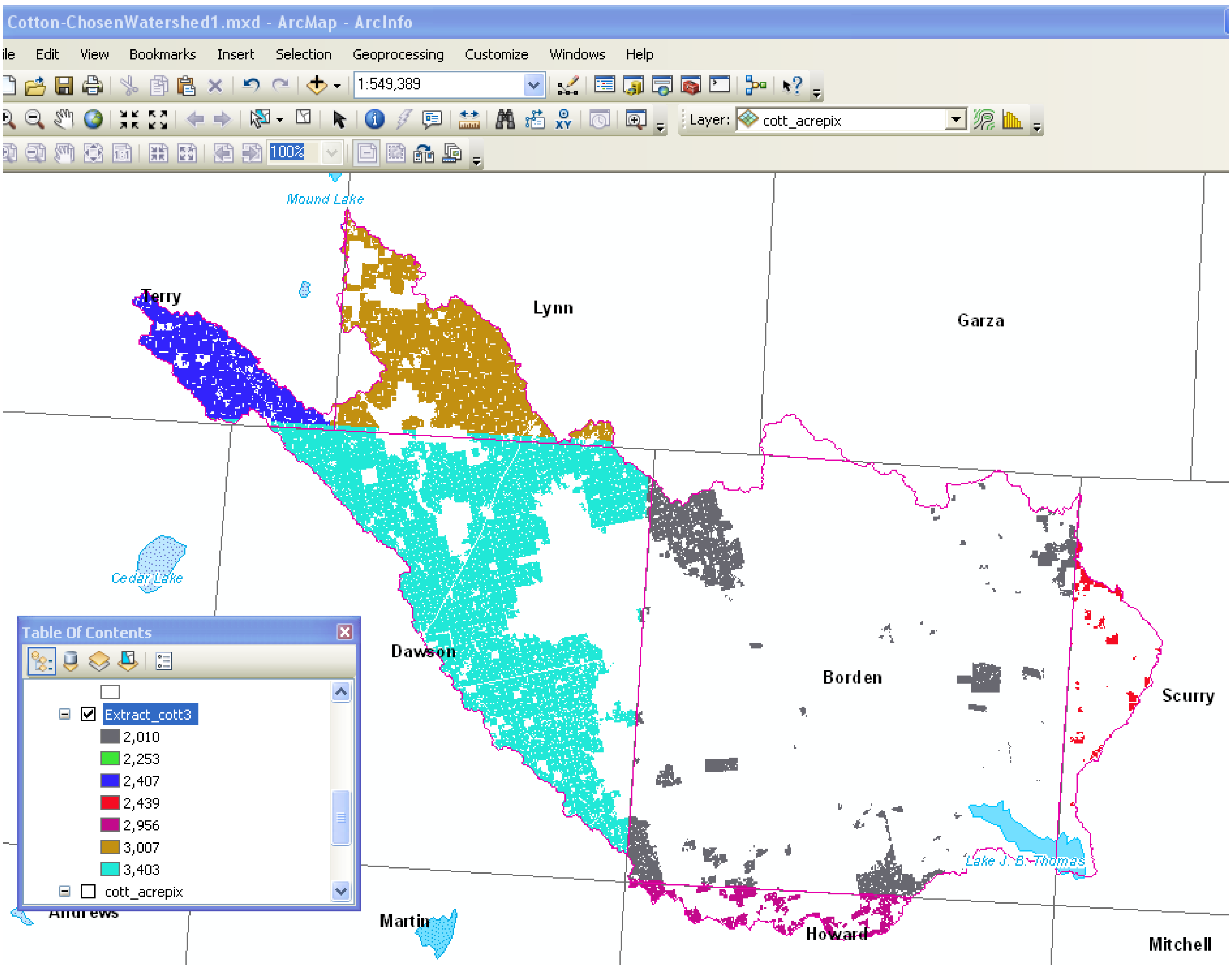


Step 5: Perform Extraction by Mask (Spatial Analyst Tools/Extraction/Extract by Mask)

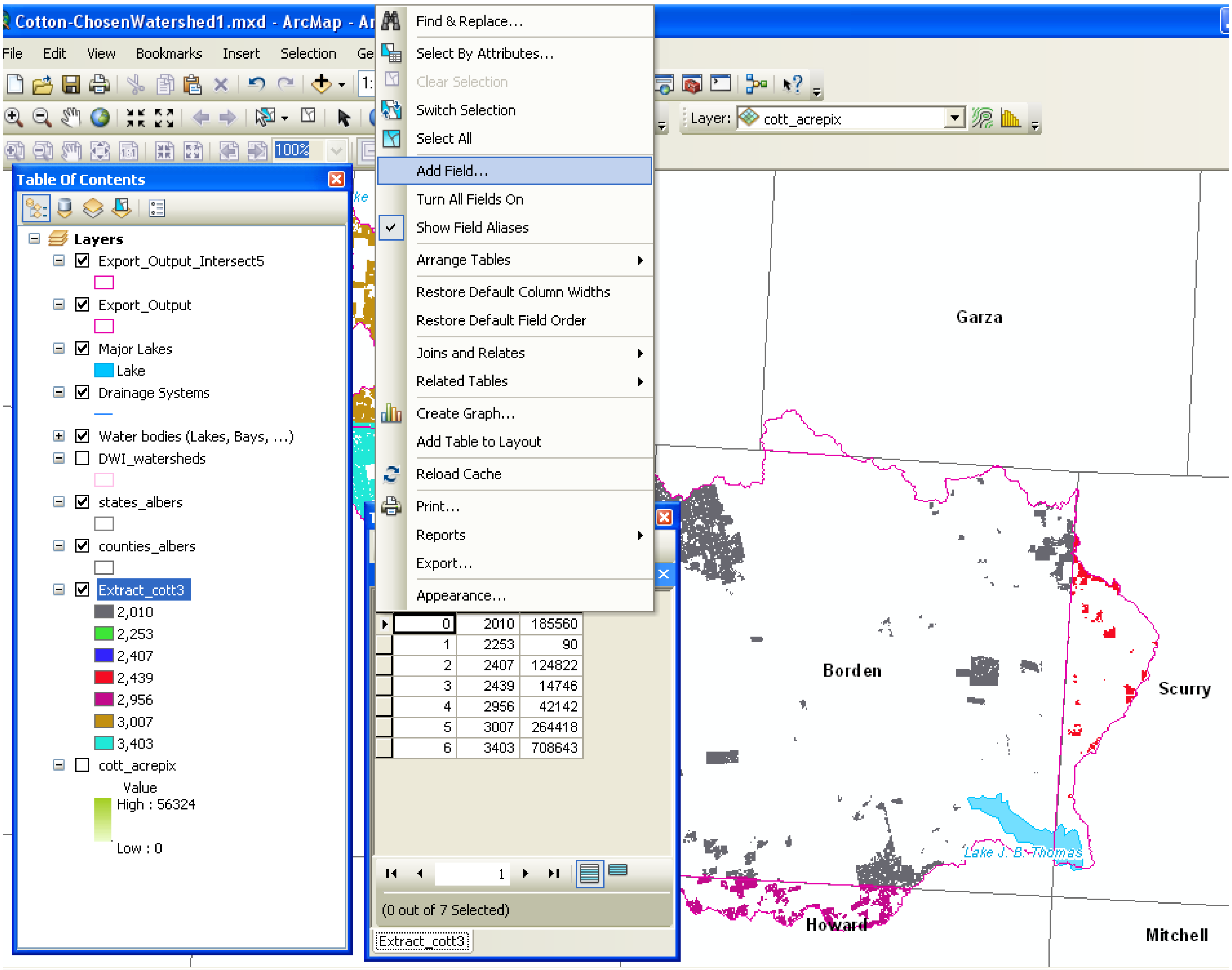
Enter: Input raster= acrepix "cott_acrepix"; Feature mask data= exported watershed data "Export_Output; and Output raster= folder where you want the extraction output of the analysis to reside, in this case "P:\CWS_PCA_Data\QA-QC Example\Extraction Results (ER)\Extract_cott3"



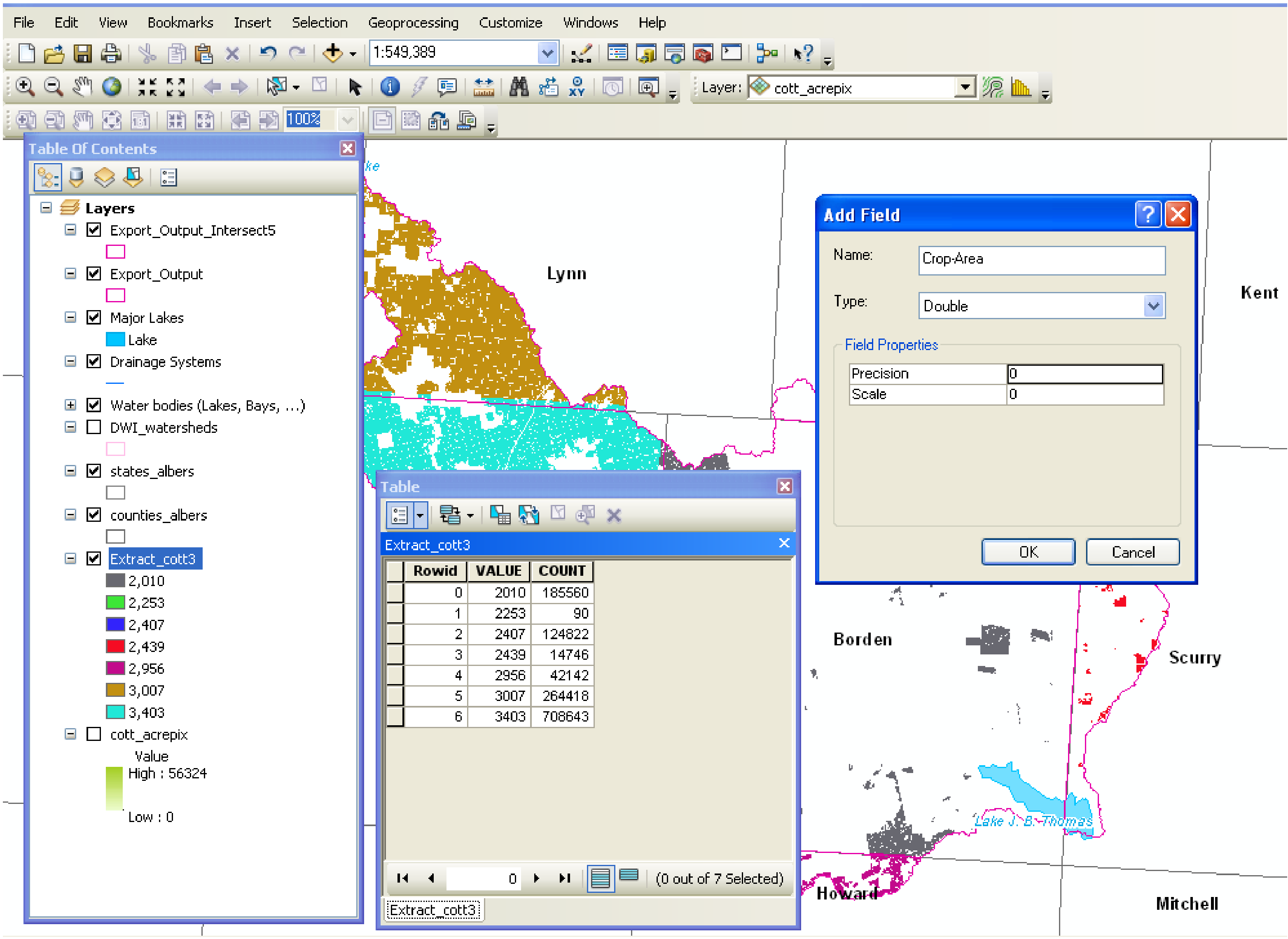
Then select "OK" and wait for completion of the extraction procedure, which may take several hours depending on the speed of the computer (please note that a moving message will be displayed stating the progress in %, e.g., "Extract by Mask 60%". Even after the value reaches 100%, the extraction results may not appear instantly; it is necessary to wait until the extraction results appear, as shown in the following screen shot:



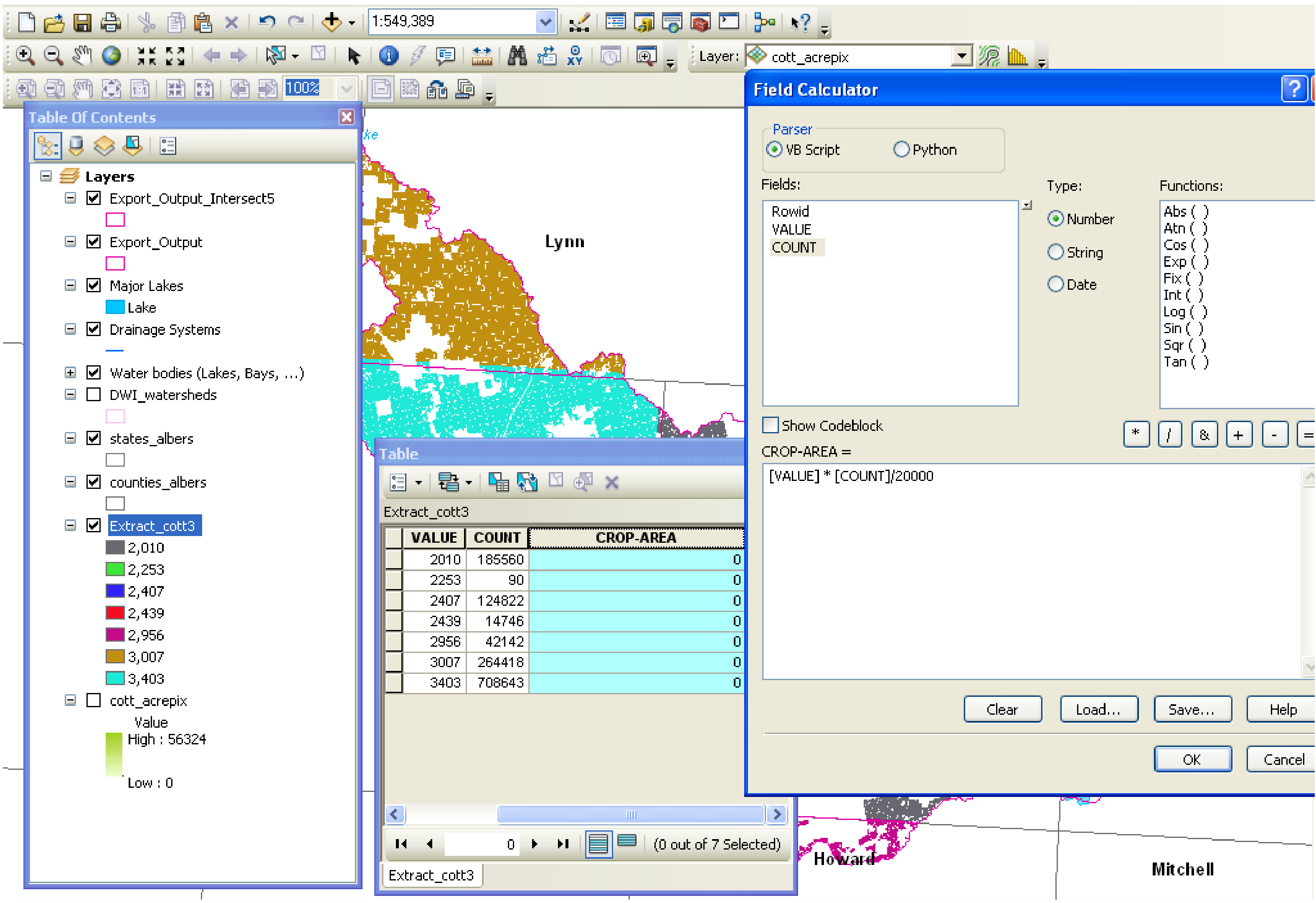
Step 6: Open the attribute Table/ Open the Table options (1st tab)



Add field (Crop-area/Double)/OK



After you press OK, the results will be as shown, below. Then right click on the newly added field to the field menu and select from it “Field Calculator:

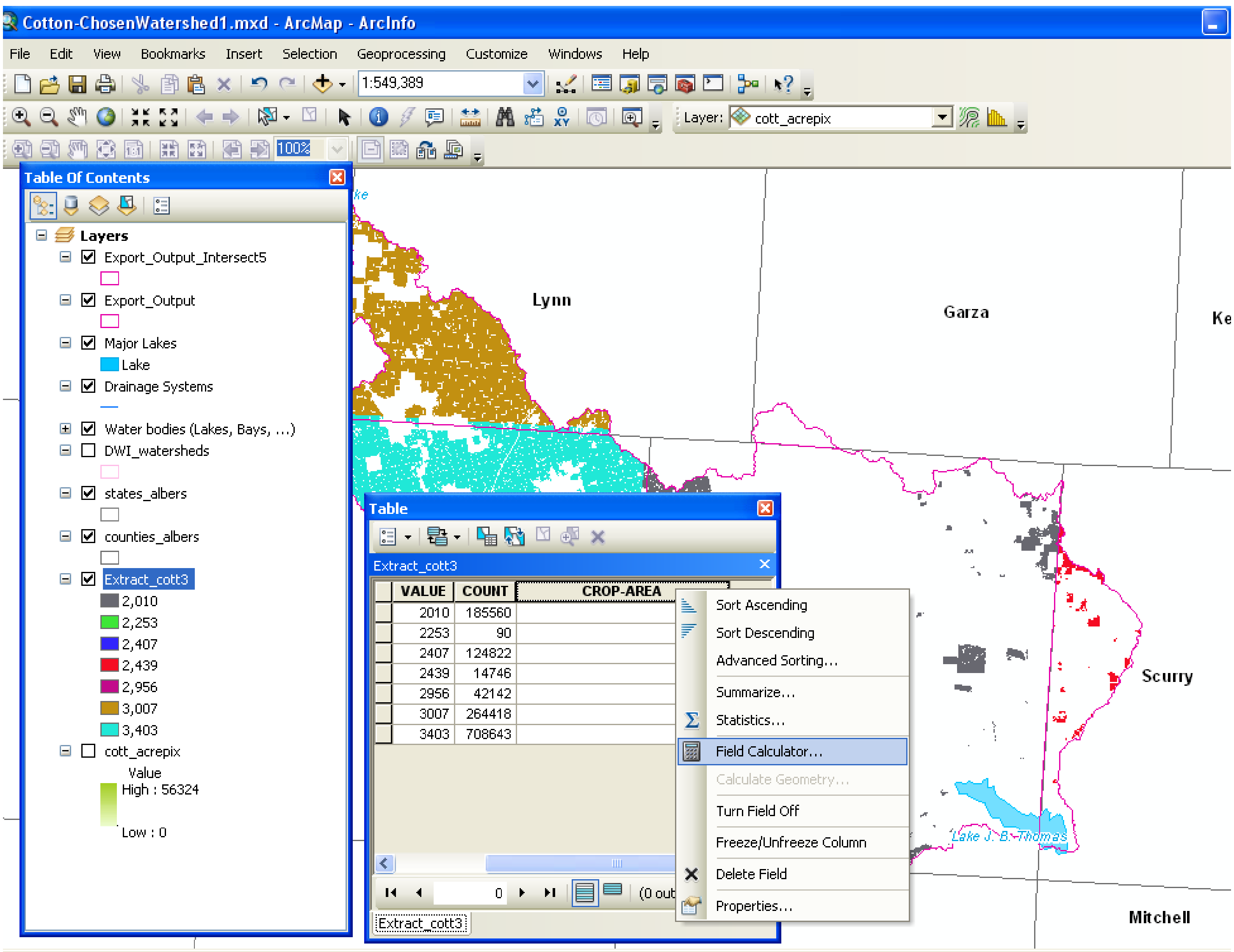


Enter the following in the field calculator by choosing "double click" the fields/calculation function from the lists as follows: [VALUE] * [COUNT]/20000; the 20,000 value is the scale factor for cotton.

Important Note:

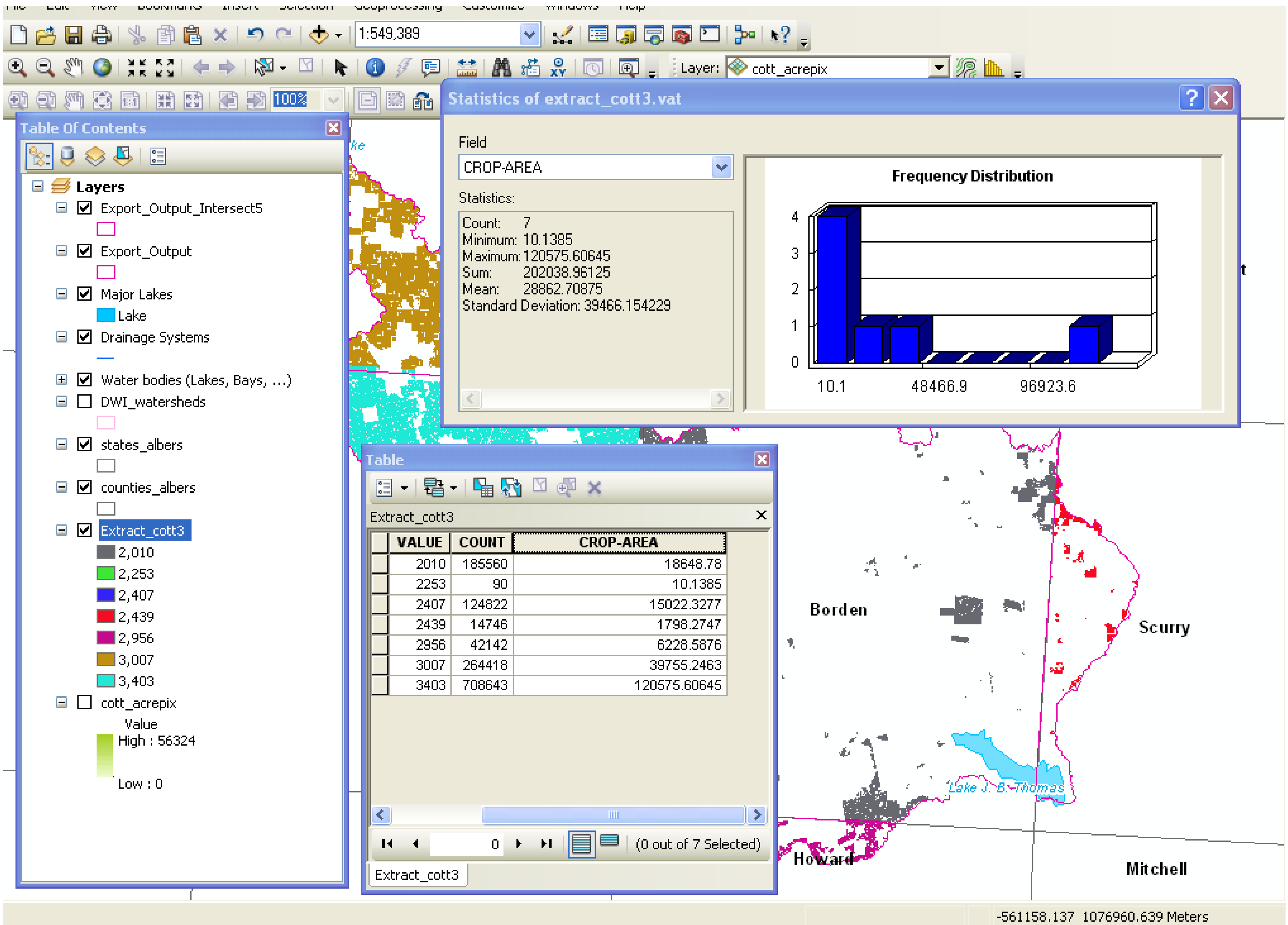
The scale factor is different for different crop/crop group as shown in the Table below:

Crop	*Scale Factor*
Corn	**4,000**
Cotton	**20,000**
Orchards	**7,000**
Rice	**60,000**



Crop	*Scale Factor*
Soybeans	**10,000**
Vegetables	**2,400**
Wheat	**5,000**

After clicking OK you get the area calculated; then get the statistics for the calculated field as



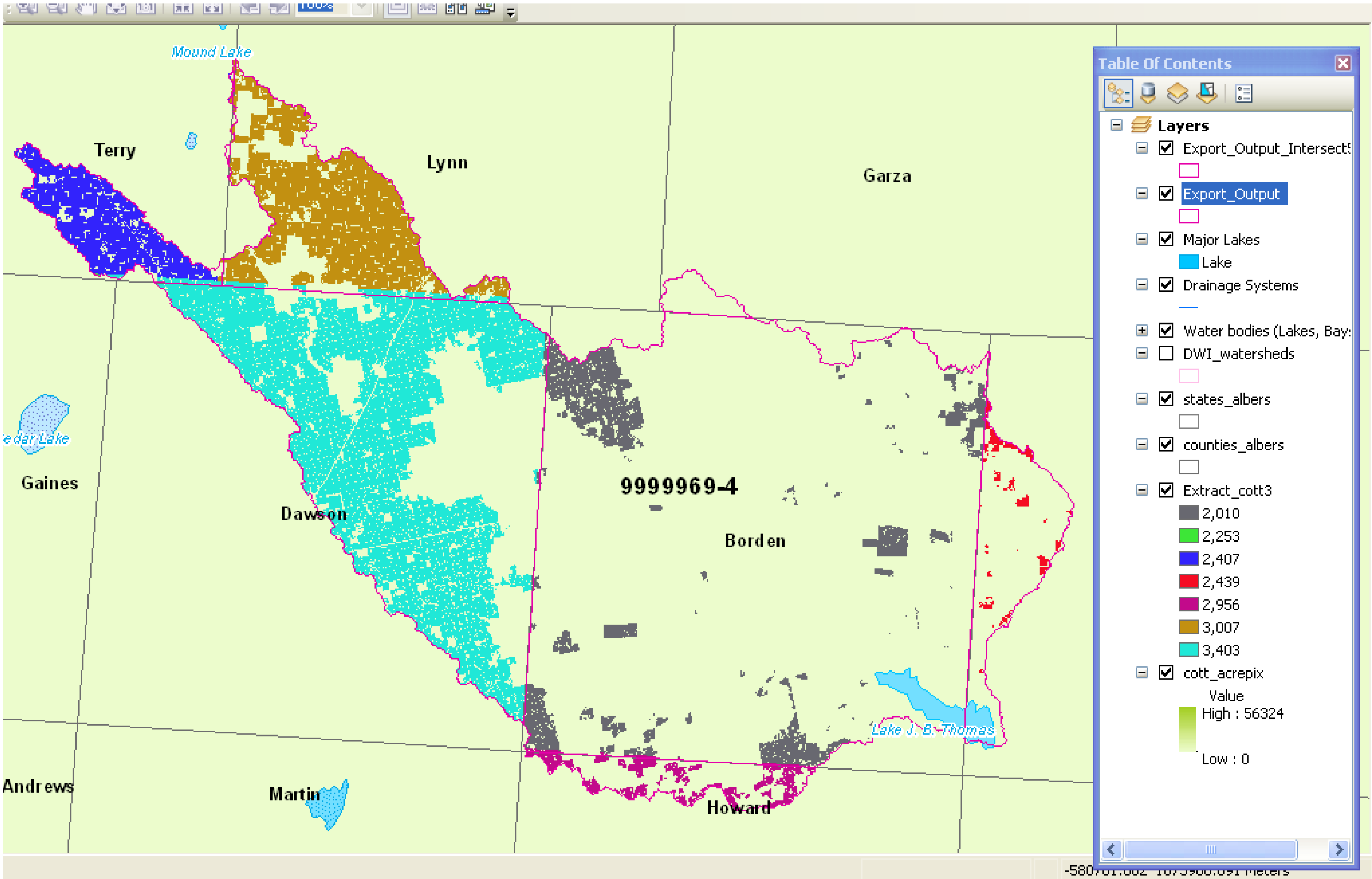
shown below:

From displayed statistics, the total Crop-area= 202038.96125 acres (=818 km^2). Enter this value in the verification spreadsheet as shown below to arrive at PCA= 818/3,945= 0.207

Basin ID	***Crop***	***A***	***B***	***C***	***D***	***E***	***Checked by***
9999969-4	***Cotton***	***3,945***	***202,039***	***817.65***	***0.2074***	***0.2073***	***Ruhman***

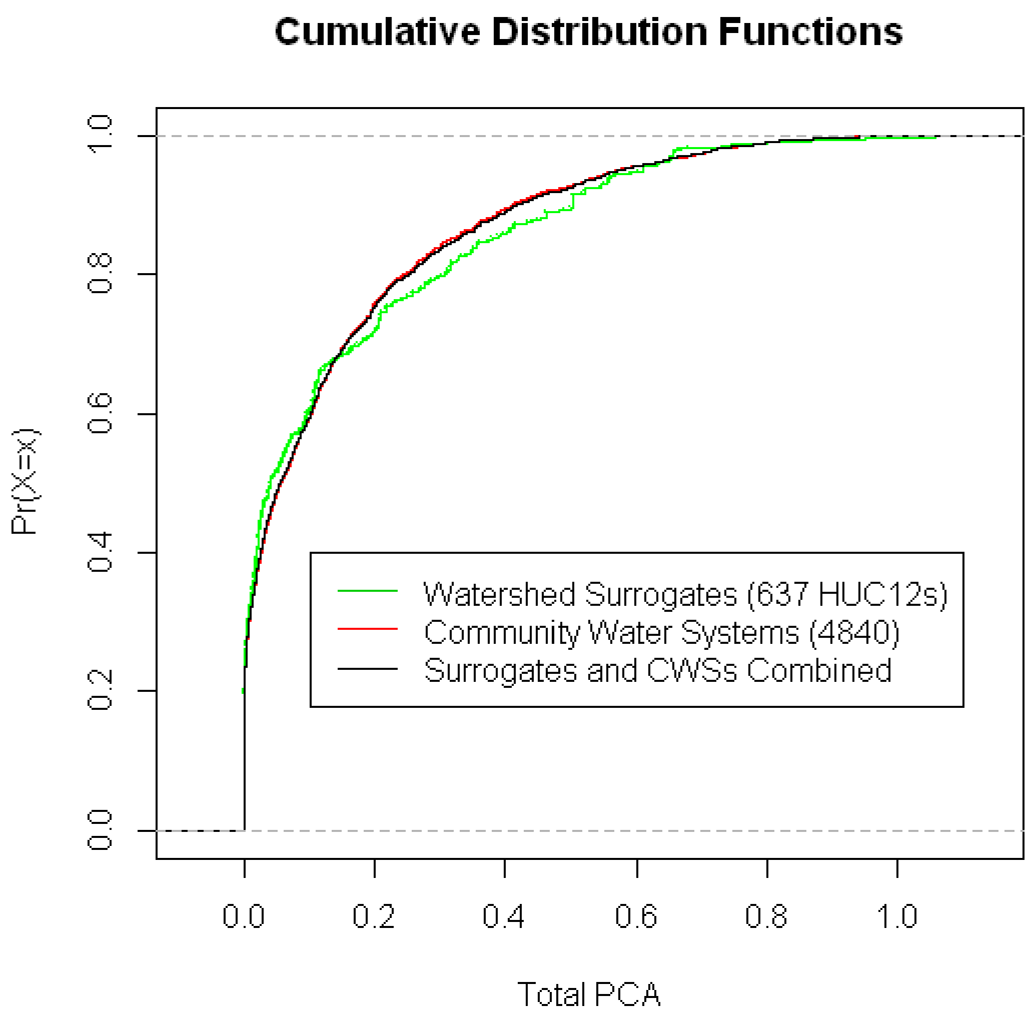
Title	***Description***	***Source***
A	Basin Area (km^2)	From map
B	Total Crop Acres	QA/QC process
C	Total Crop (km^2)	Conversion of acres to km^2 (C= B* 0.004047)
D	PCA To be checked	Data obtained by the procedure used for calculating PCAs
E	PCA calculated by the QA/QC process	E= C/A

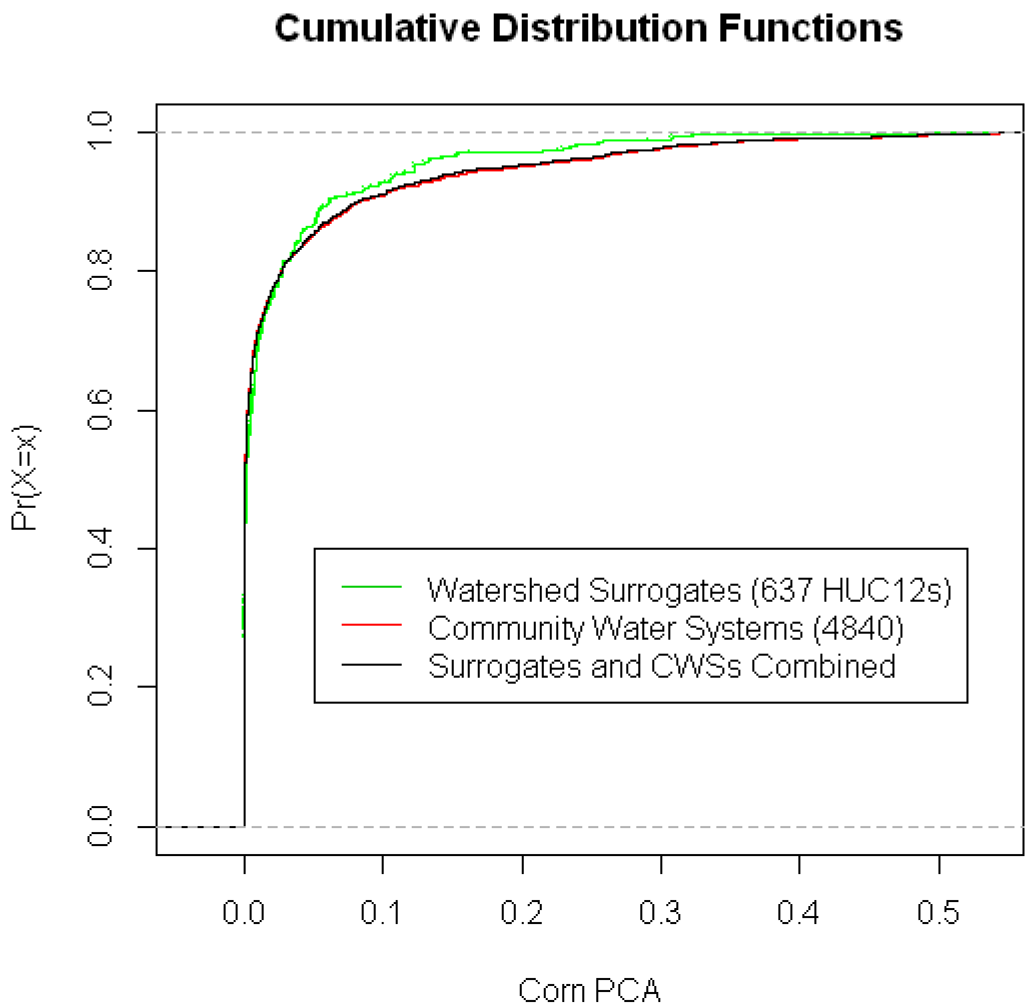
Step 7: Save the map as "Cotton PCA- 4- 9999969-4" with the final saved map in the PCA Maps-Verification Spreadsheet (PCAM-VS) folder. The map will look like the image below:


Mound Lake
Terry
Lynn
Garza
Gaines
Dawson
9999969-4
Borden
Lake J. B. Thomas
Andrews
Martin
Howard
Table Of Contents
Layers
Export_Output_Intersect
Export_Output
Major Lakes
Lake
Drainage Systems
Water bodies (Lakes, Bay
DWI_watersheds
states_albers
counties_albers
Extract_cott3
2,010
2,253
2,407
2,439
2,956
3,007
3,403
cott_acrepix
Value
High : 56324
Low : 0

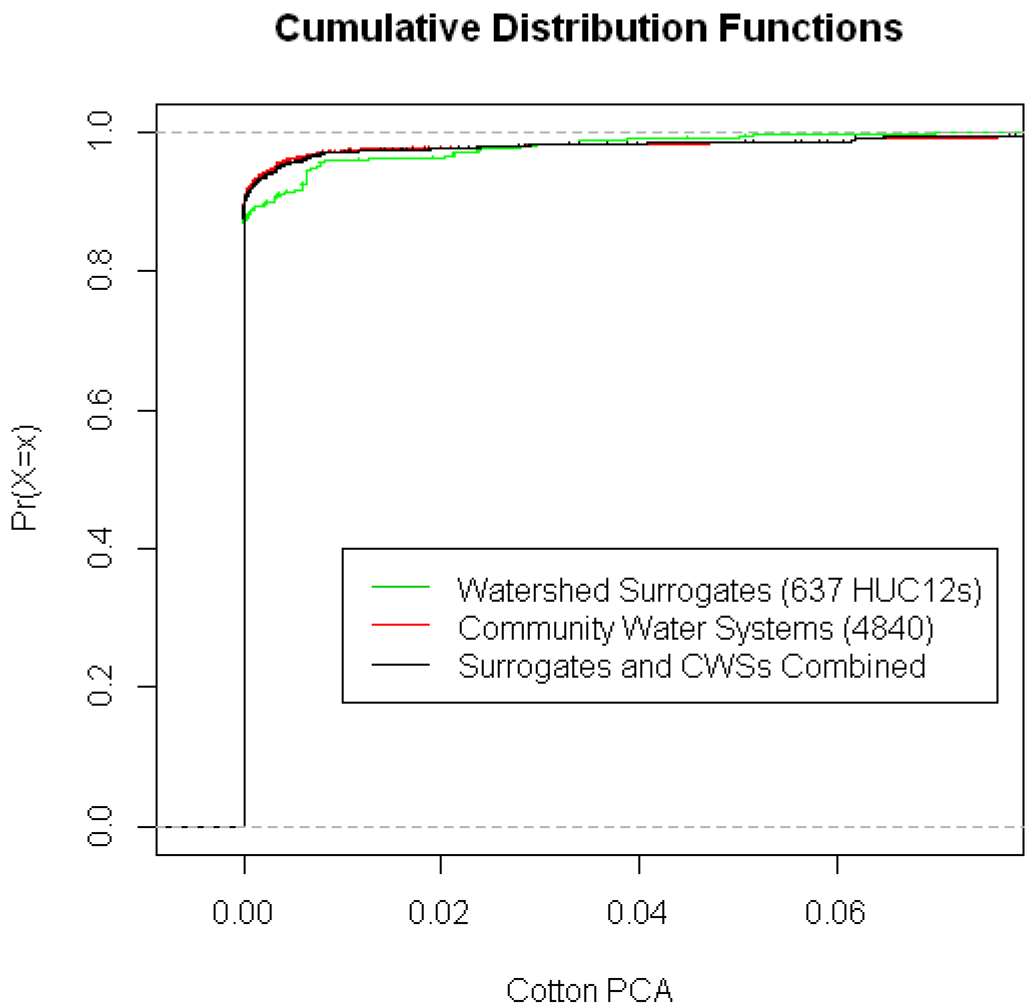
Appendix B

Cumulative Distributions of National-Scale DWI PCAs

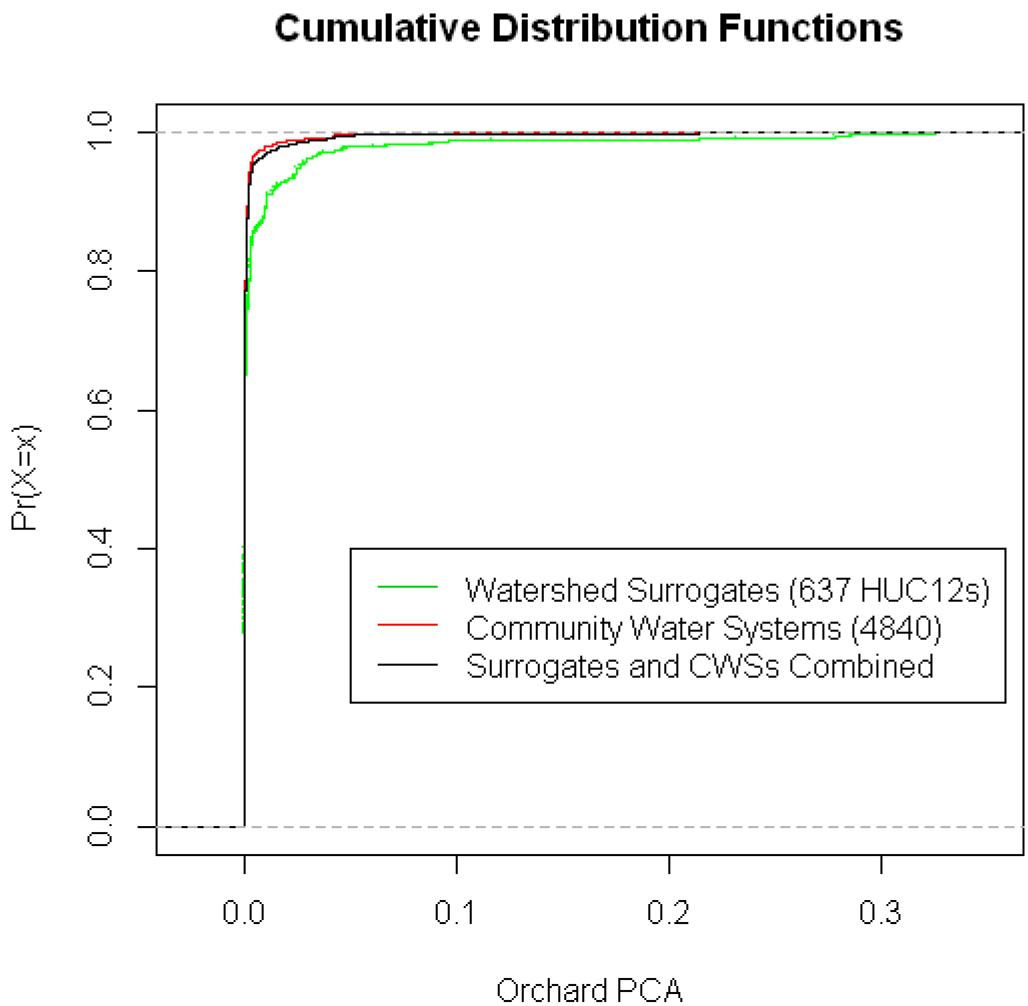


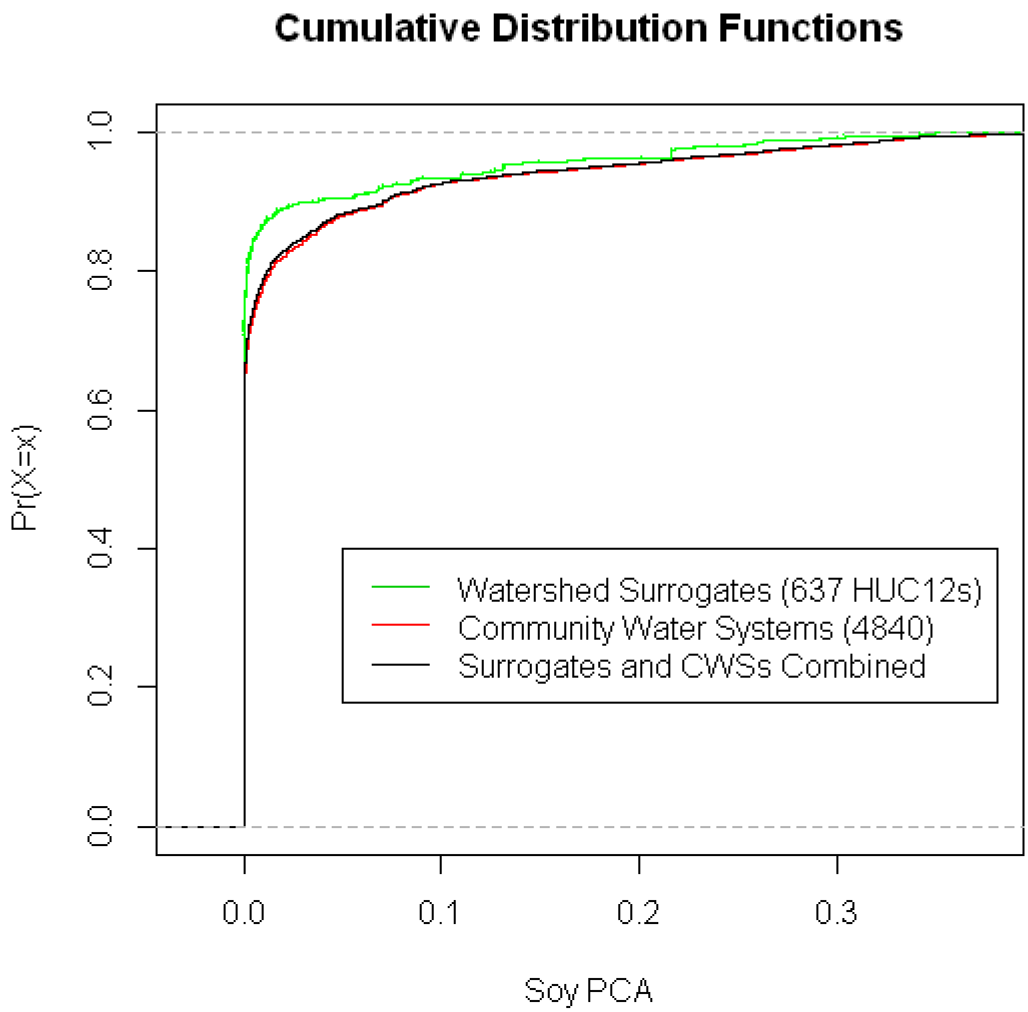


Cumulative Distribution Functions
Pr(X=x)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.1
0.2
0.3
0.4
0.5
Corn PCA
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined

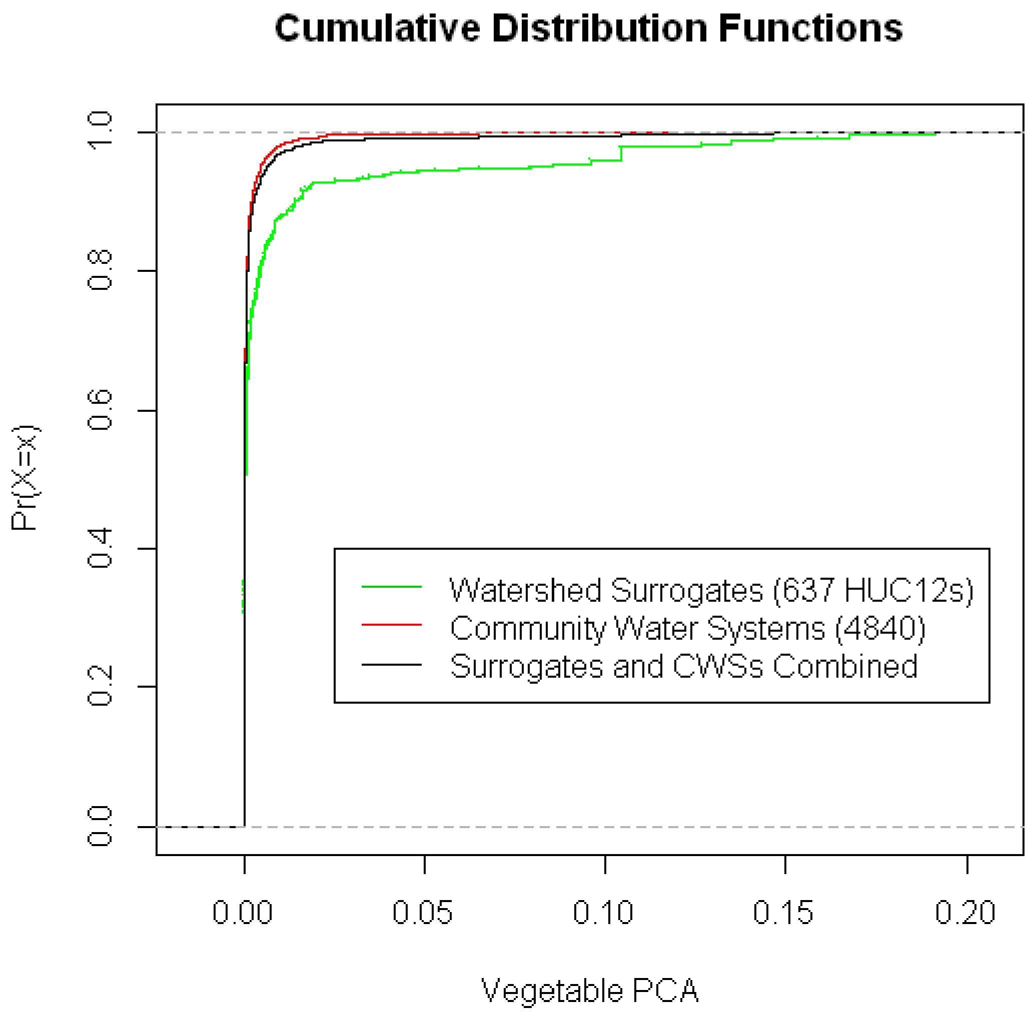


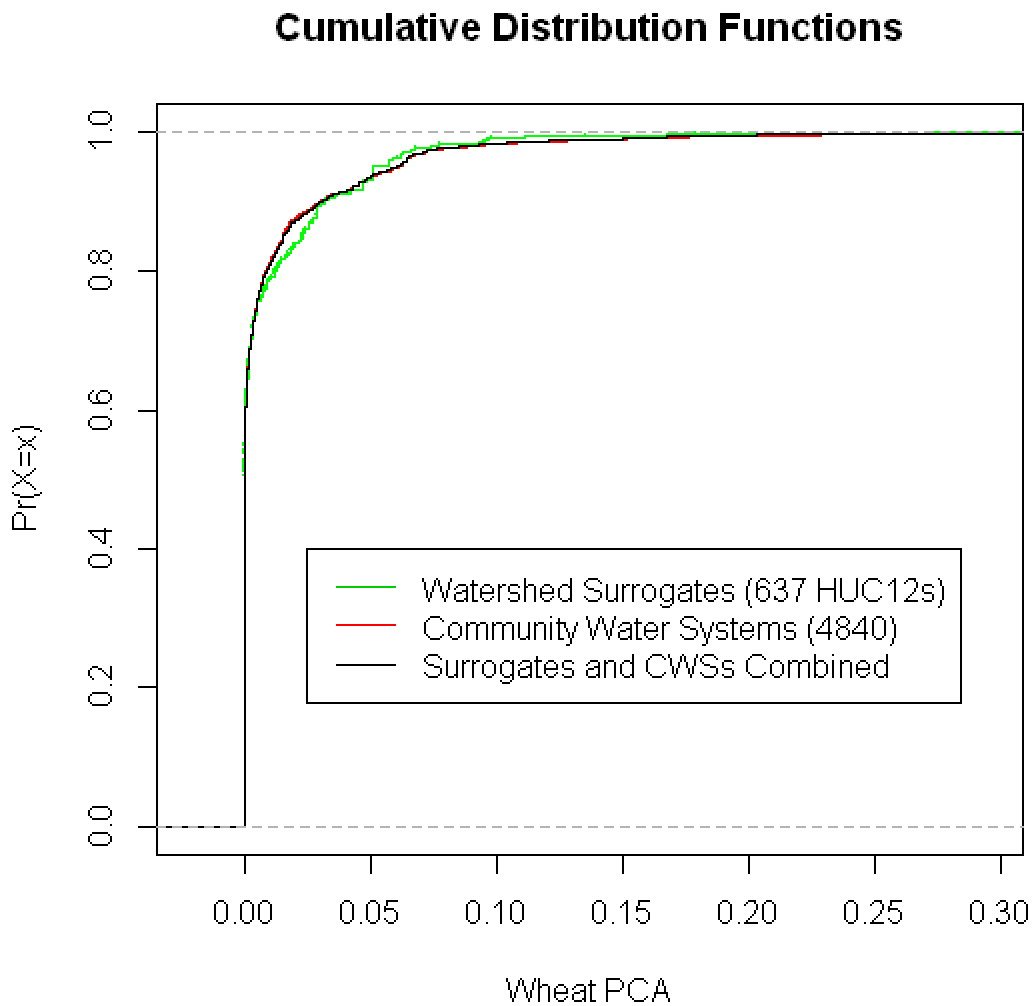
Cumulative Distribution Functions
1.0
0.8
0.6
0.4
0.2
0.0
Pr(X=x)
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined
0.00
0.02
0.04
0.06
Cotton PCA

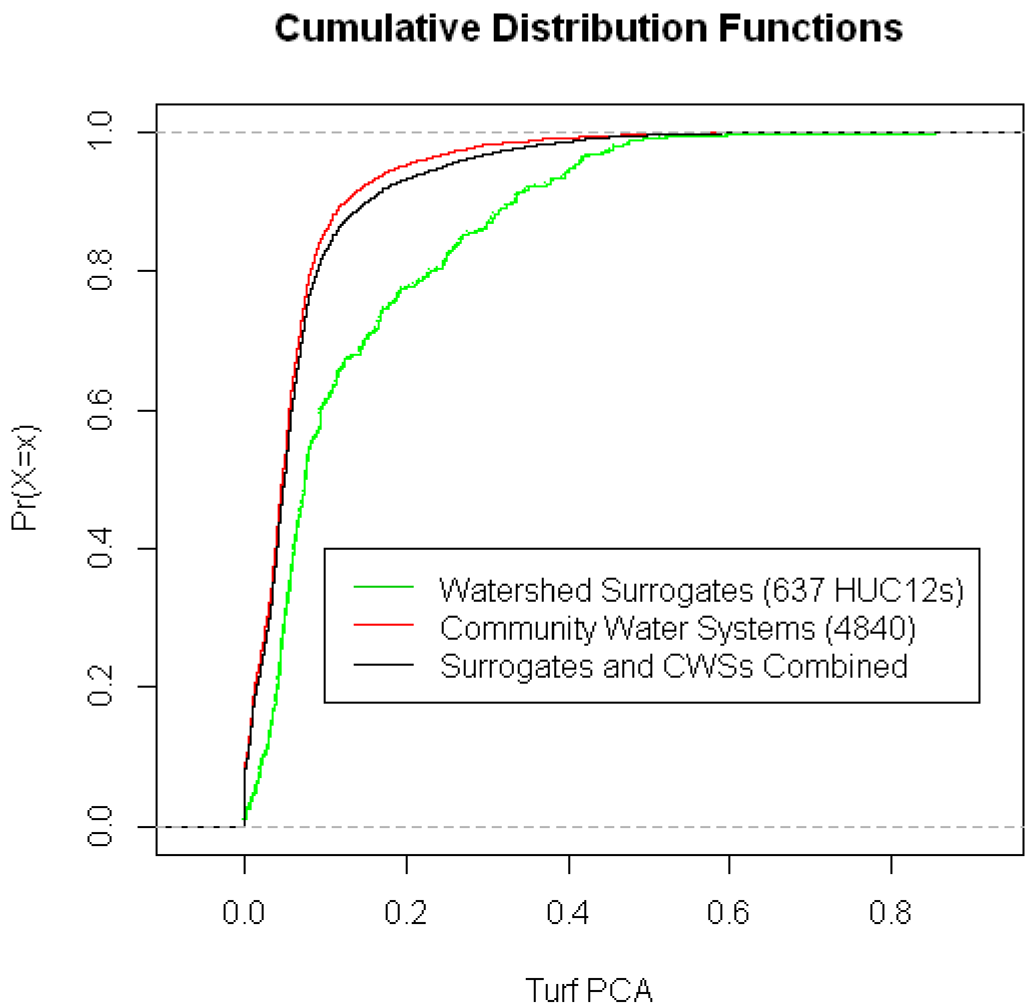

Cumulative Distribution Functions
1.0
0.8
0.6
0.4
0.2
0.0
Pr(X=x)
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined
0.0
0.1
0.2
0.3
Orchard PCA

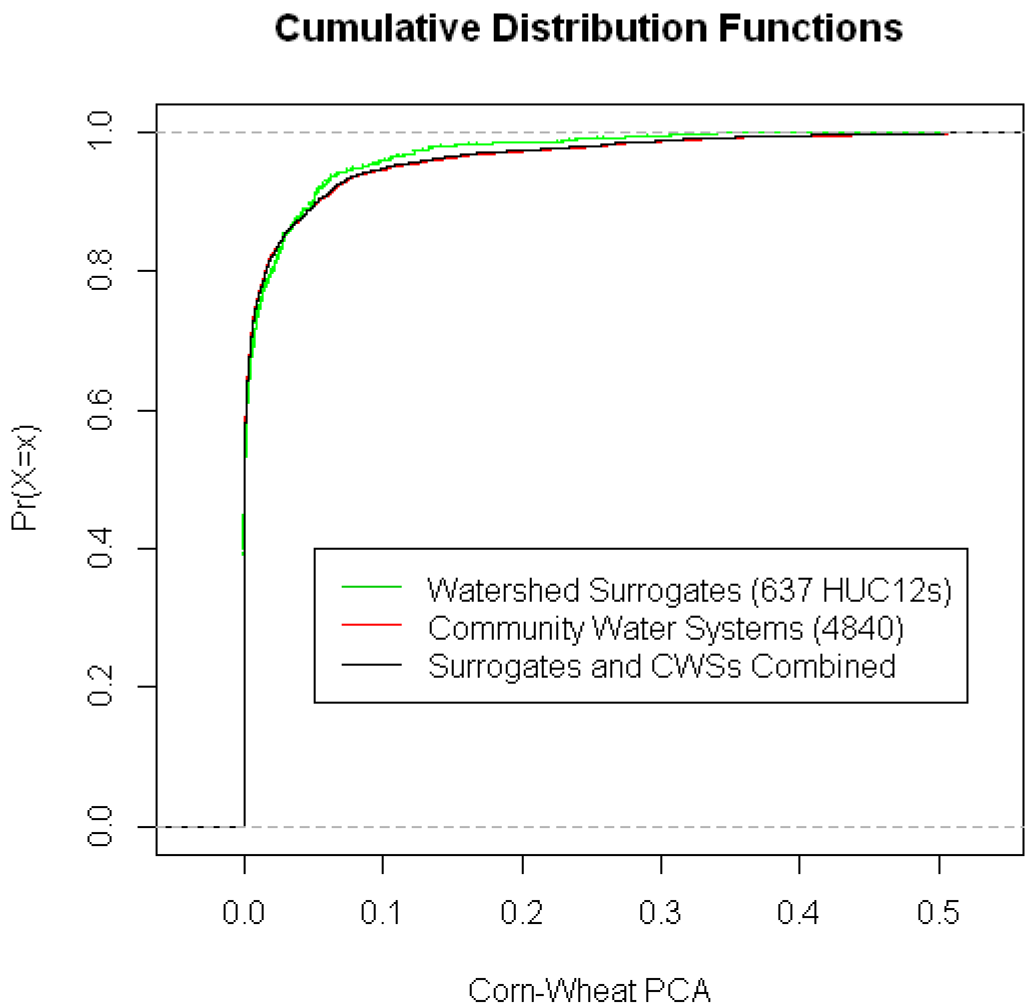


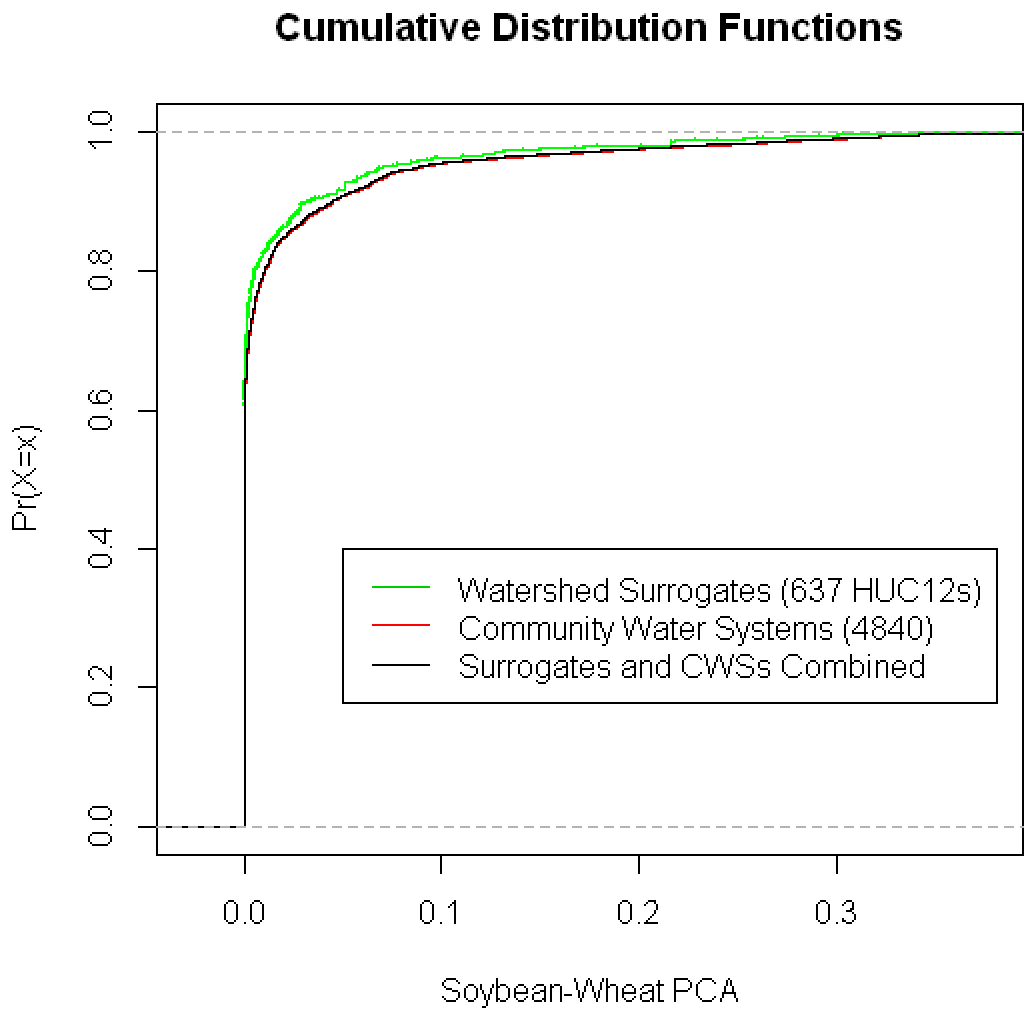
Cumulative Distribution Functions
Pr(X=x)
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.1
0.2
0.3
Soy PCA
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined

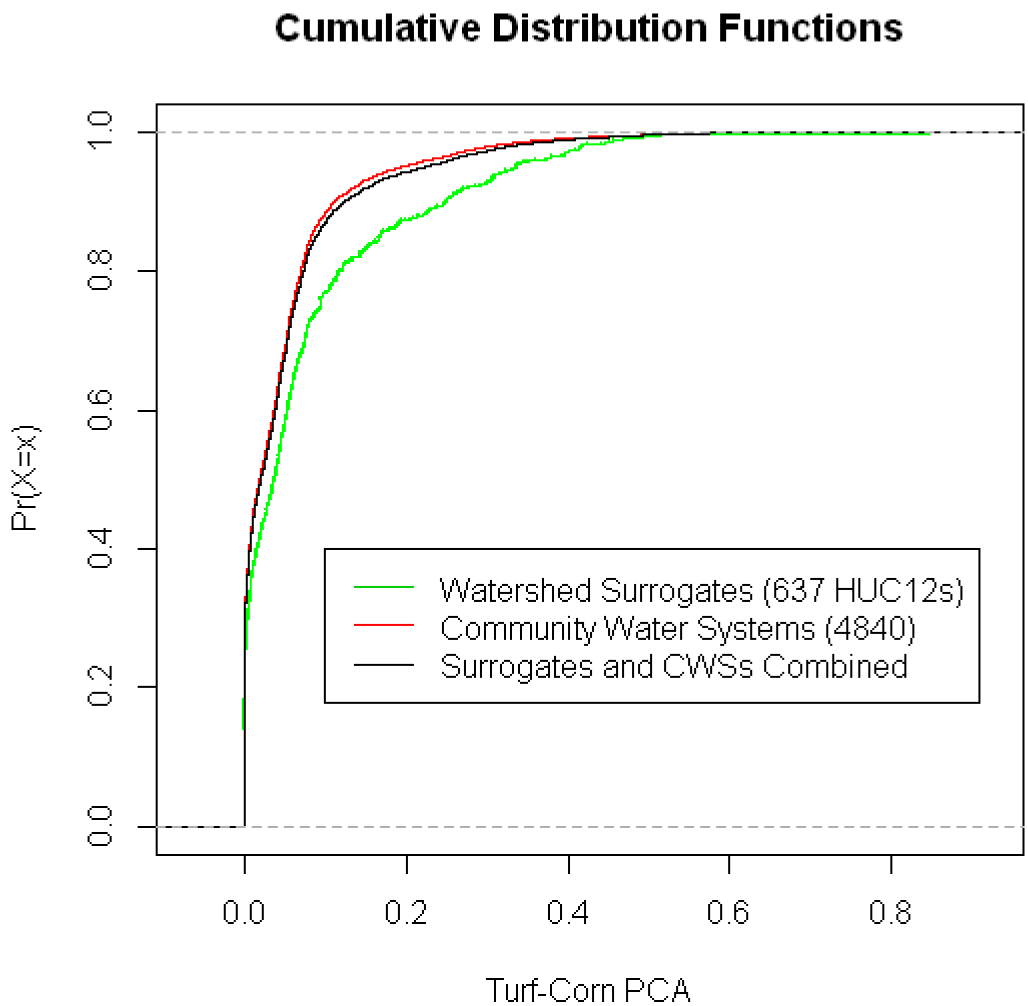

Cumulative Distribution Functions
Pr(X=x)
0.0
0.2
0.4
0.6
0.8
1.0
0.00
0.05
0.10
0.15
0.20
Vegetable PCA
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined

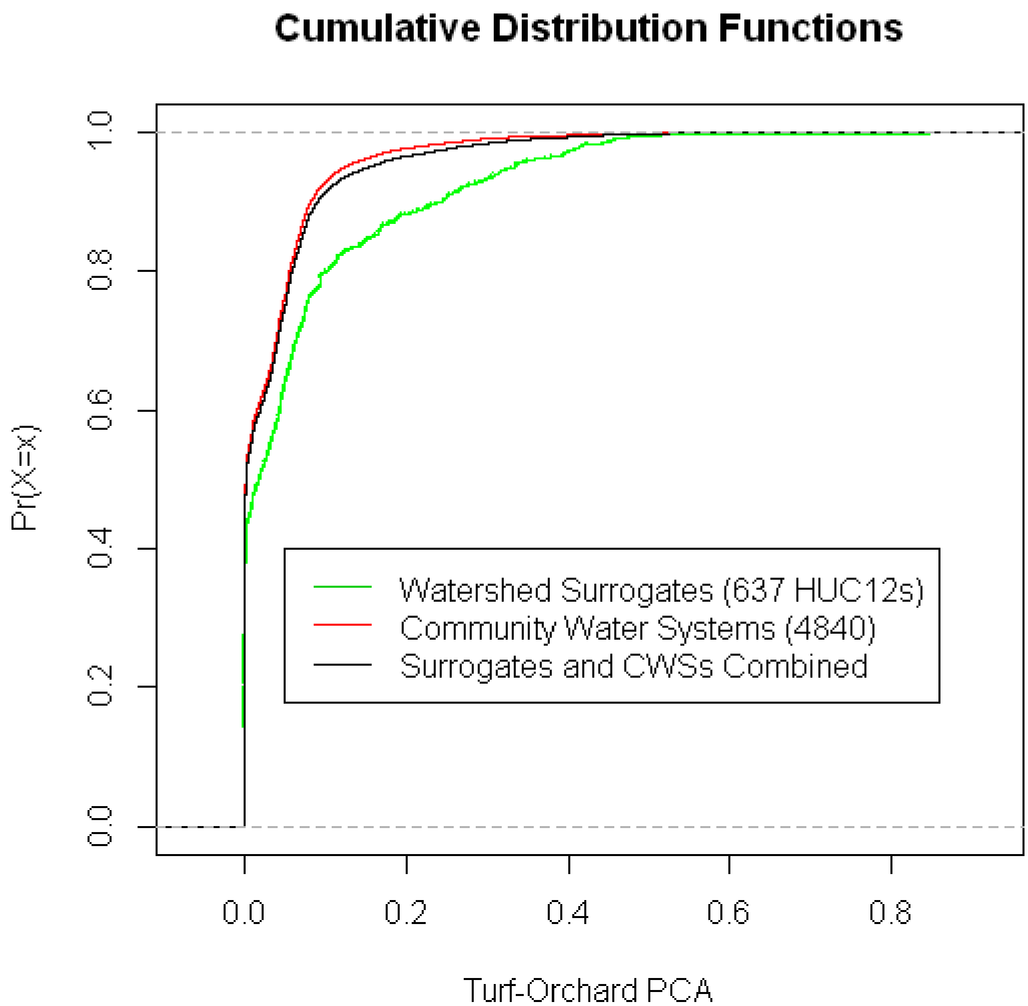

Cumulative Distribution Functions
Pr(X=x)
1.0
0.8
0.6
0.4
0.2
0.0
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Wheat PCA


Cumulative Distribution Functions
Pr(X=x)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
Turf PCA
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined

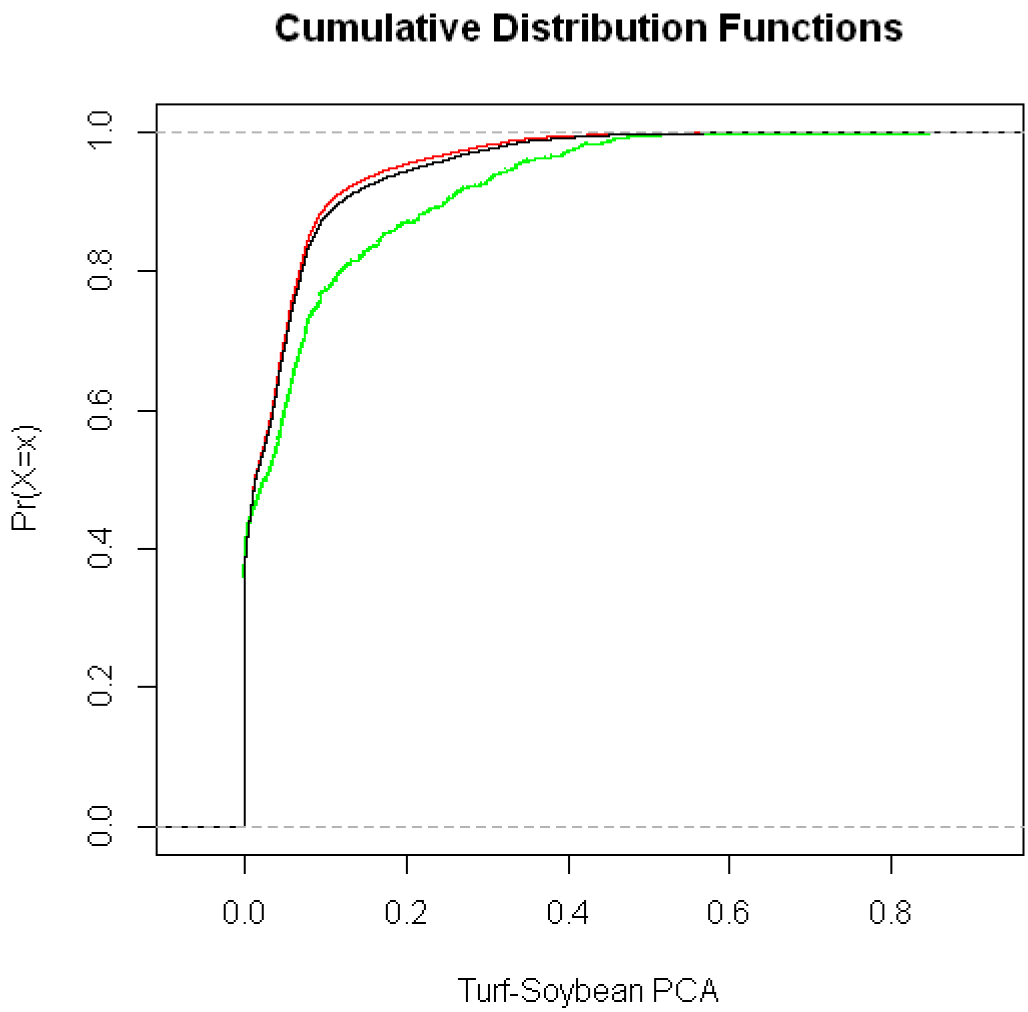

Cumulative Distribution Functions
Pr(X=x)
1.0
0.8
0.6
0.4
0.2
0.0
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined
0.0
0.1
0.2
0.3
0.4
0.5
Corn-Wheat PCA

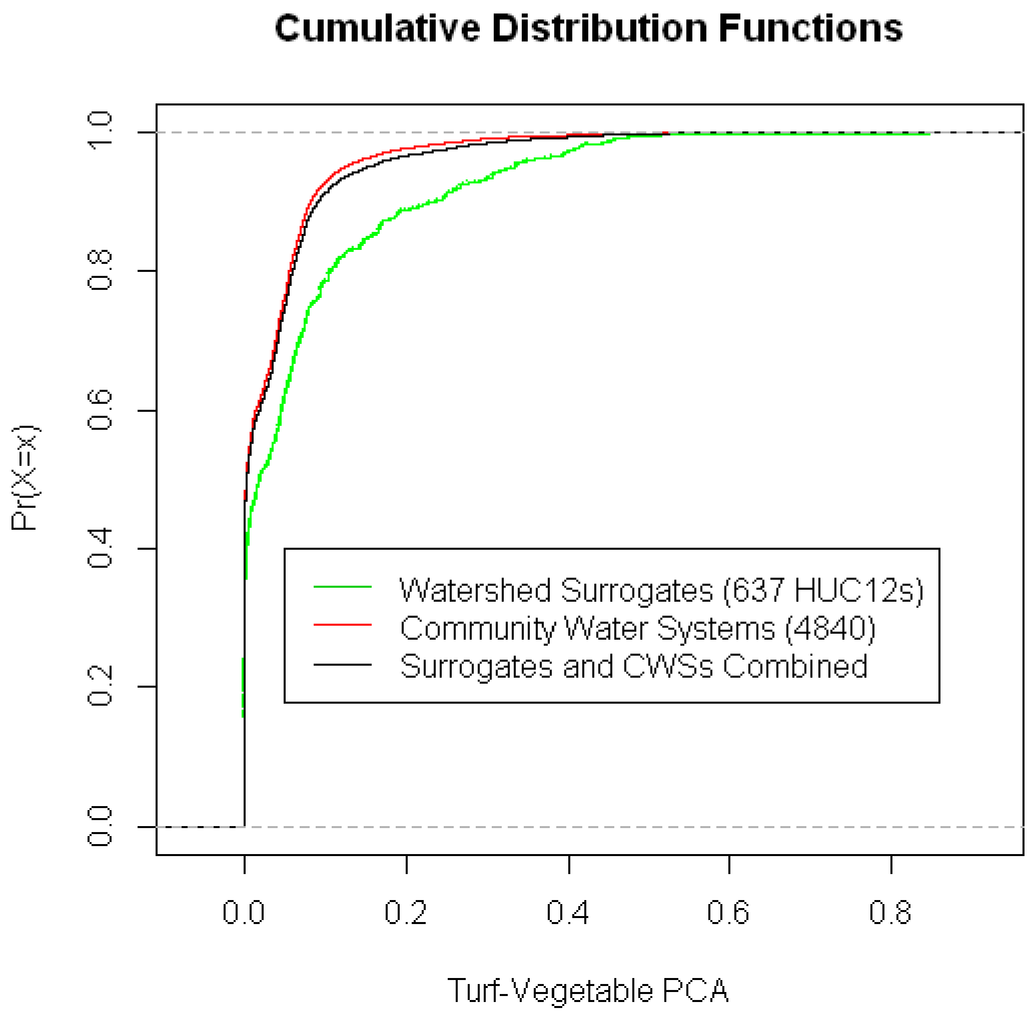

Cumulative Distribution Functions
Pr(X=x)
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.1
0.2
0.3
Soybean-Wheat PCA
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined

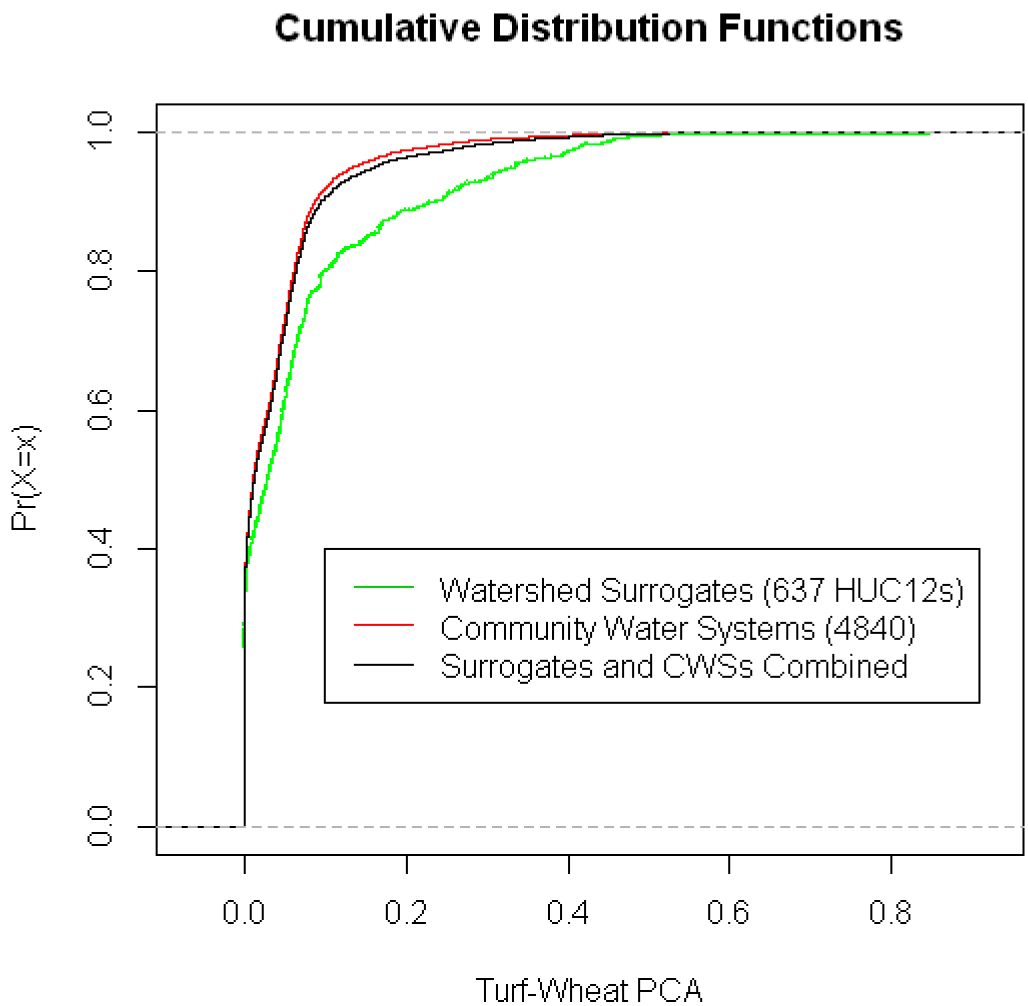

Cumulative Distribution Functions
Pr(X=x)
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
Turf-Corn PCA
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined

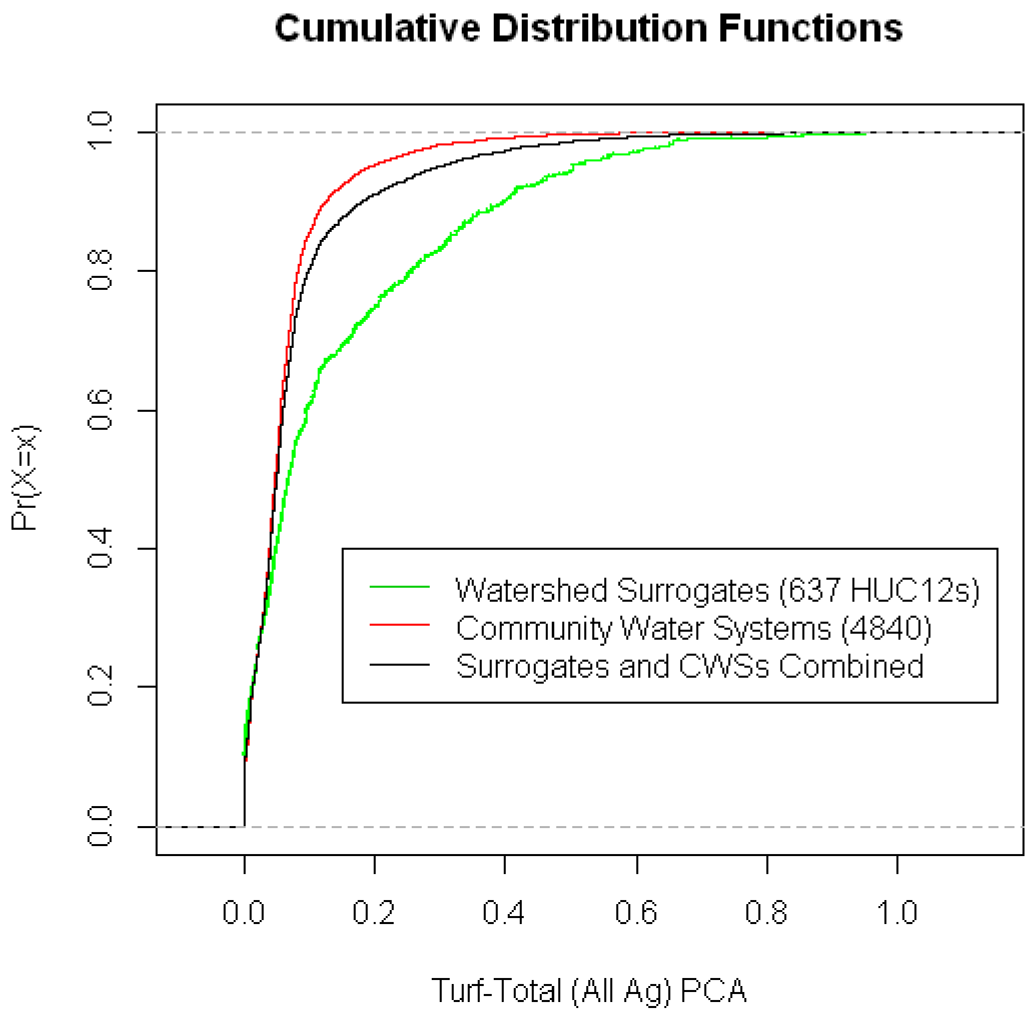


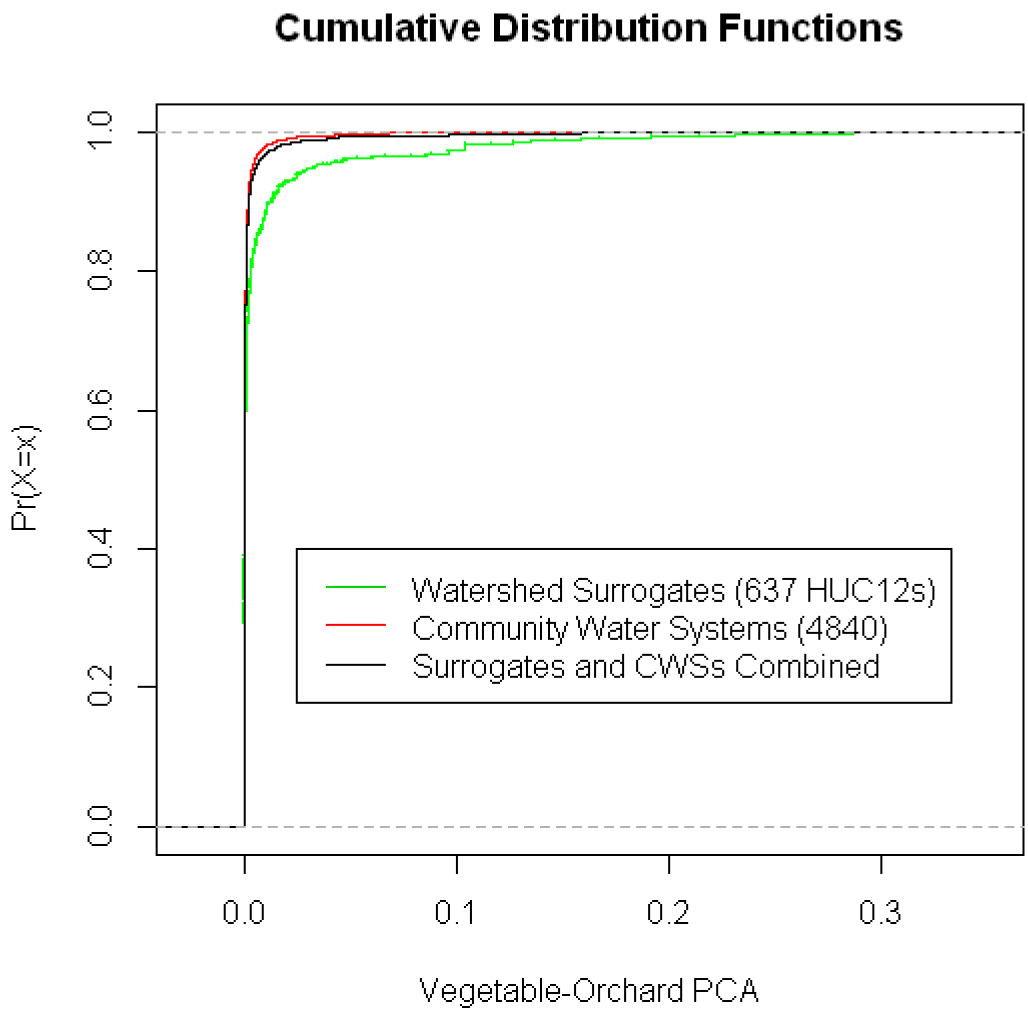
Cumulative Distribution Functions
Pr(X=x)
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
Turf-Orchard PCA
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined


Cumulative Distribution Functions
Pr(X=x)
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
Turf-Soybean PCA


Cumulative Distribution Functions
Pr(X=x)
0.0
0.2
0.4
0.6
0.8
1.0
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined
0.0
0.2
0.4
0.6
0.8
Turf-Vegetable PCA


Cumulative Distribution Functions
Pr(X=x)
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
Turf-Wheat PCA
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined


Cumulative Distribution Functions
Pr(X=x)
0.0
0.2
0.4
0.6
0.8
1.0
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined
0.0
0.2
0.4
0.6
0.8
1.0
Turf-Total (All Ag) PCA


Cumulative Distribution Functions
Pr(X=x)
1.0
0.8
0.6
0.4
0.2
0.0
Watershed Surrogates (637 HUC12s)
Community Water Systems (4840)
Surrogates and CWSs Combined
0.0
0.1
0.2
0.3
Vegetable-Orchard PCA