BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
PROPOSED AMENDMENTS TO	)	R 22-18
GROUNDWATER QUALITY	)	(Rulemaking – Public Water Supplies)
35 ILL ADM. CODE 620	)	

NOTICE OF FILING

TO: Mr. Don Brown,
Clerk of the Board
Illinois Pollution Control Board
100 West Randolph Street
Suite 11-500
Chicago, Illinois 60601
(**VIA ELECTRONIC MAIL)**

Vanessa Horton,
Hearing Officer
Illinois Pollution Control Board
100 West Randolph
Suite 11-500
Chicago, Illinois 60601
(**VIA ELECTRONIC MAIL)**

(See Persons on Attached Service List)

PLEASE TAKE NOTICE that I have today filed with the Office of the Clerk of the Illinois Pollution Control Board, **THE ILLINOIS ENVIRONMENTAL PROTECTION AGENCY'S PRE-FILED ANSWERS TO FOLLOW-UP QUESTIONS**, copies of which are hereby served upon you.

Respectfully Submitted,

ILLINOIS ENVIRONMENTAL
PROTECTION AGENCY

Dated: May 6, 2022

By: /s/ Sara Terranova
Assistant Counsel
Division of Legal Counsel

1021 North Grand East
P.O. Box 19276
Springfield, Illinois 62794-9276
(217) 782-5544
sara.terranova@illinois.gov

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
PROPOSED AMENDMENTS TO	)	R 22-18
GROUNDWATER QUALITY	)	(Rulemaking – Public Water Supplies)
35 ILL ADM. CODE 620	)	

THE ILLINOIS ENVIRONMENTAL PROTECTION AGENCY'S PRE-FILED ANSWERS TO FOLLOW-UP QUESTIONS

The Illinois Environmental Protection Agency ("Illinois EPA" or "Agency"), by and through its attorneys, submits the following Pre-filed Answers to the Follow-Up Questions.

ILLINOIS POLLUTION CONTROL BOARD

Board Question 1
Please provide the following information regarding the detection of the PFAS constituents in community water supply (CWS) wells, private wells as well as monitoring wells at other regulated sites during the last five years in a table format:

a. Name of the owner or operator of the well(s).

b. Location of the well(s). If possible, show the locations on a map.

c. Type of well (CWS, private or monitoring well).

d. For monitoring wells, identify the regulatory program under which monitoring is being conducted

e. Name of the PFAS constituent(s) detected.

f. Concentration of the constituent(s).

g. Whether the concentration exceeds the proposed standards or the preventive notification levels.

h. Whether remediation would be required to meet the proposed PFAS standards or the preventive activities requirements.

Agency Answer 1
Please refer to the Excel Spreadsheet titled, "R22-018 PFAS Detections in Illinois Groundwater." *See* Attachment 1. The spreadsheet represents PFAS groundwater data for the last five years in Agency's possession. The spreadsheet also lists finished water detections in community water supplies (CWS) that utilize groundwater as source water. The detections in finished water prompted the Agency's request to affected CWS to begin quarterly monitoring of all raw water sources and finished water entry points. Depending on the site or purpose for sampling (i.e.,

detections found during the Agency's PFAS sampling initiative of CWS), laboratories analyzed for different PFAS analytes. A sheet titled "Sampling Analytes," provides the specific PFAS analytes for each site listed and the analytical method used for analyses.

Agency Answer 1(a)
The name of the owner or operator is included in the spreadsheet. Owner information of private wells is not releasable under the Freedom of Information Act (FOIA); therefore, private owner names are not included. *See* 5 ILCS 140/7(1)(b) and 5 ILCS 140/7(1)(c).

Agency Answer 1(b)
Maps are included in the excel file under selected location file tabs. CWS data is depicted in a statewide map and maps for each region. Map ID numbers depicting CWS wells within the regional maps are listed with corresponding well sampling location on the "PFAS GW Data" sheet. *See* Attachment 1.

Agency Answer 1(c)
The type of well is included in the spreadsheet. *See* Attachment 1.

Agency Answer 1(d)
The regulatory program under which monitoring is being conducted is included in the spreadsheet. *See* Attachment 1.

Agency Answer 1(e)
The names of the PFAS constituents detected are provided in the spreadsheet. If a particular PFAS is detected at any site, it is included in the spreadsheet. Please note, the spreadsheet includes PFAS for which the Agency is not proposing groundwater quality standards, as toxicity data is not available to calculate the standards. In all, sampling detected 26 PFAS in Illinois groundwater. *See* Attachment 1.

Agency Answer 1(f)
The concentrations of the constituents are included in the spreadsheet. *See* Attachment 1.

- Detections of PFAS are highlighted in grey.
- Exceedances of the proposed PFAS standards are highlighted in orange.
- "<" means the value is less than the minimum reporting limit/detection limit
- "j" means the value is estimated. The constituent was detected; however, the detection was below the level at which a concentration could be quantified.

One site in the Federal Site Remediation Program, Rock Island Arsenal (Illinois EPA Region 3, Rock Island County), provided PFAS information to the Agency in a draft document. On April 12, 2022, the Agency submitted a FOIA Document Release Request to the Department of the Army requesting the draft document be released to allow the PFAS concentrations found as part of its investigation in the spreadsheet for full public disclosure. As of the date of this filing, the Department of the Army has not responded. Rock Island Arsenal investigations detected the following PFAS: PFBS, PFHxS, PFNA, PFOA, PFOS, PFHxA, PFHpA, PFTA, PFTrA, PFUnA, PFDA, PFDoA, PFBA, and PFPeA. PFHxS, PFNA, PFOA, and PFOS exceeded the proposed groundwater quality standards.

Agency Answer 1(g)
See Agency Answer 1(f).

Agency Answer 1(h)
Reviewing the data from the Federal Site Remediation Section sites (mostly military installations), remediation would be required due to the concentrations in groundwater. The site enrolled in the Site Remediation Program could remediate or they could use institutional controls (groundwater ordinance/Environmental Land Use Control restricting groundwater use) to address any exceedances.

Board Question 2
Based on the number of sites that may require remediation, please comment on potential cost of remediating the sites not considering exposure pathway elimination under 35 Ill Adm Code 742.

Agency Answer 2
The premise of the question is unclear. The Agency does not have information to determine the number of sites that may require remediation. We assume the question is aimed at any increase in costs to site remediation as a result of adopting standards for PFAS. It is unclear how many sites will choose to address PFAS as part of their corrective action. However, the sites that would be affected are sites where (1) the remediating party is addressing PFAS contamination and (2) the PFAS contamination being addressed extends beyond any other contamination that is being remediated. In other words, increased costs would exist only where PFAS is the sole contamination being remediated. These increased costs would be the expense of remediating that isolated PFAS contamination. This would be the case for sites in the Site Remediation Program. Since PFAS is not an indicator contaminant in the Leaking Underground Storage Tank (LUST) Program, there would be no difference in cost for LUST cleanups.

In practice, all contaminants are generally addressed together so any increase in costs due to the addition of PFAS standards is generally expected to be minimal. The ability to address multiple contaminants at once is why the use of engineered barriers and institutional controls is so effective and prevalent. For example, a groundwater ordinance prohibiting the installation of potable drinking wells prevents exposure to all contaminants in the groundwater. An engineered barrier prevents ingestion of any contaminants in the soil. Most sites that have achieved cleanup and received No Further Remediation Letters under the Site Remediation Program (5,103 out of 5,675) utilized an institutional control, engineered barrier, or both as part of their corrective action.

Board Follow-up to Agency Answer 8(b)
Please specify the dates on which each of the 20 active GMZs were established.

Agency Answer 8(b)
See Attachment 2 for the dates of GMZ approval.

Board Follow-up to Agency Answer 8(c)
For the two GMZs that were terminated after attaining the applicable Subpart D standards, what was the duration of each GMZ?

Agency Answer 8(c)
The duration of the Havana South Ash Pond system GMZ was 13 years. The duration of the Peoria Terminal GMZ was 17 years. However, corrective actions began under an interim consent order in 1991, prior to the adoption of Part 620 and the Agency's approval of the corrective action plan in a final Consent Order in 1999. *See* People of the State of Illinois ex rel. James E. Ryan Attorney General of the State of Illinois v Amoco Oil Company and Mobil Oil Corporation 90 CH 79 at 8 (April 28, 1999) for the final consent order which references the interim consent order entered January 16, 1991. Thus, there were 25 years of corrective action to achieve Subpart D groundwater standards.

Board Follow-up to Agency Answers 8(g), 8(h), 21(a), 21(b), 21(c), 21(e), and 21(f)
Would the Agency consider filing proposed amendments to Section 620.250 and Appendix D ("Confirmation of an Adequate Corrective Action Pursuant to 35 Ill. Adm. Code 620.250(a)(2)") clarifying that Appendix D is the "application" required by both subsections (a)(1) and (a)(2) of Section 620.250 and by proposed subsection (g) of Section 620.250?

Agency Answer 8(g), 8(h), 21(a), 21(b), 21(c), 21(e), and 21(f)
The Agency has proposed clarifying amendments to Section 620.250 and 620.Appendix D as requested by the Board. *See* Attachment 3.

Please explain the import of Note 3 to Appendix D, which reads: "If the facility is conducting a cleanup of a unit which is subject to the requirements of the Resource Conservation and Recovery Act (RCRA) or the 35 Ill. Adm. Code 731 regulations for Underground Storage Tanks, this confirmation process is not applicable and cannot be used."

Agency Answer
The intention of Note 3 to Appendix D is to indicate the submission of Appendix D is not adequate to meet the requirements of RCRA for confirmation of an adequate corrective action program. RCRA requires review and approval by the Agency of a facility-prepared submittal meeting the requirements of guidance documents available on the Agency website (https://www2.illinois.gov/epa/topics/cleanup-programs/rcra/remediation-projects/Pages/establishing-a-gmz.aspx) in order to demonstrate the corrective action is adequate when establishing or evaluating the corrective action, which is the basis of the GMZ.

Part 731 also requires the submission of a report to demonstrate corrective action will be conducted to meet the remediation objectives for the site. This notation should also include sites using 35 Ill. Adm. Code Parts 734 and 740.

Board Follow-up to Agency Answers 8(j) and 8(k)
Under Section 620.250(b), is the GMZ established on the date of the Agency's written "concurrence"?

Agency Answer 8(j) and 8(k)
Yes. *See* Attachment 3.

Board Follow-up to Agency Answer 8(l)
Looking at the word "continues" in Section 620.250(b), does the Agency's written concurrence determine that groundwater management will continue for a period of time consistent with the action described in subsection (a), rather than determining that groundwater management "continues" for that period?

Agency Answer 8(l)
Section 620.250(b) is written so that it is applicable to either situation in Section 620.250(a)(1) or (2). In the instance of (a)(1), it may be more grammatically correct to use the term "will continue" because the approved Agency corrective action is prospective, in that a proposed corrective action was evaluated, and is approved by the Agency, for near future implementation. In the instance of (a)(2), an owner or operator of a site as already initiated a corrective action, which the Agency subsequently reviews and approves as adequate, and the owner or operator then "continues" that action to completion. However, in the instance of (a)(1), "continues" may also be correctly applied because an Agency approved corrective action that was yet to initiated, would have a schedule for construction, operation and monitoring. The implementation of the approved activities "continues" on the schedule, until all approved actions are complete. It would also be possible to apply the phrase "will continue" in a similar manner. In the instance of (a)(1), the approved corrective actions "will continue" as scheduled and in the instance of (a)(2) the corrective actions already initiated and approved "will continue". The Agency has proposed to change the word "continues" to the phrase "will continue". *See* Attachment 3.

Board Follow-up to Agency Answer 8(n)
For this rulemaking's record, please provide a copy of both determinations that the Agency has issued under Section 620.250(c).

Agency Answer 8(n)
See Attachment 4.

Board Follow-up to Agency Answers 8(p) and 38
Section 620.250(c) appears to contemplate GMZ termination in only two scenarios, both initiated by the owner/operator:

- *The owner/operator makes a submittal demonstrating completed action and attainment of Section 620.450(a)(4)(A) concentrations. See the first sentence of subsection (c).*

- *The owner/operator makes a submittal demonstrating completed action and that Section 620.450(a)(4)(B) concentrations should be the applicable standards. See the last two sentences of subsection (c).*

Should Section 620.250(c) also address GMZ termination initiated by the Agency, such as when the owner/operator has

> *Stopped implementing the Agency-approved action?*
>
> *Refused to implement additional or different action that the Agency determines is necessary to attain the applicable Subpart D standards?*

Agency Answer *8(p) and 38*
The Agency believes it is intrinsic as a condition in Section 620.250(b), that if an owner or operator stops managing groundwater as approved, or refuses to take additional remedial measures, then the Agency may terminate the GMZ. However, in response to the Board's follow-up questions, the Agency has proposed new Sections 620.250(c)(1) and (2) clarifying that refusal to complete the corrective action from Section 620.250(b) also causes the expiration of a GMZ. *See* Attachment 3.

For clarity under Section 620.250(c), should a GMZ terminate on the date of the corresponding written Agency determination letter?

Agency Answer
The Agency has proposed a clarifying edit to Section 620.250(c). *See* Attachment 3.

Board Follow-up to Agency Answers 8(q)(ii)-8(q)(v)
If the Agency were to issue a determination letter terminating a GMZ and making Section 620.450(a)(4)(B) concentrations the applicable standards, would that letter specify:

> *The requirements to which the owner/operator would be subject for "controls and continued management" and submitting "results . . . in a written report" (Section 620.250(c))?*

Agency Answer
The type of on-going controls required would depend on the type of contaminants that had been released, how they were released and how they behave in the environment. The controls could vary from process changes which reduce or eliminate the presence of the subject contaminant to on-going maintenance of a cover system.

> *The reasons for the Agency's determination that, "[t]o the extent practicable, the exceedance has been minimized and beneficial use, as appropriate for the class of groundwater, has been returned" (Section 620.450(a)(4)(B)(i))?*

Agency Answer
Due to site specific conditions, it may not be economically feasible to remove all contaminants to concentrations below their respective groundwater standards. However, reducing the concentrations to certain levels may support some uses, even if all uses could not be met. Reducing a contaminant to a concentration that can be treated using a conventional treatment method such as aeration, instead of requiring reverse osmosis to make the water potable would be an example of how beneficial use is restored to the maximum extent practicable.

> *The reasons for the Agency's determination that "[a]ny threat to public health or the*

environment has been minimized" (Section 620.450(a)(4)(B)(ii))?

Agency Answer
Even if a contaminant cannot be reduced below the applicable standard, reducing the concentration of a contaminant to the lowest feasible level makes the groundwater safer if human or environmental contact occur. For example, a contaminant at a concentration that requires multiple exposures to cause harm poses less risk that a contaminant that can cause harm with a single exposure. Reducing the contaminant concentration can therefore reduce the risk of harm to human health and the environment.

Under Section 620.250(c), what types of "results" would the Agency expect to see in the owner/operator's "written report"?

Agency Answer
The Agency would expect to see trend analysis over several year periods showing that reductions in contaminant concentrations had stopped and had become stable at some concentration. Assuming those concentrations are above applicable groundwater standards, the Agency would expect an evaluation of alternative corrective actions that could result in additional concentration reductions, and whether implementation of those alternatives are technically and economically reasonable. Finally, the Agency would require proof that human health and the environment would be protected to the maximum extent possible, such as with water use restrictions.

Section 620.250(c) requires the Agency's review—of the on-going adequacy of controls and continued management at the site—to "take place no less often than every 5 years." For clarity under Section 620.250(c), should that initial five-year period run from the date of the Agency's determination letter terminating the GMZ and making Section 620.450(a)(4)(B) concentrations the applicable standards?

Agency Answer
Yes, the initial five-year period should start from the date of the Agency's termination letter, because until that time the corrective action and GMZ are ongoing.

Would the Agency issue a letter documenting each of its "review[s]" of "the on-going adequacy of controls and continued management at the site"?

Agency Answer
Yes, the Agency would document the review in writing.

Under Section 620.250(c), might an owner/operator ever be relieved of the requirements for "controls and continued management" and "written report[s]"? If so, what form would that relief take?

Agency Answer
Yes, and owner/operator could petition the Board for an adjusted standard.

Board Follow-up to Agency Answer 9(d)
Please describe the types of sites or facilities where "the remaining six GMZs which are not

related to CCR" are located.

Agency Answer 9(d)
Five of the remaining GMZs approved under Section 620.250(a) are for releases from refuse disposal areas at coal mines, the sixth GMZ under Section 620.250(a) is for a natural gas release at an underground natural gas storage field.

Please comment on whether providing an annual update on the status of the non-CCR related GMZs for publication in the Board's Environmental Register would place a significant burden on the Agency's resources.

Agency Answer
An annual update for publication in the Board's Environmental Register would not place a significant burden on the Agency's resources provided the listing is the name of the site with the GMZ and a short explanation of the status. For example: "Construction of corrective measures underway" or "Construction of corrective measures complete, confirmatory monitoring underway". In response to the Board's follow-up question, the Agency has proposed a new subsection (h) to Section 620.250. *See* Attachment 3.

Board Follow-up to Agency Answer 24
Must an owner/operator seeking to establish a GMZ submit Parts I, II, and III of Appendix D simultaneously?

Agency Answer 24
An owner or operator seeking a GMZ would not be required to submit Parts I, II, and III simultaneously. However, the approval of corrective actions typically evolves through Agency and owner/operator discussions with submission and review of multiple supporting documents. Therefore, Parts I, II, and III are typically submitted together. The Agency has suggested an amendment to proposed Section 620.250(g) that will require the submission of 620.Appendix D, Parts I, II, and III along with the supporting documents required by subpart (g). *See* Attachment 3.

Must an owner/operator seeking to terminate a GMZ submit Part IV of Appendix D?

Agency Answer
The Agency has supporting documentation that the information required by Part IV was available for Agency review prior to the expiration of the GMZs. However, review of Agency records does not indicate that Part IV was included with the supporting documents for either of the GMZs that have expired. The Agency has proposed an amendment to Section 620.250(c) clarifying to owners and operators wishing to terminate a GMZ and Agency staff reviewing the data submitted, that Part 620.Appendix D, Part IV requires the inclusion of Part IV as part of the information that must be submitted for expiration approval. *See* Attachment 3.

AMERICAN CHEMISTRY COUNCIL

ACC Question 1
IL EPA has indicated that USEPA SW-846 Method 8327 is available for use to analyze PFAS in non-potable drinking water.

Has IL EPA determined how many laboratories in the state are certified to conduct Method 8327?

Agency Answer 1
No. The Illinois EPA's Environmental Laboratory Accreditation Program has only recently been approved to add Method 8327 to their scope of accreditation.

ACC Question 2
In response to American Chemistry Council's (ACC) pre-filed question 5 regarding IEPA's selection of reference dose (RID) sources for the PFAS substances included in the Proposed Amendments, IEPA referred to its use of the U.S. Environmental Protection Agency's (USEPA) hierarchy of human health and toxicity values recommend for use in risk assessments. IEPA also stated "[f]urther, [Agency for Toxic Substances and Disease Registry] ATSDR's PFAS toxicity values rely on more recent toxicological studies with a broader scope of adverse effects than the studies relied upon for developing the toxicity values for USEPA's 2016 health advisory levels."

> *What analysis, if any, does IL EPA conduct to ensure the human health and toxicity values upon which it relies are scientifically sound?*
>
> *Does IL EPA have the discretion to deviate from the source hierarchy? If so, what criteria does IL EPA employ when determining whether to deviate from the hierarchy?*
>
> *What analysis or evaluation has IL EPA conducted to determine the ATSDR toxicity values rely on "more recent toxicological studies with a broader scope of adverse effects" as stated in the response to ACC pre-filed questions?*

Agency Answer 2
Pursuant to the authority granted in the Illinois Ground Water Protection Act, Illinois EPA relies upon the sources referenced in Carol Hawbaker's written testimony. *See* Exhibit 2, Attachment C. The sources listed are accepted by U.S. EPA as described in written testimony. *See* Exhibit 2. Attachment 1C, Numbers 1, 2, and 3. Please also see testimony regarding Illinois EPA's adherence to the hierarchy and toxicity values listed for U.S. EPA's Reginal Screening Levels. *See* Exhibit 2 at 6-12. The Agency reviewed both the U.S. EPA and ATSDR documents referenced in the testimony as Attachments 1D-3, 1D-4, 1D-5, 1D-6, and 1D-7. See Exhibit 2, Attachments 1D-3, 1D-4, 1D-5, 1D-6, and 1D-7.

ACC Question 3
In response to ACC's pre-filed question 7 regarding IL EPA's use of the ATSDR Minimum Risk Level (MRL) as its toxicity source for PFOS given concerns about ATSDR's derivation of the lowest-observable adverse-effect level (LOAEL), IL EPA states that "[c]oncerns regarding the basis for ATSDR's development of its toxicity values are more appropriately directed to ATSDR."

Is IL EPA aware of ATSDR's inappropriate derivation of the LOAEL in which it adopts a value of 0.4 milligrams per kilogram (mg/kg) despite the key study ATSDR relied upon identifying a 1.6 mg/kg LOAEL?

Does IL EPA agree with ATSDR's approach? Please explain.

Does IL EPA have an obligation to independently evaluate the concerns ACC identified above or other scientific shortcomings before adopting ATSDR's toxicity value as part of its Proposed Amendments? If not, please explain.

Agency Answer 3
Pursuant to the authority granted in the Illinois Ground Water Protection Act, Illinois EPA relies upon the sources referenced in Carol Hawbaker's written testimony. *See* Exhibit 2, Attachment C. The sources listed are accepted by U.S. EPA as laid out in written testimony. *See* Exhibit 2. ATSDR's toxicological profile underwent public comment, after which ATSDR released the final value. *See* Exhibit 2, Attachment 1D-5.

Concerns regarding the basis for ATSDR's development of its toxicity values are more appropriately directed to ATSDR. In applying the ATSDR values, Illinois EPA meets the requirements of 620.Appendix A.

ACC Question 4
In response to ACC's pre-filed question 8 regarding IL EPA's use of the California Office of Environmental Health Hazard Assessment (OEHHA) as its toxicity source for PFOA given concerns about its reliance on animal studies that have limited relevance to humans, IL EPA states that "[c]oncerns regarding the basis for OEHHA's development of its toxicity value are more appropriately directed to OEHHA." IL EPA also quotes OEHHA's response to comments filed in a separate action, the Notice of Intent to List Perfluorooctanoic Acid as Causing Cancer Under Proposition 65. IL EPA does not indicate whether it agrees with OEHHA's response to comments or explain how it relates to OEHHA's prior analysis.

Is IL EPA aware OEHHA relied upon animal studies assessing the cancer risk from PFOA exposure despite scientific literature concluding that observed tumors are induced through a mode of action that is dependent on activation of peroxisome proliferation (PPARa), which has limited or no relevance to humans?

Is IL EPA aware that scientific literature has questioned the relevance of these animal studies in relation to PFOA carcinogenicity, and does IL EPA agree with OEHHA's approach? Please explain.

Does IL EPA have an obligation to independently evaluate the scientific concerns ACC identified before adopting OEHHA's toxicity value as part of its Proposed Amendments?

Agency Answer 4
Pursuant to the authority granted in the Illinois Ground Water Protection Act, Illinois EPA relies upon the sources referenced in Carol Hawbaker's written testimony. *See* Exhibit 2, Attachment C. Stakeholders raised this issue specifically when California EPA's Notice underwent public comment. Please refer to Illinois EPA's March 7, 2022, answer to ACC's Question 8 for a discussion of California EPA's response to ACC's concern. Concerns regarding the basis for California EPA's development of its toxicity values are more appropriately directed to California EPA. In applying the California EPA's carcinogen value, Illinois EPA meets the requirements of 620, Subpart F.

ACC Question 5
IL EPA relies upon the International Agency for Research on Cancer's (IARC) designation that PFOA is "possibly carcinogenic to humans" despite the fact that IARC considered PFOA to be a "possible" human carcinogen but could not rule out chance, bias or confounding with reasonable confidence in its evaluation of the scientific literature.

> *Did IEPA review the IARC monograph and the underlying studies referenced therein before adopting its findings and classifying PFOA as a "carcinogen"?*
>
> *Does IEPA agree that without ruling out chance, bias or confounding there is uncertainty regarding causality in the PFOA carcinogen designation?*
>
> *IEPA explains that it did not rely upon the U.S. EPA Office of Water Lifetime Health Advisories for deriving toxicity values PFOA and PFOS, at least in part because there are more recent toxicological studies available. The Health Advisories were released in 2016. The IARC monograph for PFOA was issued in 2017. Explain why IEPA determined more recent scientific literature were not relevant in classifying PFOA as a "carcinogen"?*
>
> *In general, does IEPA believe in using the most-up-date sound science in its proposed agency actions?*

Agency Answer 5
Illinois EPA's Environmental Protection Act (Act) defines a carcinogen in the State of Illinois. The Act's definition is as follows:

> "Carcinogen" means a contaminant that is classified as a Category A1 or A2 Carcinogen by the American Conference of Governmental Industrial Hygienists; or **a Category 1 or 2A/2B carcinogen by the World Health Organization's International Agency for Research on Cancer**; or a "Human carcinogen" or "Anticipated Human Carcinogen" by the United States Department of Health and Human Service National Toxicological Program; or a Category A or B1/B2 Carcinogen by the United States Environmental Protection Agency in Integrated Risk Information System or a Final Rule issued in a Federal Register notice by the USEPA.

See 415 ILCS 5/58.2 (**emphasis added).**

In 2017, the World Health Organization's International Agency for Research on Cancer (IARC) designated PFOA a class 2B carcinogen, one year after the issuance of the U.S. EPA Health Advisories. *See* IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Some Chemicals Used as Solvents and in Polymer Manufacture. Lyon (FR): International Agency for Research on Cancer; 2017. (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, No. 110.) Concerns regarding the basis of IARC's carcinogen classification are more appropriately directed to IARC.

ACC Question 6

In her testimony on March 9, Ms. Carol Hawbaker indicated that IL EPA approaches dose additivity of substances affecting the same organ differently than USEPA's Superfund program when assessing contamination with multiple substances. While USEPA considers substances affecting the same target organ as part of a screening assessment, it only assumes additivity for substances acting by a common of action when conducting a more refined assessment. According to the language of Appendix C and Ms. Hawbaker's testimony, IL EPA does not require that the substances act by a common mode of action to apply dose additivity.

> *What is the basis for applying an approach to dose additivity that is inconsistent with that applied by USEPA?*
>
> *Please provide an example for the record of how IL EPA would apply the dose- additivity approach described in Appendix C to groundwater contaminated with more than one substance identified in Appendix E as affecting the same target organ (e.g., liver). The example should include at least one of the PFAS for which IL EPA has proposed a ground water standard*

Agency Answer 6

Section 620.615 requires the Agency to determine the need for additional health advice if mixtures of two or more substances are detected that are similar-acting in their toxic or harmful physiological effect on the same specific organ or organ system. *See* 35 Ill. Adm. Code 620.615. Guidelines for determining when dose addition of similar-acting substance is appropriate are found in Part 620, Appendix C. *See* 35 Ill. Adm. Code 620, Appendix C. The procedures for applying dose additivity are found at Part 620, Appendix B(d) – (h). *See* 35 Ill. Adm. Code 620, Appendix B(d) – (h). These provisions spell out the methods required for applying the mixture rule. Requirements and procedures for addressing mixtures of similar-acting substance in Part 620 were promulgated in November 1991 and updated October 2012. *See* R89-14(B) (November 7, 1991) and R08-18 (October 12, 2012) respectively. Mixtures for similar-acting substances are not evaluated for setting Class I potable groundwater quality standards. Mixtures of similar-acting substances are required to be evaluated only with the issuance of a Health Advisory in Part 620. *See* 35 Ill. Adm Code 620.601(d) and 620.615(b). However, Part 742, Tiered Approach to Corrective Action Objectives, requires that two or more similar-acting substances be evaluated for mixture when proposing corrective action objectives for sites in the Leaking Underground Storage Tank Program, the Site Remediation Program, or the RCRA Part B Permits and Closure Plans Program.

ACC Question 7
USEPA's Exposure Factors Handbook defines mode of action as "a sequence of key events and processes, starting with interaction of an agent with a cell, proceeding through operational and anatomical changes, and resulting in an adverse effect."

> *Is this the definition that IL EPA uses in considering mode of action?*
>
> *Do the examples "central nervous system depression, liver toxicity, or cholinesterase inhibition" given in paragraph (a) of Appendix C meet USEPA's definition of mode of action?*

Agency Answer 7
Please refer to Agency Answer 6. Yes, central nervous system depression, liver toxicity, or cholinesterase inhibition are harmful physiological effects as noted in Section 620.615.

ACC Question 8
GenX is the trade name for a proprietary technology platform used by one company in the manufacture of fluoropolymers. HFPO-DA is used as a polymerization aid in this platform and is as a polymerization aid in fluoropolymer manufacture. This company has never sold HFPO-DA (or GenX) as a fluorosurfactant for use in aqueous film forming foam (AFFF) and is not aware of such use of HFPO-DA or of the use of fluoropolymers in AFFF.

> *Does IL EPA have specific knowledge of the use of HFPO-DA (or GenX) as a surfactant in AFFF?*
>
> *Does IL EPA have specific knowledge of the use of fluoropolymers made with the GenX technology platform in AFFF?*

Agency Answer 8
Upon further review, Carol Hawbaker's testimony before the Board incorrectly identified HFPO-DA as a chemical used in AFFF.

ACC Question 9
In her March 9 testimony, Ms. Hawbaker indicated that IL EPA's source of information for the use of HFPO-DA is the Interstate Technology Regulatory Council. ACC has been unable to find a reference to HFPO-DA (or Gen-X) in the AFFF chapter in the ITRC document.

> *Please provide for the record the specific reference in the ITRC material to the use of HFPO-DA (or GenX) in AFFF.*

Agency Answer 9
Upon further review, Carol Hawbaker's testimony before the Board incorrectly identified HFPO-DA as a chemical used in AFFF.

DYNEGY

Dynegy Question 1
Under IEPA's proposal, what is the sampling methodology applicable to analyzing groundwater for inorganics under Part 620?

Agency Answer 1
Depending on the circumstances, any of the sampling procedures listed in Section 620.510(b) and incorporated by reference in Section 620.125 may be used.

Dynegy Question 2
Are there any circumstances where samples can be field-filtered to determine whether there has been an exceedance of a Class I or Class II inorganic standard? If so, what are those circumstances?

Agency Answer 2
Part 620 identifies standards for Class I and Class II groundwater, which are measured as total (unfiltered) concentrations. However, in some circumstances, samples analyzed for metals or PNAs may be biased due to turbidity of the groundwater sample. If a site has a turbidity issue, the Agency will allow filtering of samples provided the following conditions are met: unfiltered samples are collected at the same time; both samples (filtered and unfiltered) are preserved; the filtering is conducted in the field; and a pump (peristaltic or another low flow pump) with a 0.45 micron in-line filter is used.

Dynegy Question 3
Certain laboratory methods (e.g. EPA 200.7 and EPA 200.8) allow for lab-filtration prior to analysis of a sample. Under IEPA's proposal, are there any circumstances where lab- filtration of a sample is allowed prior to being compared to a Class I or Class II inorganic standard? If so, what are those circumstances?

Agency Answer 3
According to the instructions for both EPA 200.7 and 200.8, the methods may be used for either dissolved or total metals analysis. When used for dissolved metals the sample may be field-filtered or as soon thereafter as practically possible (e.g. lab-filtered). Therefore, please refer to the Agency’s response to Dynegy Question 2 for an explanation of how a lab-filtered sample could be used.

Dynegy Question 4
Please describe what irrigation practices IBPA is basing its proposed Class I and II selenium standard of 0.02mg/L upon.

> *a. What information has IBPA gathered to confirm that such practices occur in Illinois?*

Agency Answer 4(a)
An Illinois State Water Survey (ISWS) publication, reports that supplemental well water irrigation has been practiced in certain areas of Illinois since at least 1926. *See* Attachment 5. From 2013 to 2014, irrigation use in Illinois increased significantly, likely due to the 2012 drought, as discussed in the ISWS publication, "The 2012 Drought in Illinois," and according to the ISWS map publication, "Center Pivot Irrigation in Illinois 2012 and 2014." *See* Attachments 6 and 7 (respectively). Drought concerns and changes in farming practices to require guaranteed yields on crops may further expand the use of irrigation. Seed corn dealers changed contract language after the 2012 drought to require assured crop yields, resulting in seed corn farmers installing irrigation in areas that previously did not have irrigation in order to satisfy their contracts. *See* Id.

Dynegy Question 5
Please provide all of the information IBPA has considered in this rulemaking regarding the irrigation of fine-textured soils in Illinois, including but not limited to where such irrigation occurs, the amount of water usage, the frequency of water usage, and the pH of such soils.

Agency Answer 5
"Center Pivot Irrigation in Illinois 2012 and 2014," shows locations of center pivot irrigation systems in Illinois. Amount and frequency of water usage, while required for irrigation wells capable of pumping over 100,000 gallons a day, is rarely reported according to ISWS. *See* Attachment 7. An ISWS report, "The 2012 Drought in Illinois," outlined the total annual irrigation pumping in the Imperial Valley region of Mason and Tazewell counties alone from 2004 to 2013 and is shown in the table below. *See* Attachment 6. According to the ISWS, average soil pH values in Illinois vary from mildly alkaline (7.0-7.5), primarily in the central west and northwest regions of the State, to strongly acid (5.2-5.5) in extreme southern Illinois. Refer to ISWS, "pH Alternative Crop Suitability Maps," for a depiction of pH ranges in Illinois. *See* Attachment 8.

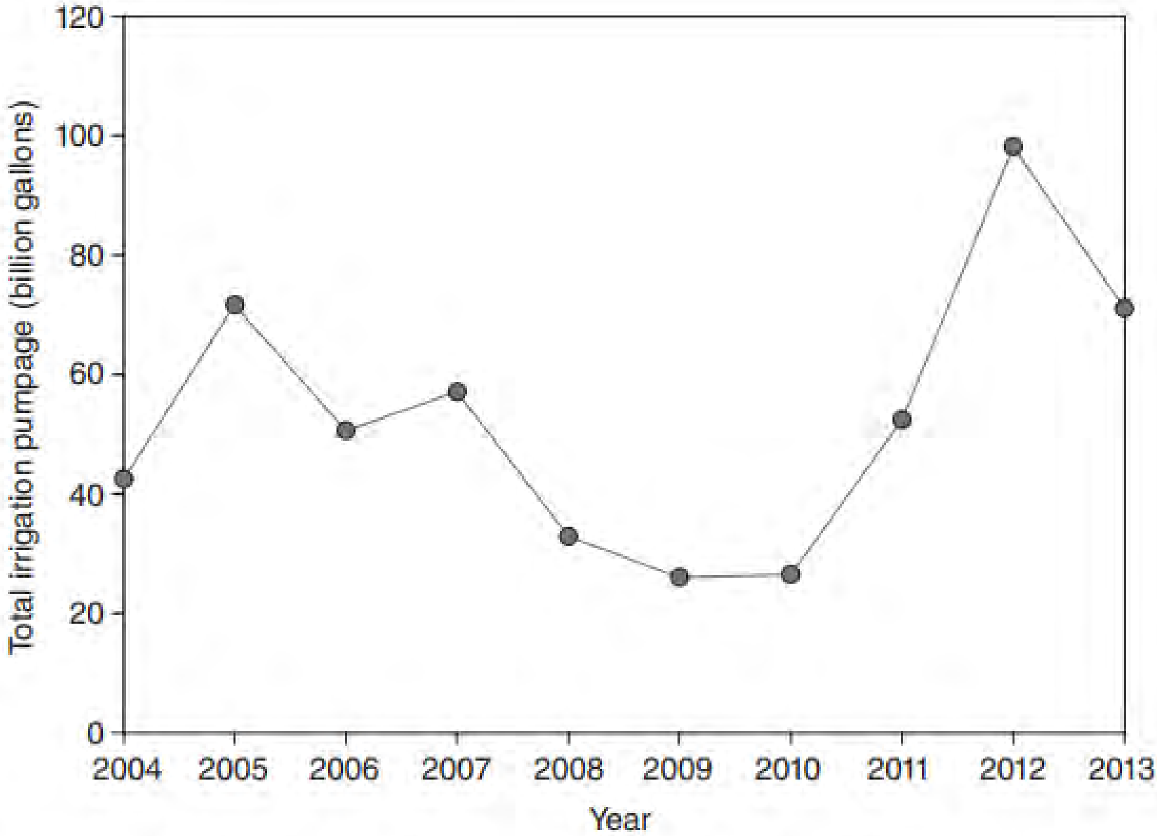


Figure 8.9 Total annual irrigation pumping in the Imperial Valley of Illinois between 2004 and 2013

Further, the Agency is using the same source for irrigation standards that has been relied on since the Board's first promulgation of the 35 Ill. Adm. Code Part 620 groundwater quality rules in 2012. The Board stated that:

> "IERG expressed concern regarding the Agency's reliance upon the National Academy of Sciences' 1972 *Water Quality Criteria* document in basing some Class II standards upon livestock watering or irrigation factors. The Board found that the Agency properly relied upon the 1972 document because some Class II standards are based upon support of a use other than potability (*e.g.*, livestock watering, irrigation, industrial use) where the different use requires a more stringent standard."

See R08-18 at 5 (2012).

Dynegy Question 6

What types of plants grow in irrigated fine-textured soils in Illinois? Are any of those plants used as forage by livestock in Illinois?

Agency Answer 6
Several types of plants are grown in fine-textured soils. One prime example of a plant grown in fine-textured soils in Illinois is corn, which is commonly used as forage.

Dynegy Question 7
Has IBPA collected any information suggesting selenium is elevated in forage consumed by livestock in Illinois? If so, what information?

Agency Answer 7
IEPA has not collected information regarding selenium concentrations in crops. The purpose of proposing a selenium irrigation standard is to protect plants from bioaccumulation of selenium in crops that may be toxic to livestock as forage. As stated in "Water Quality Criteria", included as Attachment 1I of the December 7, 2021, filing, small amounts of selenium added to soils can increase the selenium content in plants to toxic levels in livestock. Certain compounds can adversely affect crops or livestock forage through irrigation use at lower levels than have adverse effects on human drinking water use. Class I potable resource groundwater may serve as both irrigation water and drinking water and should be protected for both applications. *See* Exhibit 2, Attachment 1I.

Dynegy Question 8
Are you aware of any changes in soil conditions in Illinois since 1989?

Agency Answer 8
Soils in Illinois remain the same as in 1989.

a. Were there fine-textured soils located in Illinois as of 1989?

Agency Answer 8(a)
Fine-textured soils are found in several parts of the State.

b. Were fine-textured soils irrigated in Illinois as of 1989?

Agency Answer 8(b)
Following the 2012 drought, irrigation practices increased for crops. *See* Attachment 7.

c. Were irrigated plants on fine-textured soils used as forage for livestock as of 1989?

Agency Answer 8(c)
As irrigated crops such as corn are commonly used as forage for livestock, it may be assumed that irrigated crops are used as forage.

Dynegy Question 9
What information, if any, did IBPA look at regarding groundwater standards for inorganics in other states in connection with developing its newly proposed Class I and Class II standards for inorganics?

Agency Answer 9
In developing the proposed Class I and Class II standards for inorganic, IEPA followed the Part 620 requirements and referred to reliable sources used previously, such as the ISWS. Generally, states have established their own requirements for determining groundwater quality standards, so state-by-state comparisons are of limited quality.

NWRA

NWRA Question 1
In Response to Question 1 of the Illinois Pollution Control Board (the "Board")'s Pre-Filed Questions to the IEPA, the Agency cited guidelines promulgated by the U.S. Environmental Protection Agency ("U.S. EPA")'s Environmental Council of the States and Association of State and Territorial Health Officials PFAS Science Group ("ECOS"). Those guidelines indicate that Illinois applies SW-846 Method 8327 as its standard for analyzing PFAS in surface water, groundwater, and wastewater. See Guidelines, p. 22, available at https://www.ecos.org/wp-content/uploads/2021/04/Updated-Standards-White-Paper-Ap ril- 2021.pdf. However, the Guidelines note that SW-846 Method 8327 "does not yet provide low- level detection and is only intended for the testing of non-potable waters." Id. Further, the Guidelines note that the U.S. Department of Defense ("DOD") published a memo stating that SW- 846 Method 8327 "does not meet its needs to support decision-making and advises its use for screening purposes only." Guidelines, p. 22.

> *(a) Please explain why the Agency believes that SW-846 Method 8327 is an appropriate analytical standard to use for analyzing PFAS in surface water, groundwater, and wastewater at the groundwater quality standard (GQS) proposed.*
>
> *(b) Does the Agency disagree with DOD's assessment that SW-846 Method 8327 should be used "for screening purposes only"?*
>
> *(c) If the answer to (b), above, is in the affirmative, please explain the Agency's basis for disagreeing with the DOD's assessment.*
>
> *(d) If the answer to (a), above, is in the negative, please explain why the Agency continues to use SW-846 Method 8327 in spite of the DOD's assessment that it should be used "for screening purposes only."*

Agency Answer 1
See Attachment 2, in response to Board follow-up questions.

Agency Answer 1(a)
No FSRS response requested, however it should be noted that SW-846 Methods are not standards. Per Chapter 2 of SW-846 Compendium, SW-846 methods, with the exception of required method use for the analysis of method defined parameters, are intended to be guidance methods containing general information on how to perform an analytical procedure or technique which a laboratory can use as a basic starting point for generating its own detailed Standard

Operating Procedure (SOP), either for its own general use or for a specific project application. The performance data included in these methods are for guidance purposes only and are not intended to be and must not be used as absolute quality control (QC) acceptance criteria for the purposes of laboratory accreditation.

Agency Answer 1(b)
This is not a clear yes or no situation. The decision to use a particular method is based on the data quality needs of the project and choosing not to use a method does not make the method invalid or inappropriate. Please refer to the response to comment 1.c below.

Agency Answer 1(c)
The Department of Defense (DoD) stated in a November 22, 2019 Memorandum Establishing a Consistent Methodology for the Analysis of Per- and Polyfluoroalkyl Substances in Media other than Drinking Water that EPA Draft Method 8327 will not meet DoD's needs to support decision making for the DoD's PFAS efforts and that they were working with EPA on the development of a different method. *See* Attachment 9. Since the DoD issuance of the 2019 Memorandum, SW-846 Methods 3512 and 8327 were validated together for 24 Per- and Polyfluoroalkyl Substances (PFAS) in surface water, groundwater, and wastewater, and final versions were published in the SW-846 Compendium on July 30, 2021 and are available for use.

Section 1.1 of the Final Method 8327 states, "In addition, analysts and data users are advised that, except where explicitly specified in a regulation, the use of SW-846 methods is not mandatory in response to Federal testing requirements. The information contained in this method is provided by the U.S. Environmental Protection Agency (EPA) as guidance to be used by the analyst and the regulated community in making judgments necessary to generate results that meet the data quality objectives (DQOs) for the intended application."

It should be noted that in EPA Response to Public Comments for the SW-846 update, EPA agreed with the commenters that Methods 3512 and 8327 as validated may not provide data of sufficient sensitivity for every project application. *See* https://www.epa.gov/system/files/documents/2021-07/final-response-to-comments-update-vii-methods-3512-and-8327.pdf. Sensitivity needs are expected to be very application-dependent and should be considered as part of project planning, potentially in consultation with the testing laboratory. As with other non-required SW-846 test methods, Methods 3512 and 8327 are provided as tools for use by government and the regulated community to support their project-specific data needs, where appropriate. These methods are also performance-based and do not have a required sensitivity, and they can be modified without prior approval by EPA to meet specific project needs provided that the laboratory demonstrates acceptable performance for the intended application and the methods used and any modifications there to are acceptable to the end data user.

DoD made the decision not to use Method 8327 for their projects which is an allowable determination to make in accordance with EPA guidance. However, that does not mean Method 8327 is an invalid or inappropriate method nor only good as a screening tool. Like any SW-846 Method, DoD could have worked with an accredited laboratory to modify the existing Method 8327 to meet their project-specific data needs when a lower detection limit is needed. This is done regularly at DoD projects in Illinois to reach lower detection limits for several chemicals, SW-846 Method 8270D SIM for PAH analysis is an example. DoD chose not to follow this path. Instead, as the November 2019 memo states, they chose to help develop a new method that would not require site-specific modifications at the laboratory. *See* Attachment 9.

On December 7, 2021, the DoD issued an update to the 2019 Memorandum, Update for Establishing a Consistent Methodology for the Analysis of Per- and Polyfluoroalkyl Substances in Media other than Drinking Water. *See* Attachment 10. This 2021 Memorandum provides new guidance on the use of a new Draft Method 1633 for analysis of PFAS in matrices other than drinking water. DoD determined that Draft Method 1633 meets the precision, accuracy, and limits of quantitation needed to support sound decision making. Draft Method 1633 was developed by EPA in conjunction with DoD and a multi-laboratory validation study is underway and should be completed in late 2022.

Once the Draft Method 1633 is finalized there will be yet another acceptable EPA SW-846 validated option to analyze for PFAS. It will be up to the individual project teams to decide which method or methods will meet the needs of the project.

Agency Answer 1(d)
Please refer to the response to comment 1(c) above.

NWRA Question 2
In Response to Question 1 of the IPCB's Pre-Filed Questions to the IEPA, the Agency cited a spreadsheet from the Interstate Technology Regulatory Council, which the Agency says was published in December 2021. However, the link provided by the Agency connects to provides a document that was updated in February 2022.

> *(a) Can the Agency provide the specific information that was used as part of this proposed rulemaking?*
>
> *(b) If the information on the ITRC's website changes, how will the regulated community know what the Agency is basing its decisions upon?*

Agency Answer 2
The ITRC link is updated regularly as new information is provided.

Agency Answer 2(a)
No specific information from the ITRC link depicting other states actions played a role in the Agency's proposed Part 620 updates. Part 620 prescribes a methodology used by Illinois in developing its groundwater quality standards. The Agency provided the link for informational purposes only.

Agency Answer 2(b)
Refer to Answer 2(a).

NWRA Question 3
In Response to Question 1 of the IPCB's Pre-Filed Questions to IEPA, the Agency provided a list of adopted or proposed standards from other states, but it did not respond to IPCB's request that it comment on "how they compare with the Agency's proposal." Agency testimony on such comparison was also minimal.

> *(a) Please explain how the Agency's proposal compares to that of what other states have adopted as enforceable standards.*
>
> *(b) Please provide a comparison as to how the other states standards referenced were derived, versus how the Agency has derived its proposed standards (i.e., through the review of select testing from community water supplies).*
>
> *(c) Is the Agency aware of any state that has adopted a groundwater standard that is based upon infant risks associated with PFAS in drinking water and had those standards apply as enforceable standards relative to wastewater, leachate, surface water, or land remediation? If so, which states?*

Agency Answer 3(a)
The links provided in the Agency's answer to IPCB's prefiled Question 1 include groundwater values used by other states. A user can easily compare the Agency's proposed Part 620 standards with other states' actions regarding the adoption of enforceable standards.

Agency Answer 3(b)
For clarity, the Agency did not derive its standards through the review of "select testing from community water supplies." The Agency requested community water supplies (CWS) with detections of PFAS in finished water to conduct quarterly sampling of its finished and raw water sources. PFAS detected in CWS raw water (groundwater wells) prompted the issuance of Health Advisories in accordance with Part 620, Subpart F. Confirmation that PFAS is present in groundwater within the State satisfies the Illinois Groundwater Protection Act, which states:

> "The Agency, after consultation with the Committee and Council, shall propose regulations establishing comprehensive water quality standards which are specifically for the protection of groundwater. In preparing such regulations, the Agency shall address, to the extent feasible, those contaminants which have been found in the groundwaters of the State and which are known to cause, or are suspected of causing, cancer, birth defects, or any other adverse effect on human health according to nationally accepted guidelines."

See 415 ILCS 55.8(a)

Confirmation of PFAS in groundwater satisfies all conditions specified in the Groundwater Protection Act for the establishment of groundwater quality standards in Part 620. Illinois EPA developed the proposed groundwater quality standards in compliance with the provisions required in Part 620, as stated in Part 620.601(c). Other states have their own specific statutory and regulatory requirements for establishing standards and they are not applicable for use in Illinois.

Agency Answer 3(c)
For clarity, the proposed PFAS groundwater quality standards are not based on infant risks. The proposed groundwater standards are based on an average of a child age 0 – 6 years, with a body weight of 15 kilogram (33 pounds). The Agency does not know the exposure populations utilized by each state; however, some may utilize an infant as the exposure population.

The purpose of the Part 620 groundwater quality standards is to protect Illinois groundwater as a resource. The Groundwater Protection Act states:

> "It is the policy of the State of Illinois to restore, protect, and enhance the groundwaters of the State, as a natural and public resource. The State recognizes the essential and pervasive role of groundwater in the social and economic well-being of the people of Illinois, and its vital importance to the general health, safety, and welfare. It is further recognized as consistent with this policy that the groundwater resources of the State be utilized for beneficial and legitimate purposes; that waste and degradation of the resources be prevented; and that the underground water resource be managed to allow for maximum benefit of the people of the State of Illinois."

See 415 ILCS 55.2(b).

The Agency does not track other states' adoption of groundwater values. Wastewater, leachate, surface water, and land remediation are not pertinent to setting groundwater quality standards for the use of groundwater as a resource in accordance with the Illinois Groundwater Protection Act.

NWRA Question 4
In Question 8(a) of the IPCB's Pre-Filed Questions to the IEPA, the Board asked the Agency how many GMZs have been established pursuant to Part 620 since its inception. The Agency stated that it "searched available records" and concluded that there are "22 sites that have been approved for a GMZ pursuant to 620.250(a) and (b)."

> *(a) Is it correct that this number does not include GMZs that have been approved under§ 620.250(d), which references GMZ establishment under§ 740.530 for sites undergoing remediation pursuant to the SRP?*
>
> *(b) Have any GMZs been established in accordance with§ 620.250(d)?*
>
> *(c) If the answer to (b), above, is in the affirmative, please identify how many GMZs have been established in accordance with § 620.250(d).*
>
> *(d) Since the Agency did not include any Part 740 GMZs in its response, does the Agency consider these GMZs not created pursuant to Part 620?*

Agency Answer 4(a)
Yes, the number did not include any sites in the SRP with an approved GMZ.

Agency Answer 4(b)
Yes.

Agency Answer 4(c)
Staff can recall at least 2 GMZs that have been established under the SRP. One was closed after a No Further Remediation letter was issued and another one is currently active. A few more may exist, but the Site Remediation Program does not track the establishment of GMZs in its database. Identifying the exact number of GMZs that have been established would require a review of each individual site file for the over 6,300 sites identified in the database.

Agency Answer 4(d)
The GMZs are established pursuant to 35 Ill. Adm. Code Part 740.530.

NWRA Question 5
In Question 8(b) the Board asked how many of the GMZs established since the adoption of Part 620 were still active and then asked the Agency to specify the dates on which they were established. Of the 22 sites mentioned by Agency, the Agency stated it believed 20 were still active but it did not respond to the Board's question as to when the GMZ's were established.

> *(a)What dates were the 22 GMZs established?*
>
> *(b) If additional GMZs are identified pursuant to (4) above, what are the dates that they were established?*

Agency Response Question 5(b)
The Illinois EPA will provide an Excel spreadsheet with dates the groundwater management zones were established. *See* Attachment 13.

NWRA Question 6
In Question 8(g) and (h) the Agency responds to Board questions concerning Part 620, Appendix D, but its answers do not appear to include GMZs established at RCRA Subtitle C facilities. Instead of being required to submit information pursuant to Appendix D, the Agency has required the sites to submit the information identified on the Agency website, under "Re- evaluation of Groundwater Management Zones at RCRA Facilities".

> *(a)Are these RCRA facilities included in the 22 GMZ's cited by the Agency?*
>
> *(b) Where is the Part 620 Appendix D referenced in the Board's Part 620 rules? Is it referenced in any other Board rules?*
>
> *(c) Given the Agency's answers to Board's question 8, are the proposed Part 620 changes intended to represent a change to the Agency's current method of regulating GMZ's at RCRA facilities? If so, how?*

Agency Response Question 6(a)
RCRA facilities were not included but the Illinois EPA will provide an Excel spreadsheet with dates the groundwater management zones were established. *See* Attachment 13.

Agency Response Question 6(b)
Appendix D is essentially referenced within itself. The first paragraph of Appendix D cites to Section 620.250(a) and the use of Appendix D to "provide" the form in which the written confirmation [required under Section 620.250(a)] is to be submitted to the Agency."

Agency Response Question 6(c)
No, it will not change Illinois EPA's method of regulating GMZs at RCRA facilities.

NWRA Question 7
In response to Board question 8(q) the Agency states that the last two sentences of Section 620.250(c) (five-year evaluation requirement) only become applicable after a GMZ has expired, yet NWRA is aware of many RCRA Subtitle C GMZs where the five-year evaluation has been required by permit, as part of ongoing corrective actions - even though the GMZ has not expired at these sites.

> *(a) Is the Agency here drawing a distinction between GMZs established under Part 620 and those that are in place at RCRA Subtitle C facilities and regulated thereunder? If so, explain.*

Agency Answer 7
When responding to the Board's questions, since those questions had only referenced GMZ's under Section 620.250(a), (b), and (c), the Agency's previous responses did not consider GMZs under any other subsection of Section 620.250.

Agency Response Question 7(a)
The basis for evaluations that are required by permit as part of corrective action is not Section 620.250(c). Such evaluations are required as part of the approved corrective action to evaluate the corrective action while it is being conducted. The standard permit condition calls for annual evaluations, so it is not clear which specific permits are being referenced in this question.

NWRA Question 8
In response to Board Question 9(d) the Agency indicates that all but seven of the 22 approved GMZs it cited are associated with CCR surface impoundments. Yet, NWRA is aware of many approved GMZs that are not related to CCR surface impoundments and not approved pursuant to Part 740 (e.g., 2 at the CID RDF; 1 at the Laraway RDF; 1 at Envirofil; 5 at Valley View landfill; 2 at DeKalb RDF; 1 at Milam RDF; 1 at Wilsonville).

> *(a) Why were these GMZ's omitted in the Agency's analysis of number of GMZs it reported in its answer to the Board's questions?*
>
> *(b) Are the Agency's responses here, and its proposed changes to Part 620, intended to change how the Agency regulates or establishes GMZs at RCRA landfill sites?*

Agency Response Question 8(a)
This was an oversight. The Illinois EPA will provide an Excel spreadsheet identifying the GMZs approved under the Illinois EPA Bureau of Land's Permit Section (i.e., GMZs approved for the facilities mentioned above and other solid waste facilities). *See* Attachment 13.

Agency Response Question 8(b)
No, the changes to 620 will not change how the Agency regulates or establishes GMZs.

NWRA Question 9
In response to Board question 21 related to applications for GMZs and Part 620 Appendix D, the Agency's answers omit the Bureau of Land practice of requiring GMZ applications at RCRA landfills to be submitted in the form of a permit modification that includes the information required on the Agency's web site, under "Re-evaluation of Groundwater Management Zones at RCRA Facilities".

> *(a) Can the Agency explain its perspective as to whether and, if so how, GMZs at RCRA sites are regulated in a manner that is distinct from the Part 620 provisions - both as those provisions currently exist, and as they might change pursuant to this proposal? If not, why not?*
>
> *(b) If the Agency's proposal is adopted, would future GMZ applications and 5-year re-evaluations for RCRA Subtitle C facilities be required to follow a format different than that currently in place? If so, please explain.*
>
> *(c)Are the Agency's responses here, and its proposed changes to Part 620, intended to change how the Agency regulates GMZs at RCRA landfill sites?*

Agency Response Question 9(a)
There is no intention to regulate GMZs at RCRA sites in a manner that is distinct from the Part 620 provisions.

Agency Response Question 9(b)
No.

Agency Response Question 9(c)
No.

NWRA Question 10
In Question 25 the Board asked whether the references as to who conducts groundwater monitoring in Section 620.302(b) should be modified. In response, the Agency agreed that the list needed to be updated but should not include those persons who conduct groundwater monitoring pursuant to specific program requirements that are distinct from Part 620, specifically mentioning TACO, UST and SRP rules explaining that "these programs, like others, contain their own procedural requirements regarding groundwater monitoring and activities that must be conducted when groundwater contamination is detected" and that "they do not need to rely upon the

requirements in Subpart C of Part 620 regarding groundwater monitoring, notification and response." The Agency then added to that list of such excluded programs landfill sites regulated under Parts 807 and 811 (see second sentence of Section 620.302(b)(1)). Yet, the first sentence of that section (identifying those who conduct groundwater monitoring pursuant to Part 620) also includes Part 807. The Agency's testimony on this point was vague and inconclusive.

> *(a) Please explain the applicability of Section 620.302 (d) as to RCRA sites regulated under Parts 807 or 811.*
>
> *(b) Is corrective action required whenever a contaminant exceeds a standard set forth in Section 620.410 or 620.430, as articulated in 620.302(d) - or do more specific program requirements of Part 807 or 811 or permits thereunder apply?*
>
> *(c) To what extend does the Agency intend to have 807 or 811 permits require corrective action whenever these newly proposed PFAS standards are detected as exceedances in landfill monitoring wells?*
>
> *(d) Where a landfill permit generally references adherence to Part 620 and the Groundwater Protection Act, does the Agency intend that any detected exceedance of PFAS detected in landfill groundwater monitoring wells is an enforceable violation of the entity's permit, the Board's regulations and/or the Act? Please explain.*

Agency Response Question 10
Part 807 should be removed from the first sentence of Section 620.302(b)(1) as stated in response to Board Question 25.

Agency Response Question 10(a)
The Agency assumes the citation above is intended to be subsection (c) of Section 620.302 since there is no subsection (d). Section 620.302(c) does not apply to sites regulated under Parts 807 and 811.

Agency Response Question 10(b)
The more specific program requirements of Parts 807 or 811 and their respective permits apply.

Agency Response Question 10(c)
The Agency assumes the reference to Part 818 is intended to reference Part 811. Exceedances of these newly proposed PFAS standards would need to be assessed the same as any other exceedances to determine and confirm the source of the contamination. If a contaminant has an exceedance for two consecutive sampling quarters, an alternate source demonstration would be conducted. If the alternate source demonstration indicates that the contamination may be attributable to the subject landfill, the landfill would go into an assessment monitoring period. During the assessment monitoring period additional monitoring would be conducted to confirm whether the contamination is attributable to the landfill. Corrective action would be required where a contaminant is found to be attributable to the subject landfill.

Agency Response Question 10(d)
As noted in the response to 10(d) above, the detection of an exceedance of any contaminant triggers confirmation of the detection, an alternate source demonstration, and an assessment monitoring period to confirm whether the exceedance is attributable to the landfill. An exceedance that is attributable to the landfill would be a violation that is enforceable against the landfill.

NWRA Question 11
Question 2(e) was meant to address state accredited laboratories, not state owned/operated laboratories. Please re-state your response to reflect state accredited laboratories.

Agency Answer 11
State accredited laboratories will be required to use approved methods for analysis and meet the quantitation levels for each analyte. All necessary technical guidance is provided within each of the approved methods. If a lab cannot meet these requirements, then an alternative lab must be used.

NWRA Question 12
Question 2(f) - In setting standards, the technological capability to perform the testing for the standard must be available to the regulated community.

(a) Does the Agency agree?

(b) Does the Agency believe the testing requirement necessary for its rule proposal is technically feasible? If so, explain.

(c) Do any of the February 2022 changes impact the current proposal?

Agency Answer 12(a)
Yes, the Agency agrees.

Agency Answer 12(b)
Yes, the technological capability is available and has already been demonstrated by several accredited labs.

Agency Answer 12(c) (Carol Hawbaker)
The Agency is unaware of the changes to which NWRA is referring.

NWRA Question 13
In response to question 3 the Agency provided, as requested, the correct link. In accessing that link, it is clear that the list referenced was updated after the Agency's rule was filed.

(a) Can the Agency provide the information that was included at this link when the rule was filed?

(b) Do any of the February 2022 changes impact the current proposal?

Agency Answer 13(a)
The Agency provided the information in its December 7, 2021, filing as Attachment 1D-5 in Carol Hawbaker's testimony. *See* Exhibit 2, Attachment 1D-5.

Agency Answer 13(b)
The Agency is unaware of the changes to which NWRA is referring.

NWRA Question 14
In response to question 4 the Agency provided, as requested, the correct link. Some of the GQS chemical constituents are listed on this particular web site are listed as "In prep." or "2022 online".

> *(a) How do the changes made to this list after the proposed rule was filed, impact the current regulatory proposal?*
>
> *(b) Will the Agency provide the list of classifications that was in effect at the time that this rule-making was filed, so that the regulated community can adequately evaluate the information?*

Agency Answer 14(a)
The World Health Organization's International Agency for Research on Cancer (IARC) is regularly updating its carcinogen classifications. The question is unclear as to what GQS chemicals NWRA is referring, and the current regulatory proposal is the proposed rule filed on December 7, 2021. If toxicity values or carcinogen classifications are updated during the rulemaking process, standards may be revised.

Agency Answer 14(b)
The Illinois Environmental Protection Act and Part 620 define a carcinogen as being classified as one of the following:

- Category A1 or A2 Carcinogen by the American Conference of Governmental Industrial Hygienists (ACGIH). Please note, carcinogenicity assessments for ACGIH are based on inhalation, and not applicable for classification of the oral, or ingestion, exposure route.
- Category 1 or 2A/2B carcinogen by the World Health Organization's International Agency for Research on Cancer (IARC).
- "Human carcinogen" or "Anticipated Human Carcinogen" by the United States Department of Health and Human Service National Toxicological Program (NTP).
- Category A or B1/B2 Carcinogen by the United States Environmental Protection Agency in Integrated Risk Information System (IRIS). Please note, IRIS updated its classification terminology to refer to Category A as "carcinogenic to humans" and Categories B1/B2 and "likely to become carcinogenic to humans".

Attached is a table listing carcinogen classifications by source for the constituents having proposed groundwater quality standards calculated using the proposed Part 620, Subpart F and

Appendix A procedures. *See* Attachment 11. ACGIH classifications are not included for reasons stated above.

NWRA Question 15
In questions 7-22 the Agency has effectively refused to address how its proposed standards will be implemented in its Bureau of Land programs and yet, experience with other changes to groundwater standards would suggest that any exceedance of a newly adopted groundwater standard may be immediately enforceable as a violation of the Board's regulations, the Act, and potentially the entity's landfill permit.

Under the Administrative Procedures Act and Section 27 of the Illinois Environmental Protection Act, the regulated community has a right, and the Board an obligation, to understand how this rule will be implemented across other regulatory programs - in order to effectively assess the reasonableness of the costs of the proposed standard as it will be applied. Accordingly, NWRA reiterates its request that the Agency address the questions posed in NWRA's Pre-filed Questions and, based upon the proceeding before the Board thus far, we add the following follow-up questions:

> *(a) Will all of the new or adjusted GQS concentrations be required to be met for sites with a currently approved GMZ, prior to these sites being able to achieve completion of corrective action and release from the GMZ?*
>
> *(b) How does the Agency intend to address any conflicting requirements of Part 620 and Parts 807 and 811?*
>
> *(c) What is the Agency's view of where those programs conflict with the changes to Part 620?*
>
> *(d) Will the Agency consider modifying its proposal to ensure applicability only for those purposes consistent with the risks addressed in the Agency testimony (i.e., health risks to those who drink water with constituents in excess of the standard)?*
>
> *(e) More specifically, will the Agency agree to refrain from implementation or enforcement of any newly adopted PFAS groundwater standards as to other programs until after the Board has the opportunity to understand those relevant risks and promulgate rule changes appropriate to those programs?*

Agency Response Question 15
The Agency understands the concerns NWRA has expressed regarding the impact of revised Part 620 standards. Because the purpose of Part 620 is to establish groundwater quality standards for the State that are protective of human health and the environment, it naturally flows that these standards would be incorporated into other rules. However, how the 620 standards are utilized in and incorporated into other rules is a function of those other rules, not Part 620. The root of NWRA's concern is not the standards established in Part 620, but how those standards are utilized in and incorporated into other rules. Discussions in this rulemaking should be limited to whether the proposed amendments to Part 620 provide for the adequate protection of human

health and the environment as called for in the Illinois Groundwater Protection Act. They should not include how the standards are utilized in and incorporated into other rules, which are adopted pursuant another Act. The proper method of addressing impacts of the 620 standards under other rules and programs is to address how those standards are utilized in and incorporated into those rules and programs. In other words, the proper forum for addressing impacts and any resulting changes that need to be made is in a rulemaking to amend those other rules and programs. The proper remedy is not to weaken or forego a 620 standard, which must be protective of human health and the environment.

Agency Response Question 15(a)
Under Section 620.250(c), one requirement for the expiration of a GMZ is confirmation that the standards set forth in Subpart D of Part 620 have been attained. Therefore, it appears that if a GMZ is in existence at the time a new or revised standard takes effect and the new or revised standard has not yet been achieved, then the GMZ could not expire until the new or revised standard is achieved. Conversely, if the new or revised standard has already been achieved then this criterion for expiration of the GMZ would be met.

Agency Response Question 15(b)
The Agency incorporates the requirements of Part 620 into its permits in a manner that provides consistency between applicable rules and will continue to do so after Part 620 is amended. There should not be any conflicts.

Agency Response Question 15(c)
See the response question 15(b) above. The Agency is not aware of any proposed changes that would create an irreconcilable conflict. If an irreconcilable conflict were to arise, the Agency would look to whether the manner in which Parts 807 or 811 utilize or incorporate the standards of Part 620 warrant a change.

Agency Response Question 15(d)
Groundwater is a resource that must be protected regardless of its current use. Part 620.401 states "[g]roundwaters must meet the standards appropriate to the groundwater's class as specified in this Subpart [D] and the non-degradation provisions of Subpart C". *See* 35 Ill. Adm. Code 620.401. Those groundwater classifications and non-degradation provisions do not consider whether the groundwater is currently used as a source of drinking water. As stated in the Illinois Groundwater Protection Act:

> "it is the policy of the State of Illinois to restore, protect, and enhance the groundwaters of the State, as a natural and public resource. The State recognizes the essential and pervasive role of groundwater in the social and economic well-being of the people of Illinois, and its vital importance to the general health, safety, and welfare. It is further recognized as consistent with this policy that groundwater resources of the State be utilized for beneficial and legitimate purposes; that waste and degradation of the resources be prevented; and that the underground resource be managed to allow for maximum benefit of the people of the State of Illinois." See 415 ILCS 55/2(b).

Therefore, the groundwater standards should not be limited to only those areas where there are "health risks to those who drink water with constituents in excess of the standard".

Agency Response Question 15(e)
The Agency does not have the authority to excuse compliance with a Board regulation or to waive its enforcement. Furthermore, the Agency is proposing PFAS groundwater standards for the protection of human health and the environment. Establishment of these standards should not be delayed in favor of the administrative cleanup of other rules or programs that utilize or incorporate the Part 620 standards. That cleanup will need to be addressed in the context of a rulemaking for those other rules and programs, not this rulemaking. The Agency will continue to discuss with stakeholders potential changes to other rules and programs that may be needed in light of updates to the groundwater quality standards in Part 620.

NWRA Question 16
In follow-up to the Agency's answer to Question 27, Part 620.605(b)(l) is specific to Issuance of Health Advisories and does not address the question regarding analytical quantification.

> *(a) Based upon the Agency's response, is the Agency proposing that this statement would be applicable to all of the GQS standards and a laboratory's ability to achieve the GQS limits?*
>
> *(b) Is this concurrence by the Agency that the GQS may not always be achievable and that the LLOQ or LCMRL obtained by the laboratory would then be considered the GQS for compliance purposes?*

Agency Answer 16(a)
The Agency is proposing that this statement applies to all of the groundwater quality standards. However, this statement is not applicable to an individual laboratory's ability to achieve the GQS limits. Since labs have demonstrated the ability to achieve quantification of the proposed standards, the Agency requires the use of a lab that can meet the proposed standards.

Agency Answer 16(b)
No. Since labs have demonstrated the ability to meet the LLOQ/LCMRLs proposed, the Agency requires that these quantitation levels must be achieved.

NWRA Question 17
In follow-up to the Agency's answer to Question 30:

> *(a) If lithium and molybdenum are being added solely as a result of coal ash data, what basis is there for a statewide standard applicable to all regulatory programs?*
>
> *(b) As to HFPO-DA, please identify and locate the "monitoring wells in Illinois from Illinois EPA Bureau of Land program sites" that form the basis for the Agency's justification for proposal of this standard.*

> *(c) As to 1-methylnaphthalene, please provide a minimum of a range of detected and quantified concentrations as it has for Aluminum.*

Agency Answer 17(a)
Lithium and Molybdenum are being proposed for inclusion at this time for consistency with the groundwater metals analyses required by Part 845 (CCR rule). *See* 35 Ill. Adm. Code 845. Molybdenum has been detected in over 500 samples collected from community water supply wells, in addition to CCR sites. A Part 620 standard was previously proposed for Molybdenum based on its presence in the community water supplies (*See* R08-18), but was withdrawn due to concerns raised by IERG related to beneficial use of CCR. Sampling for Lithium was not regularly done in Illinois prior to the promulgation of 40 CFR Part 257 in 2015. Of the 18 CCR sites where Lithium samples have been collected, Lithium has been detected at all but one of them. The CCR sites are located from Lake to Massac County, and from the Mississippi River to eastern Illinois with multiple locations in between. Therefore, groundwater monitoring data from CCR sites shows that Lithium is detected state-wide.

Agency Answer 17(b)
Please refer to the Excel Spreadsheet titled, "R22-018 PFAS Detections in Illinois Groundwater Groundwater." *See* Attachment 1.

Agency Answer 17(c)
1-Methylnaphthalene is a constituent detected in groundwater during Bureau of Land Program investigations; specifically, the Resource, Conservation, and Recovery Program and the Federal Site Remediation Section. Detections in groundwater range from 0.00049 mg/L to 0.93 mg/L.

NWRA Question 18
In follow-up to question 31:

> *(a) Can you please provide examples of locations, both groundwater and surface water, with the corresponding "finished water" location, in order to allow a review of at least some of the data the Agency utilized as justification for its proposal. The IEPA "Drinking Water Watch" is a large database with numerous selections to search from, making the comparisons difficult for anyone without an extensive knowledge of the system.*

Agency Answer 18(a)
Please refer to the Excel Spreadsheet titled, "R22-018 PFAS Detections in Illinois Groundwater Groundwater." As surface water is not relevant to groundwater quality standards, surface water data is not included. *See* Attachment 1.

NWRA Question 19
In follow up to question 32(a) as Part 620 applies to drinking water from sources other than just public water supplies, will the Agency be preparing guidance, or will additional information be added to the proposed regulations to address how samples will be required to be collected, as the procedures and equipment for groundwater sampling from non-public water supplies may include wells, pumps or tubing that are currently constructed of Teflon?

Agency Answer 19
No, the Agency will not be preparing additional guidance for sample collection. The analytical methods contain requirement and guidance information in the "Interferences" and "Sample Collection, Preservation, and Storage" sections. The laboratory may also provide specific sample collection instructions.

NWRA Question 20
In follow up to question 32(b) where can the public and the Board obtain the sampling data referenced?

(a) What was the source of the data sampled?

(b) Who (i.e., what laboratory) conducted the sampling?

Agency Answer 20(a)
Please refer to the Excel Spreadsheet titled, "R22-018 PFAS Detections in Illinois Groundwater." *See* Attachment 1. The information is found on Illinois EPA's website Drinking Water Watch" database, located on the main page under "Quick Links" at:
https://www2.illinois.gov/epa/Pages/default.aspx.

Agency Answer 20(b)
The Agency received results from Eurofins Eaton Analytical, LLC, Pace Analytical Services, LLC, and American Water Central Laboratory.

NWRA Question 21
In follow up to question 33, if HFPO-DA was detected in only one location as part of the site remediation program, why is it being added for all sources?

(a) Would it not be more prudent to make this a site specific or project specific standard?

(b) If not, why not?

Agency Answer 21
HFPO-DA is proposed to be added as a constituent for Part 620 because it has been detected in groundwater within the State.

Agency Answer 21(a)
No, the Agency disagrees.

Agency Answer 21(b)
HFPO-DA may be analyzed using the same method as the other PFAS proposed. Additional tasks or costs for sampling and analyses would not be incurred, and groundwater should be protected as resource.

NWRA Question 22

In follow-up to question 34, the Agency (in response to question 27) answered as follows: "As stated in Part 620.605(b)(l) of the proposed rulemaking: "If the concentration for such substance is less than the lowest appropriate LLOQ or LCMRL for the substance, incorporated by reference at Section 620.125, the guidance level is the lowest appropriate LLOQ or LCMRL."

> *(a) It appears that the Agency's response to Question 34 indicates that the LLOQ or LCMRL should be used as the guidance level if the method cannot otherwise achieve the GQS. This answer appears to state that the analytical method must provide for a LLOQ/LCMRL below the groundwater quality standard. Which is correct?*
>
> *(b) What if the analytical method cannot achieve the GQS due to matrix interferences or other limitations?*

Agency Answer 22(a)

The LLOQ/LCMRL is used as the groundwater quality standard only if it exceeds the health-based value. Otherwise, the health-based value is the groundwater quality standard.

Agency Answer 22(b)

If matrix interferences are an issue, the lab must refer to the procedures outlined in the method interferences section to achieve the GQS.

NWRA Question 23

In follow-up to question 35, where NWRA asked for information related to the laboratories that could perform the testing required by this new Part 620 methodology, the Agency simply stated: "IEPA has identified Illinois laboratories that are capable of meeting the proposed groundwater quality standards."

> *(a) Please identify the commercial laboratories that were found to be able to meet the proposed GQS.*
>
> *(b) Are these laboratories IEPA-accredited for all of the Part 620 constituents?*

Agency Answer 23(a)

Eurofins Eaton Analytical, LLC, Pace Analytical Services, LLC, and American Water Central Laboratory have achieved these levels of quantitation.

Agency Answer 23(b)

All proposed Part 620 constituents are included the Agency's Scope of Accreditation, effective February 8, 2022.

NWRA Question 24

In follow-up to question 36, does the Agency believe that a single laboratory 'concept' is an appropriate concept to use in an interlaboratory and multiple regulated party standards-setting process?

> *(a) Where is the justification for setting standards at the LLOQ in SW-846?*
>
> *(b) The word "optimally" is used in the Agency's response. What if the LLOQ is not less than the regulatory action level? Does this infer that the Agency recognizes that an LLOQ below the proposed GQS may not always be achievable?*

Agency Answer 24
The Agency assumes that by "single laboratory concept", the NWRA is referring to the LLOQ. Yes. Labs have demonstrated achievability at these levels of quantitation; therefore, the Agency requires the use of competent laboratories.

Agency Answer 24(a)
SW-846 justifies the use of the LLOQ as the quantitation level. Part 620.605(b)(1) and (2) currently contain the same language discussing the setting of standards at the Practical Quantitation Limit (PQL) when the health-based standard calculated in accordance with Appendix A is less than the lowest PQL. *See* 35 Ill. Adm. Code 620.605(b)(1) and (2). As SW-846 has updated its basis of quantitation from PQL to LLOQ, the Agency proposed updating Part 620 to add LLOQ to reflect SW-846's update.

Agency Answer 24(b)
If the LLOQ is not less than the regulatory action level, then the GQS is listed as the LLOQ rather than the health-based guidance level. The Agency recognizes that not all labs may be able to achieve the appropriate levels of quantitation at this time. Nonetheless, to remain viable, commercial labs should expect to keep up with analytical technologies and new methodologies. The Agency requires the use of a lab able to achieve the appropriate levels of quantitation.

NWRA Question 25
In follow-up to questions 37 and 38, while the Agency is proposing changes to lab definitions like LLOQ and LCMRL to set the GQS here, those new definitions represent proposed changes to the current Part 620 definitional methodology understood and utilized by the regulated community and laboratories with whom they contract (i.e., the PQL).

> *(a) Why is the Agency not using the PQL in this rule making for setting the numeric standards?*
>
> *(b) The Agency would agree that this represents a change to Part 620 never before proposed?*

Agency Answer 25(a)
The PQL has been removed from the SW-846 Methods. The LCMRL utilizes an updated statistical approach for a single laboratory to meet its Measurement Quality Objectives (MQO). This approach provides a more accurate determination of the MQO and eliminates the issue of laboratories using multiple PQL methods to determine the MQO. SW-846 Chapter 1 uses the LLOQ.

Agency Answer 25(b)
Yes, the Agency agrees that it has never proposed the removal of the PQL.The PQL is being replaced due to updates of the SW-846 Methods.

NWRA Question 26
In follow-up to question 39, will private well owners be required or encouraged to sample and analyze their drinking water for compliance with the Class I GQS?

Agency Answer 26
The Illinois Department of Public Health oversees private wells and has conducted PFAS sampling of private wells near confirmed PFAS groundwater contamination areas for those residents who request it. Private well sampling is not required, although sampling is encouraged in areas of known contamination.

NWRA Question 27
As to question 47, the Agency's SOP details procedures for collecting samples of drinking water from sampling taps and plumbing which shall be free of materials containing Teflon or, if these cannot be avoided, to ensure the tap has been flushed for at least 5 minutes.

> *(a) Will these procedures be required by the Agency for all PFAS sampling where comparison to the Part 620 standards is required?*

Agency Answer 27(a)
The Agency's SOP applies to Method 537.1. The Agency requires that sampling procedures be followed as outlined in the specific approved method being used.

NWRA Question 28
As to question 49, the Part 811 regulations require analytical data below the PQL, to be reported as non-detect (ND).

> *(a) When analytical results are reported for compliance with BOTH the Part 811 regulations (e.g., groundwater assessment) and the proposed new Part 620 regulations, is the Agency prepared to support the regulated community reporting two potentially different sets of analytical data to ensure compliance with both the Part 620 and Part 811 regulations and to having two sets of data in the Agency's database?*
>
> *(b) Which represents the enforceable standard?*

Agency Response Question 28(a)
Section 811.320(e)(3) states:

> "The level of detection for each constituent must be the practical quantitation limit (PQL) and must be the lowest concentration that is protective of human health and the environment, and can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions."

See 35 Ill. Adm. Code 811.320(e)(3). Under this seccton, the level of detection would need to be the lowest concentration to be protective of human health and the environment which are the standards identified in Part 620. There would be no need to report two different sets of analytical data since the lowest concentration protecting human health should be reported.

Agency Response Question 28(b)
The lowest concentration protecting human health and the environment would be the enforceable standard.

NWRA Question 29
As to question 50(b), can the Agency provide the names, or at a minimum, the number of the IBPA accredited laboratories that can achieve these newly proposed GQS levels?

> *(a) Can the Agency provide the cost for analysis of each constituent, so that the regulated community can effectively determine the economical impact for the new and/or lowered standards?*
>
> *(b) As the regulated community has existing relationships with existing laboratories, based upon the existing state regulations, does the Agency appreciate the costs associated with the potential for changing laboratories or requiring the potential use of more than one laboratory for sampling groundwater from groundwater monitoring wells?*

Agency Answer 29
Accredited labs can be found in The NELAC Institute (TNI) National Environmental Laboratory Accreditation Management System (LAMS) database. The IEPA's Environmental Laboratory Accreditation Program has recently been approved to add PFAS methods to their scope of accreditation.

Agency Answer 29(a)
The cost is determined by the lab performing the analysis.

Agency Answer 29(b)
Since prices may vary between labs, the Agency is unaware of the exact cost associated with changing labs or using more than one lab.

NWRA Question 30
As to IERG's question 2, Table 5 in Method 537.1 lists DLs both higher and lower than 2.0 ng/1. These DLs are based upon reagent water.

> *(a) What were the actual DLs and MRLs for the Community Water Supply sampling drinking water analyses?*
>
> *(b) On that same theme, when will the Agency provide the information it stated it would provide in response to Member Gibson's request? (Tr. P. 53; Q: Do you have*

> *specific numbers from the community water systems? A: No, we do not, but we can provide this.)*

Agency Answer 30(a)
The MRLs for the CWS sampling initiative were set to 2.0 ng/L for all PFAS constituents.

Agency Answer 30(b)
Please refer to the Excel Spreadsheet titled, "R22-018 PFAS Detections in Illinois Groundwater. *See* Attachment 1.

NWRA Question 31
As to IERG'S question 5, if PFAS have been found in air, water and soil in Illinois, how does the Agency propose to address background concentrations for each media as potential contributors to possible background concentrations in groundwater where an upgradient source may not be the source of PFAS at a regulated facility?

Agency Answer 31
Addressing the source of background concentrations in groundwater is beyond the scope of the Part 620 rule making process.

NWRA Question 32
As to IERG'S question 7, the Agency has indicated that any actions related to the USEPA Federal Drinking Water Standard for PFAS are independent of the rulemaking for revision of the 620 Groundwater Quality Standards. Further, in the Agency's testimony (pp. 50-52) Ms. Hawbaker testified that the Agency's proposed rules do not rely on USEPA values, declaring the USEPA an unranked Tier III source for toxicology, and instead rely on ATSDR and California values - citing authority to do so in prior Board Part 620 proceedings.

> *(a) Please point to the prior opinions of the Board where the Board has specifically and knowingly determined to disregard USEPA values in favor of those from other states or agencies.*

Agency Answer 32(a)
The Agency is following the same U.S. EPA toxicity hierarchy as discussed in the previous Part 620 Rulemaking which the IPCB promulgated in 2012. (*See* R2008-18 (2012)), U.S. EPA updated its toxicity hierarchy in 2013, adding a Tier 3 source hierarchy, and in 2021, following a review of subchronic toxicity data available for certain chemicals. The original 2003 U.S. EPA toxicity hierarchy guidance, with the two updates, are included in the December 7, 2021, filing. *See* Exhibit 2, Attachments 1C-1, 1C-2, and 1C-3. Ms. Hawbaker's testimony also discusses the use of the hierarchy. *See* Exhibit 2 at 6-9.

NWRA Question 33
As to Midwest Generation's question 8, would a petition to the IPCB for an adjusted standard be required where background concentrations of a constituent are higher than the Part 620 groundwater quality standard for that constituent?

Agency Response 33
In consideration of Dynegy's initial Question 8 and Ms. Hawbaker's response, an adjusted standard would only be required if that was a programmatic requirement. Bearing in mind of course that it would be necessary to demonstrate that the concentrations exceeding the Part 620 standards do actually represent background.

NWRA Question 34
As to Midwest Generation's question 9, the Agency's answer indicates that groundwater samples are filtered during the preparation step using SW-846 Method 3512. This method is for solvent dilution of non-potable waters and has been evaluated for 24 PFAS in conjunction with method 8327. The method indicates that this preparation method may also be applicable to other target compounds, provided the laboratory can demonstrate adequate performance. The method summary indicates that samples are prepared by adding isotopically labeled analogs of PFAS target analytes.

(a) How would this be applicable to other organic or inorganic compounds?

Agency Answer 34(a)
This question is more appropriately directed to the authors of SW-846 Method 3512.

NWRA Question 35
At the Board's March 9, 2022 hearing, the Agency offered its opinion that "any results" from a sampling effort of treated water were "not helpful at all to the development of the groundwater or the proposed groundwater revisions[.]" Mar. 9, 2022 Tr., p. 17. Given this opinion, why are community water supply sampling efforts for PFAS being used as part of this proposed groundwater rulemaking?

Agency Answer 35
As stated previously, the Agency is not using any finished water data from the Statewide Community Water Supply Investigation for this rulemaking. Instead, the Agency is relying on the analytical data from raw (untreated) water collected from community water supply wells after the finished water from the respective CWS detected PFAS. It is the raw water data from the wells that prompted the issuance of the PFAS Health Advisories in accordance with Part 620, Subpart F.

NWRA Question 36
At the Board's March 9, 2022 hearing, the Agency explained that, "in practice", the Part 620 standards for PFAS will be "used for the valuation of groundwater quality for private residential wells in the state and also be used for remedial activities for potential other contaminated sites where we're looking at cleaning up or what type of remedial activities will be necessary for protecting the groundwater of the state." Mar. 9, 2022 Tr., p. 20. If true, the Part 620 standards would not be used for groundwater assessment purposes under 35 Ill. Admin. Code Part 811, since these are not private residential wells, clean-up is not being looked at, nor are types of remedial activities being reviewed. The standards would only be applicable when a site goes to remedial action.

> *(a) Does the Agency have any additional comments on applicability of the Part 620 regulations based upon the previous testimony?*
>
> *(b) Would the Agency consider adding this clarification to the regulations?*

Agency Response Question 36(a)
The Part 620 standards are currently used for groundwater assessment and corrective/remedial action for Part 811 landfills and will continue to be used as such after the adoption of amendments to Part 620.

Agency Response Question 36(b)
There is no need for such a clarification. Furthermore, any clarification regarding the use of Part 620 by the Part 811 regulations should be contained in the Part 811 regulations, not Part 620.

NWRA Question 37
At the Board's March 9, 2022 hearing, the Agency explained that it was proceeding with its proposed revisions ahead of the "IRIS assessments being finalized" because the Agency:

> *know[s] there's a groundwater threat now, and we want to take care of it. We want to address it as soon as possible. It's the same with any other toxicity update. We -- when it gets updated, then we incorporate that in new information that at this point we know it's in the groundwater. We know that people can be affected by drinking that groundwater, and it's time for us to take action.*
>
> *Mar. 9, 2022 Tr., p. 27.*

Please provide a list of all known groundwater data sources that are available to support this statement.

Agency Answer 37
Please refer to the Excel Spreadsheet titled, "R22-018 PFAS Detections in Illinois Groundwater." *See* Attachment 1.

NWRA Question 38
At the Board's March 9, 2022 hearing, the Agency explained that it set its minimum reporting standards at 2 nanograms per liter for PFOA, and that its minimum reporting standards were "generally" a "little bit" lower "across the Board" as compared to other states. Mar. 9, 2022 Tr., p. 30.

> *(a) What is the Agency's justification for using a minimum reporting level of 2 nanograms per liter?*
>
> *(b) Is the Agency aware of any analyses that would indicate that this reporting level may not be analytically achievable for groundwater analyses?*

> *(c) If the answer to (b), above, is in the affirmative, please identify all of those analyses.*
>
> *(d) In making this statement, the Agency is acknowledging that it has compared the proposed standards to other states-please identify which states were used for the comparison.*
>
> *(e) Please provide the concentrations for these other states used in the comparison.*

Agency Answer 38(a)
Multiple labs have demonstrated the ability to achieve this level of quantitation.

Agency Answer 38(b)
The Agency is aware that some labs are not capable of achieving this level of quantitation. Nonetheless, the Agency requires the use of a lab that is capable.

Agency Answer 38(c)
The Agency does not have a comprehensive list of analyses that are incapable of achieving this level of quantitation.

Agency Answer 38(d)
The Agency reviewed information on Interstate Technology and Regulatory Council's (ITRC) website and the Environmental Council of the States (ECOS) information.

Agency Answer 38(e)
Please refer to the above sources for more information on other states' MRLs. PFOA can meet its MRL of 2 ng/L; therefore, the value is appropriate.

NWRA Question 39
At the Board's March 9, 2022 Hearing, the Agency's witness indicated that if contamination is present above a groundwater standard, it's more about excluding the exposure pathway when it comes to the Bureau of Land programs, than requiring cleanup. Mar. 9, 2022 Tr., p. 40. The Bureau of Land programs related to landfills do not in general consider exposure pathways. They are based upon source identification and contaminant removal or remediation. What is the Agency's basis for this statement?

Agency Response Question 39
The witness mis-spoke as the exclusion of exposure pathways is not a consideration for Part 807 and Part 811 landfills. The exclusion of pathways is allowed for those programs using 35 Ill Adm Code Part 742.

NWRA Question 40
At the Board's March 9, 2022 Hearing, the Agency's witness indicated that the groundwater standards that they developed are based on what is in the Board's current Part 620 regulations. Mar. 9, 2022 Tr., p. 44. Is the Agency referring to the current Part 620 regulations, or the Part 620 modifications that are being proposed?

Agency Answer 40
The Agency was referring to Part 620 in general as Illinois's basis for developing groundwater quality standards. Specifically, to Question 40, the proposed groundwater quality standards are calculated using the proposed method updates.

NWRA Question 41
At the Board's March 9, 2022 Hearing, the Agency indicated that it was not sure how modifications to the remedial programs will be made when the Agency changes the regulations based on the fact that new studies are emerging. The Agency further indicated that this is a "rather common occurrence". Mar. 9, 2022 Tr., p. 48.

(a) Can the Agency provide examples of how such modifications have been made in the past?

(b) Aren't regulatory changes required?

Agency Response Question 41(a)
Updates to multiple Board rules take effect each year, and with each change the updates are implemented into the administration of the rules going forward. For example, 35 Ill. Adm. Code Part 620 and Part 742 have been updated over time based on the emergence of new studies and toxicity information and they will continue to be updated in the future. In some cases, updates unfortunately have not kept pace with advancements in science. Rules need to follow science and be continually updated if they are to provide the best protections for human health and the environment. Continually waiting on the next new study before updating a rule would result in the rule never being updated. Once the U.S. EPA completes its work on PFAS, the results of its studies are known, and it takes action pertaining to PFAS, all of that information can be digested and appropriate state level actions can be determined, including amendments to the Part 620 rules in effect at that time if amendments are warranted.

Agency Response Question 41(b)
Regulatory changes may or may not be required, depending upon the actions that are warranted.

NWRA Question42
At the Board's March 9, 2022 Hearing, the Agency indicated that they cannot ascertain the costs of remediation without first establishing a standard. Mar. 9, 2022 Tr., p. 56. Has the Agency not evaluated the cost of its proposed standard across the various programs to which it will become applicable?

Agency Answer 42
The Agency does not have information to determine the number of sites that may require remediation. We assume the question is aimed at any increase in costs to site remediation as a result of adopting standards for PFAS. It is unclear how many sites will choose to address PFAS as part of their corrective action. However, the sites that would be affected are sites where (1) the remediating party is addressing PFAS contamination and (2) the PFAS contamination being addressed extends beyond any other contamination that is being remediated. In other words,

increased costs would exist only where PFAS is the sole contamination being remediated. These increased costs would be the expense of remediating that isolated PFAS contamination. This would be the case for sites in the Site Remediation Program. Since PFAS is not an indicator contaminant in the LUST Program, there would be no difference is cost for LUST cleanups.

In practice, all contaminants are generally addressed together so any increase in costs due to the addition of PFAS standards is generally expected to be minimal. The ability to address multiple contaminants at once is why the use of engineered barriers and institutional controls is so effective and prevalent. For example, a groundwater ordinance prohibiting the installation of potable drinking wells prevents exposure to all contaminants in the groundwater. An engineered barrier prevents ingestion of any contaminants in the soil. The vast majority of sites that have achieved cleanup and received No Further Remediation Letters under the Site Remediation Program (5,103 out of 5,675) utilized an institutional control, engineered barrier, or both as part of their corrective action.

NWRA Question 43
At the Board's March 9, 2022 Hearing, the Agency acknowledged that Class 1 groundwater standards are potable water (drinking water) standards. Mar. 9, 2022 Tr., p. 88. Why is it then appropriate to utilize these PFAS standards for groundwater monitoring wells that are not used as drinking water source?

Agency Answer 43
Part 620 Class I potable (drinking) water resource groundwater quality standards are based on groundwater's fitness for potability, not whether it is currently being used as a potable resource. When discussing Class I potable resource groundwater, the Board stated the following in its Final Opinion and Order for R89-14(B):

> "The Board believes that among the most necessary facets of the State's groundwater protection program is the need to protect all drinkable water at a drinkable level. Similarly, the Board does not believe that current actual use should be the sole control of whether potable groundwater is afforded the protection necessary to maintain potability; we simply cannot allow the sullying of a resource that future generations may need. For the same reason the term "Potable Resource Groundwater", rather than "Potable Use Groundwater", is employed in the title of this class."

See R89-14(B) (1991). Groundwater monitoring wells are commonly used to determine potability when the groundwater is not currently used as a potable resource.

NWRA Question 44
At the Board's March 9, 2022 Hearing, the Agency explained that Method 8327 has recently been added to EPA's SW-846 methods manual for analyses of PFAS in various media other than drinking water. However, the Agency indicated that they recommend Method 537.1 be used, which is a drinking water method the Agency uses for community water supply wells and surface water. Mar. 9, 2022 Tr., p. 108.

(a) Is Agency is recommending that Method 537.1 be used for PFAS analyses in groundwater, and potentially contaminated groundwater, instead of an approved USEPA Method 8327 for this type of matrix?

Agency Answer 44(a)
Method 537.1 is an analytical method for drinking (potable) water; regardless of where the potable water originates. Class I groundwater is potable resource groundwater; a resource that may be used as drinking water. Method 8327 is a method for non-potable water. To determine groundwater's fitness for potability, Method 537.1 should be used.

NWRA Question 45
At the Board's March 9, 2022 Hearing, the Agency's witness indicated that Method 537.1 was the only test method approved for drinking water for compliance determinations, but appeared uncertain as to whether this was limited to drinking water in public water supplies. Mar. 9, 2022 Tr., p. 111.

(a)Could the Agency clarify its answer at this time?

(b) Has the Agency reviewed other applicable analytical methods, especially those already included in Part 620.125, and determined whether those methods may also be appropriate?

Agency Answer 45(a)
Method 537.1 is not limited to drinking water in public water supplies. It applies to drinking (potable) water, regardless of the source. To determine compliance with Class I potable resource groundwater standards, Method 537.1 is the only method meeting the PFOA LCMRL of 2 ng/L at this time.

Agency Answer 45(b)
U.S. EPA Method 533 is also approved for drinking water analyses.

NWRA Question 46
At the Board's March 9, 2022 Hearing, the Agency indicated that they did not believe that Method 8327 could be used as, "I do not believe they're LLOQ meets the minimum reporting level". Mar. 9, 2022 Tr., p. 112.

(a) Who's LLOQ is the Agency referring to in their statement?

(b) Based on this statement, can we conclude that the Agency is requiring compliance with the proposed standards, based upon a method which has not been approved for the specific analytical matrix (groundwater) and requiring instead that a drinking water method be used? If not, please explain.

(c) Both methods (Method 537.1 and Method 8327) are specified in the proposed regulations. Can the EPA SW-846 approved method for groundwater analyses

(Method 8327) be used if the quantification/reporting level is at or below the Part 620 standard?

Agency Answer 46(a)
The PFOA LLOQ of 10 ng/L presented in U.S. EPA's, "Additional Performance Data Associated with Multi-Laboratory Validation of SW-846 Methods 3512 and 8327." *See* Attachment 12.

Agency Answer 46(b)
No. Method 537.1 is a drinking (potable) water method. Its matrix is potable water, indeterminate of whether the source is groundwater or finished water.

Agency Answer 46(c)
SW-846 Method 8327 is not specified in the proposed regulations; however, it is included in the SW-846 Compendium, cited in Part 620.125. If quantitation levels are at or below the Part 620 groundwater quality standards, the method may be used.

NWRA Question 47
At the Board's March 9, 2022 Hearing, the Agency indicated that, "for Class 2 groundwater in this particular place, it does not have the treatability. It does not have the chemical specific factors to qualify it to have a treatability factor." Mar. 9, 2022 Tr., p. 119. Yet in the Agency's Answer 46 to the NWRA pre-filed questions, the Agency has indicated that treatment factors have been applied for 2 inorganic constituents and for the organic constituents at 620.420(b)(l). The testimony is confusing as it appears to indicate that the Class II standards are not based upon treatability, yet the response to the NWRA comments appears to indicate that the standards are based upon treatability.

(a) Can the Agency clarify this apparent inconsistency?

(b) The Agency has further indicated that "One of the factors with Class 2 groundwater is the ability to make it for beneficial use, make it available to be used as Class 1 groundwater if treated." What are the other factors?

(c) A Class 2 groundwater is not solely dependent upon the ability to be treated to a Class 11 standards. The Class 1 requirements specified in 35 IAC 620.210(a)(2-4) are not quality dependent, but based upon the characteristics of the aquifer or groundwater zone. Thus, a Class 2 groundwater may never be able to achieve the Class 1 standards due to factors other than treatability. Can the Agency please clarify this point?

Agency Answer 47(a)
The Agency was speaking specifically to PFAS constituents not meeting the chemical-specific criteria for treatment factors to be assigned.

Agency Answer 47(b)
Other factors, including irrigation and watering of livestock are considered when developing Class II general resource groundwater quality standards.

Agency Answer 47(c)
The final opinion and order of the Board in R89-14(B) states that:

> "Section 620.420 establishes standards for Class II: General Resource Groundwaters. Because groundwaters are placed in Class II because they are quality-limited, quantity-limited, or both (see Subpart B discussion above), it is necessary that the standards that apply to these waters reflect this range of possible attributes. Among the factors considered in determining the Class II numbers are the capabilities of treatment technologies to bring Class II waters to qualities suitable for potable use (R3 at 75). Thus, many Class II standards are based on MCLs as modified to reflect treatment capabilities. For some parameters the Class II standards are based on support of a use other than potability (e.g., livestock watering, irrigation, industrial use) where the different use requires a more stringent standard (R3 at 114-8)."

See R89-12 at 19-20 (1991). The capabilities of treatment technologies to bring Class II groundwater suitable for potable use has been a consideration for developing Class II general resource groundwater since Part 620's promulgation.

NWRA Question 48
At the Board's March 9, 2022 Hearing, the Agency indicated that Method 3512 (filtration) must be used as a preparation step for all groundwater analyses using SW-846 methods, not just PFAS. Mar. 9, 2022 Tr., p. 126. This would not provide compliance with the standards in the regulations as they listed as TOTAL concentrations - not filtered or dissolved. As such, SW- 846 Method 8327 cannot be used for analyses as it would be required to go through the sample preparation steps of Method 3512 (filtration) prior to analyses.

> *(a) Can the Agency clarify why the SW-846 methods are in the regulation if they cannot be used for compliance purposes based upon this information?*
>
> *(b) The majority of constituents that require groundwater analyses under other Agency programs (e.g., Subtitle C and Subtitle D groundwater) are required to be analyzed based upon unfiltered samples. If samples are required to be collected as part of an approved GMZ at these sites, will they be required to be analyzed in accordance with BOTH the RCRA programs requirements and the Part 620 requirements to provide both filtered and unfiltered samples?*

Agency Answer 48(a)
Upon further review, SW-846 Method 3512 is a preparation method conducted in a laboratory for non-potable water samples applicable to Method 8327 analyses only.

Agency Answer 48(b)
SW-846 Method 3512 is a preparation method conducted in a laboratory to increase accuracy and precision of PFAS analyses.

NWRA Question 49
At the Board's March 9, 2022 Hearing, the Agency indicated that when determining whether there is an exceedance of a Class I or Class II groundwater standard, they prefer samples not to be filtered in the field, but they've also indicated there are some cases where that has happened. Mar. 9, 2022 Tr., p. 130. The regulations specify total concentrations. As such, a field filtered sample would not be an acceptable sample for comparison to the Class I or Class II standards and therefore, cannot be an exceedance. Can the Agency please explain its rationale for considering a field filtered sample to be an exceedance of a proposed standards?

Agency Answer 49
The following is an incorrect statement: "As such, a field filtered sample would not be an acceptable sample for comparison to the Class I or Class II standards and therefore, cannot be an exceedance." If a field-filtered sample exceeds a Class I or Class II groundwater standard, then there is undoubtedly an exceedence, because a total sample will not less than a filtered sample (within the margin of lab error). However, a field-filtered metals sample would not be unable to demonstrate compliance with a Class I or Class II standard if the result is below the applicable standard, because the total analysis concentration may be higher. Further, in instances where a demonstration is being made that a concentration of a metal is protective of human health and/or the environment the evaluation must be made in comparison to a total metal analysis. Total metal analysis does not include field or lab filtering of a metals sample.

NWRA Question 50
At the Board's March 9, 2022 Hearing, the Agency indicated that as to explosives, it would have to go back to the testimony from the previous rulemakings to determine how the RSCs were developed for explosives. Mar. 9, 2022 Tr., p. 134. Yet, the proposed standards for explosives represent a change to existing rules. Can the Agency now clarify how the RSCs were developed, and on what basis the Agency seeks to make this change?

Agency Answer 50
The Agency does not understand the question. The RSCs utilized to calculate the proposed Class I groundwater quality standards are the same RSCs used to calculate the standards currently in Part 620.410.

NWRA Question 51
At the Board's March 9, 2022 Hearing, the Agency indicated that it would look at the zone of attenuation in Part 817 to determine if it should be included under Section 620.440(8). Mar. 9, 2022 Tr., p. 158. Has the Agency had an opportunity to look at this issue, and what is its conclusion?

Agency Answer 51
Part 817 should be added as a reference at Section 620.440(b).

NWRA Question 52
At the Board's March 9, 2022 Hearing, the Agency indicated that the technical feasibility and economic reasonableness was addressed in Section 6 of their Statement of Reasons, beginning on Page 22. That Statement of Reasons merely references prior evaluations and determinations as

the basis for considering the technical feasibility and economic reasonableness of the current proposal. The referenced Board Determinations in R08-18 considered existing programs under TACO (part 742) and for RCRA facilities requiring modifications to permits under Part 702, and Closure and Post-Closure Plans under Part 725. Here, there is no such coordination or testimony as to how the Agency expects these proposed standards to be applied pursuant to Part 807 and Part 811. Without such understanding, how does the Agency justify its conclusion of economic reasonableness and technical feasibility simply on the basis of prior Board proceedings?

Agency Answer 52
How the proposed standards will be applied pursuant to Parts 807 and 811 are a function of the rules in Parts 807 and 811, not Part 620. The Agency has begun discussions with stakeholders regarding potential impacts of the Part 620 amendments based upon how Parts 807 and 811 utilize or incorporate Part 620 standards, and changes that may be needed to Parts 807 and 811 as a result. If those rules' utilization or incorporation of a Part 620 standard creates an issue, Parts 807 or 811 can be amended as appropriate. Part of any rulemaking to amend those rules would include consideration of the economic reasonableness and technical feasibility of how the Part 620 standards are utilized/incorporated into those rules.

NWRA Question 53
A key component of landfill operations is leachate management, specifically disposal and treatment. 35 IAC 811.308 and 811.309 require the collection, disposal and treatment of landfill leachate. The impacts from the potential implementation of PFAS constituent limits and standards have already resulted in local POTW's refusing to accept MSWLF leachate due to concerns over impacts on POTW biosolids land application programs and concerns over future rule changes affecting the POTW discharge standards and imposed discharge limits. A question was posed to Illinois EPA staff during the August 19, 2021 video conference with members of the NWRA: Is there any intention to add PFAS limits to 35 /AC Part 309, impacting treated discharge or discharge to a treatment works as listed in Sections 81J.309(c)(5) and (e), respectively? The resulting answer was "this would be addressed later". This is an issue that needs further consideration as the impacts are significant with respect to operation and the economics of the landfill industry.

> *(a) POTW Discharge (POTW)- What modifications will be needed at the POTW to ensure discharge limits will be met? Residuals/wastes of PFAS treatment technologies will need to be disposed of in some manner and there is a potential concern on whether or not disposal in a landfill is appropriate.*
>
> *(b) POTW Sludge Disposal - Waste water treatment sludge is often utilized as an amendment to the vegetative cover at disposal facilities to facilitate vegetative growth as well as land-applied to agricultural fields. Will surface application of such sludge be prohibited due to implementation of PFAS constituent standards/limits? If so, the sludge would need to be disposed at landfill facilities impacting available landfill capacity and significant increased cost to POTW's. (The sludge is often disposed in the landfills. Refusal of POTWs to accept leachate from the landfill company may result in refusal of the landfills to accept the treatment sludge.)*

(c) NPDES/SWPPP Outfall Monitoring - Discharge limits may impact landfill operations, particularly if wasted water treatment sludge was utilized in final cover soil amendment. Does the Agency intend to modify discharge limits in NPDES and SWPPP permits to account for any new PFAS groundwater standards?

(d) Discharge Limits (Privately Owned Treatment Plants) - Since it is not unreasonable to assume that several POTWs will follow suit in denying acceptance of leachate in the future. How does the Agency anticipate handling this issue based on the currently proposed PFAS water quality standards? (This issue will result in hauling leachate further distances for disposal, significantly impacting costs and increasing the carbon footprint. This may also result in permitting, construction and operation of onsite or regional treatment plants with the substantial economic impact being passed on to consumers.)

Agency Answer 53

The comments concerning PFAS in leachate have no direct relevance to Part 620, however, the following responses are based on what we know at this time. There is no intention to revise 35 Ill. Adm. Code Part 309 to address PFAS. Part 309 governs the requirements for, and the issuance of, construction and operating permits as well as NPDES permits. While it is unknown what regulatory efforts by the Agency may be necessary in the future, there are currently no plans to develop or adopt statewide pretreatment limitations for PFAS related constituents. It is expected that U.S. EPA will likely develop aquatic life criteria applicable to NPDES permits, and also develop pretreatment standards for certain industrial sources in the coming months or years.

Agency Answer 53(a)

There are currently no pretreatment standards or limits, which have been developed in Illinois or on the federal level. However, it is the understanding of the Agency that U.S. EPA is working on the development of potential PFAS limits, controls, and/or Best Management Practices for certain industry sources. It is not known if such efforts include the landfill sector.

Agency Answer 53(b)

The Agency does not have any standards or limitations applicable to PFAS in municipal biosolids. Given that there are no standards or limitation, the Agency is unable to address any potential prohibition affecting the land application of biosolids.

Agency Answer 53(c)

Neither the State of Illinois, nor U.S. EPA, have adopted technology or water quality standards applicable to surface water discharges from facilities such as POTW's. Absent such standards, the Agency would not be able to provide any meaningful answer to the question.

Agency Answer 53(d)

The current rulemaking is for the adoption of groundwater quality standards in Part 620. Discharges from POTW's are not subject to the groundwater quality standards of Part 620. The Agency is not currently proposing a surface water quality standard or a pretreatment standard.

Until such standards are adopted by either the Illinois Pollution Control Board, or U.S. EPA, the Agency is not able to answer this question.

NWRA Question 54
The Illinois EPA provided comments to the technical feasibility and economic reasonableness of implementation of the proposed rule changes in Section VI of the Statement of Reason. Most of the comments referenced past studies dating back to the inception ofR89-14(B). The technical feasibility is still in question largely due to the extremely low standards for the proposed constituent additions proposed in Section 620.410. The Illinois EPA cites in Section VI of the Statement of Reason numerous times the past studies for implementation of 35 IAC Part 620 and subsequent revisions. However, incorporation of Hexafluoropropylene Oxide Dimer Acid (HFPO-DA Gen X), perfluorobutanesulfonic Acid (PFBS), perfluorohexanesulfonic Acid (PFHxS), perfluorononanoic Acid (PFNA), Perfluorooctanoic Acid (PFOA), and Perfluorooctane Sulfonic Acid (PFOS), collectively referenced as PFAS constituents, with such low limits are significantly different than previous constituent additions. The potential impact of the additions and planned implementation are dissimilar and far greater than the changes previously proposed and approved to 35 IAC Part 620. Does the Agency not agree that a detailed feasibility and economic impact study prior to implementation of the rule changes is warranted not only for its 5 IAC Part 620, but as to regulatory programs/rules that will be affected by implementation of the changes it proposes to 35 IAC Part 620?

Agency Answer 54
No, a feasibility and impact study for the regulatory programs that utilize or incorporate the Part 620 standards is not warranted in this rulemaking. Any economic impact or technical feasibility regarding those programs' utilization or incorporation of the Part 620 standards is a function of those rules, not Part 620. The proper context for addressing the impacts of those programs' utilizations or incorporations is a discussion of any amendments needed to those rules as a result of changes to Part 620. For example, consideration of whether an adopted Part 620 standard should be required to be monitored at a landfill is properly discussed within the context of the landfill program. Likewise, consideration of whether an adopted Part 620 standard should be utilized as a cleanup standard under the TACO rules is properly discussed within the context of the TACO rules.

NWRA Question 55
Some facilities are employing corrective action and related monitoring/reporting pursuant to CERCLA and/or consent orders. The USEPA has not approved any limits in groundwater at this time. It is assumed the proposed revisions to 35 IAC Part 620 will not be required in monitoring and assessment of these existing programs at this time.

> *(a) Will the Agency please verify whether that is its understanding?*
>
> *(b) It is understood that the USEPA will propose to add only four PFAS constituents as hazardous substances (perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorobutane sulfonic acid (PFBS), and GenX) to 40 CFR Part 261, Appendix VIII. Can it be construed that when approved by the USEPA,*

only those four PFAS parameters will be applicable to RCRA programs within Illinois?

Agency Answer 55(a)
The stated assumption is not correct for facilities subject to CERCLA.

At this time, it is true that U.S. EPA does not have any Maximum Contaminant Levels (MCLs) for PFAS compounds. However, both U.S. EPA and Illinois EPA have issued health advisories (HA). Since January 2021 Illinois EPA has issued HAs for six per- and polyfluoroalkyl substances. Because PFAS are not currently hazardous substances, and the federal and state HAs are not applicable or relevant and appropriate requirements (ARARs) as defined by federal rule (40 CFR 300.5), the HAs are currently being used as pertinent To Be Considered (TBC) criteria for nature and extent delineation and developing preliminary remediation goals (PRGs) during the Remedial Investigation (RI) phase, in the same manner as promulgated chemical-specific ARARs are used. By definition TBCs are local, state, and federal policies and rules that do not meet the definition of an ARAR but nonetheless have substantive bearing on the site situation. In the absence of promulgated standards (ARARs), pertinent TBCs should be considered during remedial alternative evaluation in the Feasibility Study (FS). Actual selection in the Record of Decision (ROD) and follow-on use of TBCs during remedial action is possible in the absence of ARARs if contaminant risks are unacceptable. Following their use for screening and remedy evaluation, CERCLA PRGs (ARARs and/or TBCs) become final upon their selection in the ROD and are then referred to as Remedial Goals (RGs).

The Federal Site Remediation Section investigates and remediates Superfund, DoD and consent order sites pursuit to CERCLA, a Federal regulation. FSRS has no program specific State regulations to update in relation to this rulemaking, unlike other Agency programs. As such, FSRS's Superfund, DoD and consent order sites will be subject to the revised 35 Ill. Adm. Code Part 620 upon its promulgation. Upon promulgation the new PFAS standards will be chemical-specific ARARs.

How FSRS implements the changes to 35 IAC 620 will depend on what CERCLA stage the project is in:

- For sites that are post ROD and the remedy has already been implemented, the CERCLA Five-Year Review Process builds in a review of new or revised regulations that would impact protection of human health and the environment. Should site circumstances indicate PFAS may be present, during the Five-Year Review FSRS would request a new investigation into PFAS in the groundwater and acknowledges it may require a new or amended consent order.
- For sites still in the investigative stage that potentially have PFAS issues, FSRS would request PFAS be added to the investigation as soon as possible as ARARs may be identified through completion of the ROD. If an interim groundwater monitoring program exists, FSRS might request PFAS be added to the sampling analysis list. Otherwise, a new investigation for PFAS may be indicated.
- DoD has already done preliminary assessments and basic site investigations of PFAS at their active facilities in Illinois. DoD has also initiated PFAS RIs at a few facilities. The promulgation of 35 Ill. Adm. Code 620, will require DoD to address PFAS in groundwater during full CERCLA remedial investigation and risk assessment.

Agency Answer 55(b)
Under CERCLA, Superfund, DoD, and consent order facilities would have to investigate and remediate all PFAS constituents with groundwater standards in the revised 35 Ill. Adm. Code 620. More conversative promulgated State regulations (ARARs) take precedence over less conservative and unpromulgated Federal advisories (TBCs).

NWRA Question 56
The Illinois Department Transportation (IDOT) requires all state highway projects, local projects, and other transportation projects affecting right-of-way or roads under !DOT jurisdiction to comply with Chapter 27 of the Bureau of Design and Environmental (BDE) Manual. Due care shall be exercised to determine whether regulated substances may be present on or located adjacent to property being considered for use for state highway project purposes and supporting highway operations and maintenance. A Preliminary Environment Site Assessment (PESA) is IDOT's fundamental method of demonstrating "due care". Thus, a PESA is required on every applicable fundamental project. The Illinois State Geological Survey (ISGS) conducts all BDE PESAs. If the PESA report indicates that the property(ies) investigated within IDOT's project limits has a recognized environmental condition (REC), a Preliminary Site Investigation (PSI) is conducted on the properties identified in the PESA as having a recognized environmental condition (REC). However, in IDOT's District 1 (Cook, Lake, McHenry, Kane, DuPage, and Will Counties) a PSI is conducted on all properties identified within the project limit. The PSI characterizes the nature and extent of contaminants in soils, if any, within the sampled areas and estimates the volume and cost to handle and/or dispose of such soils. The investigations also evaluate the groundwater quality that is encountered within the projected excavation. All excavated soils produced during construction must be either managed on-site, off-site as "uncontaminated soils" to a CCDD or Uncontaminated Soil Fill Operation (USFO) facility, to a solid waste landfill, or off-site as excess soil (unrestricted). Groundwater produced during construction are managed on- site, permitted sanitary sewer, or POTW.

Studies conducted by IDOT indicates over 5,000,000 cubic yards of impacted soils are removed annually (variable from year-to-year) and disposed at either a CCDD or USFO facility or solid waste landfill as part of State roadway construction projects within District 1. Within District 1, most soils are transported offsite to either CCDD facilities, and to a much lesser extent, permitted landfills depending upon analytical results. Some soils are managed onsite if adequate space allows. PFAS constituents are present in industrialized and highly urban areas, which constitutes most areas of roadway expansion within District 1. This should be evaluated prior to approval of the proposed rule change as it can have a significant impact to available airspace of the landfill industry.

> *(a) Does the Agency not agree to the influx of PFAS contaminated soil from IDOT roadway work within District 1 could overwhelm the currently readily available air space, assuming the landfill facilities will accept the waste?*
>
> *(b) Will CCDD facilities be able to accept soil with PFAS constituents? And if so, at what level?*

(c) Has the Agency considered the increased cost of disposal of large quantities of soil, which could cause the state an additional $3,000,000,000, depending upon the volume and disposal rates?

Agency Answer 56(a)
Part 620 sets forth quality standards for groundwater, not soil. No soil objectives are proposed in this rulemaking and no soil objectives for PFAS have been established. Any discussion of the landfilling of PFAS contaminated IDOT soils would be speculation.

Agency Answer 56(b)
Part 620 sets forth quality standards for groundwater, not soil. No soil objectives are proposed in this rulemaking and no soil objectives for PFAS have been established. Any discussion of CCDD fill sites' acceptance of soil containing PFAS constituents would be speculation.

Agency Answer 56(c)
Part 620 sets forth quality standards for groundwater, not soil. No soil objectives are proposed in this rulemaking and no soil objectives for PFAS have been established. Any discussion of the disposal of soil containing PFAS constituents would be speculation.

PFAS REGULATORY COALITION

PFAS Regulatory Coalition Question 1
Attached as Exhibit A is the set of comments submitted to IEPA by the PFAS Regulatory Coalition (also referred to here as the "Coalition") as to the first version of the proposed standards, which was released in December 2019. Please state how IEPA considered each specific comment, including whether the Coalition's comment was accepted or rejected and the basis for that action.

Agency Answer 1
The Agency's considerations for comments submitted by the PFAS Regulatory Coalition, dated February 28, 2020, in response to Outreach conducted February 13, 2020, are listed below:

I. The Agency considered all comments received.

II. The Agency provided its basis (U.S. EPA's toxicity hierarchy) for utilizing ATSDR's toxicological values during the February 13, 2020, Outreach Power Point Presentation, included in Attachment 3 of its December 7, 2021, filing. *See* Exhibit 2, Attachment 3. This basis is also discussed in Carol Hawbaker's testimony filed December 7, 2021. *See* Exhibit 2.

III(A). Updated toxicological studies, including toxicity assessments, have issued final toxicity data for developing groundwater quality standards. The presence of the proposed PFAS in Illinois groundwater provides the basis for proposing standards in accordance with the Illinois Groundwater Protection Act, which states:

> "The Agency, after consultation with the Committee and the Council, shall propose regulations establishing comprehensive water quality standards which are specifically for the protection of groundwater. In preparing such regulations, the Agency shall address, to the extent feasible, those contaminants which have been found in the groundwaters of the State and which are known to cause, or are suspected of causing, cancer, birth defects, or any other adverse effect on human health according to nationally accepted guidelines."

See 415 ILCS 55.8(a).

III(B). Toxicological studies, including toxicity assessments, have updated since the U.S. EPA issued its 2016 recommended PFOA and PFOS Health Advisory Levels. Other accepted sources within U.S. EPA's toxicity hierarchy have issued assessments based on more up-to-date studies. Further, U.S. EPA Office of Water issued updated draft toxicity assessments for PFOA and PFOS, that indicate significantly lower doses may cause adverse effects.

The Agency also notes the U.S. EPA Health Advisories are intended for drinking water from municipal water supplies. Part 620 addresses groundwater as a resource.

III(C). Please refer to the Agency's Answer to II. ATSDR finalized its PFAS Toxicological Profile May 2021.

III(D). The Agency is not proposing any combined PFAS standards.

III(E). All of the proposed PFAS are capable of being tested with validated analytical methods.

III(F). Several labs across the country, including labs in Illinois, are accredited by TNI-NELAC. All PFAS chemicals are listed Illinois EPA's Scope of Accreditation for the following methods: U.S. EPA 537.1, U.S. EPA 533, SW-846 8327, and SW-846 3512. All proposed PFAS standards, can be met using one these methods.

III(G). Testing is available for PFAS in groundwater. Discussions regarding treatment and disposal are not applicable for Part 620. Part 620 provides standards based on groundwater quality, not treatment and disposal.

III(H). Discussions regarding treatment and disposal are not applicable for Part 620. Part 620 provides standards based on groundwater quality, not treatment and disposal.

PFAS Regulatory Coalition Question 2

Attached as Exhibit B is the set of comments submitted to IEPA by the PFAS Regulatory Coalition as to the second version of the proposed standards, which was released in May 2021. Please state how IEPA considered each specific comment, including whether the Coalition's comment was accepted or rejected and the basis for that action.

Agency Answer 2

The Agency's considerations for comments submitted by the PFAS Regulatory Coalition, dated June 25, 2021, in response to Outreach conducted May 26, 2021, are listed below:

I. The Agency considered all comments received.

II. The Agency provided detailed discussions regarding shift of exposure populations in noncancer calculations from an average adult to a child age 0 – 6 years in the during the May 26, 2021, Outreach Power Point Presentation, included in Attachment 4 of its December 7, 2021, filing. *See* Exhibit 2, Attachment 4. This basis is also discussed in Carol Hawbaker's testimony filed December 7, 2021. *See* Exhibit 2. Further, the basis for using age-adjusted child exposure factors in calculating health-based groundwater quality standards is discussed in Carol Hawbaker's testimony, and included as Attachment 1(F)(1) in the December 7, 2021 filing. *See* Exhibit 2, Attachment 1(F)(1).

III(A). Updated toxicological studies, including toxicity assessments, have issued final toxicity data for developing groundwater quality standards. The presence of the proposed PFAS in Illinois groundwater provides the basis for proposing standards in accordance with the Illinois Groundwater Protection Act, which states:

> "The Agency, after consultation with the Committee and the Council, shall propose regulations establishing comprehensive water quality standards which are specifically for the protection of groundwater. In preparing such regulations, the Agency shall address, to the extent feasible, those contaminants which have been found in the groundwaters of the State and which are known to cause, or are suspected of causing, cancer, birth defects, or any other adverse effect on human health according to nationally accepted guidelines."

See 415 ILCS 55.8(a).

III(B). Toxicological studies, including toxicity assessments, have updated since the U.S. EPA issued its 2016 recommended PFOA and PFOS Health Advisory Levels. Other accepted sources within U.S. EPA's toxicity hierarchy have issued assessments based on more up-to-date studies. None of the work U.S. EPA is conducting with regard to PFAS, prohibits Illinois from setting groundwater quality standards for potable resource groundwater.

III(C). The Agency provided a detailed methodology and explanation of it derived the proposed standards at the May 26, 2021 Outreach. The information provided at the May 26, 2021, Outreach is included in the Agency's December 7, 2021 filing as Attachment 4. *See* Exhibit 2, Attachment 4. Carol Hawbaker's testimony included in the December 7, 2021, filing also further explained the updates to the methodologies and toxicity values, resulting in updated proposed standards. . *See* Exhibit 2.

III(D). The Agency provided its basis (U.S. EPA's toxicity hierarchy) for utilizing ATSDR's toxicological values during the May 26, 2021, Outreach Power Point Presentation, included in Attachment 3 of its December 7, 2021, filing. . *See* Exhibit 2, Attachment 3. This basis is also discussed in Carol Hawbaker's testimony filed December 7, 2021. *See* Exhibit 2.

III(E). The Agency is not proposing any combined PFAS standards.

III(F). For clarity, Class I groundwater quality standards are potable (drinking) resource water standards. There are presently two validated drinking water standards (U.S. EPA Methods 537.1 and 533). Further, SW-846 Method 8327 is approved for groundwater.

III(G). Discussions regarding treatment and disposal are not applicable for Part 620. Part 620 provides standards based on groundwater quality, not treatment and disposal.

PFAS Regulatory Coalition Question 3
The State of Wisconsin has adopted groundwater standards for PFAS substances that are less stringent than the IEPA's proposal. Please explain how the scientific basis for those standards, including assessment of PFAS risks, differs from the scientific basis for the IEPA's proposal, and please explain why IEPA is choosing a different outcome than the State of Wisconsin.

Agency Answer 3
For clarity, Wisconsin adopted drinking water standards for municipal water supplies. Wisconsin failed to adopt groundwater standards. The Agency relies on U.S. EPA's toxicity hierarchy for its selection of toxicity values. The selection of values used to determine the Agency's PFAS standards is based on toxicity profiles from ASTDR and CalEPA – ranked Tier 3 sources under U.S. EPA's toxicity hierarchy. As PFOA meets the Illinois' definition of a carcinogen, the Agency's proposed PFOA standard is calculated as a carcinogen; whereas, Wisconsin based its proposed groundwater value on noncancer toxicity. The methods proposed for calculating the proposed PFAS standards are based on U.S. EPA's use of child exposure as a more sensitive population when developing noncancer screening levels. The State of Wisconsin's scientific basis for Wisconsin's PFAS groundwater standards would be considered an unranked Tier 3 source under the referenced hierarchy and was therefore not considered by the Agency when selecting toxicity values.

PFAS Regulatory Coalition Question 4
The State of Michigan has adopted groundwater standards for PFAS substances that are less stringent than the IEPA's proposal. Please explain how the scientific basis for those standards, including assessment of PFAS risks, differs from the scientific basis for the IEPA's proposal, and please explain why IEPA is choosing a different outcome than the State of Michigan.

Agency Answer 4
Michigan's scientific basis for Michigan's PFAS groundwater standards would be considered an unranked Tier 3 source under the referenced hierarchy and was therefore not considered by the Agency when selecting toxicity values.

PFAS Regulatory Coalition Question 5
The State of New Jersey has adopted groundwater standards for PFAS substances that are less stringent than the IEPA's proposal. Please explain how the scientific basis for those standards, including assessment of PFAS risks, differs from the scientific basis for the IEPA's proposal, and please explain why IEPA is choosing a different outcome than the State of New Jersey.

Agency Answer 5
New Jersey's scientific basis for New Jersey's PFAS groundwater standards would be considered an unranked Tier 3 source under the referenced hierarchy and was therefore not considered by the Agency when selecting toxicity values.

PFAS Regulatory Coalition Question 6
Attached as Exhibit C is a report by the Environmental Council of the States ("ECOS"), entitled "Processes & Considerations for Setting State PFAS Standards." The appendices to the report list PFAS standards and criteria issued or proposed by State agencies, and for each of those levels, provides information as to the data, studies, and input values that were used to derive those levels. Many of those State-derived levels for PFAS substances are significantly more stringent than the levels in the IEPA proposal. For each of those levels derived by other States, please explain how the scientific basis for those levels, including assessment of PFAS risks, differs from the scientific basis for the IEPA's proposal, and please explain why IEPA is choosing a different outcome than those other States.

Agency Answer 6
Each state relies on its own criteria for setting groundwater quality standards. The Agency set proposed numerical groundwater quality standards based on proposed updated procedures in Part 620. Information regarding other states methods and criteria for setting groundwater quality standards are not applicable for the Agency's methods for developing standards under Part 620.

PFAS Regulatory Coalition Question 7
Attached as Exhibit D is a set of comments submitted by the PFAS Regulatory Coalition to EPA's Science Advisory Board ("SAB") concerning EPA draft risk assessments for PFAS substances. As to those aspects of the comments that relate to studies or methods that were used in deriving the levels specified in IEPA's proposal, please provide IEPA's response to those comments.

Agency Answer 7
For clarity, the comments submitted to U.S. EPA's Science Advisory Board (SAB), are the subject of draft PFOA and PFOS toxicity assessments conducted by U.S. EPA Office of Water and submitted for Public Comment in November 2021. The Agency did not rely on the draft toxicity assessments in its development of Part 620 PFAS standards.

PFAS Regulatory Coalition Question 8
Attached as Exhibit E is a set of comments submitted by the American Chemistry Council to EPA's Science Advisory Board ("SAB") concerning EPA draft risk assessments for PFAS substances. As to those aspects of the comments that relate to studies or methods

that were used in deriving the levels specified in IEPA's proposal, please provide IEPA's response to those comments.

Agency Answer 8

For clarity, the comments attached as Exhibit E and prepared by the American Chemistry Council, dated December 30, 2021, were submitted to U.S. EPA's Science Advisory Board (SAB) in response to SAB's Notice of Public Meetings issued November 10, 2021, regarding draft updated PFOA and PFOS toxicity assessments prepared by U.S. EPA Office of Water. The Agency did not rely on U.S. EPA Office of Water's draft toxicity assessments in its development of Part 620 PFAS standards.

PFAS Regulatory Coalition Question 9

Attached as Exhibits F, G and H are sets of comments submitted by 3M Corporation to EPA's Science Advisory Board ("SAB") concerning EPA draft risk assessments for PFAS substances. As to those aspects of the comments that relate to studies or methods that were used in deriving the levels specified in IEPA's proposal, please provide IEPA's response to those comments.

Agency Answer 9 (Carol Hawbaker)

For clarity, the comments attached as Exhibits F, G, and H and prepared by 3M Corporation, dated December 30, 2021, January 14, 2022, and February 10, 2021, respectively, were submitted to U.S. EPA's Science Advisory Board (SAB) in response to SAB's Notice of Public Meetings issued November 10, 2021, regarding draft updated PFOA and PFOS toxicity assessments prepared by U.S. EPA Office of Water. The Agency did not rely on U.S. EPA Office of Water's draft toxicity assessments in its development of Part 620 PFAS standards.

PFAS Regulatory Coalition Question 10

Attached as Exhibit I is a set of comments submitted by the National Council for Air and Stream Improvement, Inc. to EPA's Science Advisory Board ("SAB") concerning EPA draft risk assessments for PFAS substances. As to those aspects of the comments that relate to studies or methods that were used in deriving the levels specified in IEPA's proposal, please provide IEPA's response to those comments.

Agency Answer 10

For clarity, the comments attached as Exhibit I and prepared by the National Council for Air and Stream Improvement, Inc., dated December 22, 2021, were submitted to U.S. EPA's Science Advisory Board (SAB) in response to SAB's Notice of Public Meetings issued November 10, 2021, regarding draft updated PFOA and PFOS toxicity assessments prepared by U.S. EPA Office of Water. The Agency did not rely on U.S. EPA Office of Water's draft toxicity assessments in its development of Part 620 PFAS standards.

PFAS Regulatory Coalition Question 11

Attached as Exhibit J is a set of comments submitted by Toxicology Excellence for Risk Assessment to EPA's Science Advisory Board ("SAB") concerning EPA draft risk assessments for PFAS substances. As to those aspects of the comments that relate to studies or methods that were used in deriving the levels specified in IEPA's proposal, please provide IEPA's response to those comments.

Agency Answer 11
For clarity, the comments attached as Exhibit J and prepared by the Toxicology Excellence for Assessment, unsigned and undated, were submitted to U.S. EPA's Science Advisory Board (SAB) in response to SAB's Notice of Public Meetings issued November 10, 2021, regarding draft updated PFOA and PFOS toxicity assessments prepared by U.S. EPA Office of Water. The Agency did not rely on U.S. EPA Office of Water's draft toxicity assessments in its development of Part 620 PFAS standards.

PFAS Regulatory Coalition Question 12
IEPA has stated that the only USEPA-approved method for measuring PFAS in groundwater is SW-846 Method 8327. However, IEPA's proposal requires measurement of PFAS levels in all types of groundwater (including groundwater that is not used for drinking water supply, or which must be treated before drinking water use) with a different method, Method 537.1, which is approved only for use in measuring PFAS levels in drinking water. Please confirm that IEPA is requiring use of a method to measure compliance with all groundwater quality standards for PFAS substances that is not approved for measuring PFAS levels in groundwater.

Agency Answer 12
Samples collected to determine compliance with Part 620 Class I potable resource groundwater quality standards should be analyzed using a method that achieves the groundwater quality standard. Presently, the method is U.S. EPA Method 537.1.

Respectfully Submitted,

ILLINOIS ENVIRONMENTAL
PROTECTION AGENCY

Dated: May 6, 2022

By: /s/ Sara Terranova
Assistant Counsel
Division of Legal Counsel

1021 North Grand East
P.O. Box 19276
Springfield, Illinois 62794-9276
(217) 782-5544
sara.terranova@illinois.gov

CERTIFICATE OF SERVICE

I, the undersigned, hereby certify that I have electronically served **THE ILLINOIS ENVIRONMENTAL PROTECTION AGENCY'S PRE-FILED ANSWERS TO FOLLOW-UP QUESTIONS** on May 6, 2022, to the following:

Mr. Don A. Brown Clerk of the Board Illinois Pollution Control Board 100 West Randolph Street Suite 11-500 Chicago, Illinois 60601 Don.Brown@illinois.gov	Vanessa Horton Hearing Officer Illinois Pollution Control Board 100 West Randolph Street Suite 11-500 Chicago, Illinois 60601 Vanessa.Horton@illinois.gov
Renee Snow General Counsel Illinois Department of Natural Resources One Natural Resource Way Springfield, Illinois 62702 renee.snow@illinois.gov	Melissa Brown Hepler Broom LLC 4340 Acer Grove Drive Springfield, Illinois 62711 Melissa.brown@heplerbroom.com
Jorge T. Mihalopoulos, Head Assistant Attorney Jorge.mihalopoulos@mwrd.org Susan T. Morakalis, General Counsel morakaliss@mwrd.org J.Mark Powell, Senior Attorney PowellJ@mwrd.org Metropolitan Water Reclamation District of Greater Chicago 100 East Erie Street Chicago, Illinois 60611	Fredric P. Andes fandes@btlaw.com Barnes & Thronburg 1 North Wacker Drive Suite 4400 Chicago, Illinois 60606
Claire Manning Cmanning@bhslaw.com Anthony D. Schuering aschuering@bhslaw.com Brown, Hay & Stephens LLP 205 South Firth Street, Suite 700 PO BOX 2459 Springfield, Illinois 62705	Nessa Coppinger ncoppinger@bdlaw.com Daniel Schulson dschulson@bdlaw.com Matthew Schneider mschneider@bdlaw.com Beveridge & Diamon, PC 1900 N. St. NW Washington, DC 20036
Ellen F. O'Laughlin Ellen.Olaughlin@ilag.gov Jason James Jason.James@ilag.gov	Joshua R. More jmore@schiffhardin.com Bina Joshi bjoshi@schiffhardin.com

Assistant Attorney General 69 West Washington Street Suite 1800 Chicago, Illinois 60602	Sarah L. Lode slode@schiffhardin.com Schiff Hardin, LLP 233 South Wacker Drive Suite 6600 Chicago, Illinois 60606
James M. Morphew jmmorphew@sorlinglaw.com Sorling, Northrup, Hanna, Cullen & Cochran Ltd. 1 North Old State Capitol Plaza, Suite 200 PO Box 5131 Springfield, Illinois 62705	Stephen R. Risotto Senior Director, CPT srisotto@americanchemistry.com Michele Schoeppe Assistant General Counsel Michele_schoeppe@americanchemistry.com American Chemistry Council 700 2nd Street, NE Washington, DC 20002

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

Dated: May 6, 2022

By: /s/ Sara G. Terranova

Sara G. Terranova
Assistant Counsel
Division of Legal Counsel
Sara.Terranova@illinois.gov

1021 N. Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794
217-782-5544

Attachment

1

Attachment

2

Listing of groundwater management zones (GMZs) approved under Section 620.250(a),which have not expired, in response to the Board's follow-up questions regarding Agency answer to Board question 8(b).

Baldwin Fly Ash Complex	August 16, 2016
Duck Creek Ash Ponds 1 and 2	November 23, 2016
Hennepin West 1 & 3	November 8, 1997*, revised June 19, 2018
Hennepin East 2 and 4	November 8, 1996, revised May 2, 2019
Will County Station	Summer 2013[#]
Powerton Generating Station	October 3, 2013
Prairie Power Pearl Ash Pond	August 16, 2013
Prairie State Generating	October 28, 2014
Wood River Station	December 13, 2000, revised May 25, 2017
Venice Station	May 6, 2011
Hutsonville Station	March 30, 2017
Meredosia Station	November 1, 2017
Grand Tower Generating	November 15, 2019[%]
Joliet 29	August 8, 2013
Monterey Mine #2	June 24, 2002
Riola Mine	June 26, 2008
Springfield Coal, Crown III	December 12, 2019
Eagle 2 Mine	December 6, 2006
Macoupin Energy Shay #1	January 7, 2016
Peoples Gas	September 25, 2020[$]
Havana South Ash Pond	June 1996, Terminated May 22, 2009
Amoco (BP) Peoria Terminal	Began with ICO April 1991, GMZ 1999, Terminated December 9, 2016

*Hennepin: A reference to a November 8, 1997 approval was found in Agency records, but not the approval letter. The approved 2018 revision is in Agency records.

[#]Will County: A reference to an approval between July 2013 and October 2013 was found in Agency records, but not the approval letter.

[$]Peoples Gas: The GMZ approval included conditions that must be met to continue the GMZ

[%]A reference to a November 15, 2019 approval was found in Agency records, but not the approval letter.

Attachment

3

ATTACHED 2 (Lynn Dunnaway)

Agency proposed amendments to Part 620 in response to Board's follow-up questions regarding Agency Answers 8(g), 8(h), 8(p), 8(q), 9(d), 21(a), 21(b), 21(c), 21(e), 21(f) and 24:

TITLE 35: ENVIRONMENTAL PROTECTION
SUBTITLE F: PUBLIC WATER SUPPLIES
CHAPTER I: POLLUTION CONTROL BOARD

PART 620
GROUNDWATER QUALITY

SUBPART A: GENERAL

SUBPART B: GROUNDWATER CLASSIFICATION

SUBPART C: NONDEGRADATION PROVISIONS
FOR APPROPRIATE GROUNDWATERS

SUBPART D: GROUNDWATER QUALITY STANDARDS

Section

SUBPART E: GROUNDWATER MONITORING AND ANALYTICAL PROCEDURES

Section

SUBPART F: HEALTH ADVISORIES

Section

AUTHORITY: Implementing and authorized by Section 8 of the Illinois Groundwater Protection Act [415 ILCS 55/8] and authorized by Section 27 of the Illinois Environmental Protection Act [415 ILCS 5/27].

SOURCE: Adopted in R89-14(B) at 15 Ill. Reg. 17614, effective November 25, 1991; amended in R89-14(C) at 16 Ill. Reg. 14667, effective September 11, 1992; amended in R93-27 at 18 Ill. Reg. 14084, effective August 24, 1994; amended in R96-18 at 21 Ill. Reg. 6518, effective May 8, 1997; amended in R97-11 at 21 Ill. Reg. 7869, effective July 1, 1997; amended in R01-14 at 26 Ill. Reg. 2662, effective February 5, 2002; amended in R08-18 at 36 Ill. Reg. 15206, effective October 5, 2012; amended in R08-18(B) at 37 Ill. Reg. 16529, effective October 7, 2013.

Section 620.250 Groundwater Management Zone

a) Within any class of groundwater, a groundwater management zone may be established as a three-dimensional region containing groundwater being managed to mitigate impairment caused by the release of contaminants from a site:

1) That is subject to a corrective action process approved by the Agency; or

2) For which the owner or operator undertakes an adequate corrective action in a timely and appropriate manner and provides a written confirmation to the Agency. Such confirmation shall must be provided using Part 620.Appendix D with the information required by Section 620.250(g) attached in a form as prescribed by the Agency.

b) A groundwater management zone is established on the date of the Agency's written concurrence upon concurrence by the Agency that the conditions as specified in subsection (a) are met and groundwater management will continue continues for a period of time consistent with the action described in that subsection.

c) A groundwater management zone expires on the date of its written approval that upon the Agency's has received receipt of appropriate documentation, including 620.Appendix D, Part IV, which confirms the completion of the action taken pursuant to subsection (a) and which confirms the attainment of applicable standards as set forth in Subpart D. The Agency shall review the on-going adequacy of controls and continued management at the site if concentrations of chemical constituents, as specified in Section 620.450(a)(4)(B), remain in groundwater at the site following completion of such action. The review shall must take place no less often than every 5 years and the results shall be presented to the Agency in a written report.

1) The Agency may also determine that a groundwater management zone expires if a person with a groundwater management zone refuses or is financially unable to continue the agreed upon corrective action, or

2) The person with a groundwater management zone refuses to amend the currently approved corrective action to include additional measures that can be reasonably expected to result in significant improvement in groundwater quality related to the subject release.

d) Not withstanding subsections (a) and (b) above, a groundwater management zone as defined in 35 Ill. Adm. Code 740.120 may be established in accordance with the requirements of 35 Ill. Adm. Code 740.530 for sites undergoing remediation pursuant to the Site Remediation Program. Such a groundwater management zone shall remain in effect until the requirements set forth at 35 Ill. Adm. Code 740.530(c) are met.

e) While the groundwater management zone established in accordance with 35 Ill. Adm. Code 740.530 is in effect, the otherwise applicable standards as specified in Subpart D of this Part shall not be applicable to the "contaminants of concern", as defined at 35 Ill. Adm. Code 740.120, for which groundwater remediation objectives have been approved in accordance with the procedures of 35 Ill. Adm. Code 740.

f) Notwithstanding subsection (c) above, the review requirements concerning the ongoing adequacy of controls and continued management at the site shall not apply to groundwater within a three-dimensional region formerly encompassed by a groundwater management zone established in accordance with 35 Ill. Adm. Code 740.530 while a No Further Remediation Letter issued in accordance with the procedures of 35 Ill. Adm. Code 740 is in effect.

g) All groundwater management zone applications submitted pursuant to subsection (a) shall, in addition to 620.Appendix D, Parts I, II and III, contain the following:

1) Facility information. This includes the name, address, and county where the site is located.

2) Identification of specific units (operating or closed) present at the facility.

3) Maps and engineering drawings showing the facility and units at the facility.

4) Statement of the groundwater classification(s) at the facility.

5) Identification of the chemical constituents released to the groundwater.

6) Description of how groundwater will be monitored to determine the rate and extent of the release, and if it has migrated off site.

7) Schedule for investigation of the extent of the release.

8) Results of available soil testing and groundwater monitoring associated with a release, locations and depths of samples, and monitoring well construction details with well logs.

9) Remedy

A) Description of selected remedy and why it was chosen;

B) Results of groundwater contaminant transport modeling or calculations showing how the selected remedy will achieve compliance with the applicable groundwater standards;

C) Description of the fate and transport of contaminants with selected remedy over time; and

D) A statement of how groundwater at the facility will be monitored following implementation of the remedy to ensure that the groundwater standards have been attained.

10) Information requested by the Agency, necessary for its review of the groundwater management zone application.

h. At least annually, the Agency shall publish in the Illinois Environmental Register a listing of the groundwater management zones approved pursuant to Section 620.250(a) that have not expired, along with a brief statement of the groundwater management zone's status.

(Source: Amended at __ Ill. Reg. ______, effective __________)

(Source: Amended at, effective)

Section 620.APPENDIX D Confirmation of an Adequate Corrective Action and Groundwater Management Zone Application Pursuant to 35 Ill. Adm. Code 620.250(a)(1) and (a)(2)

Pursuant to 35 Ill. Adm. Code 620.250(a) if an owner or operator provides a written confirmation to the Agency that an adequate corrective action, equivalent to a corrective action process approved by the Agency, is being undertaken in a timely and appropriate manner, then a groundwater management zone may be established as a three-dimensional region containing groundwater being managed to mitigate impairment caused by the release of contaminants from a site. This document provides the form in which the written confirmation is to be submitted to the Agency.

Note 1. Parts I and II are to be submitted to IEPA at the time that the facility claims the alternative groundwater standards. Part III is to be submitted at the completion of the site investigation. At the completion of the corrective process, a final report is to be filed which includes the confirmation statement included in Part IV.

Note 2. The issuance of a permit by IEPA's Division of Air Pollution Control or Water Pollution Control for a treatment system does not imply that the Agency has approved the corrective action process.

Note 3. If the facility is conducting a cleanup of a unit which is subject to the requirements of the Resource Conservation and Recovery Act (RCRA) or the 35 Ill. Adm. Code 731 regulations for Underground Storage Tanks, this confirmation process is not applicable and cannot be used.

Note 4. If the answers to any of these questions require explanation or clarification, provide such in an attachment to this document.

Part I. Facility Information

Facility Name ______________________________

Facility Address ______________________________

County ______________________________

Standard Industrial Code (SIC) ______________________________

1. Provide a general description of the type of industry, products manufactured, raw materials used, location and size of the facility.

2. What specific units (operating or closed) are present at the facility which are or were used to manage waste, hazardous waste, hazardous substances or petroleum?

	YES	NO
Landfill	________	________
Surface Impoundment	________	________
Land Treatment	________	________
Spray Irrigation	________	________
Waste Pile	________	________
Incinerator	________	________
Storage Tank (above ground)	________	________
Storage Tank (underground)	________	________
Container Storage Area	________	________
Injection Well	________	________
Water Treatment Units	________	________
Septic Tanks	________	________
French Drains	________	________
Transfer Station	________	________
Other Units (please describe)		
______________________	________	________
______________________	________	________

3. Provide an extract from a USGS topographic or county map showing the location

of the site and a more detailed scaled map of the facility with each waste management unit identified in Question 2 or known/suspected source clearly identified. Map scale must be specified and the location of the facility must be provided with respect to Township, Range and Section.

4. Has the facility ever conducted operations which involved the generation, manufacture, processing, transportation, treatment, storage or handling of "hazardous substances" as defined by the Illinois Environmental Protection Act? Yes ___No ___ If the answer to this question is "yes" generally describe these operations.

5. Has the facility generated, stored or treated hazardous waste as defined by the Resource Conservation and Recovery Act? Yes___ No ___If the answer to this question is "yes" generally describe these operations.

6. Has the facility conducted operations which involved the processing, storage or handling of petroleum? Yes ___No ____If the answer to this question is "yes" generally describe these operations.

7. Has the facility ever held any of the following permits?

   a. Permits for any waste storage, waste treatment or waste disposal operation. Yes ___ No ___ If the answer to this question is "yes", identify the IEPA permit numbers.

   b. Interim Status under the Resources Conservation and Recovery Act (filing of a RCRA Part A application). Yes ___ No ___ If the answer to this question is "yes", attach a copy of the last approved Part A application.

   c. RCRA Part B Permits. Yes ___ No ___ If the answer to this question is "yes", identify the permit log number.

8. Has the facility ever conducted the closure of a RCRA hazardous waste management unit? Yes ___ No ___

9. Have any of the following State or federal government actions taken place for a release at the facility?

   a. Written notification regarding known, suspected or alleged contamination on or emanating from the property (e.g., a Notice pursuant to Section 4(q) of the Environment Protection Act)? Yes ___ No ___ If the to this question is "yes", identify the caption and date of issuance.

   b. Consent Decree or Order under RCRA, CERCLA, EPAct Section 22.2 (State Superfund), or EPAct Section 21(f) (State RCRA). Yes ___ No ___

c. If either of Items a or b were answered by checking "yes", is the notice, order or decree still in effect? Yes ___ No ___

10. What groundwater classification will the facility be subject to at the completion of the remediation?

Class I ____ Class II ___ Class III ____ Class IV ____
If more than one Class applies, please explain.

11. Describe the circumstances which the release to groundwater was identified.

Based on my inquiry of those persons directly responsible for gathering the information, I certify that the information submitted is, to the best of my knowledge and belief, true and accurate.

Facility Name	Signature of Owner/Operator
Location of Facility	Name of Owner/Operator
EPA Identification Number	Date

PART II: Release Information

1. Identify the chemical constituents release to the groundwater. Attach additional documents as necessary.

Chemical Description	Chemical Abstract No.

2. Describe how the site will be investigated to determine the source or sources of the release.

3. Describe how groundwater will be monitored to determine the rate and extent of the release.

4. Has the release been contained on-site at the facility?

5. Describe the groundwater monitoring network and groundwater and soil sampling protocols in place at the facility.

6. Provide the schedule for investigation and monitoring.

7. Describe the laboratory quality assurance program utilized for the investigation.

8. Provide a summary of the results of available soil testing and groundwater monitoring associated with the release at the facility. The summary or results should provide the following information: dates of sampling; types of samples taken (soil or water); locations and depths of samples; sampling and analytical methods; analytical laboratories used; chemical constituents for which analyses were performed; analytical detection limits; and concentrations of chemical constituents in ppm (levels below detection should be identified as "ND").

Based on my inquiry of those persons directly responsible for gathering the information, I certify that the information submitted is, to the best of knowledge and belief, true and accurate and confirm that the actions identified herein will be undertaken in accordance with the schedule set forth herein.

______________________________	______________________________
Facility Name	Signature of Owner/Operator
______________________________	______________________________
Location of Facility	Name of Owner/Operator
______________________________	______________________________
EPA Identification Number	Date

Part III: Remedy Selection Information

1. Describe the selected remedy.

2. Describe other remedies which were considered and why they were rejected.

3. Will waste, contaminated soil or contaminated groundwater be removed from the site in the course of this remediation? Yes ___ No ___ If the answer to this question is "yes", where will the contaminated material be taken?

4. Describe how the selected remedy will accomplish the maximum practical restoration of beneficial use of groundwater.

5. Describe how the selected remedy will minimize any threat to public health or the environment.

6. Describe how the selected remedy will result in compliance with the applicable groundwater standards.

7. Provide a schedule for design, construction and operation of the remedy, including dates for the start and completion.

8. Describe how the remedy will be operated and maintained.

9. Have any of the following permits been issued for the remediation?

   a. Construction or Operating permit from the Division of Water Pollution Control. Yes __ No ___

   b. Land treatment permit from the Division of Water Pollution Control. Yes ___ No ___ If the answer to this question is "yes", identify the permit number.

   c. Construction or Operating permit from the Division of Air Pollution Control. Yes ___ No ___ If the answer to this question is "yes", identify the permit number.

10. How will groundwater at the facility be monitored following completion of the remedy to ensure that the groundwater standards have been attained?

Based on my inquiry of those persons directly responsible for gathering the information, I certify that the information submitted is, to the best of my knowledge and belief, true and accurate and confirm that the actions identified herein will be undertaken in accordance with the schedule set forth herein.

Facility Name	Signature of Owner/Operator
Location of Facility	Name of Owner/Operator
EPA Identification Number	Date

PART IV: Completion Certification

This certification must accompany documentation which includes soil and groundwater monitoring data demonstrating successful completion of the corrective process described in Parts I-III.

Facility Name ______________________________

Facility Address ______________________________

____

County ______________________________

Standard Industrial Code (SIC) ______________________________

Date ______________________________

Based on my inquiry of those persons directly responsible for gathering the information, I certify that an adequate corrective action, equivalent to a corrective action process approved by the Agency, has been undertaken and that the following restoration concentrations are being met:

Chemical Name	Chemical Abstract No.	Concentration (mg/L)
______________________	______________	__________
______________________	______________	__________
______________________	______________	__________

______________________	______________________
Facility Name	Signature of Owner/Operator
______________________	______________________
Location of Facility	Name of Owner/Operator
______________________	______________________
EPA Identification Number	Date

(Source: Amended at 36 Ill. Reg. 15206, effective October 5, 2012)

Attachment

4

ATTACHMENT 3

PEORIA TERMINAL

and

HAVANA SOUTH ASH POND SYSTEM

GMZ EXPIRATION LETTERS

W1179010003
Electronic Filing: Received, Clerk's Office 05/6/2022

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276 • (217) 782-3397
BRUCE RAUNER, GOVERNOR   ALEC MESSINA, ACTING DIRECTOR

December 9, 2016

Mr. Greg Frisch, Operations Project Manager
Remediation Management Services Company
BP Products North America Inc.
1114 North Court Street #25
Medina, Ohio 44256

Re: Response to the Post Remedial Monitoring, Remedial Action Closure Report; Former Amoco Peoria Terminal, Dated October 14, 2016, Creve Coeur, Illinois

Dear Mr. Frisch:

The Illinois Environmental Protection Agency ("Agency") has reviewed the Post Remedial Monitoring, Remedial Action Closure Report ("RACR"), dated October 14, 2016, prepared by Stantec on behalf of BP Products North America, Inc. ("BP").

As demonstrated by the post remedial monitoring presented in the RACR and the previously submitted annual reports, BP has met applicable groundwater standards pursuant to 35 Ill. Adm. Code 620.450(a)(4)(A). Therefore, the groundwater management zone expires pursuant to 35 Ill. Adm. Code 620.250(c), and no further remedial activities are required.

Please insure that all remaining monitoring wells associated with this site (not including the community water supply wells) are properly abandoned pursuant to the Illinois Water Well Construction Code, 77 Ill. Adm. Code 920.120.

If there are further questions please contact Lynn Dunaway of my staff or me at (217) 785-4787.

Sincerely,

William E. Buscher

William E. Buscher, P.G.
Supervisor, Hydrogeology and Compliance Unit
Groundwater Section
Division of Public Water Supplies
Bureau of Water

cc:

Rebecca Burlingham, Sr. Assistant Attorney General
James Pickett, Esquire, BP

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276 – (217) 782-3397
JAMES R. THOMPSON CENTER, 100 WEST RANDOLPH, SUITE 11-300, CHICAGO, IL 60601 – (312) 814-6026

DOUGLAS P. SCOTT, DIRECTOR

W1250200004
06 J

May 22, 2009

Mr. Rick Diericx
Senior Director, Operations Environmental Compliance
Dynegy Midwest Region Operations
604 Pierce Boulevard
O'Fallon, Illinois 62269

Dear Mr. Diericx:

This letter is in response to Dynegy's "2008 Closure Work Plan Annual Report" (Annual Report) and cover letter for the Havana South Ash Pond System, received by the Illinois Environmental Protection Agency (Illinois EPA) on October 6, 2008.

In the cover letter, Dynegy requests that the Illinois EPA give written approval for the discontinuation of all Groundwater monitoring at the South Ash Pond site and provide a declaration of closure. Such action will cause the groundwater management zone (GMZ) established June 1996, in accordance with consent decree 89-CH-5, to expire.

Pursuant to 35 IAC 620.250(c):

A groundwater management zone expires upon the Agency's receipt of appropriate documentation which confirms the completion of the action taken pursuant to subsection (a) and which confirms the attainment of applicable standards as set forth in Subpart D.

The Annual Report provides data indicating that during the most recent five years of monitoring, four monitoring wells Well 04, Well 15, Well 23 and Well 25 have had boron and/or manganese concentrations higher than the Class I numerical groundwater standard. No other monitoring wells have exceeded the Class I numerical groundwater standards (35 IAC 620.410) during that time period.

Based on the data provided, Well 23 is within the outer most edge (620.240(f)(1)) of the closed impoundment. The applicable groundwater standard is Class IV groundwater. The Class IV groundwater standards are equal to existing concentrations (i.e. constituent concentrations must not increase). The monitoring data provided indicates that both boron and manganese concentrations show a decreasing trend in Well 23. Therefore, Well 23 appears to be in compliance with the applicable standards of 35 IAC 620.

While Well 25 is within 25 feet of the edge of the closed impoundment, available data indicates that the well is screened more than 15 feet below the base of the impoundment, and is therefore monitoring Class I groundwater. Wells 04 and 15 are down gradient and are also monitoring Class I groundwater. During the most recent five years of monitoring all three of these wells have had manganese concentrations higher than the Class I numerical groundwater standard.

Pursuant to 35 IAC 620.410(a)

Inorganic Chemical Constituents
Except due to natural causes or as provided in Section 620.450, concentrations of the following chemical constituents must not be exceeded in Class I groundwater:

Based on a review of the monitoring data provided and the conclusions of the 2002 EPRI report, the concentrations of manganese in these three wells appear to be due to natural aquifer conditions. Under these circumstances, Wells 04, 15 and 25 are in compliance with the applicable standards of 35 IAC 620.450(a)(4)(A), and no reporting pursuant to35 IAC 620.450(a)(5) is required.

Based on the Illinois EPA's review and interpretation of the data submitted by Dynegy, the requirements of 35 IAC 620.250(c) have been satisfied. Therefore, the Havana South Ash Pond GMZ shall expire as of the date of this letter. The Havana South Ash Pond is considered to be closed and no further monitoring or reporting is required pursuant to the GMZ.

I trust this responds to your needs. If you have further questions or concerns please contact Lynn Dunaway of my staff or me at (217) 785-4787.

Sincerely,

William E. Buscher

William E. Buscher, P.G.
Supervisor, Hydogeology and Compliance Unit
Groundwater Section
Division of Public Water Supplies
Bureau of Water

CC: Al Keller, BOW Permits
Connie Tonsor, DLC
Mike Garretson, CAS
Lynn Dunaway
Groundwater File

Dunaway, Lynn

From:	Davis, Thomas L [Thomas.L.Davis@dynegy.com]
Sent:	Monday, October 20, 2008 11:30 AM
To:	Dunaway, Lynn
Cc:	Diericx, Rick
Subject:	FW: Havana Power Station; South Ash Pond; Primary Cell
Importance:	High
Attachments:	Wel HA23.pdf

Lynn,

Good morning!

Please find attached and below the information that you requested during our telephone conversation last Thursday. I hope this information answers the questions that you had. If not, please contact me.

Have a great day!!

Thomas L. Davis, P.E.
Sr. Environmental Engineer
Operations Environmental Compliance
Dynegy Midwest Generation, Inc.
604 Pierce Blvd.
O'Fallon, IL 62269
Office No. 618-206-5931
Blackberry No. 217-519-1446
Fax No. 618-206-5891
9/80 Schedule "B"

From: Stuart Cravens [mailto:kelron@egix.net]
Sent: Friday, October 17, 2008 9:19 AM
To: Davis, Thomas L
Subject: Re: Havana Power Station; South Ash Pond; Primary Cell
Importance: High

Tom, answer to questions below.

(1) Well construction log for HA-23 is attached. Ground surface is 493.7 feet. Top and Bottom screen elevation is 440.7 to 450.7 feet (43 to 53 feet below ground surface).

(2) Ash in Primary Pond is on average about 30 feet thick and above the water table. Capping added another 3 to 4 feet of silty sand on top of the ash. Bottom elevation of ash is estimated between 453 and 457 feet.

(3) Original ground elevation at Primary Cell site is estimated at 463 to 464 feet.

Stu

----- Original Message -----
From: Davis, Thomas L
To: Stuart Cravens

Cc: Diericx, Rick ; Morris, Phil L
Sent: Thursday, October 16, 2008 3:16 PM
Subject: Havana Power Station; South Ash Pond; Primary Cell

Stu,

As you suggested in your September annual report, we requested that the IEPA declare the primary cell of the south ash pond system closed in the cover letter transmitting your report.

In response to our request, Lynn Dunaway in the Groundwater Section of the IEPA Division of Public Water Supplies called me this afternoon. He requested the following information:

(1) the construction log sheet for well no. 23. More specifically, IEPA would like to know the top and bottom elevations of the screen.

(2) the bottom elevation of the deposited ash, and

(3) the original ground elevation of the site where the primary cell is located.

I am certain you can provide the information requested in (1). Would you know or also have the information requested in (2) and/or (3)?

Thanks

Thomas L. Davis, P.E.
Sr. Environmental Engineer
Operations Environmental Compliance
Dynegy Midwest Generation, Inc.
604 Pierce Blvd.
O'Fallon, IL 62269
Office No. 618-206-5931
Blackberry No. 217-519-1446
Fax No. 618-206-5891
9/80 Schedule "B"

BORING HAMW-23

PROJECT: HAVANA ASH IMPOUNDMENT SITE
PROJECT NO: 1309-07-01
DATE: 4/21/93
DRILLING CONTRACTOR: WHITNEY & ASSOCIATES
DRILLING METHOD: 4.25 IN. HOLLOW STEM AUGER
SAMPLING METHOD: 2 FT. SPLIT SPOONS

INSPECTOR: PAUL MAYWOOD
WELL ELEVATION (FT):
DEPTH TO WATER (FT): 41.35 FT.
DATUM: MSL
LOCATION: STATION F

SPLIT SPOON SAMPLE DEPTH (ft)	BLOWS PER 6"	PERCENT RECOVERY
5-7	6,17 31,33	1.7
10-12	7,16 20,31	2.0
15-17	7,8 10,12	1.9
17-19	2,1 1,3	1.9
19-21	1,1 1,5	1.7
21-23	18,12 16,18	1.5
23-25	16,22 27,40	1.0
25-27	26,62 63,41	2.0
27-29	20,44 49,50	1.6
29-31	21,53 52,61	1.7

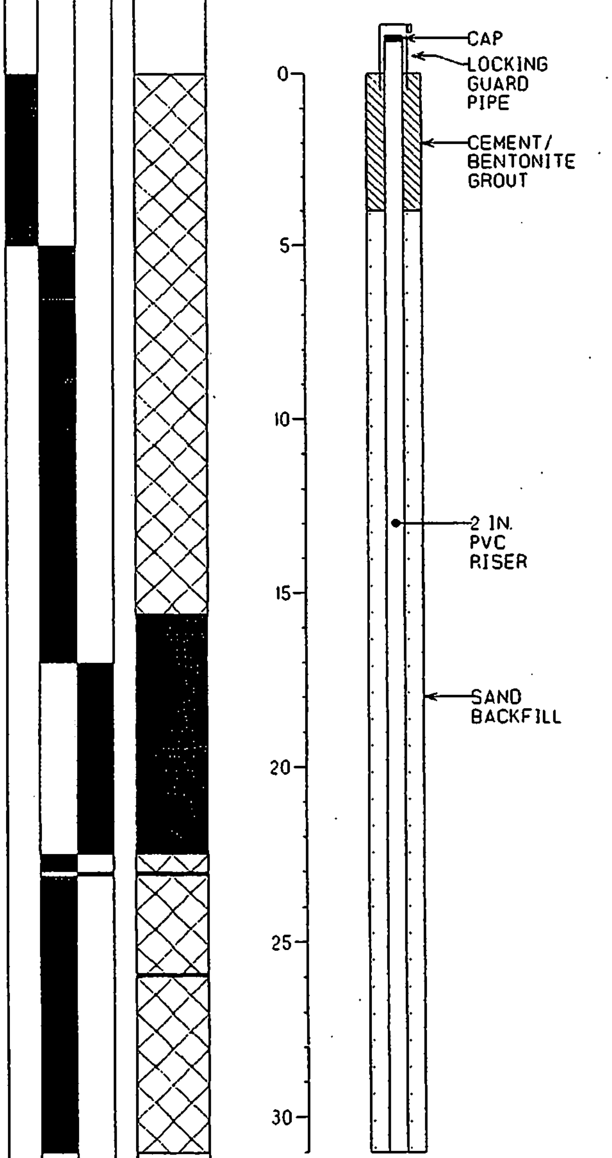
SOIL DESCRIPTION (color, density, SOIL,admixture, moisture, other notes, ORIGIN)

- Engineered FILL, brown, sandy.
- Brown to dark gray silty and sandy FILL, well compacted, almost bricklike in parts, very slightly moist in parts, thin dark gray to black bands.
- Light olive gray to dark grayish brown silty and sandy FILL, loose to medium stiff, mostly fairly compacted, slightly moist, some very silty zones, thin dark gray to black bands, no odor.
- FLY and BOTTOM ASH, light olive gray to very light gray cinders and stratified microdebris, moderately compacted, wood and coal fragments, moist with few wet zones, no odor.
- FLY and BOTTOM ASH, light olive gray to very light gray cinders and stratified microdebris, loose, wet, mostly silty texture, wood and coal fragments, no odor.
- Gray, wet to saturated.
- Yellowish brown silty and sandy FILL, loose, moderately compacted from 22.5 to 23, moist, no odor.
- Thin zone of saturated ASH at 23.
- Layer of ASH from 25.9 to 26.
- Orange-brown to brown, well compacted.
- Light brown sandy FILL, fine grained, loose, featureless, moist, no odor.

MOISTURE CONTENT: DRY | MOIST | WET — SAMPLE ANALYSIS — LITHOLOGY — DEPTH (FT.)

WELL CONSTRUCTION

WELL HAMW-23



ATLANTIC

BORING HAMW-23

PROJECT: HAVANA ASH IMPOUNDMENT SITE
PROJECT NO: 1309-07-01
DATE: 4/21/93
DRILLING CONTRACTOR: WHITNEY & ASSOCIATES
DRILLING METHOD: 4.25 IN. HOLLOW STEM AUGER
SAMPLING METHOD: 2 FT. SPLIT SPOONS

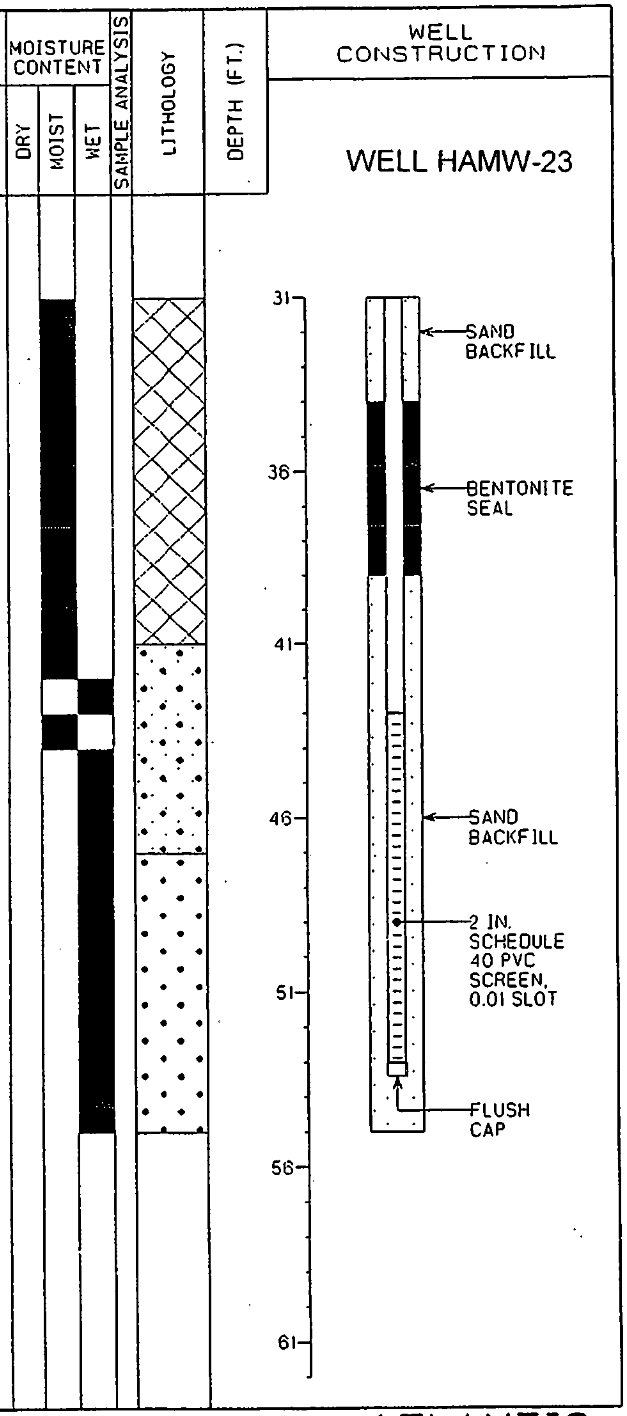
INSPECTOR: PAUL MAYWOOD
WELL ELEVATION (FT):
DEPTH TO WATER (FT): 41.35 FT.
DATUM: MSL
LOCATION: STATION F

SPLIT SPOON SAMPLE DEPTH (ft)	BLOWS PER 6"	PERCENT RECOVERY
31-33	18,41 76,67	1.8
33-35	17,41 89,67	1.9
35-37	20,44 59,57	2.0
37-39	21,43 57,59	1.6
39-41	4,17 16,19	1.4
41-43	7,8 10,9	1.7
43-45	5,6 6,7	1.5
45-47	4,5 5,6	1.8
47-49	6,7 9,10	1.3
49-51	6,8 8,14	1.0
51-53	14,21 23,26	0.8
53-55	9,14 9,7	0.8

SOIL DESCRIPTION

color, density, SOIL, admixture, moisture, other notes, ORIGIN

- Grading to light yellowish brown in parts, some zones very well compacted.
- Thin reddish brown zones at 33.1.
- Grading to brown.
- Grading to moderately reddish brown at 40.1.
- Dark brown fine to medium SAND with thin clay lenses, moist, no odor.
- Brown fine to medium SAND, subrounded, well sorted, wet at 43 grading to moist at 44.
- Brown fine to medium SAND, subangular, moderate to poorly sorted, loose, some varied color grains, wet to saturated, medium to coarse grained layer from 45.8 to 46.5, carbonaceous layer from 46.5 to 46.6.
- Brown to light yellowish brown medium to coarse SAND, angular to subangular, poorly sorted, loose, saturated, poorly cemented, some varied color grains, no odor.
- Brown medium to coarse SAND, angular to subangular, poor to moderately sorted, saturated, poorly cemented, fine grained in parts, no odor.
- Light brown medium to coarse SAND with silt matrix, angular to subangular, poorly sorted, saturated, trace fine to medium rounded to subrounded gravel, poorly cemented, fine grained in parts, some varied color grains, no odor.
- TO 55



Dynegy Midwest Region Operations
A Division of Dynegy Inc.
604 Pierce Boulevard
O'Fallon, IL 62269

DYNEGY

September 30, 2008

Illinois Environmental Protection Agency
P. O. Box 19276
Springfield, Illinois 62794-9276

Attn: Mr. William Buscher
Supervisor, Hydrology and Compliance Unit
Groundwater Section; Division of Public Water Supplies
Bureau of Water

Dear Mr. Buscher:

Havana Power Station;
South Ash Pond System;
2008 Closure Work Plan Annual Report

In accordance with the "Schedule of Modeling and Reporting Events" section of Dynegy Midwest Generation, Inc's. (DMG's) Closure Work Plan (CWP) for its Havana Power Station South Ash Pond (SAP), approved by the Illinois Environmental Protection Agency (IEPA) on June 27, 1996, and the amendment to the CWP approved by the IEPA on July 31, 1998, DMG is submitting two copies of its 2008 Annual Report. This report reviews boron, manganese, and groundwater elevation data that have been collected since 1993 and compares that data to the model predictions. Also enclosed is a diskette containing the annual groundwater monitoring data in electronic format.

Groundwater at the SAP has followed the predictive modeling. Boron concentrations in all downgradient compliance monitoring wells are in compliance with the Class 1 groundwater standard (2.0 mg/L). Manganese concentrations have been researched by EPRI and their results demonstrate that most of the observed manganese exceedances of the Class 1 standard (0.15 mg/l) at the SAP are from naturally-occurring manganese unrelated to the presence of the SAP. In 2008, the manganese concentrations in one wells – no. 15 –exceeded the standard. Based on the EPRI research report, which was completed and submitted to the IEPA in September 2002, Dynegy concludes that manganese concentrations in the groundwater downgradient from the SAP that currently exceed Class 1 standards are unlikely to meet the standard in the future due to naturally-occurring factors unrelated to the presence of the SAP.

For these reasons, Dynegy is requesting herein that it be allowed to discontinue all groundwater monitoring at the South Ash Pond site effective December 31, 2008. Dynegy is also requesting herein that the IEPA declare in writing that the primary cell of the South Ash Pond system is "closed" and that no further groundwater monitoring is required.

Should you have any questions regarding the report or attached data, please feel free to call me at 618-206-5912 or Tom Davis at 618-206-5931.

Sincerely,

DYNEGY MIDWEST GENERATION, INC.

Rick Diericx
Sr. Director, Operations Environmental Compliance

Enclosures

<u>File Location</u>
H:\Groundwater\HAVANA\September 2008 South Ash Pond Closure Work Plan Annual Report Letter of Transmittal.doc

bc: A.K. Millis - Havana Power Station (w/o attachment)
J.B.Watson - Havana Power Station
B. Hensel - Natural Resources Technology, Inc. (w/o attachment)
S. Cravens - Kelron Environmental (w/o attachment)
P.Morris/T.L.Davis/Groundwater File – O'Fallon, IL Office
B. Voelker - Decatur, IL Environmental Laboratory
Rick Diericx Reading File (w/o attachment) – O'Fallon, IL Office

Attachment

5

REPORT OF INVESTIGATION NO. 11 1951

STATE OF ILLINOIS

ADLAI E. STEVENSON, *Governor*

IRRIGATION IN ILLINOIS

W. J. ROBERTS

DEPARTMENT OF REGISTRATION AND EDUCATION

C. HOBART ENGLE, *Director*

STATE WATER SURVEY DIVISION

A. M. BUSWELL, *Chief*

URBANA, ILLINOIS

(Printed By Authority of State of Illinois)

REPORT OF INVESTIGATION NO. 11 **1951**

STATE OF ILLINOIS

ADLAI E. STEVENSON, ***Governor***

IRRIGATION IN ILLINOIS

W. J. ROBERTS

DEPARTMENT OF REGISTRATION AND EDUCATION

C. HOBART ENGLE, ***Director***

STATE WATER SURVEY DIVISION

A. M. BUSWELL, ***Chief***

URBANA, ILLINOIS

(Printed By Authority of State of Illinois)

CONTENTS

SUMMARY

During the 1950 and 1951 growing seasons a survey was made to determine the extent of irrigation practiced in Illinois and the relation of irrigation water demands to existing municipal and industrial water needs.

Field inspection located 164 places where irrigation water is pumped. Further information indicated that there are approximately 40 additional irrigation systems in operation at various times throughout the state. The 164 systems have a total pumping capacity of over 25, 000 gallons per minute. Forty-five percent of the pumpage is from groundwater sources and fifty-five percent from rivers, ditches, lakes and ponds.

The area of the state receiving irrigation is estimated at 9000 acres devoted to five principal crops: truck, flowers, pasture, forestry and corn. This represents an investment of over $500, 000 in irrigation equipment. Forty-five percent of this acreage is located in eastern Cook and eastern Kankakee Counties and is devoted to truck and gladioli crops. Nearly all the systems are composed of sprinklers and aluminum pipe. Users are experimenting with sprinkler discharge for specific crops and better ways of moving pipe. The number of irrigation systems in the state is steadily increasing.

This report has not included data on design or agricultural aspects of irrigation since these are already covered in the literature. A few articles on these subjects are listed under References.

ACKNOWLEDGEMENT

Material for this report has been obtained by field investigations and through the cooperation of the following representatives of irrigation equipment manufacturers: John Effa, Chicago; John Terpstra, Munster, Indiana; and E. G. Young, Woodstock. Two agricultural engineering students working in this field at the University of Illinois, George Vriend and Arnold Moodie, contributed the names of a number of growers who use irrigation equipment. Eighty-five of the state farm advisers cooperated through a questionnaire in adding data and verifying information already obtained. The report was prepared under the supervision of H. E. Hudson, Jr., Head of the Engineering Subdivision of the Survey.

INTRODUCTION

The land that is artifically watered in Illinois is probably not more than five per cent of the acreage receiving supplemental irrigation in the midwest; which, in turn, is a small area when compared to the irrigated land in the western states. Climatic laws govern this distribution; whereas a large percentage of irrigated land in the western states would be barren without efficiently operated irrigation projects, most of the land in the central states has had a good record of productivity. Thus irrigation has not been a necessity in Illinois.

Use of irrigation systems in Illinois has' been limited to farmers who have seen that supplemental moisture would materially increase the cash return from their land. They look upon irrigation systems as instruments for increasing yields rather than ensuring them. Obviously a farmer growing hybrid seed corn at $7 to $12 pex bushel can afford to invest several thousand dollars per field in a modern sprinkling system. With care he may double his yield a-nd pay off* his investment in one or two normal years. But the average Illinois corn grower would probably retire his investment only through the increased yield during extended periods of drouth.

Truck farmers show a great appreciation for supplemental irrigation. Critical deficiencies in rainfall can arise at any time during the growing season, and the application of one-half inch of moisture at a critical point during the growing season may forestall a complete crop loss.

One group of gladioli growers in Kankakee County has used irrigation equipment for over 25 years. These growers were convinced that supplemental irrigation is an absolute necessity, because the main crop, gladioli, and secondary crops, require more moisture than is normally available from precipitation durin g the growing season.

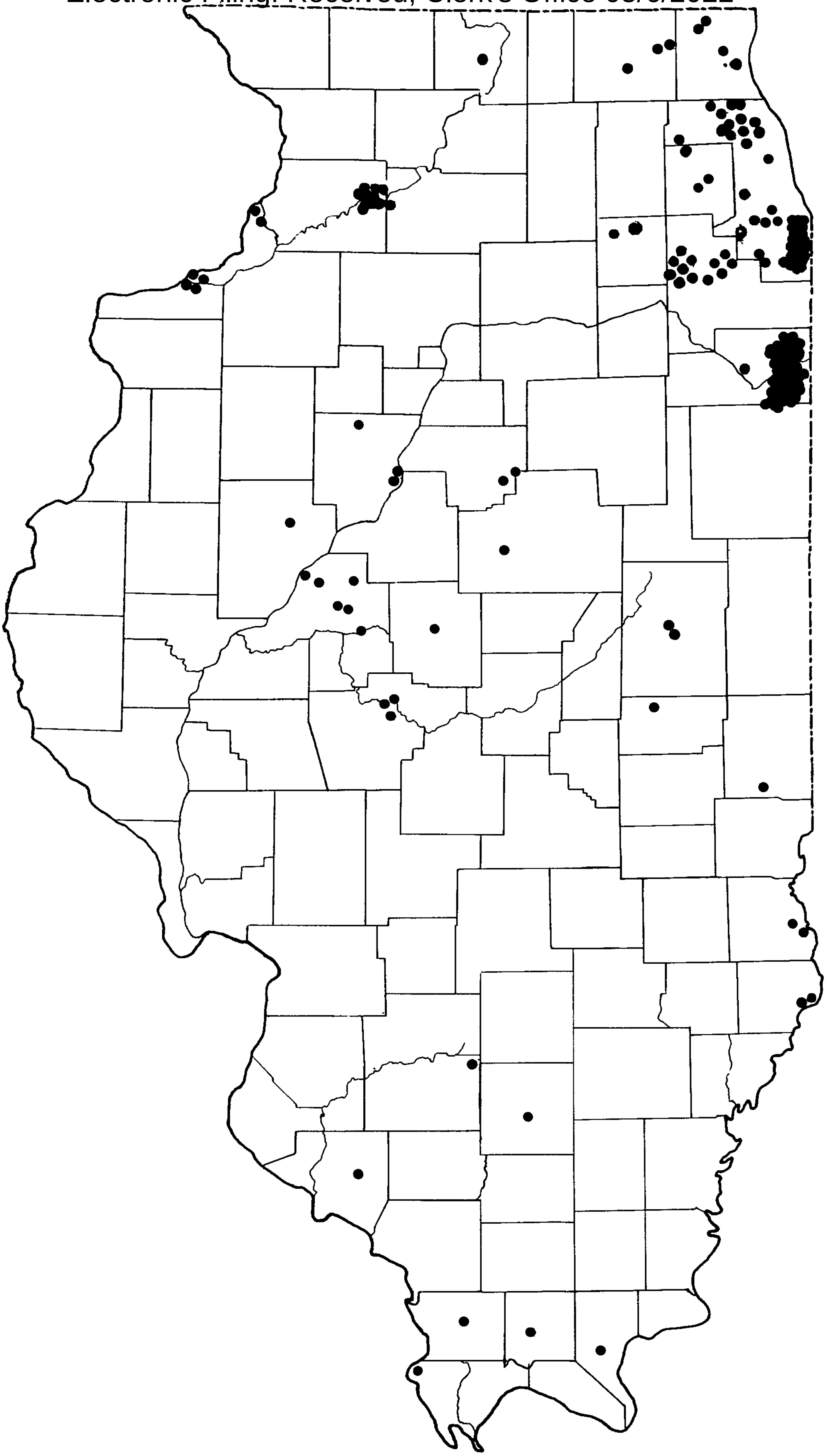


FIGURE 1. LOCATION OF IRRIGATION SYSTEMS IN ILLINOIS.

EXTENT OF IRRIGATION

Irrigation has been practiced in Illinois in certain areas for 25 years or more. Some of the gladioli growers in Kankakee County have been supplementing natural rainfall with well water since 1926. The University of Illinois and many nurseries have operated experimental plots and areas devoted to irrigation of small trees. Golf courses have equipment for watering greens and fairways, and many factories and residences regularly water their lawns. Since this study was initiated for the purpose of determing the amount of crop irrigation carried on in Illinois, fringe agricultural activities are omitted.

A survey of Illinois irrigation systems was started in the summer of 1950. Data on installations were obtained from irrigation equipment companies, farmers, farm advisers and other interested persons. From this information and field inspections made in the summer of 1951, 164 systems were located in the state. Forty additional systems are reported to be operated occasionally but no data on them have been obtained.

It is estimated that a total of 9000 acres is irrigated in Illinois. The 164 systems have an installed pumping capacity of over 25,000 gallons per minute. Fifty-five percent of the pumpage is from rivers, ditches, lakes or ponds and forty-five percent is from wells.

Figure 1 shows the locations of irrigation systems in Illinois. The greatest concentration appears to be in an area of three square miles north of St. Anne, Kankakee county, and in eastern Cook County north and east of Chicago Heights. Over 4000 acres receive irrigation in these two areas. In addition, about forty separate systems are located in Cook, DuPage and Will Counties. Most of these are near Joliet or north of Des Plaines.

A few systems are installed in Lake and McHenry Counties, and one new system has been operated in Winnebago County. A farmer in Boone County was reported to have irrigated potatoes for two growing seasons prior to 1940 but no record of later irrigation at this location is available.

There are at least ten systems in the vicinity of Sterling and Rock Falls, and six in Rock Island County.

Twenty systems are scattered through ten Central Illinois Counties and a few are found near the Wabash River in Crawford and Lawrence Counties. One grower in McLean County irrigated over 200acres of tomatoes for three successive growing seasons but discontinued irrigation in 1950 and moved his equipment to Georgia.

Four systems were located in the American Bottoms area in Madison and St. Clair Counties. One near McDaniel Lake was operated for several years prior to 1947 when the owner died. Another located on an island in Horseshoe Lake has not been used for several years. Two other systems are owned by horse-radish growers **but** they are seldom used.

There are isolated systems located in seven southern Illinois counties. One of these is located in Pope County and is operated by the University of Illinois Dixon Springs Experiment Station.

Figure 2 indicates the distribution of irrigation systems by crops in Illinois. Approximately 48 percent water truck crops and 36 percent irrigate the gladioli fields in Kankakee County. Ten percent irrigate pasture, mostly in northern Illinois and 3 percent water hybrid corn fields in Central Illinois. Another 3 percent of the systems irrigate nursery stock. Some of the specific truck crops being irrigated in the State are: mint, tomatoes, potatoes, strawberries, melons and onions. A few orchards also use irrigation systems.

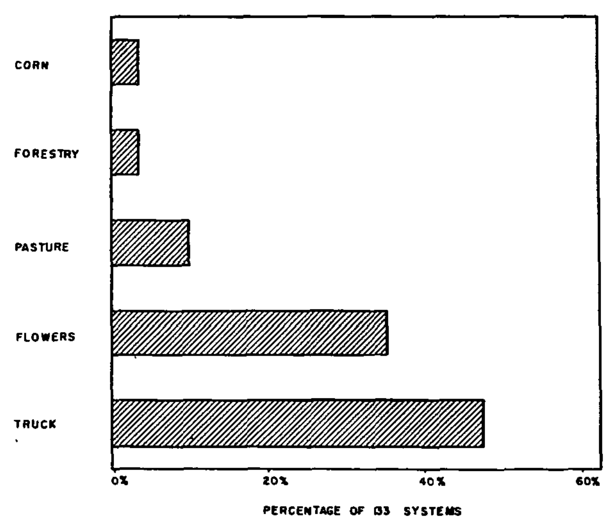


FIGURE 2. DISTRIBUTION OF IRRIGATION SYSTEMS BY CROPS.

NEED FOR IRRIGATION EQUIPMENT

Although irrigation is a relatively new agricultural practice in Illinois, it is filling a definite need for many farming groups. The gladioli growers in Kankakee County would not be without their systems. Those few growers in the area who depend entirely upon natural precipitation for a good crop are considered lucky by some of their better-equipped neighbors when their crops compare with the irrigated flowers. The sandy loam soil covering the area, is a major factor here in necessitating supplemental sprinkling; but these growers feel they cannot take a chance on lack of natural moisture during the growing season and therefore value their irrigation equipment highly.

Certain nurseries could not start some of their seedlings without additional precipitation provided by overhead sprinkling systems. Some of these systems are installed permanently as an inherent part of the nursery. At the Mason State Tree Nursery 45 of the 80 acres in the nursery are watered by a permanently installed irrigation system.

Onion and potato growers in southeast Cook County have invested heavily in sprinkler irrigation systems. The amount of water available for irrigation during a dry spell in this area is not sufficient to meet the demand when all irrigation pumps in the area are operated. In 1948 there were water shortages in two drainage ditches serving several irrigation systems in this area during a dry period in the early growing season. Fortunately these deficiencies were largely offset by above-normal precipitation during the late spring and summer and no appreciable deficiency in rainfall has occurred in this area since that time. There will be strong competition for the water available when the next drouth makes itself felt.

Truckfarmers in the Sterling region generally rate the value of their sprinkling systems highly, as do isolated vegetable and fruit growers scattered throughout the stage.

FIGURE 4. FIVE ACRE PASTURE IRRIGATION FIELD AT UNIVERSITY OF ILLINOIS DIXON SPRINGS EXPERIMENTAL STATION.

Two promising crops to irrigate are pastures and hybrid corn. The University of Illinois has irrigated a five-acre pasture plot at the Dixon Springs Experiment Station in southern Illinois for over three years. An adjoining five-acre pasture plot is used for control. Irrigation, in combination with fertilizer, is being tested to prevent permanent wilting of grass and allow more livestock to use pasturage during summer droughts.

A hybrid seed corn producer at El Paso, Illinois has used irrigation to increase yield of his corn and also to foster the growth of alfalfa between the corn rows. One important indirect advantage due to irrigation has been the watering of alfalfa directly after seeding. During the spring of 1950 the alfalfa planted in one 160-acre field was brought through a 3-week dry spell by constant irrigation. When the dry spell was followed by excessive precipitation, the surrounding fields were badly eroded, whereas the irrigated field had a cover of alfalfa which resisted erosion and profited from the rains.

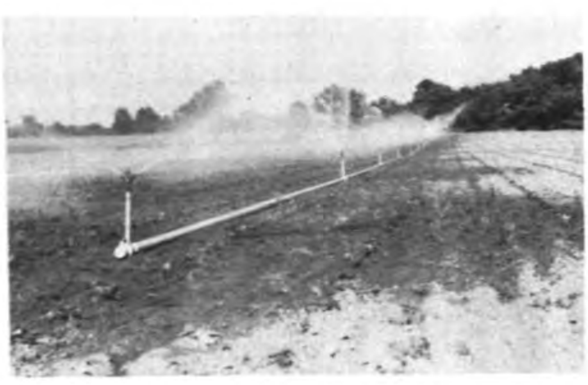


FIGURE 3. IRRIGATING STRAWBERRY PLANTS, SANGAMON COUNTY, ILLINOIS.

FIGURE 5. PORTABLE ENGINE-DRIVEN IRRIGATION PUMP, McLEAN COUNTY, ILLINOIS.

SOURCES OF IRRIGATION WATER

Supplying water for irrigation systems in Illinois presents varied problems. Over 40 per cent of the systems are located in two areas of the northeast part of the state. Approximately 50flower growers and truck farmers in eastern Kankakee County obtain groundwater from rock wells. The average well is 100to 150feet deep, 6 inches in diameter and the pumping level of the water is within 25 feet of the ground surface.

There are over 30 irrigation systems in the area east and north of Chicago Heights. They depend upon drainage ditches and ponds for their water supply. During periods of drouth, pumps for two or three of the systems can almost drain two of the ditches running through the area without satisfying the demand.

Approximately 20 systems are operated in other outlying sec tions of the Chicago area. These depend upon wells, ponds and ditches for their water. The systems operated in Lake and McHenry Counties in northeast Illinois, with one notable exception, use surface water. The exception is the C. J. Papas farm in McHenry County where a gravel well 75 feet deep is reported to provide up to 1,000 gallons per minute. The non-pumping water level at this point is 20 feet below the ground surface.

The irrigation systems in the Rock River valley near Sterling , obtain water from sand points. Little water is taken directly from the river for irrigation. In the Rock Island area three vegetable growers use city water while a fourth uses a pond as a source of water.

The remaining systems scattered throughout the state use whatever supply is available. At Sherman, Sangamon County, C. B. Mayfield uses a series of ponds, two of which canbe kept full by pumping from the Sangamon River. Six miles west at the Jefferies Orchards, a pond was constructed as an irrigation supply for watering strawberries. At the farm of the Lincoln State School and Colony, Logan County, five acres of corn are irrigated by using the City of Lincoln water supply, which also serves the institution.

A groundwater development for irrigation in Illinois is taking place near El Paso where Lester Pfister has two large areas of hybrid seed corn under cultivation. One 160-acrefie Id south of town has a well centrally located with pump and dieselengine installed in a frame building. Prior to drilling the wells, five test holes, each 120 feet deep, were bored to obtain information on character and extent of the water-bearing formation. The cost of test boring was £1170. The we1I, 12-inches in diameter and 113 feet deep, cost $3750. This includes a 60-slot screen, 24 feet long, and 90 feet of 12-inch casing. Pumping equipment consists of 750 gallon per minute turbine pump and Diesel engine which cost $8,640 installed.

The distribution system consists of 2340 feet of 6-inch steel main line pipe and twelve special couplers. This line is buried and bisects the field in a north-south direction. Laid on the surface in an east-direction are 20 lines of 6-inch welded steel laterals each 1170 feet long, three-inch pipe risers and caps are spaced every 260 feet to supply 10 sprinkler nozzles. Cost of the distribution system including welding and labor costs to lay all pipe was $23,990.

The total cost of the complete irrigation system was £37,400. This works out a cost of about £250 per acre for this system.

For puposes of comparison it may be noted that the Dixon Springs Experiment Station irrigation system, which was designed for 5 acres, and has a capacity of 300 gallons per minute, cost £1,000. This amounts to a cost of approximately £200 per acre. According to one manufacturer's representative, the average cost of an irrigation system, using 1951 prices, is $72.00per acre. It would seem from other data that this latter figure is more nearly representative for average conditions.

FIGURE 6. IRRIGATION PUMP ON C. J. PAPAS FARM McHENRY COUNTY.

LEGAL RIGHTS TO WATER

The ancient law regulates man to so use his property that no injury is done to neighbors. This limits riparian owners to a reasonable use of the water of a stream with due regard to the needs and rights of all other riparian land owners. Such use infers that the natural size, flow and purity of the stream shall be protected against any material diversion or pollution.

The law also defines the rights of adjoining land owners to use of waters resulting from natural rainfall and melting snow before they reach well-defined channels. These are called surface waters. One land owner may use or retain as much surface water as he desires and thus prevent any of it from flowing upon or percolating into adjacent land. However, he may not deflect it or artificially drain it off onto adjoining land where it does not flow under natural conditions. This is the reasonable use doctrine.

Illinois is using its groundwater more intensively than surface water. Illinois groundwaters have provided adequate water supplies for over 75 years, but at certain locations concentrated extractions have created growing problems. The Illinois Courts have held that percolating water is as much a part of the land as the other materials beneath the surface. The land owner has a right to use the well water on his property regardless of the effect on his neighbor's well. The Supreme Court in 1899 adopted this rule in the case of the Edward v. Haeger, 180 Ill. 99. While some states have limited this common-law rule to what is referred to as reasonable use of the land owner's percolating water, the Illinois Courts have not. The owner who has the most powerful irrigation pumps, or the most favorable hydrologic situation, has the legal right to render wells on surrounding property useless.

Until the Illinois Legislature speaks on water rights, the common-law prevails. However in **1945** the State Water Resources and Flood Control Board was created by Act of trie Illinois Legislature, Section 1 of the Act declared that "The general welfare of the people of this state requires that the water resources of the state be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such water is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare. The right to water or to the use of flow of water in this state is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not

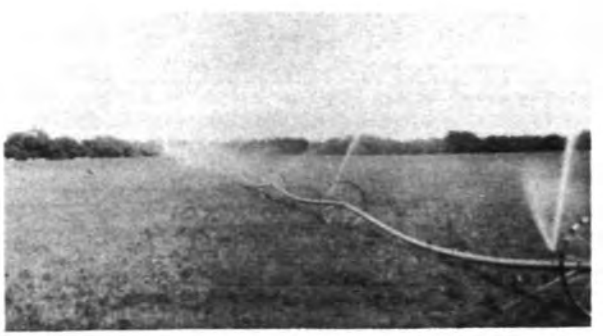


FIGURE 7. THIS 600 FOOT LATERAL, SUPPORTED BY WHEELS, IS MOVED BY ONE MAN USING A RATCHET MECHANISM.

and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water".

The Board of Water Resources and Flood Control has been given power to "arbitrate and provide ways and means for the equitable reconciliation and adjustments of various conflicting claims and rights to water by various users and uses", but no actual test cases have been brought either to Court or to the Board.

In January 1950, the President's Water Re------- Policy Commission was established under the Executive Order 10095. The Commission has studied and made recommendations to the President regarding desirable legislation or changes in existing legislation relating to the development, utilization, and conservation of water resources. Legislative proposals based on these recommendations have been drafted but are not available as yet.

In the meantime irrigation equipment dealers, who have had experience with the water rights in western states, are urging their customers to record with their County Clerks the sources and amount of water they are removing for irrigation purposes. Any future water policy might be expected to recognize the rights of prior usage provided such use is within the doctrine of "reasonab1e use" enunciated but not implemented in 1945.

FIGURE 8. PERMANENTLY INSTALLED OVERHEAD SPRINKLER SYSTEM AT STATE TREE NURSERY, MASON COUNTY.

QUALITY OF IRRIGATION WATER

The purpose of irrigation is to increase the productivity of crops by replenishing the root-zone reservoir of the soil. The quality of irrigation water effects the growth of plants by altering the status of the soil where the plant is growing. There is considerable variation in composition and concentration of dissolved minerals in natural waters. Too high a mineral content is harmful and a high proportion of sodium to hardness (calcium and magnesium) causes a soil to become sticky, undrainable and hard. Hard water, on the other hand, keeps a soil softandfriable. There is sufficient normal precipitation in Illinois to prevent excessive salting of the soil by highly mineralized irrigation water. However, for efficient management of an irrigation project, attention should be given the water quality by periodic chemical analyses of both the source water and the soil.

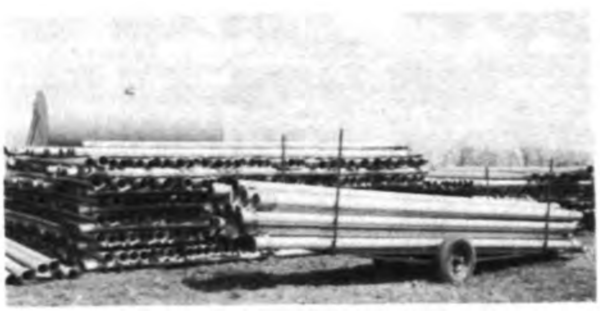


FIGURE 9. IRRIGATION PIPE USED TO DISTRIBUTE WATER TO FIELDS PRODUCING HYBRID CORN NEAR EL PASO, ILLINOIS.

DISTRIBUTION OF PRECIPITATION

The normal annual precipitation over Illinois varies from approximately 30 inches in the north to 48 inches in the south. Approximately 59 per cent of this moisture is received during the growing season, which begins in southern Illinois in early April and about May 1 in northern Illinois and continues into October. There is generally a maximum of precipitation in either March, May or June.

During the wettest years on record, average precipitation has been 149 per cent of normal, whereas the average during the driest years has been 65 per cent of normal. During the growing season, rainfall has averaged 58 per cent of normal for the driest years and 151 per cent for the wettest years.

Figure 10 shows the Illinois normal precipitation for the 45 year period 1898 to 1942.

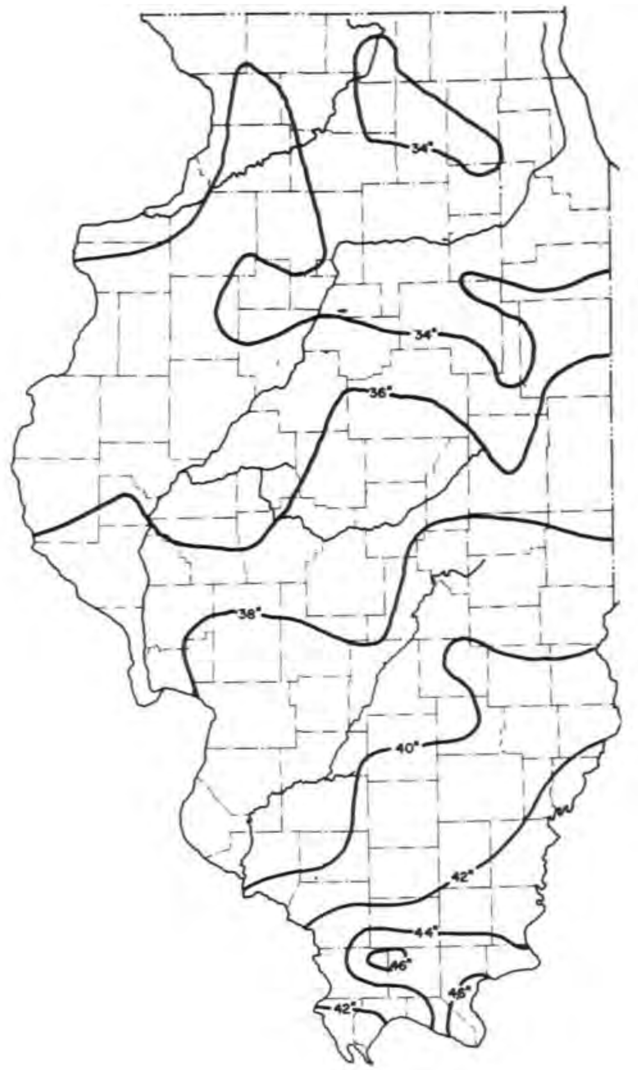


FIGURE 10. ILLINOIS STANDARD PRECIPITATION. DATA FROM UNITED STATES WEATHER BUREAU FOR 45-YEAR PERIOD 1898-1942.

FIGURE 11. PASTURE IRRIGATION ON C. J. PAPAS FARM, McHENRY COUNTY.

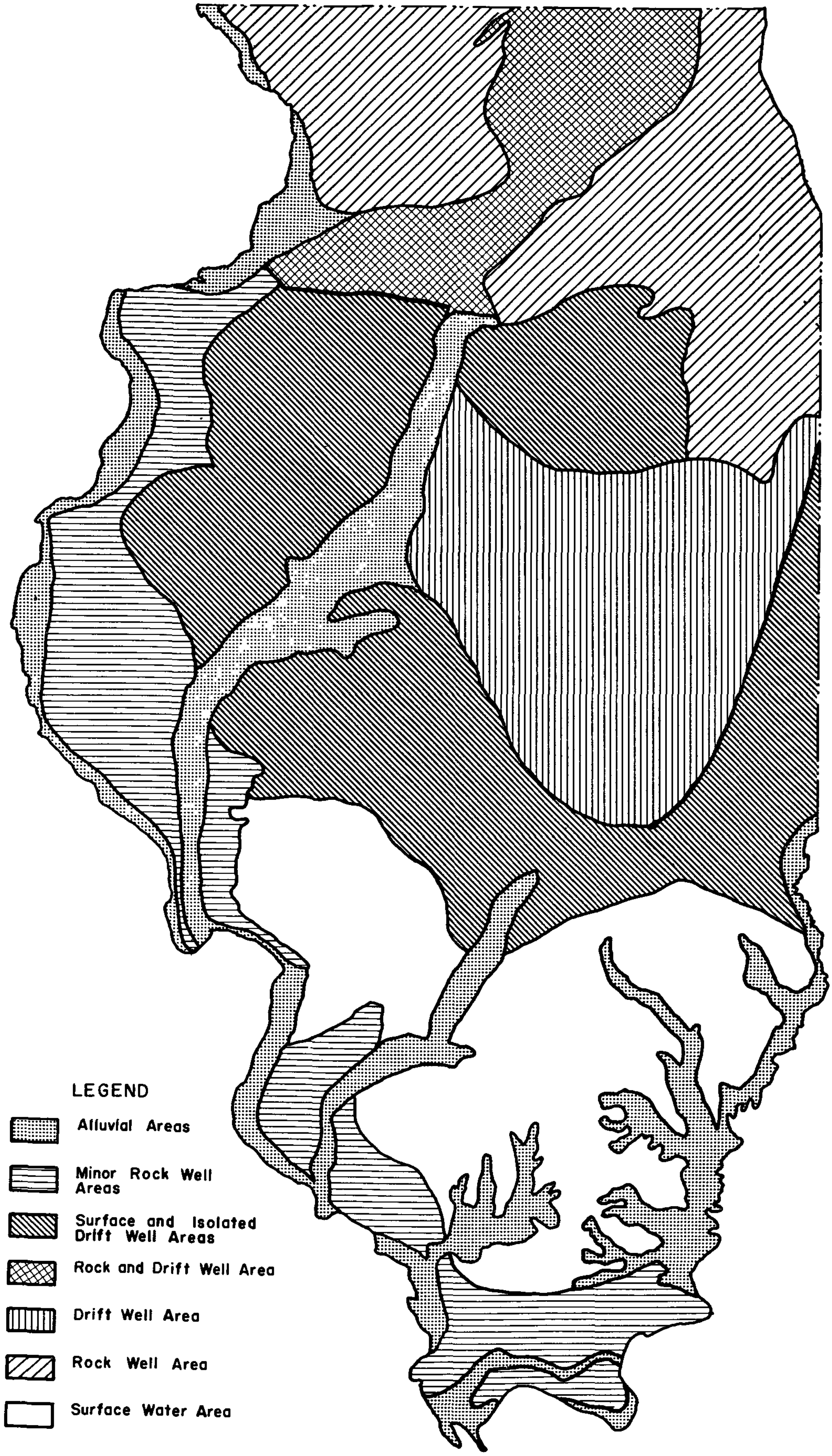


FIGURE 12. WATER RESOURCES IN ILLINOIS.

WATER RESOURCES AVAILABLE FOR IRRIGATION

It is significant that the most important irrigation installations in Illinois are located in areas of moderate to adequate water resources.

Figure 12 shows the principal sources of water supplies in the State. The legend indicates the more reliable water sources and not necessarily the sources now being used. For example, while most irrigators in the northern one-third of the State use surface water at present, they would probably find it necessary to obtain groundwater during an extended dry period. In this are the wells vary in depth from 20 to 1500 feet depending upon whether they are finished in shallow sand or deep rock aquifers. Wells penetrating the deep rock aquifers in the Chicago region have non-pumping levels from 300 to 450 feet below the ground surface.

Most systems in the Chicago areamake use of surface water because it is generally less expensive to pump. The truck farmers in eastern Cook County use surface water because adequate low cost groundwater supplies are not available. The irrigation water is pumped from drainage ditches which provide an adequate supply during years of normal rainfall but fail to meet the demands of all irrigators who need water during a drouth. Lansing Ditch which parallels the Illinois-Indiana State line in T. 35 N., R., 15 E., has a drainage area of 8. 3 square miles. A stream-gaging station measures the flow at the boundary line between Sections 8 and 17. Close to this point farmers have irrigation installations that require 3000 gallons per minute. During years of normal precipitation Lansing Ditch has a mean flow of 12 second-feet (1949-1950), or 5400 gallons per minute.

FIGURE 13. 1000 GALLONS-PER-MINUTE IRRIGATION PUMP AND DIESEL ENGINE INSTALLATION NEAR EL PASO, ILLINOIS.

FIGURE 14. THIS NOZZLE SPRAYS 750 GALLONS-PER-MINUTE ON CORN FIELD NEAR EL PASO, ILLINOIS.

Deer Creek, with a drainage area of 24. 4 square miles, has a gaging station 1. 5 miles northeast of Chicago Heights. In 1949 the ditch had a mean flow of 10.4 second feet and 22.5 second feet in 1950. During a large part of both growing seasons its flow was approximately 4 second feet which was one-tenth of the available irrigation pumping capacity in the area.

In these situations, it is evident that the low flows in the waterways are not sufficient to supply the simultaneous needs of those equipped to draw from them. At present there is no system for scheduling the withdrawals by the various irrigators; in fact, the question as to whether there is enough water for all under a schedule of taking has not been investigated.

The Water Survey is the major sponsor of the cooperative stream-gaging program carried onin Illinois by the United States Geological Survey. Under this program, stream flow is systematicallymeasured at 172 locations in the state and on its borders. Records of these measurements are available at the Water Survey office and at the office of the United States Geological Survey, Champaign.

In southeastern Kankakee County practically all the growers with irrigation systems use drilled wells because groundwater at shallow depths is available and practically no surface water sources have been developed. Elsewhere in the northern third of the State, water is taken directly from streams, pond's, or through shallow sand points near rivers.

In much of Central Illinois water may be obtained from drift wells or from sand points in river bottoms. In places where drainage ditches are used the supply available for irrigation depends almost entirely on rainfall and may be unreliable during dry periods.

The southern one-third of Illinois has good groundwater deposits only at isolated locations. In many part of the area small ponds and res - ervoirs maybe constructed to impound a limited amount of water for irrigation purposes. Water may be obtained from shallow wells in the alluvial valleys of the Mississippi, ohio, Cache , and Wabash Rivers.

The development of an adequate source of water for a specific irrigation project requires a detailed hydrologic and economic study beyond the scope of this paper.

Adetailed groundwater study should include collection of all available data on wells in the area. A program of test hole drilling should be undertaken to determine the occurrence and characteristics of the water-yielding formations. A pumping test of the well finally constructed is valuable if accompanied by careful measurements of flow and water levels in the pumped well and of water levels in nearby observation wells. Regular observations ofwell water levels should parallel the extraction of groundwater so that the effect of pumping and the safe yield of the water-bearing formation may be determined.

Requests for water resource information at specific locations will be answered by spe------- - prepared reports on the available resources. In the case of groundwater information these reports are prepared in cooperation with the Illinois State Geological Survey.

Information on groundwater and surface water supplies for all parts of Illinois is available at the offices of the State Water Survey, Box 232, Urbana.

CONCLUSION

The present maximum use of water by irrigation systems in Illinois is only 0.0006 percent of the combined municipal and industrial use.

At present, irrigation does not compete for water with municipal and industrial demands , and there are no trends toward increasing use that cause concern.

However, there are areas in which future intensive development of irrigation could seriously tax the available resources.

REFERENCES

The following have been chosen as representative of literature available.

The Status of the Common-Law, by W. O. Pendarvis. Report to State Water Survey, 1948.

Legal Rights to Water Sources in Illinois, by H. E. Hudson, Jr. , The Illinois Engineer, April 1948.

Illinois Farm Drainage Law, by H. W. Hannah, Circular 660, University of Illinois, College of Agriculture.

The Quality of Water for Irrigation Use, Technical Bulletin No. 962, U. S. Department of Agriculture, September 1948.

The Climate of Illinois, by John L. Page. Bulletin 532. Agricultural Experiment Station, University of Illinois, Urbana, 1949.

The Influence of Supplemental Irrigation on Corn Yields in Indiana by O. W. Luetkemeier and Helmut Kohnke, Soil Science Society of America Proceedings (1949) Vol. 14, 1950.

Summary of Sprinkler Irrigation Research in the Humid Region, by F. W. Peikert, mimeographed from Proceedings of December 20, 1950 meeting, American Society of Agricultural Engineers.

Investigation of Pasture Irrigation, Experiment 19, Dixon Springs Experiment Station, University of Illinois, Urbana, Illinois

Many pump companies manufacture irrigation pumps and have literature available.

Designing A Portable Sprinkler Irrigation System, Stout Irrigation, Inc. Kenton Station, Portland, Oregon.

Sprinkler Irrigation Handbook, Rain Bird Sprinkler Mfg. Corporation, Glendora, California.

Irrigation Equipment, by H. D. Bruhn and O. I. Berge, mimeographed report. Department of Agricultural Engineering, College of. Agriculture, University of Wisconsin, Madison Wisconsin.

Agricultural Sprinklers, Circular No. 449, The Skinner Irrigation Company, Troy, Ohio.

Aluminum Automatic Irrigation Pipe Couplings, Circular, Champion Corporation, Hammond, Indiana.

"Effect-O-Rain", Bulletin No. 6, Irrigation Equipment Co. , Inc. , Eugene, Oregon.

Irrigation principles and Practices by Orson W. Israelsen, John Wiley & Sons, Inc. , New York, 1950.

Irrigation Engineering, Volume 1., by Ivan E. Houk, John Wiley & Sons, Inc. , New York, 1951.

Profits from Pipelines, by John Strohm, September 1949 issue of Country Gentleman, Curtis Publishing Company.

Also articles in Prairie Farmer, Farm Journal, Capper's Farmer, The Nation's Agriculture, Illinois Agricultural Association Record.

REPORTS OF INVESTIGATIONS

ISSUED BY THE STATE WATER SURVEY

No. 1. Temperature and Turbidity of Some River Waters in Illinois. 1948.

No. 2. Groundwater Resources in Winnebago County, with Specific Reference to Conditions at Rockford, 1948.

No. 3. Radar and Rainfall. 1949.

No. 4. The Silt Problem at Spring Lake, Macomb, Illinois. 1949.*

No. 5. Infiltration of Soils in the Peoria Area. 1949.

No. 6. Groundwater Resources in Champaign County. 1950.

No. 7. The Silting of Ridge Lake, Fox Ridge State Park, Charleston, Illinois. 1951*

No. 8. The Silting of Lake Chautauqua, Havana, Illinois. 1951.

No. 9. The Silting of Carbondale Reservoir, Carbondale, Illinois. 1951.

No. 10. The Silting of Lake Bracken, Galesburg, Illinois. 1951.

No. 11. Irrigation in Illinois. 1951.

No. 12. The Silting of West Frankfort Reservoir, 1951.

No. 13. Studies of Thunderstorm Rainfall with Dense Raingage Networks and Radar. 1951.

*Out of print.

Attachment 6

The 2012 Drought in Illinois

H. Vernon Knapp, James R. Angel, Jennie R. Atkins, Luke Bard, Elias Getahun, Kenneth J. Hlinka, Laura L. Keefer, Walton R. Kelly, George S. Roadcap

Report of Investigation 123

ILLINOIS STATE WATER SURVEY
PRAIRIE RESEARCH INSTITUTE

ILLINOIS STATE WATER SURVEY
Prairie Research Institute
University of Illinois at Urbana-Champaign

Front cover: *Dry conditions on the Sangamon River as viewed from the Old Route 48 Bridge near Monticello.*

The 2012 Drought in Illinois

H. Vernon Knapp, James R. Angel, Jennie R. Atkins, Luke Bard, Elias Getahun, Kenneth J. Hlinka, Laura L. Keefer, Walton R. Kelly, George S. Roadcap

Report of Investigation 123

ILLINOIS STATE WATER SURVEY
Prairie Research Institute
University of Illinois at Urbana-Champaign
2204 Griffith Drive
Champaign, Illinois 61820-7463
http://www.isws.illinois.edu

Suggested citation:
Knapp, H. V., J. R. Angel, J. R. Atkins, L. Bard, E. Getahun, K. J. Hlinka, L. L. Keefer, W. R. Kelly, and G. S. Roadcap. 2017. The 2012 Drought in Illinois. Illinois State Water Survey Report of Investigation 123. Champaign, IL.

CONTENTS

Tables

Figures

Chapter 1: Identifying and Characterizing Drought in Illinois

Introduction

Drought severity is generally defined by its impacts (Changnon et al., 1996). Such impacts can range from comparatively short-term effects on agriculture and horticulture to long-term effects on shallow groundwater and surface water supplies, and include a variety of associated socio-economic losses and environmental damages. As described in this report, the primary impact of the 2012 drought in Illinois was to agriculture. Significant precipitation deficits, leading to much-reduced soil moisture and worsened by extreme high temperatures, stressed crops, pasture, and livestock. Corn yields in particular were noticeably reduced throughout large portions of the state, and some of that crop was tainted with aflatoxins. The drought also posed concerns about water resources and water supply that may have developed into greater specific threats had the drought lasted longer. The developing potential for water supply shortages was lessened, and in some cases removed entirely, after abundant precipitation produced by the remnants of Hurricane Isaac occurred at the end of August 2012. Fish kills associated with low stream levels, high water temperatures, or algal blooms were reported in numerous streams and rivers. In a few cases in northeastern Illinois, water quality treatment problems emerged related to excessively high amounts of algae in rivers. Although the drought also diminished rural groundwater supplies and caused navigation concerns on some major rivers, ultimately the overall impacts to these resources were limited by the relative brevity of the drought.

This report focuses on 1) the scientific data that describe the climatic and hydrologic conditions during the drought; 2) analyses and descriptions of drought impacts; and 3) the interpretative steps taken by the Illinois State Water Survey (ISWS) to identify the emerging drought conditions in the 2012 spring and early summer, leading to an official declaration by the Governor's Office and State Water Plan Task Force and the convening of the Governor's Drought Response Task Force (DRTF).

A previous report, *The Drought of 2012* (IDNR, 2013), was jointly prepared by the Illinois Department of Natural Resources (IDNR) and DRTF, focusing on state agency activities and responses during the drought, general impacts, and associated technical and policy issues for Illinois agencies.

Although impacts are the central theme of any drought, they do not often provide the most consistent quantitative measures regarding the severity and historical context of a drought. Impacts can vary substantially depending on locality and the timing and duration of the drought's precipitation deficit. Human-related factors can also change over the years, making it difficult to directly compare the effects of different drought events. For example, crop yields are often the best available measure regarding agricultural impacts, but yield totals and their drought susceptibility have changed substantially over time with improvements in hybrids. Similarly, over time, water supply systems can become more or less susceptible to drought effects as a community's population and industry change, or as supplemental supplies become available or unavailable.

For this reason, scientists also turn to long-term climatological and hydrological records for comparison when characterizing the relative severity of a drought. Measures of the 2012 drought (climatic or hydrologic measurements taken during the drought and their associated statistics) are used to describe the drought; for example, 1) the statewide precipitation from January to July 2012 was the third driest such period when compared to historical records dating back to 1895; and 2) 5 of the 15 wells in the ISWS's shallow groundwater monitoring network experienced record low water levels for several months during the 2012 drought. Although measures such as these are important for providing reference points and context in describing the drought, they do not necessarily correspond directly or correlate to specific impacts associated with the drought. Thus it remains problematic to characterize a drought's severity with either a single metric or category of impact. In this report, an attempt has been made to distinguish between such quantitative measures of drought with the actual impacts to humans or the environment.

Drought Indices and Terminology

There is no uniformly accepted terminology for drought. The U.S. Drought Monitor (USDM) has become the most widely accepted source for identifying drought conditions in the United States, and uses what appears to be easy-to-understand drought severity levels (progressing from "abnormally dry" to "exceptional drought"). But, as described later in this section, a "severe" drought in Illinois, as classified by the USDM, in many instances, can represent a somewhat common event that produces few notable impacts. Thus, depending upon the index or source, a given drought or dry episode could be described as being anywhere in the range from a moderate to severe or extreme drought event.

The common characteristic of drought, regardless of location, is the associated lack of precipitation. Thus, the available metrics or indices to describe drought severity are typically based mostly or entirely on meteorological measurements. Three such indices and their application to Illinois conditions are described in this chapter.

Precipitation Deviation from Normal

Changnon (1987) proposed two categories of precipitation (or meteorological) drought severity for Illinois: "moderate drought" and "severe drought." These two categories are defined by the departure of precipitation from the expected average over specified time periods as identified in Table 1.1. Changnon (1987) also placed an areal-expanse requirement on the precipitation deviation, indicating that the size of the region falling below the precipitation thresholds defined in Table 1.1 should be more than

Table 1.1 Severity of Illinois Precipitation Droughts (Changnon, 1987) Expressed as a Percent of Normal Precipitation

Duration (months)	Moderate drought (%)	Severe drought (%)
3	45–60	≤44
6	56–70	≤55
12	70–80	≤69
24	78–90	≤77

Table 1.2 Severe Droughts in Illinois Using the Changnon Criteria, 1900–2015

Based on Statewide Normal Precipitation		
1901–02	1936	1976–77
1908	1940–41	1988–89
1914–15	1953–54	2005–06
1930–31	1963–64	2012
1933–34		
Additional Regional Droughts Covering at Least 40 Percent of Illinois (based on climate division normal precipitation)		
1923	1980–81	
1944–45	1992	

40 percent of the state. It can be argued that the percentages for the three-month and six-month periods in Table 1.1 should apply to the warmer seasons of the year when precipitation is normally at its greatest. Because normal precipitation is low in the fall and winter, it is difficult to create much of a precipitation deficit during those seasons. For example, the statewide normal total precipitation from December through February is 6.97 inches; a precipitation of 60 percent of normal would relate to a three-month precipitation deficit of just 2.79 inches. Meanwhile, the normal total precipitation from June through August is 11.85 inches; 60 percent of that summer normal would yield a much larger deficit of 4.75 inches. Easterling and Changnon (1987) noted this problem in their study with many three-month drought periods starting in the fall season, but that this was, "to some extent, an artifact of the drought definition technique" of using percentages of normal instead of precipitation deficits from normal. In addition, the demands on soil moisture are greatly reduced during the colder months of the year after crops are harvested and vegetation becomes dormant.

If only warm season precipitation values are used for shorter durations, then a moderate drought, as defined by Changnon (1987), would be expected to have a cumulative precipitation deficit of 5 inches or more. Similarly, a severe drought would be expected to have a precipitation deficit of at least 7 inches for a three-month period, 10 inches for a six-month period, and 12 inches for a 12-month period. Consequential impacts to groundwater and surface water resources are typically associated with sizeable cumulative precipitation deficits (Winstanley et al., 2006). ISWS hydrologists have informally noted that a 10-inch deficit is a rough threshold for encountering such water resource impacts.

From precipitation frequency maps provided in Changnon (1987) for a 12-month period, it can be suggested that moderate droughts occur roughly once in four to five years for each individual climate region across Illinois. Similarly, severe droughts occur on average about once in eight years in southern and central Illinois and once in 10 years in northern Illinois. Table 1.2 lists the drought years that qualify as severe events based on the Changnon criteria. The 1999–2000 drought fell slightly outside of the criteria envelope for regional drought.

Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) is calculated based on precipitation and temperature data, as well as a calculated local available water content (awc) of the soil based on that data. The objective of the PDSI is to provide measurements of moisture conditions that were standardized so that comparisons using the index could be made between locations and between months. It is most effective at indicating impacts sensitive to soil moisture conditions, such as agriculture (Willeke et al., 1994). The index was developed by W.C. Palmer in 1965, and was the first comprehensive drought index developed in the U.S. (National Drought Mitigation Center). The PDSI is purely a quantitative index and thus is not influenced by either perceived conditions or observed drought impacts. The four categories of drought corresponding to the PDSI are "mild drought" (-1 to -1.99), "moderate drought" (-2 to -2.99), "severe drought" (-3 to -3.99), and "extreme drought" (-4 or less).

The National Oceanic and Atmospheric Administration (NOAA) defines nine climate divisions in Illinois, shown in Figure 1.1, that are used to aggregate and report regional climate data. The U.S. Department of Agriculture (USDA) also uses these same divisions as crop reporting districts. Table 1.3 describes the number of years since 2000 in which at least one climate division in Illinois has been designated by the PDSI as being in drought. Extreme drought has occurred in at least one climate division of Illinois in five years, representing four separate events: 2000, 2003, 2005–2006, and 2012. From 2000 to 2015, each individual climate division has received an extreme drought classification at least once and up to three separate years with an average value of roughly two such droughts for each division. Thus, for the 16 years, the extreme PDSI drought classification is expected to occur for each division roughly once in eight years on average.

Similarly, for each climate division the PDSI severe drought classification has occurred an average of three times during the 16 years (roughly once in five years) and the moderate drought classification an average of 5.7 times (once in three years). At least one division has experienced a severe PDSI drought in 8 of the 16 years, and a moderate PDSI drought in 13 of the 16 years.

Table 1.3 Number of Years (2000–2015) Each Illinois Climate Division Has Been Identified as Being in Drought, According to the PDSI

Drought Severty	NW	NE	W	C	E	WSW	ESE	SW	SE
Extreme	2	3	3	3	1	1	1	1	1
Severe	2	4	4	3	4	5	2	3	1
Moderate	4	5	9	7	4	5	5	6	6

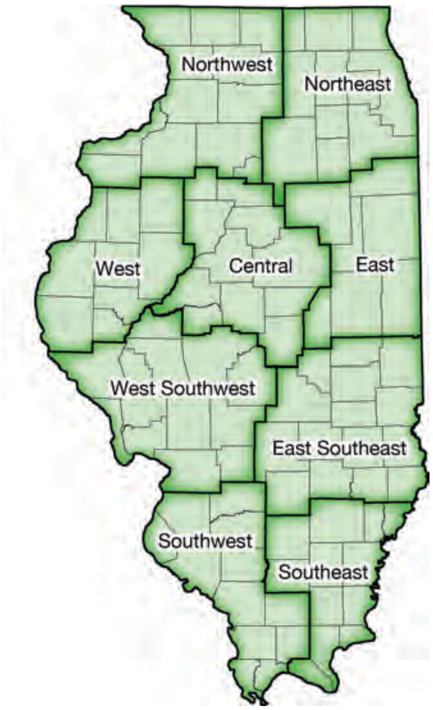


Figure 1.1 Illinois Climate Divisions

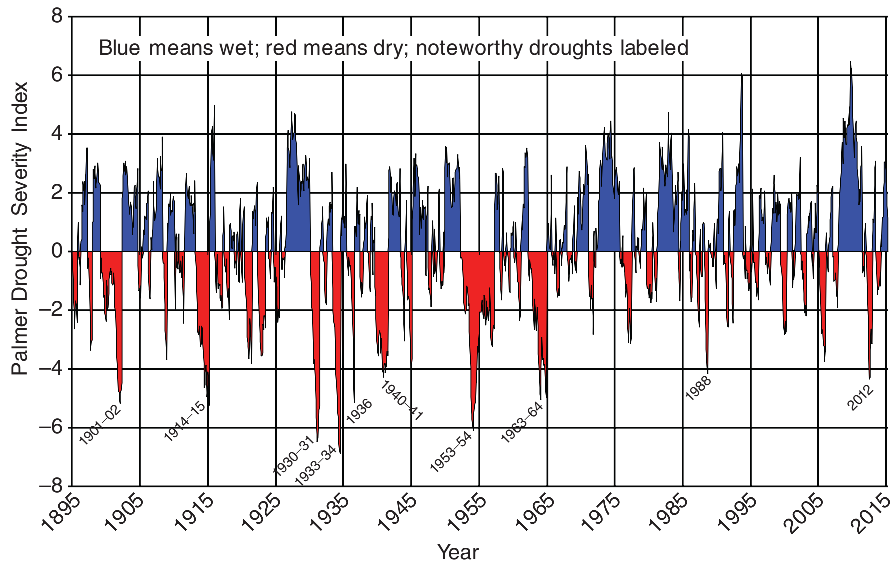


Figure 1.2 Monthly Palmer Drought Severity Index values for Illinois using statewide-averaged data, 1895–2015

Historical PDSI values Figure 1.2 provides the calculated PDSI values for the 1895–2015 period using statewide averages. As shown in this figure, 10 historical drought events (1901–1902, 1914–1915, 1930–1931, 1933–1934, 1936, 1940–1941, 1953–1954, 1963–1964, 1988, and 2012) are shown to have PDSI values of less than -4, considered extreme drought. Thus, such droughts may be expected to occur roughly once in 10 to 11 years on average.

When the PDSI values are examined for individual climate divisions in Illinois for the 1900–2015 period, the PDSI's extreme classification is shown to occur for 10 additional drought events, giving a total of 21 events (Table 1.4). However, this list is irrespective of which region of Illinois was affected by an event.

Whereas an extreme PDSI drought might be expected to occur once in 10 to 11 years on average for any specific region of Illinois, the list in Table 1.3 indicates that an extreme PDSI drought might be expected to occur *somewhere* in Illinois roughly once in five to six years.

Table 1.4 indicates that from the mid-1960s through the 1990s, a reduced frequency of PDSI extreme droughts occurred. Also, since the mid-1960s there have been fewer multi-year drought events, and the average number of climate divisions per event has been reduced. The number of climate divisions shown in Table 1.4 measures the areal extent of a drought but not that drought's severity or impact. This tendency for less frequent droughts is reflected in the statewide precipitation records as well. The records show the average annual precipitation in the first 64 years of the 20th century to be 9 percent drier than the average annual precipitation since 1965.

Table 1.4 Drought Events Classified as Extreme by the PDSI for One or More Climate Divisions in Illinois, 1900-2015

Drought Event	CDs*
1901-1902	7
1908-1909	5
1910-1911	3
1914-1915	8
1920-1921	3
1923	2
1930-1931	9
1933-1934	9
1936	7
1940-1941	5
1944-1945	5
1953-1954	6
1956-1957	3
1963-1964	8
1977	2
1981	1
1988-1989	5
2000	1
2003	1
2005-2006	4
2012	8

*CDs = Number of Illinois Climate Divisions with an Extreme Classification

Comparison to the Changnon (Precipitation Deviation) Categories When the PDSI and Changnon (1987) drought classifications are compared, it is obvious that the designated moderate and severe categories do not match up well and occur with different frequencies. However, this is primarily a difference related to terminology. When comparing drought events listed in Tables 1.2 and 1.4, the events listed for the Changnon severe category appear to match up very well with the PDSI extreme category. Furthermore, when computed using statewide data, the PDSI extreme category occurs with roughly the same frequency as the Changnon severe category (once in 8 to 11 years). Similarly, the PDSI severe category occurs roughly as often as the Changnon moderate category (once in five years).

As will be discussed later with regards to the Illinois Drought Response Task Force, drought conditions were officially "declared" in Illinois during three separate events over the past 16 years: 1999–2000, 2005–2006, and 2012. In retrospect, the PDSI extreme category appears to effectively coincide with the occurrence of official drought conditions in Illinois for most cases. However, the timing of the PDSI extreme designation tends to be delayed, coming after a drought would have already been recognized by state agencies, scientists, and water managers. For example, during the 2012 drought, the PDSI extreme category was not designated for Illinois until the end of July. With the 2005 drought, the extreme designation (for northern Illinois) did not occur until October of that year, four months after the State of Illinois had already declared the existence of the drought. Similarly, for the 1999–2000 drought, the extreme designation (west-southwest Illinois) did not occur until March 2000. Thus, the PDSI extreme designation is not very effective for identifying the onset of drought. That designation, however, does appear to do well during the later stages of drought, identifying continuing dry conditions such as associated with lingering hydrologic effects.

U.S. Drought Monitor

The U.S. Drought Monitor is a composite index that includes a number of quantitative indicators including the PDSI, the standardized precipitation index, soil moisture modeling results, and observed streamflow. In addition, the USDM also considers qualitative assessments (local reports) from a large number of expert observers including State Climatologists; thus it is not strictly a quantitative product. As described by the USDM literature, "the community of drought observers lends credibility to the state-of-the-art blend of science and subjectivity that goes into the map." The USDM is produced jointly by the National Drought Mitigation Center, the USDA, and the NOAA.

The USDM uses five levels of drought severity, beginning with abnormally dry (D0), to moderate (D1), severe (D2), extreme (D3), and ending with exceptional (D4) and highlights these levels on a color map. The USDM map indicates whether drought is short-term (S), fewer than six months in duration, and primarily affecting agriculture, or long-term (L), more than six months, and affecting hydrology, ecology, and water supplies.

The USDM was initiated in January 2000. Table 1.5 lists the number of instances since that time when the individual climate divisions of Illinois have been categorized as in moderate drought (D1) to exceptional drought (D4). Only those instances are listed when at least half (50 percent) of the climate division had reached the designated level of drought, with one exception. The exceptional (D4) drought occurrence in 2012 in southeastern Illinois is listed here, but in fact was estimated to have covered only 49 percent of the SE climate division.

As designated by the USDM, there have been only two extreme droughts in Illinois, in 2005–2006 and 2012. The 2005–2006 drought was primarily located in northern and west-central Illinois, and thus the extreme drought affected only a portion of climate divisions in Illinois. As a result, Table 1.5 shows that individual climate divisions received an extreme drought classification with an average value of 1.5 events during the 16-year period from 2000 to 2015. Based on this relatively short sample of years, the D3 extreme drought classification is estimated to occur for each division roughly once in 10 to 11 years.

For individual climate divisions, the D2 severe drought classification has occurred an average of four times during the 16 years (roughly once in four years) and the moderate drought classification an average of eight times (every other year, on average). But across Illinois, at least one climate division has experienced a severe USDM drought in 10 of the 16 years, and a moderate USDM drought in 12 of the 16 years. Thus, in most years, some region in Illinois is considered by the USDM to have experienced severe drought.

Although the USDM includes a classification for long-term droughts of over six months, by all appearances the USDM for Illinois instead focuses predominantly on shorter-term meteorological and agricultural effects and gives less overall consideration to long-term water storage concerns. In both the 2005–2006 and 2012 droughts in Illinois, for example, regional concerns about low water levels in water supply reservoirs and groundwater continued for many months after the drought level had been downgraded by the USDM. The 1999–2000 drought, in particular,

Table 1.5 Number of Years (2000-2015) that Each Illinois Climate Division Has Been Identified as Being in Drought, According to the U.S. Drought Monitor. In each case, at least 50 percent of a division has achieved the designated drought severity.

Drought Severity	NW	NE	W	C	E	WSW	ESE	SW	SE
Exceptional (D4)	0	0	0	0	0	0	0	0	1
Extreme (D3)	2	1	2	2	1	2	1	1	1
Severe (D2)	5	4	6	6	4	4	2	3	4
Moderate (D1)	7	6	10	10	8	7	7	8	7

was by far the most threatening drought to water supplies in Illinois since 1989, but was not recognized as an extreme event by the USDM (or for that matter by other precipitation-centric indices). Water storage considerations appear to be given greater consideration by the USDM for the western United States.

The drought severity categories defined by the USDM appear to match up roughly with the PDSI categories. A comparison of Tables 1.3 and 1.5 indicates that the extreme category represents an event that is likely to occur roughly once in 8 to 11 years for any given location in Illinois, with the PDSI designation having a slightly higher frequency. For any given climate division in Illinois, the severe category is expected to occur roughly once in four years using the USDM designation and roughly once in five years with the PDSI. However, for both indices, a region somewhere in Illinois is likely to receive the severe drought designation roughly every other year.

The USDM is likely to identify drought conditions, such as an extreme event, sooner than the PDSI, in part because of feedback from the community of drought observers. In this respect, the USDM is regarded the better tool for identifying the onset of drought. Although the sample size is small, the USDM may not be as effective as the PDSI in recognizing longer-term hydrologic effects of drought. In a drought's later stages, it is observed that the USDM is more likely to downgrade a drought event sooner than the PDSI.

Official Drought Designations in Illinois

The DRTF was created in 1983 under the recommendation of the State Water Plan Task Force (SWPTF) to provide an organized multi-agency approach in dealing with drought problems in Illinois. During times of drought, the DRTF is convened either by the Governor or by the Director of the IDNR Office of Water Resources (OWR) so that the existing state and federal programs for drought and emergency interruption of supplies may be organized and in a state of readiness. Thus, the process of convening the DRTF essentially creates an official or declared state drought condition. The DRTF is co-chaired by the Director of the OWR and the Manager of the Public Water Supply Section of the Illinois Environmental Protection Agency (IEPA). Other typically represented agencies include the ISWS, the Illinois Department of Agriculture, the Illinois Department of Public Health, the IDNR Division of Fisheries, the Illinois Emergency Management Agency, the Illinois Commerce Commission, the Illinois Department of Commerce and Economic Opportunity, the U.S. Geological Survey, and the Office of the Governor. Each agency has technical expertise and capabilities in specific areas of drought management and assistance.

In its first 15 years of organization, the DRTF was convened on seven different circumstances. In most of these circumstances, dry conditions leading the DRTF to convene were either short-lived or localized. In two cases, the DRTF convened following heat waves unrelated to a lack of precipitation, including the Chicago heat wave of July 1995 which was responsible for 739 heat-related deaths. In retrospect, for only one of the seven first circumstances (the 1988–1989 Illinois drought) did the DRTF meet during what today would be clearly recognized as a noteworthy drought episode.

Since 1999, the DRTF has been convened only three times: during the 1999–2000, 2005–2006, and 2012 droughts. In each of these cases, the drought concerns were not short-lived; rather, in all cases the drought concerns continued to escalate beyond the convening of the DRTF, leading the DRTF to continue addressing drought concerns for six months or longer. In the early stages leading to these droughts, the ISWS played a critical role in monitoring the developing dry weather conditions and the level of decline in water supplies and other resources being affected, identifying projected impacts, communicating these observations with the Director of the OWR, and ultimately advising when conditions have advanced to the stage requiring attention and response from the DRTF. The ISWS has a continued role in providing updates on the dry weather and hydrological conditions during each DRTF meeting until drought concerns have dissipated.

In several other notable dry periods (2003, 2007, 2011), the ISWS issued press releases or drought advisories, describing developing dry conditions in various regions of Illinois. But in these cases, the ISWS, in consultation with OWR, assessed that the dry conditions either did not have sufficient areal impact or had not yet progressed to the stage of a declared drought.

Identifying the Onset of Drought in Illinois

The ISWS and SWPTF have established a strong, positive record in the early and reliable identification of drought conditions in Illinois. Although it is recognized that the USDM will continue to provide an important and the most visible resource for tracking dry conditions, the watchfulness and ongoing assessment of climatic and hydrologic conditions by the ISWS have allowed Illinois to successfully identify and forecast the tangible impacts for which state agencies must be prepared and responsive. As documented in the following, the ISWS and DRTF have been able to declare recent Illinois drought conditions in advance of what could have occurred by referring to the USDM alone, under the assumption that the USDM's extreme drought designation is roughly equivalent to a declared Illinois drought:

- The ISWS issued two press releases in spring 2012, on April 10 and May 25, discussing the state's dry conditions. The May 25 release was labeled as a "drought advisory," indicating that there was greater than a 50 percent probability that drought impacts would occur in the summer. On June 19, the ISWS gave the SWPTF an assessment indicating that drought impacts were imminent, resulting in the activation of the DRTF. In comparison, less than one-third of Illinois was considered by the USDM to be in severe drought on June 19, and it was not until July 24, 2012 when it designated most of Illinois in the extreme drought category.

- In 2005, the DRTF was activated on June 26, again with the ISWS recommendation. In comparison, the USDM designated extreme drought conditions on July 5 of that year.
- In 1999, the DRTF convened in July with regards to heat wave conditions in Illinois, and then reconvened from November 1999 to June 2000 to address developing water supply concerns in the state. Although the USDM did not begin to issue drought condition maps until January 4, 2000, it never designated extreme drought conditions that year for Illinois, and did not designate severe drought until February 29, 2000.

Furthermore, in declaring an official drought condition for Illinois, the ISWS and DRTF deem that it is important that such declarations not happen often for episodes or short-lived dry conditions that do not produce substantial impacts. Such “false alarms” would unnecessarily use State resources and could produce a “cry wolf syndrome” in which drought declarations would carry less weight and the potential that they might be disregarded or less regarded by the public, state agencies, and others tasked with addressing drought concerns. Although quick reversals in weather patterns or misdiagnoses of developing drought conditions by the ISWS and DRTF are possible, such circumstances have not occurred since the 1990s when the criteria for convening the DRTF were not as well defined.

Monitoring of developing climatic and hydrologic conditions by the ISWS offers several advantages in early identification of drought in Illinois compared with the use of a national index, specifically 1) the ability to project conditions using weather forecasts; 2) the evaluation of seasonal factors affecting drought impacts and hydrologic conditions; and 3) having detailed information and hydrologic data concerning local or regional impacts. The areal or regional coverage of a drought, including an assessment of how many communities might be experiencing impacts, is also a considered factor when deciding the seriousness of a drought event.

Projecting Near-Future Conditions and Impacts

The USDM and PDSI are based solely on observational data and information, unaffected by the likelihood or prognosis of future or developing conditions. In contrast, during abnormally dry conditions, the ISWS often attempts to evaluate how soil moisture, streamflow, reservoir levels, and crop conditions may be expected to change in future weeks, particularly when faced with a fixed dry-weather pattern that includes a 14-day National Weather Service forecast showing little or no opportunities for rainfall. Although the National Weather Service releases monthly and seasonal temperature and precipitation forecasts, the skill of these forecasts, especially for summer rainfall, is too low to provide any guidance beyond 14 days. In nearly every case, when the ISWS issues a drought advisory or recommends that the DRTF convene, it is made in circumstances when there are very few opportunities for rain in the 14-day forecast. Because appropriate responses to drought conditions by Illinois agencies often require preparation, the ability to project the onset of impacts can be critical. When the DRTF was convened on June 19, 2012, it was expected that agricultural impacts and other concerns were likely to materialize by early July.

Effect of Seasonality when Identifying and Projecting Impacts

Drought impacts can vary substantially depending on which season precipitation deficits occur. Most readers will readily understand the effects of drought seasonality with regards to agriculture, particularly corn and soybean crops. Precipitation deficits in the cool seasons have an especially low agricultural impact in Illinois because there are relatively few acres of cool-season agriculture such as pasture and winter wheat.

Drought seasonality also greatly affects impacts to water resources and supply. The greatest rates of decline in soil moisture, stream, reservoir, and shallow groundwater levels occur during the summer when evapotranspiration rates (and water withdrawals) are typically greatest. Water levels will typically continue to decline, although at a slower rate, in the fall and early winter before soil moisture has been replenished. Streams and rivers typically experience their lowest flows in the fall, whereas reservoirs and groundwater can continue to decline through early winter. But once fall and winter precipitation has allowed soil moisture to rebound, more of the precipitation occurring in winter and spring replenishes streams, reservoirs, and shallow groundwater. Even during the worst hydrologic droughts, such as occurred in the 1950s, levels in water supply reservoirs will typically level off, and often partially rebound between January and May. The greatest concern during the most extreme droughts is that the amount of replenishment in reservoirs and shallow groundwater will be insufficient to avoid shortages during a second summer and fall season of drought. Furthermore, water supply droughts in Illinois would likely never begin in January to May because there is limited potential during this time to diminish streams, reservoirs, and groundwater storage.

For descriptive and interpretative purposes, Illinois droughts fall into three conceptual types:

> *Drought onset in early season (May–June)* These droughts usually occur after an abnormally dry spring, with low precipitation typically beginning in March and precipitation deficits accumulating to 5 to 6 inches or more by the end of May. Even following such dry springs in Illinois, there is usually sufficient moisture in the soil to provide for early crop growth. Impacts to corn and soybeans may not become evident until the latter half of June, and it is at this time that the ISWS and DRTF would likely decide to convene if little or no rainfall is in the forecast. In other words, given the seasonal nature of soil moisture in Illinois, it is unlikely that any new drought would be declared prior to June. If dry conditions persist into mid-summer, the early-season drought is the type most likely to

produce substantial damages to crops, particularly to corn if sufficient water is not available in the short time-frame in July when tasseling and silking occur. Water supply reservoirs could begin to show early drawdowns unseasonably early, by mid-June to early July, creating the threat that reservoir supplies could continue to diminish throughout the remainder of the year, potentially leading to shortages in certain supplies by winter. The 1988, 2005, and 2012 droughts are all examples of early summer droughts, and in each case the call for the DRTF to convene occurred in June.

Drought onset in mid-season (July–August) Mid-season droughts are characterized by extremely low precipitation amounts in July and August, often creating a precipitation deficit of 5 to 6 inches in the summer months alone. Analysis by Easterling and Changnon (1987) indicate that events with large precipitation deficits in the summer are the ones most likely to extend through the winter and spring, developing into a multi-year drought episode. The 1913–1915, 1930–1931, and 1953–1954 droughts are examples of mid-season droughts that turned into multi-year episodes. These droughts typically have near-normal precipitation or moderate deficits leading into the early summer. The most intense precipitation deficit may occur late enough in the summer so that there is adequate soil moisture for crucial crop development (corn tasseling and silking) to avoid the most severe crop damages. Water levels in streams, reservoirs, and shallow groundwater would typically drop precipitously in late summer, potentially threatening the few water supplies that are susceptible to short drought episodes, but the biggest water resource threat is the potential development into a multi-year drought. For these events, drought conditions might not be declared or recognized until late July or early August.

Drought onset in late season (September-December) These late-season droughts are less common and can occur stealthily because their onset happens after the heat of the summer and during months when precipitation is normally low. There are few if any agricultural concerns, and the recognition of the drought is almost entirely driven by low reservoir levels. In the 1999–2000 drought, it was not until November (the driest month in the drought) when low water levels became a concern to the DRTF. With these droughts, there is a low threat that water supply shortages might occur in its first year; rather, the greatest threat is the possibility of a multi-year episode. The spring of 2000 was particularly dry, and it was not until late May and early June 2000 when water levels in Lake Springfield and other affected water supply reservoirs in that region of the state saw recovery.

Identifying Impacts and Specific Concerns Regarding Agriculture and Water Resources

The primary role of the ISWS during the onset of drought conditions in Illinois has been to translate available climatic and hydrologic data to identify emerging and potential drought impacts and determine if these impacts have crossed a threshold in which the DRTF needs to be activated and state agencies alerted. Some of the information available to ISWS scientists for this evaluation, such as precipitation data, U.S. Geological Survey (USGS) streamflow data, and USDA crop progress and condition reports, are information sources also used by the USDM. The ISWS will also query state agencies and local contacts about specific concerns. The ISWS often receives information from well drillers around Illinois when shallow groundwater wells are experiencing problems and need to be drilled deeper. But the ISWS also contributes its own sets of data and analyses that provide valuable insight into drought processes and context with regard to certain historical drought episodes.

As part of its Water and Atmospheric Resources Monitoring program (WARM), the ISWS maintains long-term records of many climatic and hydrologic variables that can be valuable in diagnosing the onset of drought conditions. The three most pertinent sets of data in WARM are 1) the soil moisture monitoring network; 2) the shallow groundwater wells network; and 3) the surface water reservoir observation network. The long-term records provided for each network allow ISWS scientists to compare and contrast current events, such as a developing drought situation, to similar observations in historical dry years. The reservoir observation network also provides information on which reservoirs and regions are experiencing drawdown and how soon communities are likely to be concerned about their available supplies. The ISWS has also developed water budget models for nearly every community reservoir supply in Illinois, and with these models can project reservoir drawdown and compare them with simulated conditions associated with historical drought episodes. As drought conditions are emerging, the month-end water supply reservoir observations are often supplemented with additional queries to the water treatment operators at these and other lakes. Once the DRTF is activated, the IEPA maintains constant contact with these operators.

Real-time streamflow data from the USGS are also evaluated. A reliable symptom of drought conditions is the occurrence of streamflow that is in its lowest 10th percentile for a specific date. Although reports of low-percentile streamflows provide an effective warning, they usually must occur in mid-summer to correlate with specific low flow impacts on streams (such as fish kills or water supply intake problems). For example, low-percentile flows occurred in spring 2012. However, flows are typically highest in spring in Illinois, so a relatively low flow in spring still represents sufficient water to avoid the kinds of low-flow conditions or impacts more often found in summer. Thus again, ISWS scientists attempt to focus less on data metrics and give greater emphasis to emerging impacts.

Some regions of Illinois are more susceptible to significant impacts than others. For example, regions of Illinois that depend on reservoirs and shallow groundwater for their water supplies are more likely to have drought-related impacts. In contrast, water supplies in northwestern Illinois are predominantly provided by bedrock aquifers that are well buffered from the impacts of drought. If a precipitation deficit in that region does not affect agriculture, it is very possible that there could be few or no hydrologic impacts; thus the need for an official drought declaration might be circumvented despite the region being categorized by other available drought indices.

Summary

The USDM will likely continue to be the primary resource that many agencies and the public will use for information regarding drought. But it is highly recommended that users understand that the terminology associated with the USDM (and PDSI) drought categories, such as moderate or severe drought, is subjective and semantic and may not necessarily correspond to tangible drought impacts. The severe drought category, in particular, is a designation that occurs in some portion of Illinois as frequently as every other year, often describing a comparatively undeveloped drought condition having limited overall impact to agriculture or water resources. This is not to infer that impacts cannot occur within the severe drought category, but, if so, they are more likely to be local and isolated incidents.

The USDM's extreme drought category, on the other hand, more accurately reflects an Illinois drought condition in which tangible impacts have developed to a threshold requiring state agency preparation and responses. Thus, this category more closely identifies circumstances that would cause the DRTF to convene, and would therefore essentially amount to a State of Illinois official declaration of drought.

Identification of emerging drought conditions in advance is crucial for convening the DRTF and preparing state agencies for response to drought impacts. The USDM products are based entirely on current observed conditions, and thus do not project how droughts or dry conditions are apt to develop in the near future. In contrast, the ISWS specifically examines weather and climate forecasts to provide a prognosis of drought conditions and impacts including not only current observations, but also climatic and hydrologic analysis and prediction. The drought prognoses and thresholds that the ISWS and SWPTF have used since 1999 successfully provide an early identification of emerging drought impacts, often well in advance of an extreme drought designation from either the USDM or PDSI.

Of equal concern is that Illinois' drought declarations show discretion and restraint, so that when the DRTF convenes, there should be a high likelihood or inevitability that tangible impacts or credible threats and concerns are forthcoming. Important additional factors in the ISWS drought evaluations are the knowledge and familiarity of its scientists regarding 1) specific ongoing and developing impacts in Illinois; 2) areas of concern based on past drought episodes; and 3) influence of drought seasonality on the development and progressions of agricultural and hydrologic impacts.

Chapter 2: Drought Conditions, Causes, and Predictability across the Central U.S.

Introduction

The central U.S. drought of 2012 was widespread and devastating for the region. A 2015 report (Fuchs et al., 2015) provided a damage assessment for Colorado, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wyoming. Longer-term drought prevailed in many states in the West and Southwest as well. A National Centers for Environmental Information (NCEI) report on billion-dollar weather and climate disasters listed the 2012 drought as a $31.2 billion loss across the U.S., primarily from widespread damage to corn, soybeans, forage crops, and pasture (NCEI, 2016).

This chapter reviews the regional aspects of the 2012 drought using regional precipitation deficits and U.S. Drought Monitor maps and examines the causes of this drought and its predictability. A more detailed description of the drought in Illinois is provided in Chapter 3.

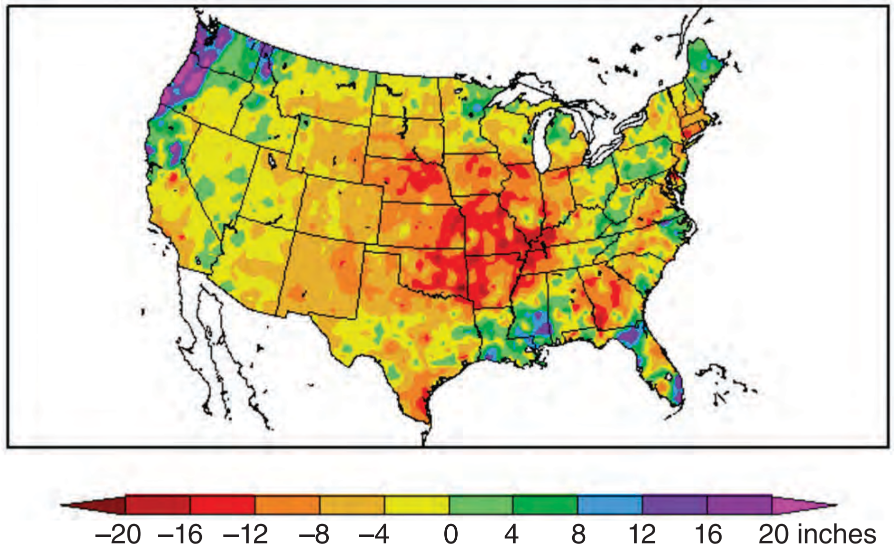


Figure 2.1 Map of U.S. precipitation anomaly in inches during 2012

Regional Precipitation

A large portion of the conterminous United States experienced drought conditions to varying degrees during 2012. In terms of precipitation departures from normal, the driest conditions occurred in the Great Plains and Midwest. Since precipitation departures are a defining feature of drought and one of many factors included in the assessment of the USDM, this section provides a discussion of regional precipitation anomalies.

The total precipitation departure from normal for 2012 (Figure 2.1) illustrates the widespread dryness across much of the United States. The Great Basin was near normal to slightly below normal, while drier conditions were experienced eastward toward the Rocky Mountains. The Great Plains, Texas to the Dakotas, were 4 to 12 inches below normal in most locations with some drier isolated areas. The mid-Mississippi River valley was the driest, and some areas, especially Missouri, Illinois, Arkansas, and western parts of Kentucky and Tennessee, were 12 to 16 inches or more below normal. The Southeast U.S. and Mid-Atlantic piedmont also were below normal, as well as parts of New England. The abnormally wettest locations were the coastal Pacific Northwest, Gulf Coast of Mississippi and Louisiana, and parts of Florida.

An examination of seasonal precipitation (Figure 2.2) showed when deficits occurred. Winter 2011–2012 was near normal, within 5 inches, for most of the nation. The Great Plains and Midwest experienced near- to above-normal precipitation. Meanwhile, the East and West Coasts of the U.S. experienced below-normal precipitation. This anomalous pattern nearly reversed in spring 2012. The Great Basin averaged 0 to 4 inches below normal, while the mid-Mississippi River valley from Illinois to Tennessee averaged as much as 8 inches below normal. The West Coast and Atlantic Southeast received much-needed relief. Conditions in the Great Plains and Midwest rapidly deteriorated in summer 2012. Locations from Texas to Minnesota, including Illinois, averaged 8 inches below normal, while parts of Nebraska, Kansas, Missouri, and Iowa were 12 inches below normal. The Gulf Coast was soaked with above-normal rainfall from Hurricane Isaac. The tropical cyclone remnants made its way to the Midwest, contributing to the above-normal precipitation in Illinois, Indiana, and Ohio during fall 2012.

Meanwhile, the Great Plains and upper Midwest, including northern Illinois and the Gulf Coast, remained largely dry in fall 2012. Precipitation was above normal for the Midwest and eastern half of the U.S. during winter 2012–2013. By spring 2013, the Midwest was exceptionally wet with precipitation 3 to 6 inches above normal. Western Illinois and Iowa received up to 15+ inches above normal precipitation, essentially ending any remaining concerns of drought across the Midwest.

Focusing on the Midwest, monthly maps of percentage-of-normal precipitation show the progression of the drought as well as the spatial and temporal variability across the region (Figure 2.3). The beginning of 2012 was largely characterized by extremes in precipitation on a regional scale. The Ohio River valley was wet, while eastern Kansas

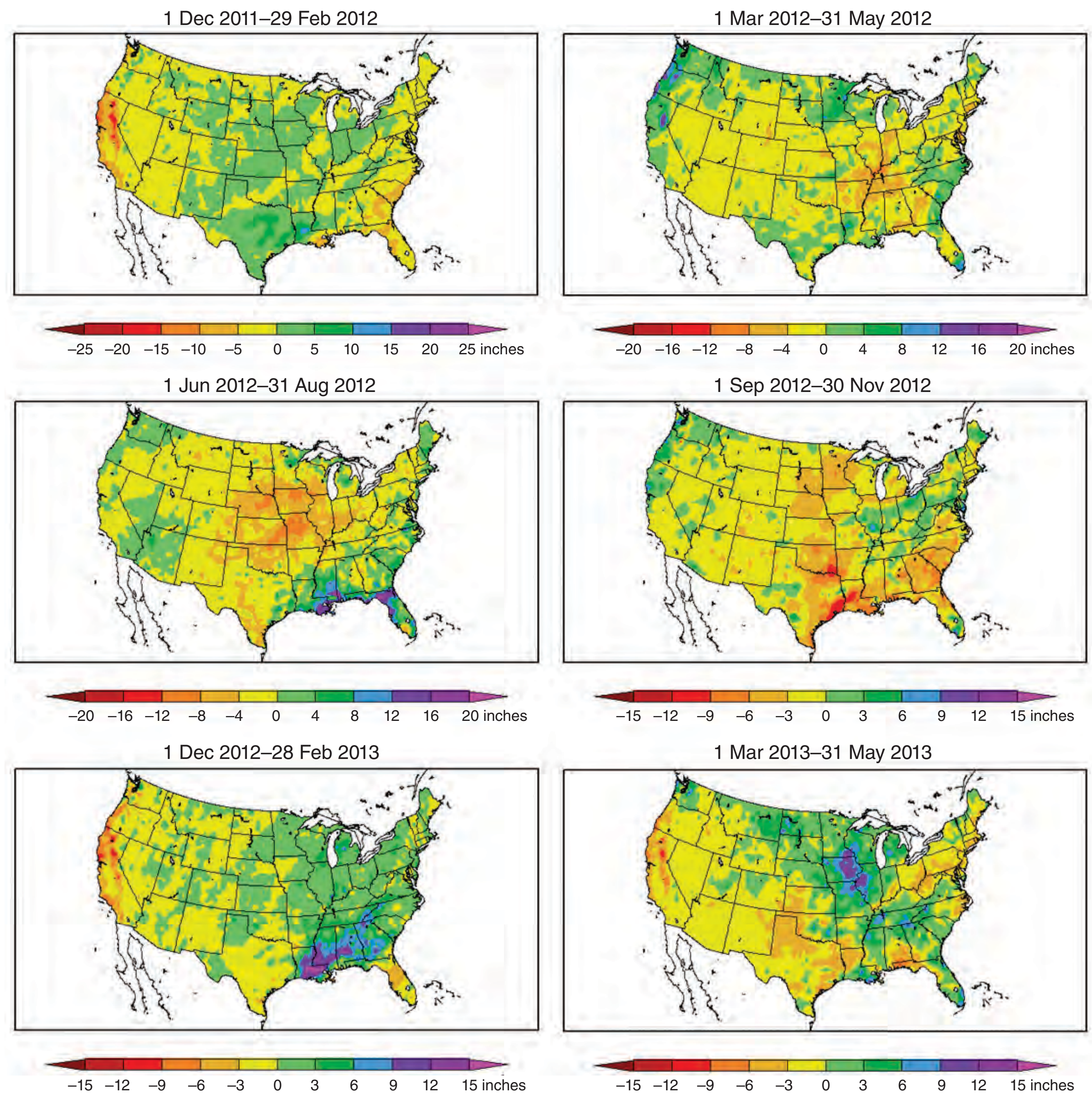


Figure 2.2 Seasonal precipitation departures in inches from the 1971–2000 mean in the contiguous United States

received almost no precipitation. Illinois was in between the two extremes with near-normal precipitation across the state, except for western Illinois, which was related to the dryness to the west. This precipitation pattern reversed in February. Kansas, Nebraska, western Iowa, southern Minnesota, and eastern South Dakota were inundated with precipitation, while locations farther east, including Illinois, saw less than 75 percent of normal precipitation. March and April were also relatively dry in Illinois compared with neighboring states. Missouri and Minnesota received a surplus of springtime precipitation. From April through July, the Midwest grew increasingly dry as larger portions of the Midwest fell below 50 percent of the normal monthly precipitation. Most of the region was dry during August, although parts of central Illinois and Indiana received near-normal rainfall. However, the greatest reduction in the drought was made by the remnants of Hurricane Isaac, which gave central Illinois and Indiana, southeast Missouri,

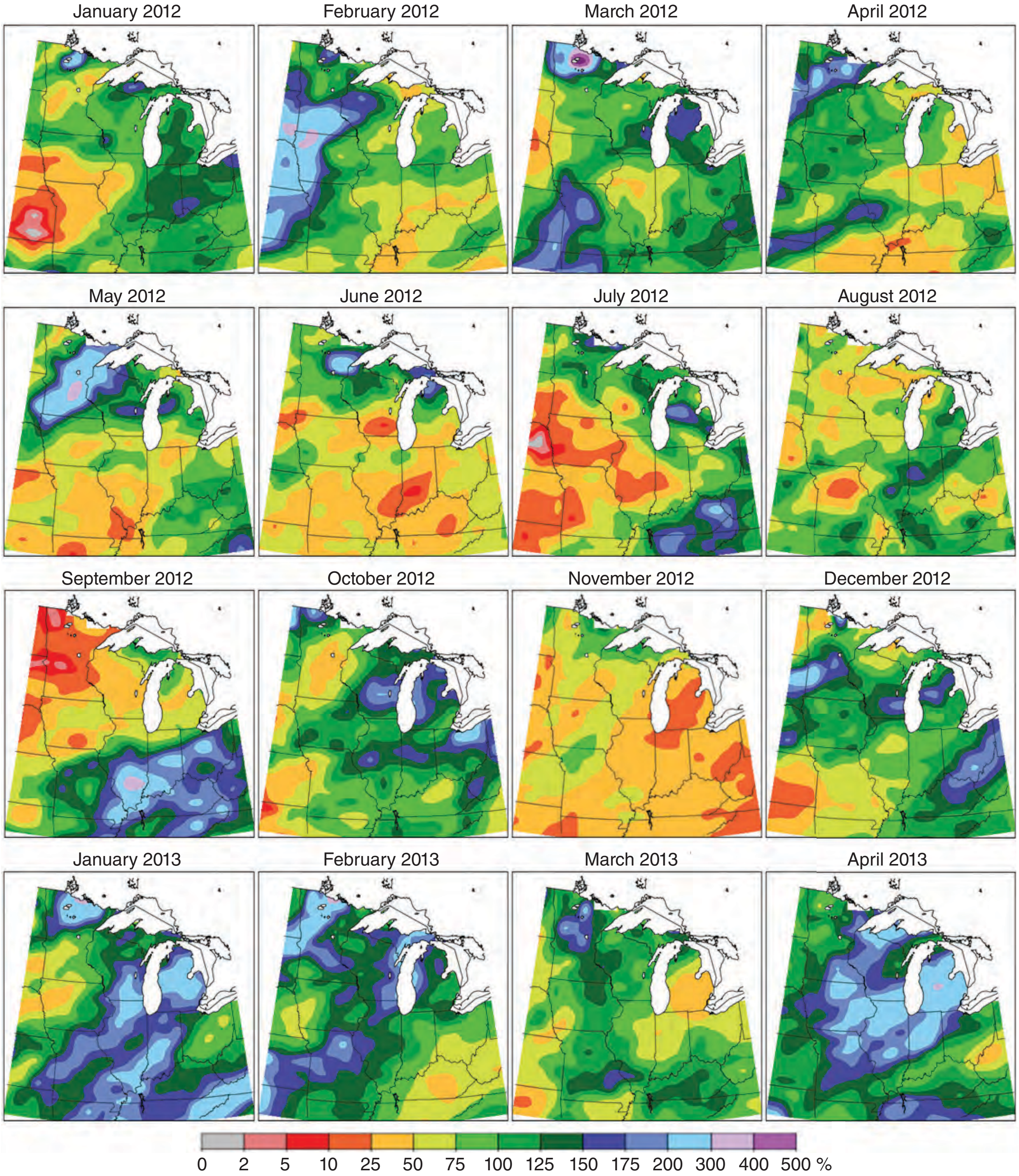


Figure 2.3 Percent of mean precipitation by month, January 2012–April 2013, based on the 1971–2000 climatological mean for the U.S. Midwestern region

and western Kentucky an abundance of rainfall at the beginning of September. Precipitation also increased across the region during the month, allowing south-central Illinois to receive up to four times the normal precipitation for September. After near-normal precipitation in October, another wave of dry conditions engulfed the region in November. A secondary dry spell can occasionally be observed after a major drought event (Changnon, 1987). As precipitation increased across the Midwest during winter 2012–2013, the drought slowly receded westward. January, February, and April 2013 were notably wet for many Midwestern states including Illinois, which received two to three times the normal precipitation during these months. This wet period signified the end of the drought for Illinois and the Midwest.

U.S. Drought Monitor

USDM is a map product collaboratively provided by federal agencies. These maps are updated weekly. The process behind the USDM is explained in more detail by Svoboda (2002). Figure 2.4 shows USDM maps from the first update of each month, April 2012 to March 2013, the approximate period when drought conditions were experienced in Illinois. Abnormal dryness first appeared in western and central Illinois with the March 27, 2012 USDM update, on the heels of a waning but historic 2011 drought in the southern plains of Texas and a moderate/severe drought that had developed in the upper Midwest, Southern Plains, and Northern Plains during the winter. These conditions persisted through April and early May as abnormal dryness began in Illinois. By June, droughts in the upper Midwest and southern plains had vastly improved; however, the once patchy abnormal dryness in Illinois had filled in the central U.S. along with patches of moderate drought in Arkansas, Kansas, Missouri, Iowa, and Illinois. Localized severe drought conditions had developed near the confluence of the Ohio and Mississippi Rivers.

By June, the drought accelerated rapidly. Most of the Mississippi and Ohio River valleys experienced drought to varying degrees during July and August, including a vast majority of the contiguous U.S. The worst of the drought during these months occurred in a region that stretched from western Indiana through southeast Illinois, western Kentucky, southeast Missouri, and most of northern Arkansas. Another sizeable portion of exceptional drought enveloped parts of the central plains, including Kansas and Oklahoma. These harsh conditions occurred in the context of the extreme drought that engulfed much of the central U.S.

A small amount of relief arrived in the second half of August. Hurricane Isaac came ashore August 28, 2012 on the southeastern coast of Louisiana and tracked northwestward into the parched center of the country. The storm's winds weakened as it progressed inland through Arkansas, Missouri, and Illinois; however, much-needed rain fell across these states during the first three days of September. Between August 31 and September 3, as much as 5 inches of rain fell in the mid-Mississippi and lower Ohio River valleys with local higher totals. While Isaac did not erase drought from the Midwest, the storm at least ameliorated the situation.

Conditions improved only slightly in the Midwest through the end of 2012. Exceptional drought conditions were widespread in the Great Plains from South Dakota to Oklahoma. Patches of extreme drought were seen from Minnesota to Arkansas, including a swath through far northwestern Illinois. Through autumn, drought conditions diminished substantially in Ohio, Michigan, Indiana, and Kentucky. Recovery was slow to propagate westward. Remarkable improvements arrived in Illinois during late January into February 2013. As of the April 9, 2013 USDM update, Illinois was officially drought free, though most of the western half of the United States remained in some stage of drought.

Possible Causes of the 2012 Drought

Hoerling et al. (2014) conducted a detailed observational and modeling study of the 2012 drought. Potential climatic causes such as sea surface temperature patterns and increases in greenhouse gasses did not play significant roles in the drought. Instead, this was a classic warm season central U.S. drought dominated by meteorological features. The first two of these features were the reduced atmospheric moisture transport from the Gulf of Mexico and reduced cyclone and frontal activity in the spring. The drought persisted and intensified in summer as normal summer convective precipitation (i.e., thunderstorms) was inhibited as high pressure dominated the region in July and August. By the second half of August, this pattern had begun to breakdown, allowing rains to return to the Midwest.

Predictability

One question of any significant drought event is: Could it have been foreseen? Unfortunately, predicting drought is an extremely difficult task that requires not only the identification of large-scale circulation features in advance, such as a persistent ridge of high pressure, but also the impacts of local feedbacks such as the drying of the land surface, which are not well measured or understood.

The National Weather Service routinely issues short-term temperature and precipitation forecasts. However, a group within the National Weather Service, called the Climate Prediction Center (CPC), issues monthly and seasonal average temperature and precipitation forecasts for the United States. Figure 2.5 shows the seasonal precipitation issued in January 2012 prior to the onset of the drought. In this figure, the contours on the maps indicate the total probability percentages of precipitation falling into one of three categories: above (A), below (B), and the near-normal category (N).

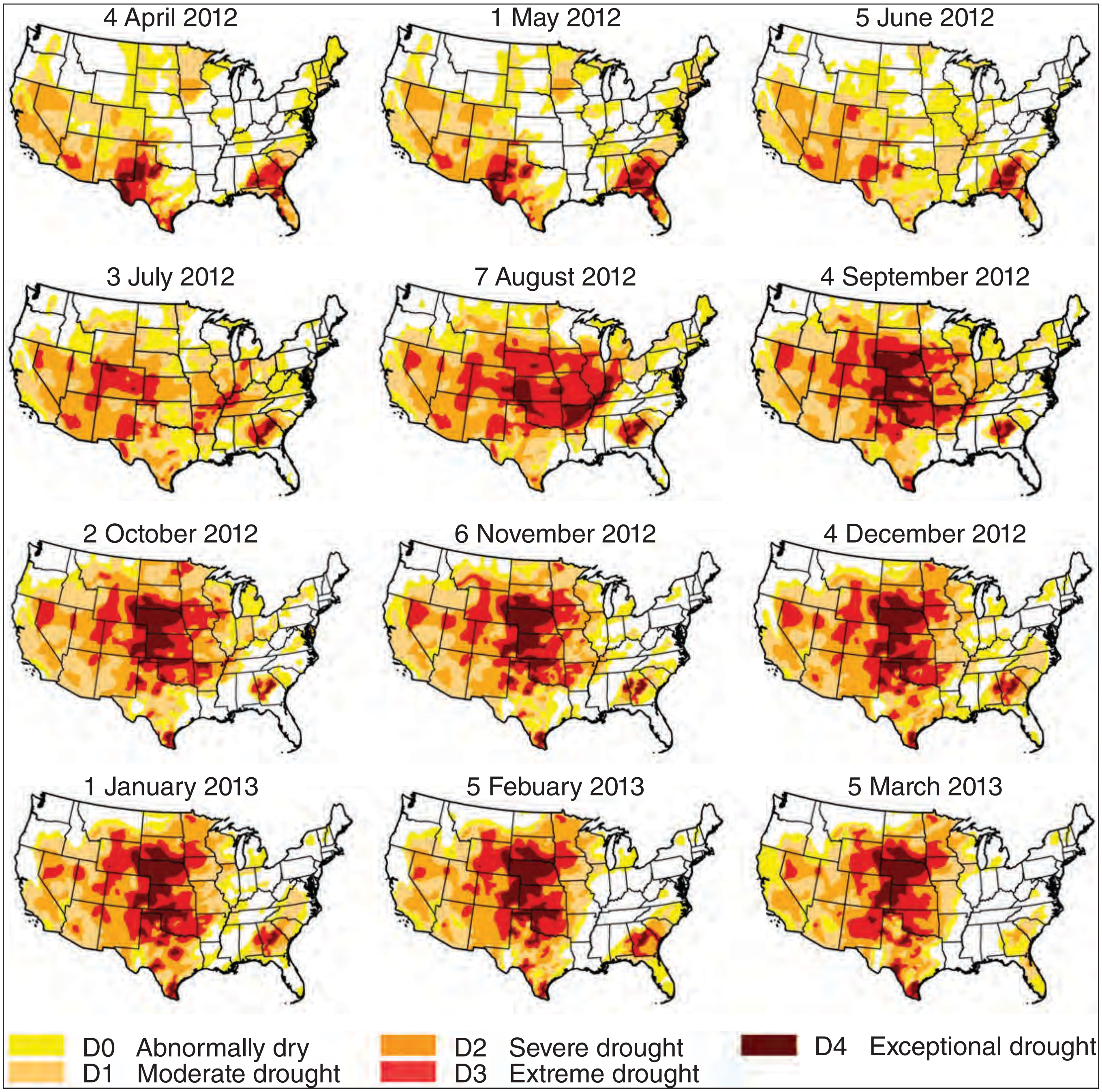


Figure 2.4 Time evolution of the U.S. Drought Monitor indices from April 2012 to March 2013. The U.S. Drought Monitor is updated every Tuesday.

At any point on the map, the sum of all three probabilities is 100 percent. Shading indicates probabilities exceeding 33.3 percent in that particular category. The three categories are defined from the 30-year climatology from 1981 to 2010. The coldest or driest third of the climatology (10 years) defines the B category, the warmest or wettest third (10 years) defines the A category, and the remaining 10 years in between define the N category. In regions where no climate prediction tools favor the chance of either above- or below-normal conditions, the region is labeled "EC," meaning equal chances of above-, below-, or near-normal conditions. For example, an area with brown shading with the "B" label and a contour of 50 percent would indicate a 50 percent chance of below-normal precipitation for that region, which is a much greater risk of dryness than expected by chance (33.3 percent).

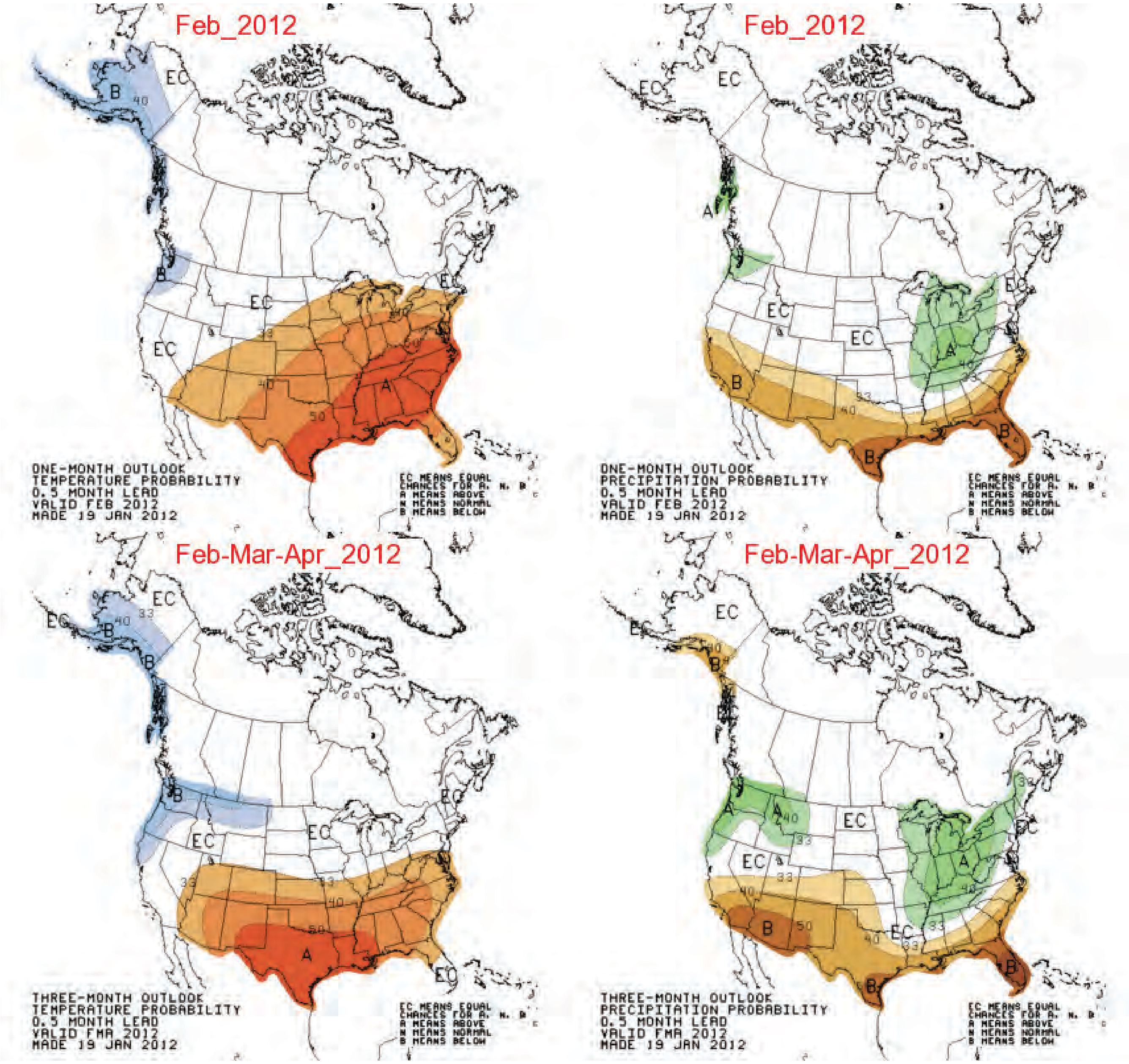


Figure 2.5 Monthly and seasonal forecasts of temperature and precipitation issued by the Climate Prediction Center in January 2012

While the monthly and seasonal (three-month) outlooks issued by the CPC are not specifically designed to forecast upcoming droughts, they can indicate an increased risk of being drier and/or warmer than normal, which could lead to drought conditions at some point. The monthly forecast for February (Figure 2.5) shows much of the eastern two-thirds of the U.S. with an increased chance of above-normal temperatures. There was an increased chance of above-normal precipitation in the Great Lakes region and an increased chance of below-normal precipitation extending from California to the Carolinas. For the three-month forecast of February–April, the southern U.S., including the southern half of Illinois, had an increased chance of being warmer than normal. Meanwhile, the Great Lakes and Ohio River Valley had an increased chance of above-normal precipitation. An examination of Figure 2.3 shows that the Great Lakes/Ohio River Valley region actually received below-normal precipitation during this period.

The forecast released in mid-April for May and May–July is shown in Figure 2.6. The forecast for one and three months shows the Midwest in equal chances (EC) for above, below, and near-normal temperatures and precipitation.

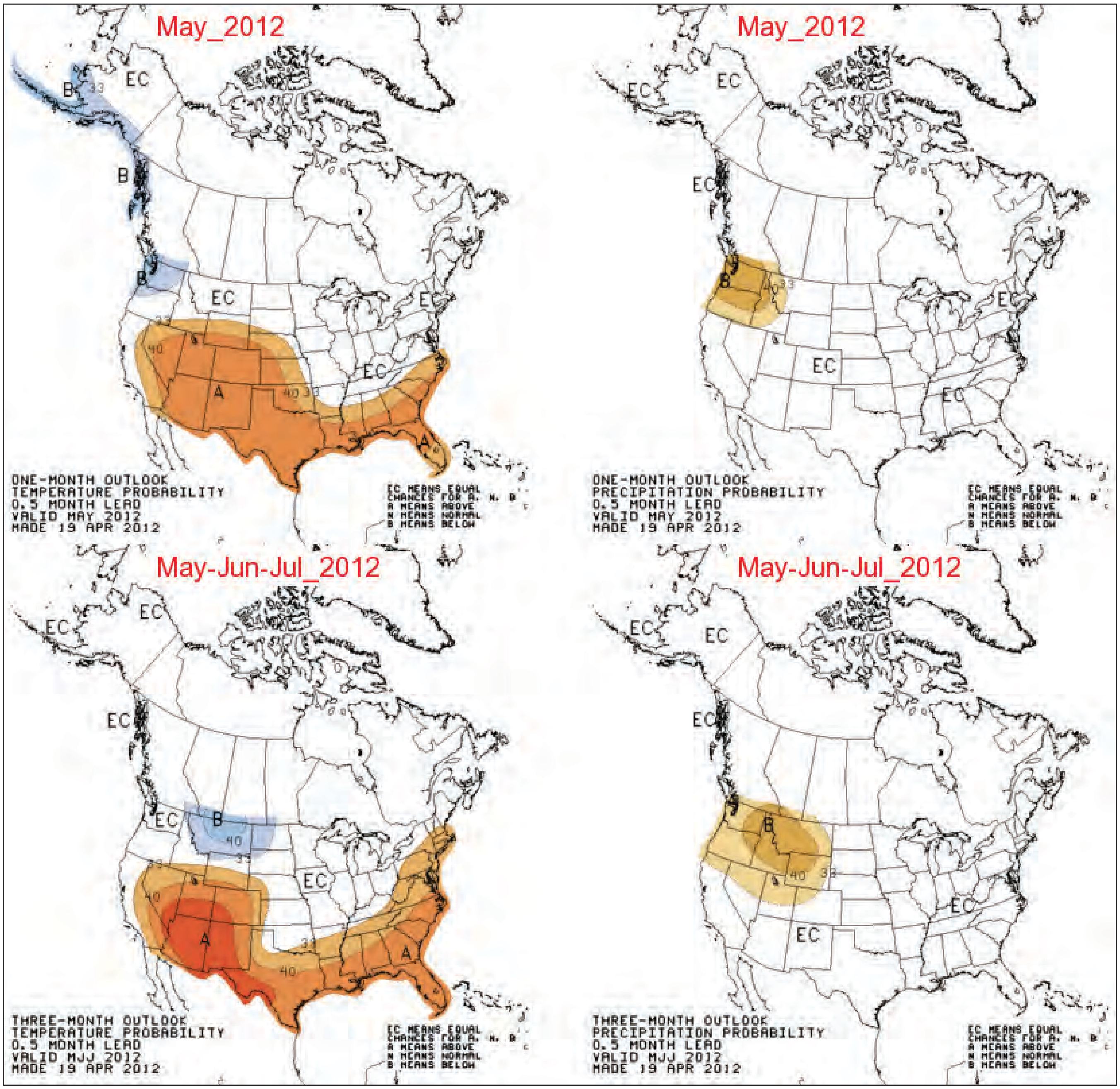


Figure 2.6 Monthly and seasonal forecasts of temperature and precipitation issued by the Climate Prediction Center in April 2012

The forecast released in mid-June for July and July–September (Figure 2.7) finally showed the Midwest with an increased chance of above-normal temperatures, driven primarily by the reductions in soil moisture already evident in June. The July forecast also shows a relatively small area of the Midwest with an increased chance of below-normal precipitation. The July–September precipitation forecast shows equal chances of above-, below-, and near-normal conditions across the central U.S. In reality, the western half of the Midwest received below-normal precipitation, while the eastern half received above-normal precipitation. This was largely due to the effects of Hurricane Isaac, which were beyond the ability of the forecasters to predict in mid-June.

Hoerling et al. (2014) examined the potential predictability of the 2012 drought and found that precipitation trends in the region did not show any trend towards an increased risk of such a short, intense drought. In fact, they called the 2012 drought a “climate surprise from such empirical evidence alone.” In the near-term, conditions

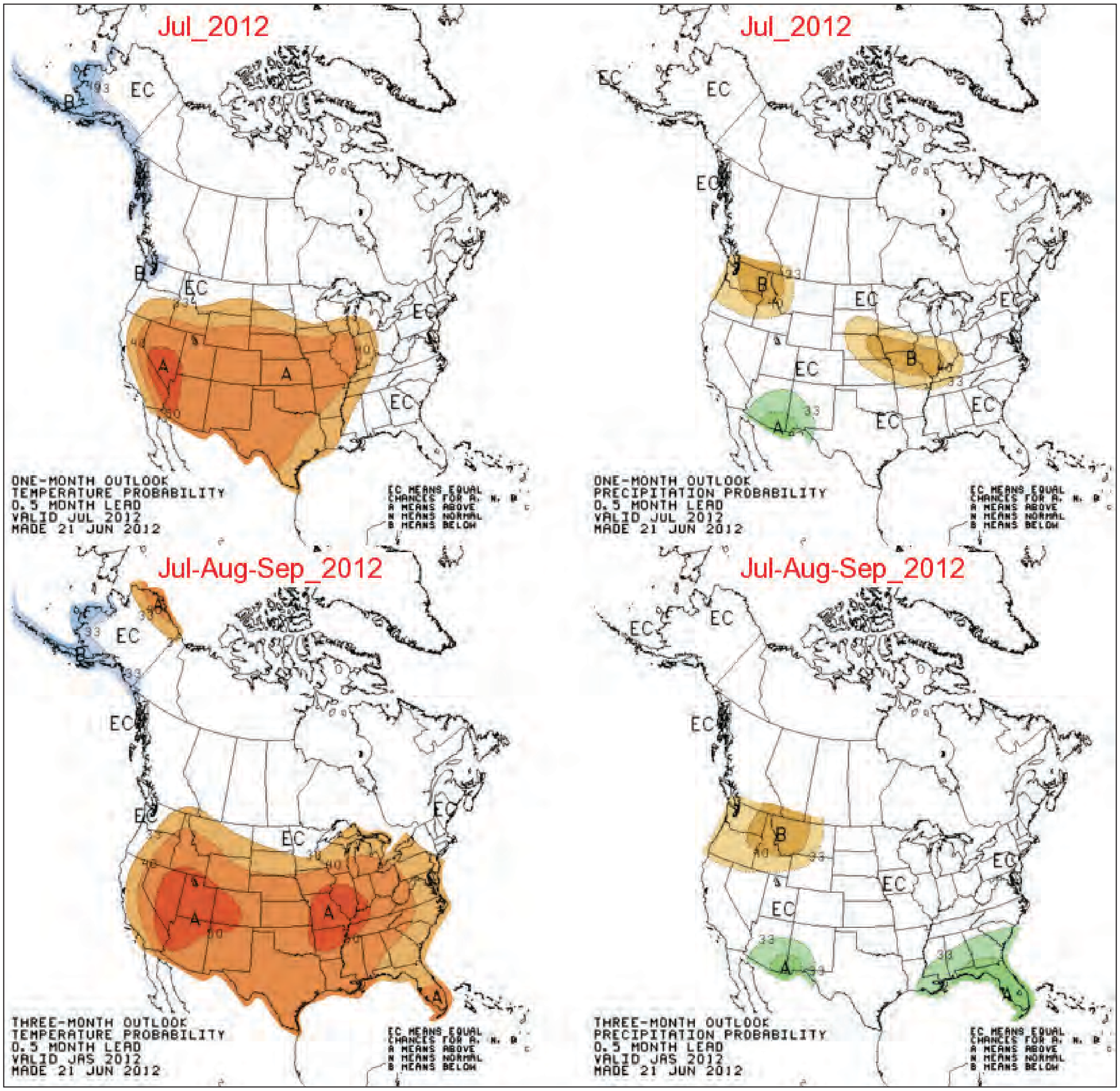


Figure 2.7 Monthly and seasonal forecasts of temperature and precipitation issued by the Climate Prediction Center in June 2012

even through the end of April were near- normal across the region with no widespread pattern of dryness. Based on their careful analysis of observations and extensive climate modeling, they concluded that this extreme drought event would have been very difficult to forecast.

Summary

The drought in Illinois was part of a larger-scale drought across the central U.S. in 2012. Although Illinois was hard hit by the drought, most of the U.S. experienced drought conditions throughout 2012 with the largest precipitation deficits in the Central Plains and Midwest.

The winter 2011–2012 was near to above normal on precipitation. Once spring arrived, drier conditions developed across parts of the Midwest. By summer, the drought was widespread across the central U.S. Recovery began in the eastern parts of the Midwest in the fall, aided by Hurricane Isaac. However, full recovery for the central region did not occur until the following winter and spring. The 2012 drought appeared to be due to natural variability and not related to sea surface temperature patterns or long-term climate change. A spring with less atmospheric moisture and a lack of low-pressure systems and cold-warm fronts was followed by a summer dominated by high pressure that inhibited normal thunderstorm activity. Prior to the onset of the drought, monthly and seasonal precipitation and temperature forecasts did not indicate an increased risk of either below-normal precipitation or above-normal temperatures in the Midwest. An assessment afterwards concluded that there were no warning signs of the impending drought.

Chapter 3: Climate Conditions in Illinois

Introduction

The drought of 2012 was one of the most severe to strike Illinois since the 1988 drought. This chapter discusses weather and climate factors associated with the 2012 drought and how it compared with historical conditions. In general, dry conditions were seen in west-central Illinois as early as fall 2011. However, the drought became fully developed only in the spring and summer of 2012 before coming to an abrupt end in September and October.

Precipitation and Temperature

Daily average statewide precipitation measurements were collected from the National Weather Service Cooperative Observer Network. Additional precipitation data were compiled from the all-volunteer Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network and from National Weather Service radar-estimated precipitation. These were aggregated by the National Climatic Data Center into monthly averages by climate division and by state for ranking considerations. Statewide records of temperature and precipitation extend to 1895 in Illinois. References to “average” or “normal” refer to the standard 1981–2010 averaging period, unless otherwise noted.

2011

Despite a wet spring across Illinois in 2011, the region between Interstates 70 and 80 experienced below-average precipitation, and some areas in west-central Illinois experienced much-below-normal precipitation in July and August. Precipitation in those areas was 4 to 6 inches below normal. Other areas between Interstates 70 and 80 were 2 to 4 inches below normal. This intense dryness was coupled with temperatures 2 to 4 degrees above normal, resulting in high rates of evapotranspiration. Evapotranspiration (ET) is a combination of the evaporation of water from land and water surfaces and transpiration from plants. The combination of planting delays because of the wet spring and the hot, dry summer resulted in corn and soybean yields that were below the five-year average in many Illinois counties.

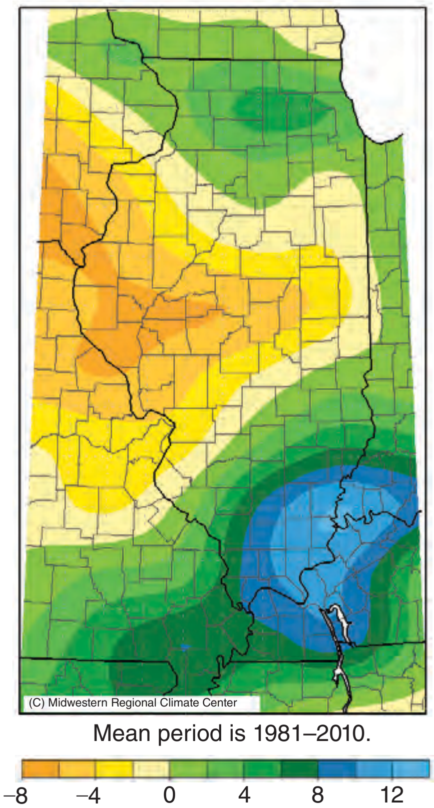


Figure 3.1 Precipitation departures from normal for July 1 to December, 31, 2011, showing the dryness present in western Illinois

Although conditions eased somewhat in the fall with the return of precipitation and cooler temperatures, the second half of 2011 remained dry. In particular, the area between St. Louis, Moline, and Decatur remained 4 to 6 inches below normal through the end of December (Figure 3.1). As a result, this area was already primed for severe drought impacts in 2012.

January–April 2012

For the rest of Illinois, the drought began in 2012. Figure 3.2 shows the monthly statewide precipitation departures during 2012. Precipitation was below normal for each month from January through April. Although none of the four months was exceptionally dry (Table 3.1), together the statewide average precipitation was 8.58 inches, which was 2.28 inches below normal and the 28th driest January–April on record.

Another key factor in the early stages of the 2012 drought was the extensive warm weather at the beginning of the year. Monthly temperature departures for the state (Figure 3.3 and Table 3.2)

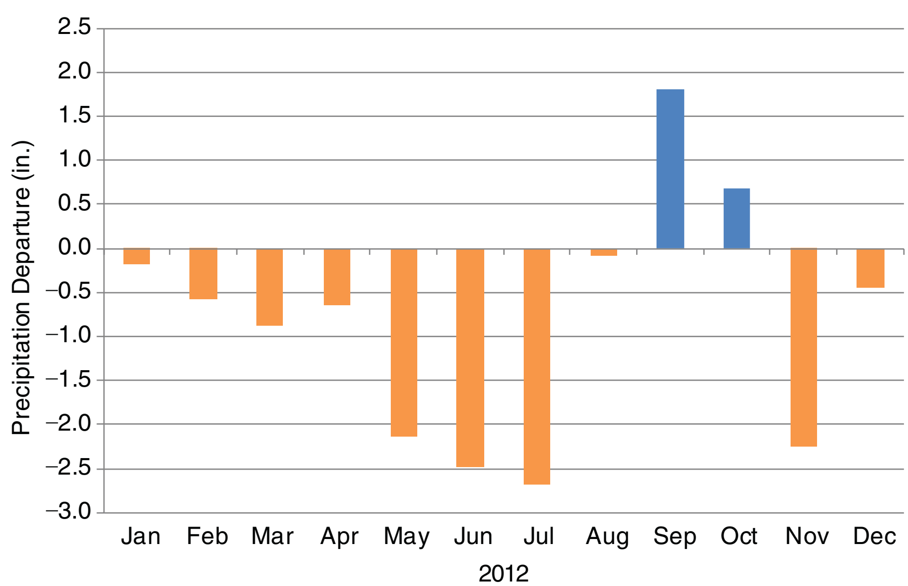


Figure 3.2 Monthly precipitation departures from the 1981–2010 average for Illinois in 2012

Table 3.1 Illinois (statewide) Precipitation Rankings by Month and Year for 2012. Period of rankings spans 1895–2012.

Period (2012)	Rank	Precipitation (in)	Normal (in)	Departure (in)	% normal
January	66th driest	1.89	2.07	−0.18	91
February	40th driest	1.48	2.06	−0.58	72
March	30th driest	2.08	2.96	−0.88	70
April	48th driest	3.13	3.78	−0.65	83
May	21st driest	2.47	4.60	−2.13	54
June	8th driest	1.73	4.21	−2.48	41
July	4th driest	1.40	4.08	−2.68	34
August	65th driest	3.50	3.59	−0.09	97
September	17th wettest	5.04	3.23	1.81	156
October	23th wettest	3.93	3.24	0.69	121
November	14th driest	1.21	3.47	−2.26	35
December	61th driest	2.25	2.69	−0.44	84
January–December	10th driest	30.11	39.96	−9.85	75

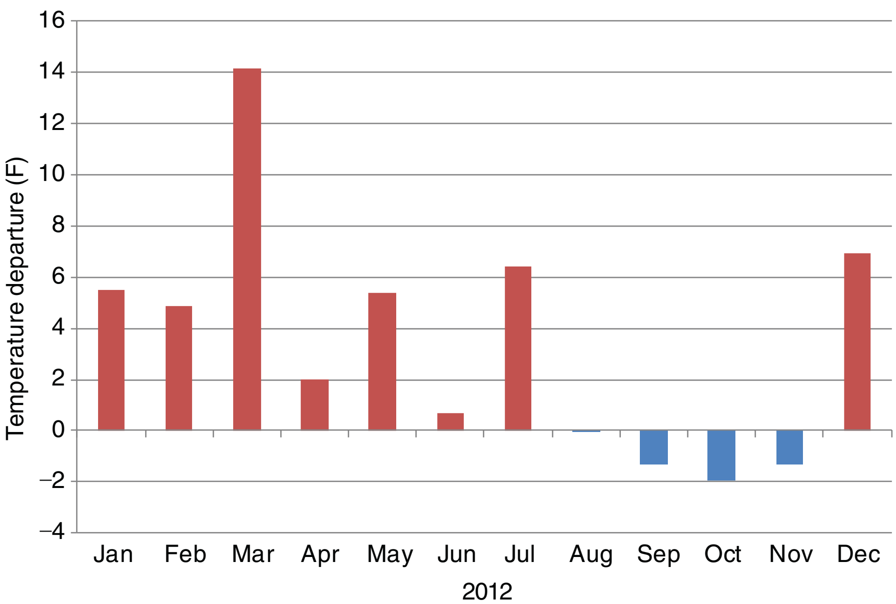


Figure 3.3 Monthly temperature departures from the 1981–2010 average for Illinois in 2012

show that January, February, March, and April were all well above normal on temperatures. Although all four months were warmer than normal, March was outstanding as the warmest March on record and 14.2 degrees above normal Temperatures in the 70s and 80s were common in March. This warm start to 2012 meant that the below-normal snowfall from the winter was long melted. In addition, soils remained unfrozen, which allowed water to drain quickly, and rivers and streams were unimpeded by ice. Furthermore, above-normal temperatures increased the evaporation rates, which are historically low during this time of year.

Spatially, precipitation was below normal across most of Illinois from January to April (Figure 3.4). One area with the driest conditions was east of Moline where precipitation was 3 to 4 inches below normal. However, hardest hit was far southern Illinois where precipitation was 3 to 7 inches below normal. The only area with above-normal precipitation in Illinois during this time was to the east of St. Louis.

Although 2012 started out hot and dry, precipitation was only slightly below normal in April, suggesting a chance for a last-minute recovery before the growing season. Unfortunately, April was only a temporary pause in the developing drought. This situation illustrates one of the challenges in monitoring droughts when the brief return of precipitation may signal a false drought recovery. It is now clear that this drier and warmer four-month stretch set the stage for rapid deterioration of conditions later by depleting soil moisture, as well as lowering water levels in rivers, lakes, and streams during a time of the year when they are typically highest.

Table 3.2 Illinois (statewide) Average Temperature Ranking by Month and Year for 2012. Period of ranking spans 118 years, 1895–2012.

Period (2012)	Rank	Temperature (°F)	Normal (°F)	Departure (°F)
February	14th warmest	35.8	30.9	4.9
January	12th warmest	31.9	26.4	5.5
March	1st warmest	55.5	41.3	14.2
April	20th warmest	54.6	52.6	2.0
May	6th warmest	68.1	62.7	5.4
June	42nd warmest	72.6	71.9	0.7
July	2nd warmest	81.8	75.4	6.4
August	58th warmest	73.6	73.6	0.0
September	37th coolest	64.9	66.2	–1.3
October	29th coolest	52.5	54.4	–1.9
November	58th coolest	41.2	42.5	–1.3
December	6th warmest	36.8	29.9	6.9
January–December	1st warmest	55.9	52.4	3.5

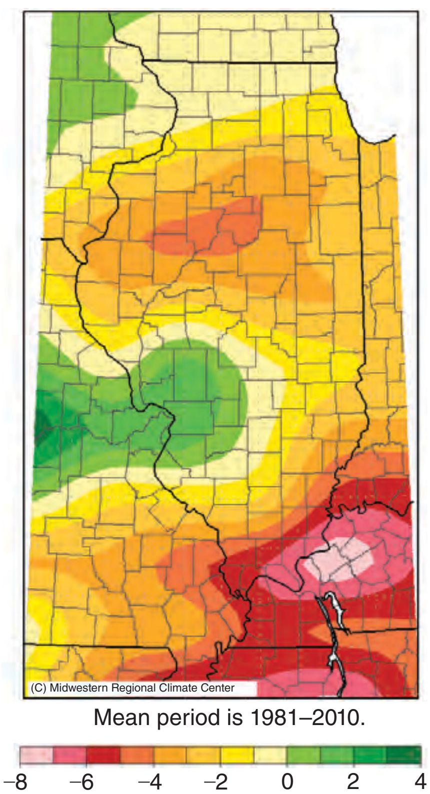


Figure 3.4 Precipitation departures from normal from January 1 to April 30, 2012, showing the dryness in north-central Illinois and southeastern Illinois

May–July 2012

After the brief recovery in April, May was much drier with only 2.5 inches of precipitation, 58 percent of normal, and the 21st driest May on record. Even drier conditions prevailed in June and July as only 1.8 inches of precipitation fell in the eighth driest June on record, and 1.5 inches fell in the fourth driest July on record.

These three months combined represent the core of the drought in terms of both the lack of precipitation and subsequent impacts, especially in agriculture. The three-month total precipitation was 5.60 inches, 43 percent of normal, and the third driest May–July on record (Table 3.3 and Figure 3.5). The driest May–July on record was 1936 with 4.95 inches, 38 percent of normal. The second driest was 1988 with 5.25 inches, 41 percent of normal. Spatially, the precipitation deficits were widespread and severe during this period (Figure 3.5). In general, much of central and southern Illinois were 8 to 10 inches below normal, while northern Illinois was 6 to 8 inches below normal.

Temperatures were above normal for winter, spring, and summer (Table 3.4). March through May was outstanding with temperatures 7.2 degrees

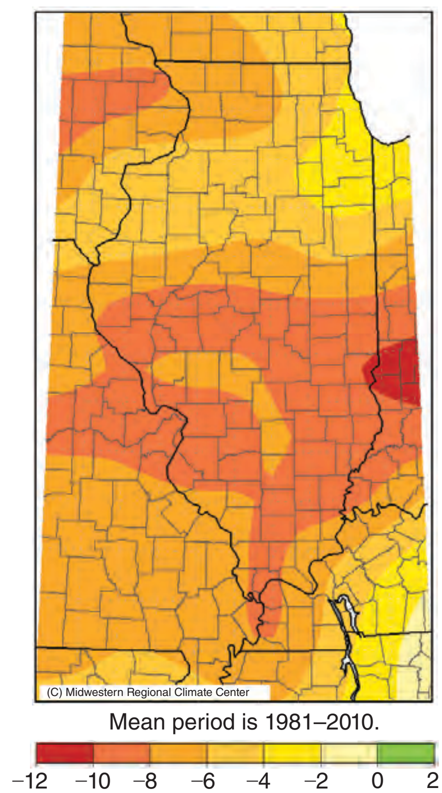


Figure 3.5 Precipitation departures from normal for May 1 to July 31, 2012, showing the widespread dryness across the state

Table 3.3 Illinois (statewide) Precipitation Ranking by Season. Period of rankings spans 118 years, 1895–2012.

Period	Rank	Precipitation (in)	Normal (in)	Departure (in)	% Normal
December–February 2012	66th driest	6.72	6.82	−0.10	99
March–May	17th driest	7.68	11.34	−3.66	68
May–July	3rd driest	5.60	13.02	−7.42	43
June–August	6th driest	6.63	11.88	−5.25	56
September–November	37th wettest	10.18	9.94	0.24	102
December–February 2013	11th wettest	8.71	6.82	1.89	128

Table 3.4 Illinois (statewide) Average Temperature Ranking by Season/Three-Month Periods. Period of rankings spans 118 years, 1895–2012.

Period	Rank	Temperature (°F)	Normal (°F)	Departure (°F)
December–February 2012	4th warmest	34.5	29.1	5.5
March–May	1st warmest	59.4	52.2	7.2
June–August	11th warmest	76.0	73.6	2.4
September–November	33rd coolest	52.9	54.4	−1.5
December–February 2013	15th warmest	32.0	29.1	2.9

above normal and the warmest spring on record. This is a typical feature of droughts in Illinois: elevated temperatures, which further increase the stress of drought on water supplies, crops, livestock, and humans. On average, 100-degree weather is rare in Illinois, occurring only one to two days on average in southern Illinois and only once every two years on average in northern Illinois. However, as Figure 3.6 shows, 100-degree days were numerous and widespread across Illinois. Southern Illinois experienced 15 to 20 days, central Illinois experienced 10 to 20 days, and northern Illinois experienced 2 to 10 days with temperatures of 100 degrees or more.

By the end of July, precipitation deficits for 2012 had reached 12 to 15 inches below normal for counties along the Wabash and Ohio River valleys (Figure 3.7). Areas to the east of St. Louis and in northern Illinois fared better with deficits of 6 to 9 inches. The rest of central and southern Illinois faced precipitation deficits of 9 to 12 inches.

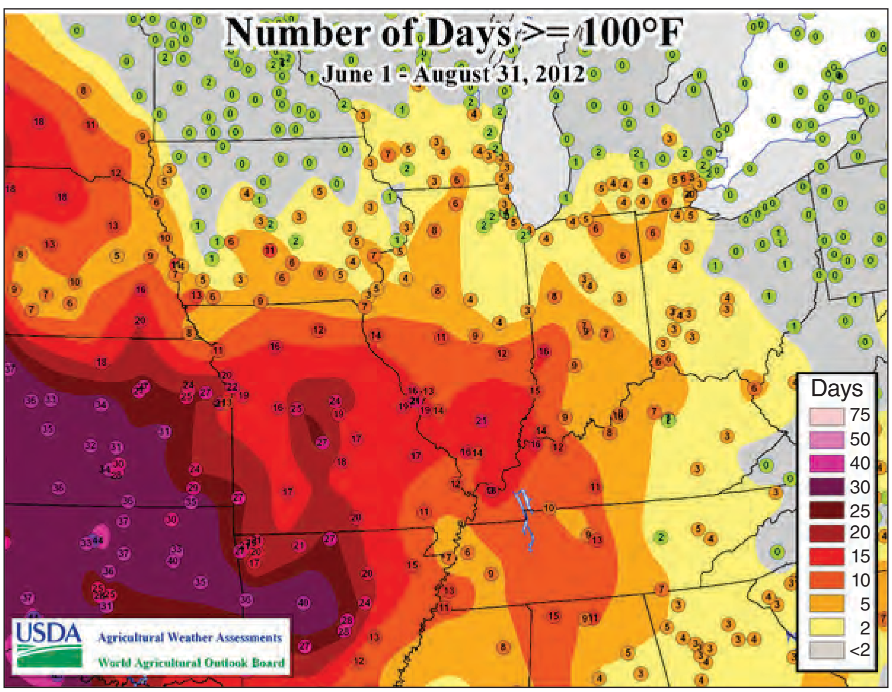


Figure 3.6 Map showing the number of days at or above 100 degrees from June 1 to August 31, 2012

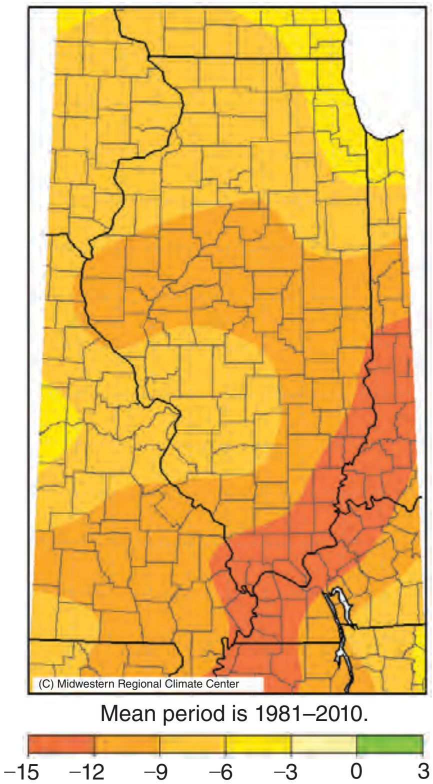


Figure 3.7 Precipitation departures from January 1 to July 31, 2012, showing widespread dryness with the largest departures in southeastern Illinois

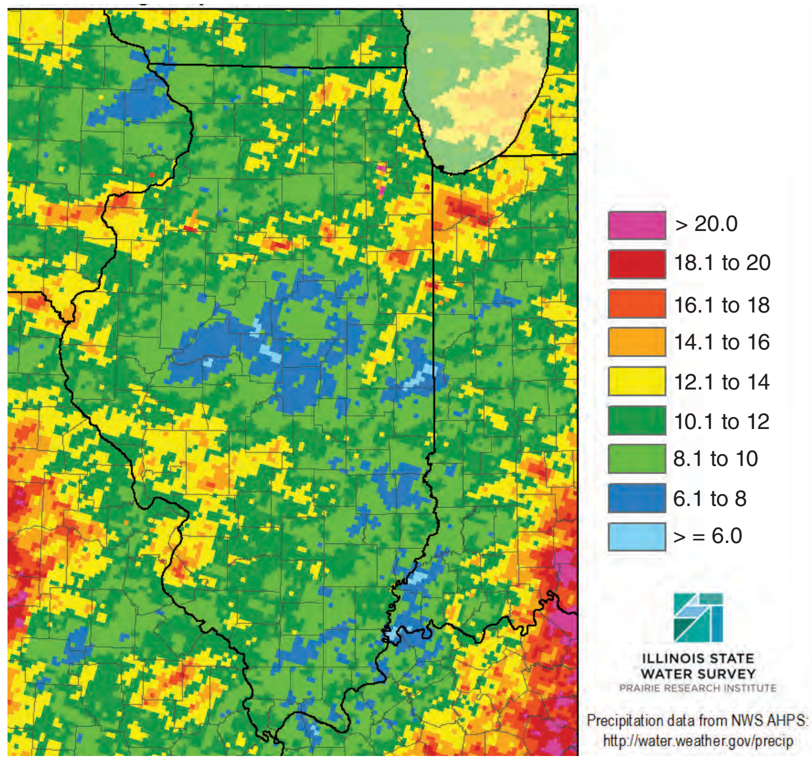


Figure 3.8 Radar raingage precipitation from March through July 2012. The resolution of this product is 4 km.

A newer monitoring product provided by the National Weather Service uses raingage data to adjust the radar-estimated precipitation estimates. This product is called the Multi-sensor Precipitation Estimate (MPE). By itself, the radar-estimated precipitation has a resolution of 4 km. However, it is limited in accuracy by assumptions about the drop size distribution within the storm (i.e., all large drops or small drops), nearby storms blocking out storms behind them, and the curvature of the earth. The role of the sparse and irregularly spaced raingage network is to recalibrate the radar estimates using equations. The result is a high-resolution, moderately accurate estimate of precipitation.

The MPE maps for the total precipitation (Figure 3.8) and the departure from normal (Figure 3.9) feature the precipitation deficits during the heart of the drought from March through July. The higher resolution reveals that even during the worst of the drought, a few

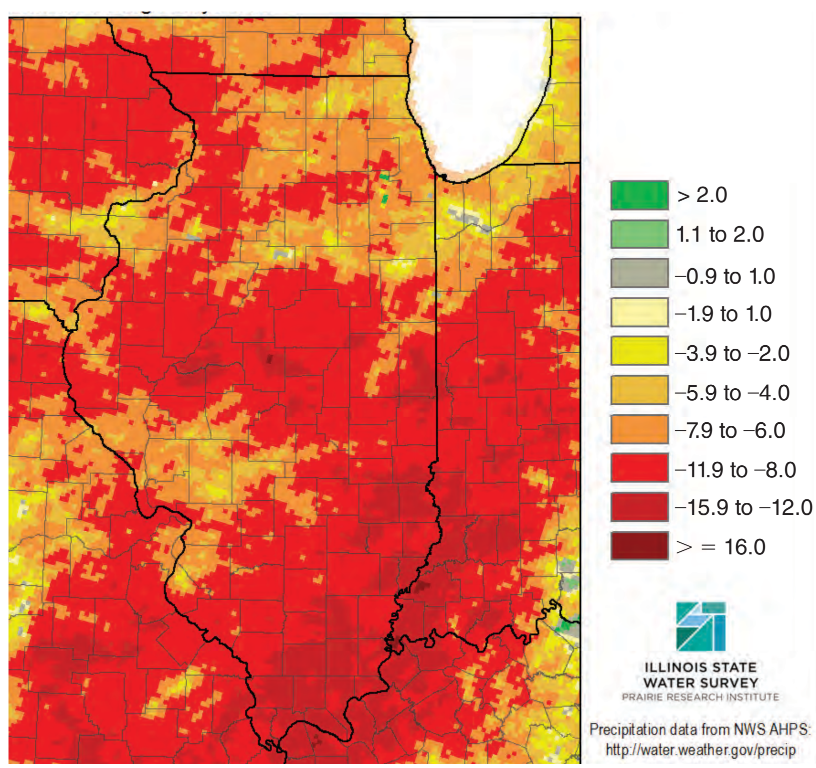


Figure 3.9 Radar raingage precipitation departure from normal (inches) for March through July 2012

areas did see precipitation amounts close to normal. These areas included from Moline to St. Louis on the Illinois side, a stretch along Interstate 80, and some parts of Kankakee and Iroquois counties. Although the precipitation was still below normal in those areas, the effect of timely precipitation amounts made an enormous difference in reducing the agricultural impacts in those areas.

Evapotranspiration

The lack of precipitation is the primary factor for producing a drought, but evapotranspiration can play a critical role as well. Evapotranspiration rates can be higher than average during the initial stages of drought due to the increased temperatures, sunshine, and wind. This wide imbalance between reduced supply and increased demand can rapidly use up available water in the landscape. In fact, evapotranspiration rates will drop with the depletion of soil moisture and surface dryness.

Although evapotranspiration data are limited in time and space, what are available indicate very high rates during the 2012 drought. One basic measure of evaporation is the water level in a 3-foot evaporation pan. Some of the longest complete records are from Champaign and extend back to 1980. For 2012, the evaporation rate was 0.5 inches above average for May, 1.5 inches above average for June, 2.2 inches above average for July, and 1.8 inches above average for August. That is 6 inches above the 1980–2014 average for Champaign and represents about one-and-one-half months of summer precipitation. The total water loss from the evaporation pan in July 2012 was 8.83 inches, the most of any month on record for the site.

Although evaporation can be measured from an evaporation pan, measuring transpiration is considerably more difficult because measurements have to be made from the leaves of the relevant vegetation. One instrument deployed in Champaign at the beginning of the 2012 growing season was a reference evapotranspiration gage. This instrument is an evaporimeter, resembling a raingage, only modified with a ceramic evaporating cup covered in a green canvas to simulate the albedo and leaf properties of a cut-grass covered surface. The gage is filled with distilled water, and water loss readings are made daily. When compared with daily precipitation readings, a water balance for the season can be constructed.

During the 2012 growing season, readings began in May, and evapotranspiration rates quickly outpaced the incoming precipitation, resulting in a water deficit. By May 31, the water deficit was 2.6 inches, meaning that 2.6 inches more water left the evapotranspiration instrument than the amount that fell in the nearby raingage. By June 30, the water deficit was 6.5 inches and by July 31 it had reached 12.5 inches. The worst deficit occurred on August 9 at 13.8 inches. However, some rains kept the deficit from growing and even reduced it slightly by August 31 with a deficit of 12.2 inches. With the rains in September and October, the water deficit started to ease with a reading of 9.1 inches on September 30 and a reading of 4.1 inches on October 30 when the gage was taken down for the season to prevent freeze damage. By comparison, the water balance in Champaign for 2013 was positive through the end of August before a dry spell caused a late-season deficit of 3 inches.

August 2012

The first signs of relief from drought conditions occurred in August, in particular the second half, when most of the state began to see both temperatures and precipitation that were close to normal. In fact, eastern and southern Illinois saw above-normal precipitation for the first time in 2012 (Figure 3.10). The regions receiving above-normal precipitation experienced moderate increases in soil moisture and streamflow. Although this precipitation was too late in the growing season for corn, it appeared to have some benefit for soybeans.

Hurricane Isaac and Drought Recovery

On September 1-3, 2012, the remains of Hurricane Isaac tracked across the Midwest, bringing widespread and heavy precipitation across the region (Figure 3.11). Although it does not happen often, tropical systems can reach Illinois on occasion. By the time they arrive here, they are generally weaker while still bringing widespread precipitation. A detailed precipitation map based on radar and calibrated by precipitation gages (Figure 3.12) shows how extensive the precipitation was in Illinois. Much of central and southern Illinois received 2 to 4 inches of precipitation over a three-day period. Because the precipitation was slow and steady and spread out over three days, most was able to soak into the soil, recharging the topsoil and subsoil. The precipitation extended all the way up to Interstate 80 before stopping.

In the two-week period from August 27 (before Hurricane Isaac) to September 9, U.S. Department of Agriculture's National Agricultural Statistics Service (NASS) reported that topsoil moisture in the "very short" category went from

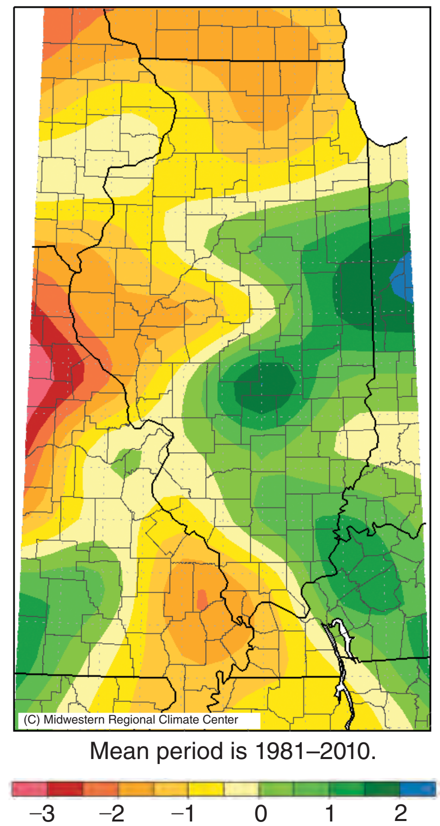


Figure 3.10 Precipitation departures from August 1 to 31, 2012, showing the return of precipitation, especially in eastern and southern Illinois

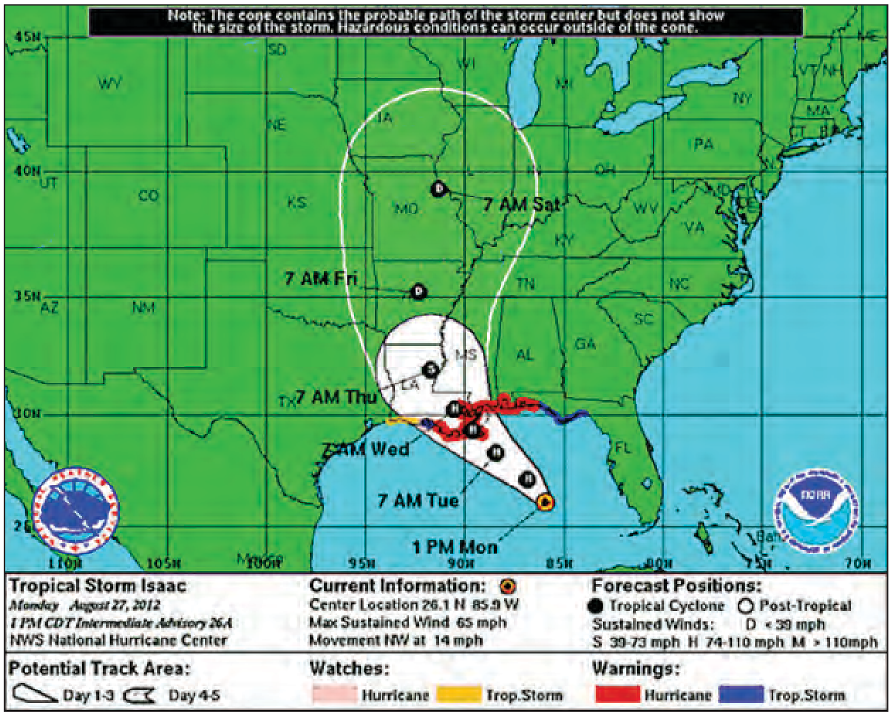


Figure 3.11 Storm track of Hurricane Isaac as it moved through Illinois over Labor Day weekend. Figure courtesy of NOAA National Hurricane Center.

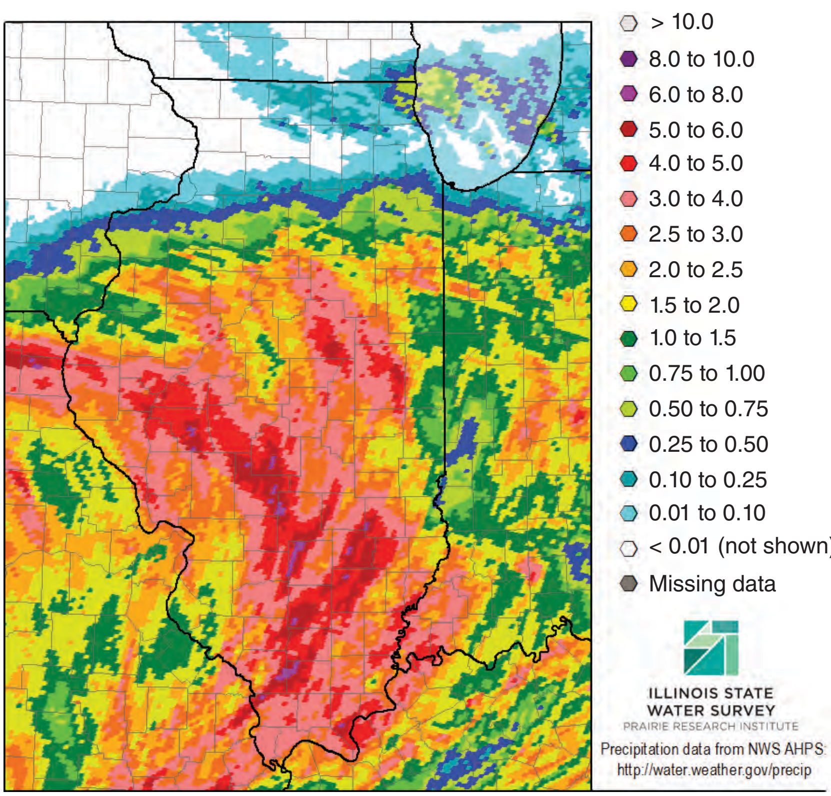


Figure 3.12 High-resolution map of the precipitation from Hurricane Isaac. Many areas in central and southern Illinois received 2 to 4 inches over the course of three days.

57 to 16 percent. Topsoil moisture in the "short" category went from 30 to 31 percent, and topsoil moisture in the "adequate" category rose from 13 to 52 percent. Although these are qualitative categories based on field soil surveys, they illustrate how the topsoil showed significant improvement in short order. NASS considers topsoil to be the top 6 inches of soil. Subsoil moisture showed similar improvements over the same period with 74 percent of soils in Illinois in the very short category before the storm and 36 percent in that category after the storm. NASS considers subsoil to be the layer from 6 to 24 inches. In general, this layer is both slower to dry out and slower to recover than topsoil.

With the help of Hurricane Isaac, September finished with precipitation almost 2 inches above normal and the 17th wettest September on record (Table 3.1). September temperatures were 1.3 degrees below normal which helped relieve drought stress as well. In addition, October was wetter and cooler than normal. October precipitation was 0.7 inches above normal, while temperatures were 1.9 degrees below normal.

It is not unusual in past episodes of drought for brief periods of dry conditions to return. That was the case for November 2012 with only 1.24 inches of precipitation and the 14th driest November on record. Temperatures were 1.3 degrees below normal for the month. December was back to near-normal precipitation, while temperatures were 6.9 degrees above normal.

By the end of December, the precipitation deficits still remained sizeable in Illinois despite the wet fall (Figure 3.13). Most of the state was still 6 to 12 inches below normal, and a few counties in far southern Illinois were 15 to 18 inches below normal. However, above-normal precipitation prevailed in January and February 2013. Any lingering concerns of drought were gone after near record precipitation in spring 2013. April 2013 received 6.93 inches and was the third wettest April on record. May 2013 received 6.57 inches and was the 13th wettest May on record.

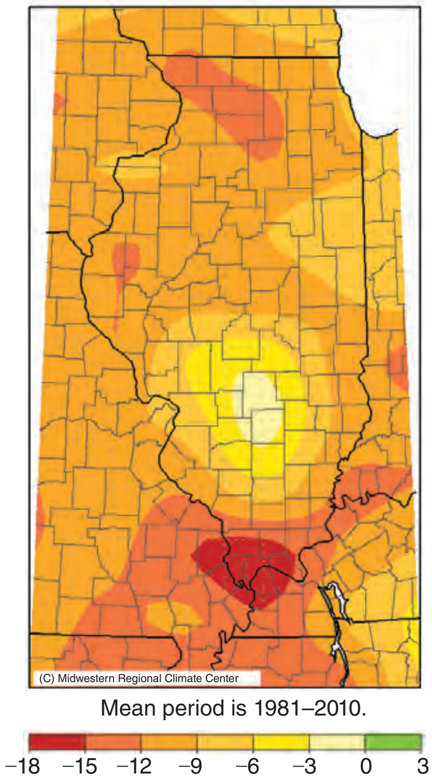


Figure 3.13 Precipitation departures from normal by the end of 2012. While some areas were recovering from the drought, the deficits remained sizeable and were finally erased in spring 2013.

U.S. Drought Monitor

According to the U.S. Drought Monitor (USDM), Illinois experienced drought conditions statewide during the epic drought of 2012 to varying degrees. Some of the harshest drought conditions in the Midwest occurred in Illinois. Figure 3.14 puts into perspective the intensity and duration of the 2012 drought compared with recent dry and drought conditions since 2000. Dry conditions were quite common throughout the early and mid-2000s with a wet period in the late 2000s. Dryness came in spurts since 2010, mainly during summer months.

However, conditions in the summer of 2012 turned out to be more significant. Southeastern Illinois experienced exceptional drought conditions from mid-July to late August. At the drought's peak, about 8 percent of the state was affected by these conditions. This was the first time this century that Illinois experienced such conditions. About 81 percent of the state had at least extreme conditions at the peak of the drought, almost twice the spatial coverage than the 2005 drought. The drought of 2012 was not only intense but also brief compared with 2005. The onset of severe and extreme drought conditions spread rapidly after springtime precipitation failed. Extreme drought conditions covering more than 10 percent of the state lasted about a month in 2012 and nearly six months in 2005.

Comparison with Past Drought and Trends in Drought

The 2012 event is the most recent drought in Illinois history, but how does it compare to previous droughts and what are the trends over time? As already mentioned, it's hard to compare droughts directly because the onset, duration, and intensity of each major drought are unique.

One way to measure droughts over time is by using the Palmer Drought Severity Index (PDSI). It uses temperature and precipitation departures from average and a simple water-balance model to determine drought conditions. However, its drawbacks include its insensitivity to droughts shorter than about nine months and its undesirable bi-modal distribution (e.g., too wet or too dry, without many months in the middle). In any event, it is one of the few tools available that allow us to examine droughts back to 1895 on a somewhat

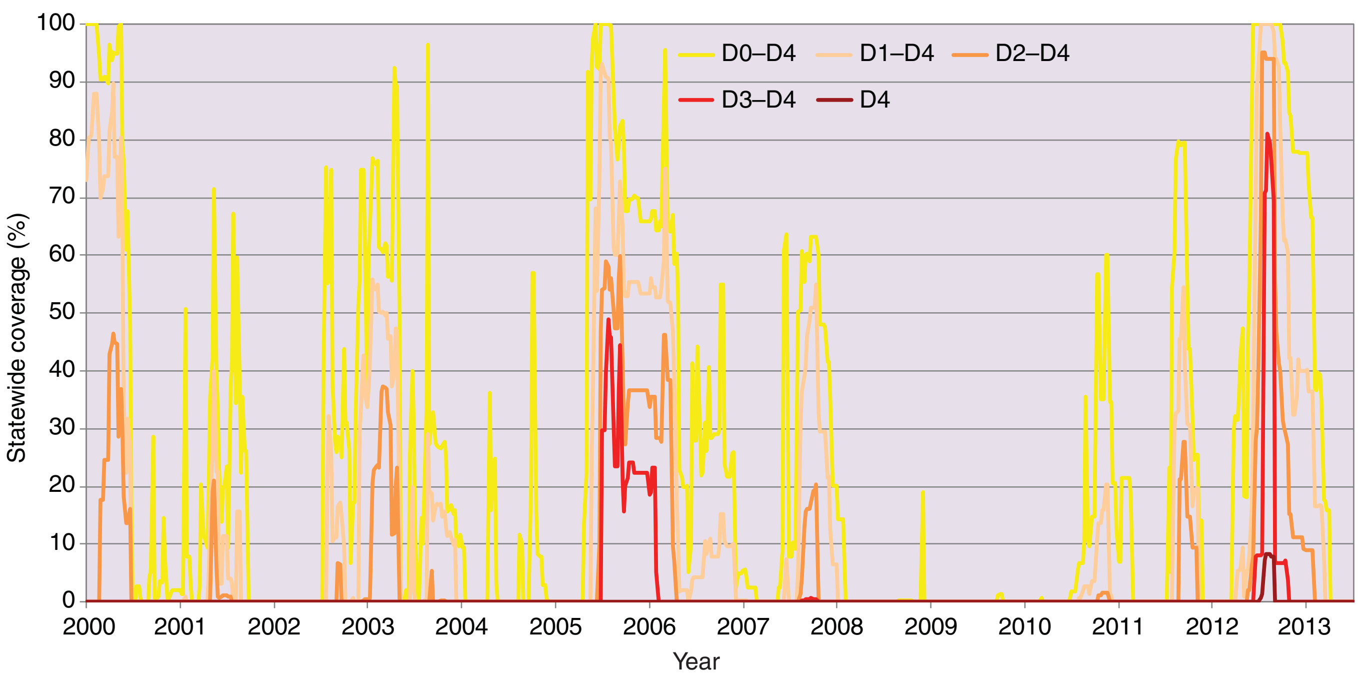


Figure 3.14 Time series of U.S. Drought Monitor indices Jan 4, 2000–Jul 9, 2013. Area percentage of Illinois under drought conditions. D0-D4, D1-D4, D2-D4, D3-D4, D4 correspond, respectively, with abnormally dry, moderate drought, severe drought, extreme drought, and exceptional drought conditions.

equal basis (Figure 1.2). From 1895 to 1965, according to the PDSI, droughts were quite common in Illinois. The years classified as extreme statewide droughts with a PDSI value of -4 and the number of months spent in extreme drought were: 1901–1902 (9 months), 1914–1915 (9 months), 1930–1931 (11 months), 1933–1934 (9 months), 1936 (2 months), 1940–1941 (5 months), and 1953–1954 (11 months). In addition, each of these droughts was considered lower-grade droughts for much of the time.

After 1965, droughts became less frequent and of a shorter duration. The droughts and the number of months considered "extreme" include: 1988–1989 (3 months), 2005 (1 month), and 2012 (2 months). All three cases had substantial agricultural impacts, and in the case of the 1988–1989 event, substantial water supply impacts by modern standards. However, none of the three events were that extraordinary by pre-1965 standards. Given the impacts and disruptions seen in recent droughts, it is hard to determine the magnitude of the impacts on modern-day Illinois of a 1930–1931 or 1953–1954 type of drought.

Summary

Illinois was one of several focal states to be affected by the historic U.S. drought of 2012. An examination of precipitation and temperature observations indicated several key features of the drought's impact on Illinois. Data for Illinois indicate that 2012 was the warmest year on record with a mean temperature of 55.9 degrees (3.5 degrees above normal) and the 10th driest year with 30.11 inches of precipitation (9.85 inches below normal). The year began with near-normal precipitation on the heels of an abnormally wet start to the 2011–2012 cold season. March experienced record warmth with relatively dry conditions, resulting in the rapid drying of soils across Illinois. Some improvements were seen in April but were quickly lost during an abnormally dry May. Conditions rapidly deteriorated through the summer months. At its worst, the May–July period was the third driest on record, only slightly less severe than in 1936 and 1988. The precipitation in late August and September, and in particular the remains of Hurricane Isaac, marked the turning point in the 2012 drought. However, complete recovery from the 2012 drought did not occur until the heavy rains of the following spring.

Chapter 4: Soil Conditions

The Illinois Climate Network (ICN) monitors soil temperatures and moisture levels hourly at each of its 19 stations. The locations of these monitoring stations are shown in Figure 4.1. These measurements are part of a wide array of weather and soil parameters monitored at each station that provide a larger view of current conditions and long-term trends as well as specific conditions related to events such as the 2012 drought. Most of the ICN sites also provide shallow groundwater observations combined with soil and enhanced weather observations that provide unique long-term datasets available at only a limited number of other locations in the United States.

Soil Temperatures

Soil temperatures were higher than the long-term average across Illinois for the first eight months of 2012 (Figures 4.2 and 4.3). Soil temperatures at depths of 4 inches over sod averaged 61.3 degrees for January–August 2012, 4.2 degrees above the long-term average for the period. Temperatures were also higher at 8 inches, averaging 60.7 degrees for the period or 3.9 degrees above the long-term average. Soil temperatures dropped closer to normal levels for most of the last four months of 2012 with temperatures averaging 1.5 to 2.0 degrees above the long-term average.

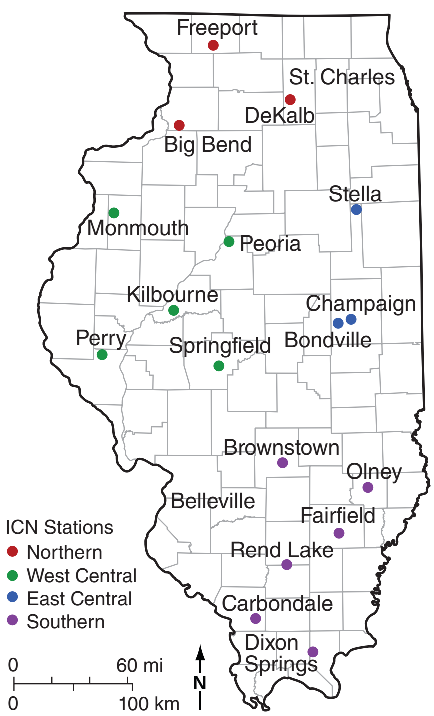


Figure 4.1 Locations of the 19 ICN monitoring stations

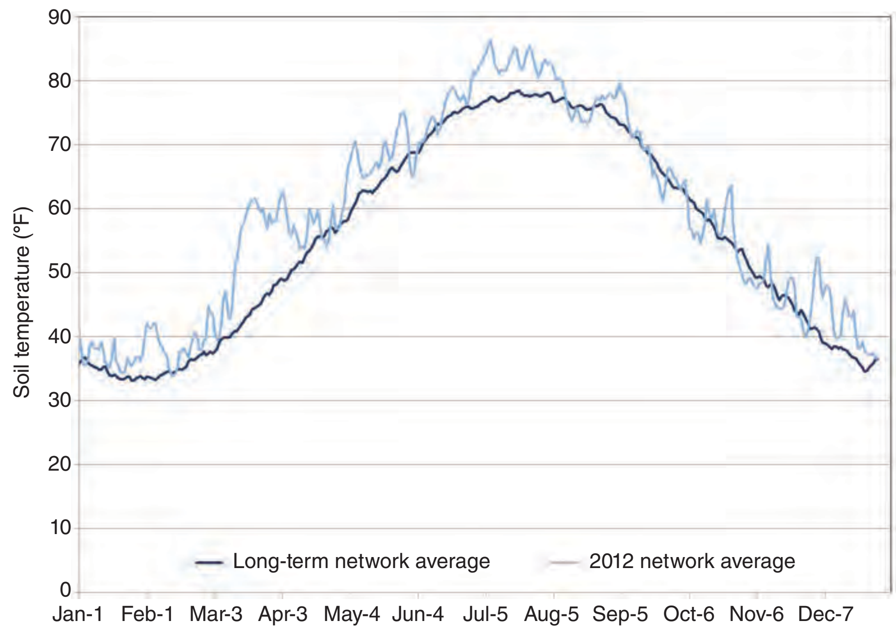


Figure 4.2 Average soil temperature for all ICN stations; 4-inch depth

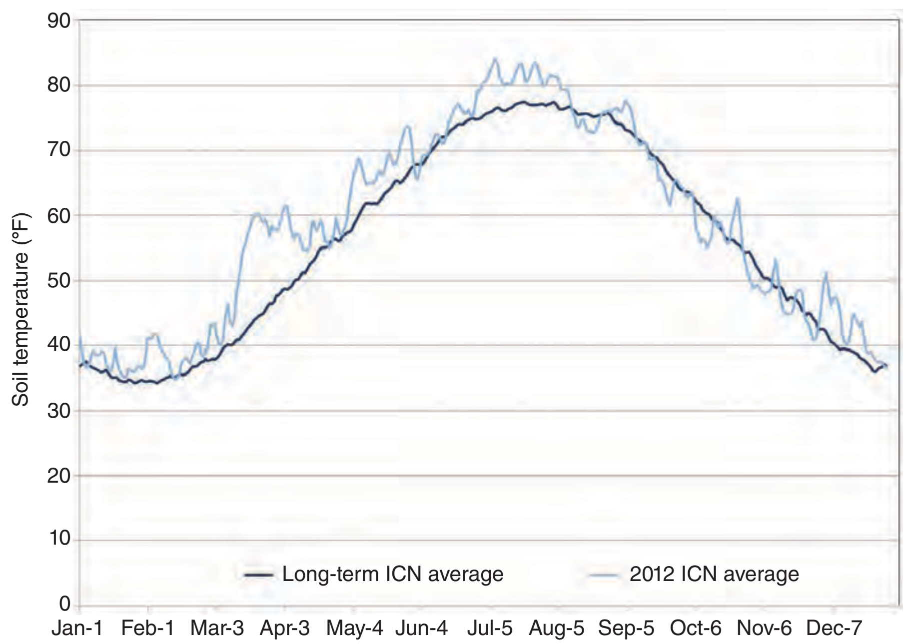


Figure 4.3 Average soil temperature for all ICN stations; 8-inch depth

Although soil temperatures were above normal for most of the first eight months of 2012, there were two periods with exceptionally high temperatures. One was in March 2012, when Illinois experienced its warmest March on record with an average air temperature of 55.5 degrees, 14.2 degrees above normal. The statewide average soil temperature that month rose above 60 degrees, more than 17 degrees above normal. Another exceptionally warm period was from late June into August, during which time the Olney station in southern Illinois recorded a maximum soil temperature at 4 inches under sod of 99.9 degrees. During July, four ICN stations (Olney, Carbondale, Springfield, and Brownstown) recorded record high soil temperatures at the 4-inch level under sod.

Soil Moisture

Figures 4.4 to 4.9 present the average soil moisture conditions for the 19 ICN sites in 2012 as compared with the previous eight-year monitoring period (2004–2011) at eight different levels of soil depth ranging from 2 inches to 50 inches. Regional averages were also computed and are shown in Figures 4.10 to 4.13.

The ICN average soil moisture from 2004–2011, shown in Figures 4.4 to 4.9, show the normal seasonal pattern of soil moisture in Illinois. Moisture in the shallower layers of soil is typically greatest in March and April, and then tends to decline throughout much of the growing season from late April through August as evaporation from the soil increases and vegetation takes water from the soil. The soil moisture at 2, 4, and 8 inches typically begins to recover immediately after the growing season. The soil moisture at 20 and 39 inches follows a similar seasonal cycle, but with a lagged effect. Soil moisture at 59 inches shows a scant seasonal pattern and is usually diminished only during abnormally dry years.

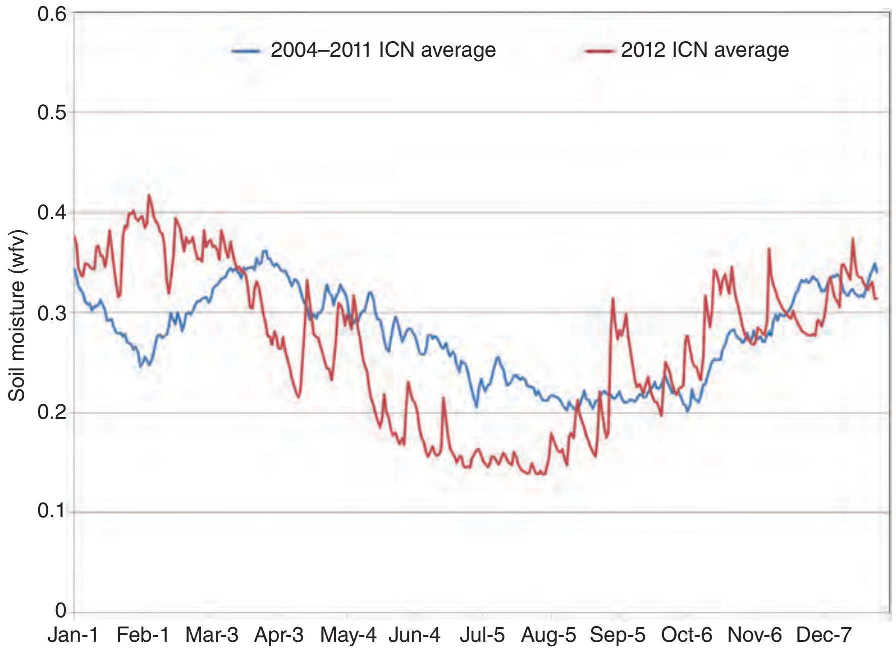


Figure 4.4 Average soil moisture at 2 inches; comparison of 2012 with the eight previous years

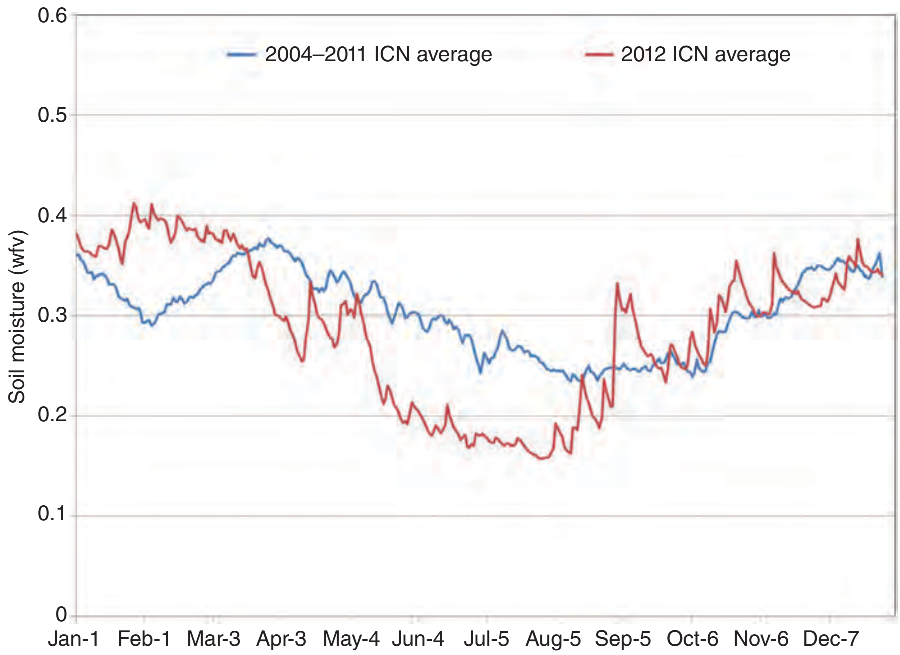


Figure 4.5 Average soil moisture at 4 inches; comparison of 2012 with the eight previous years

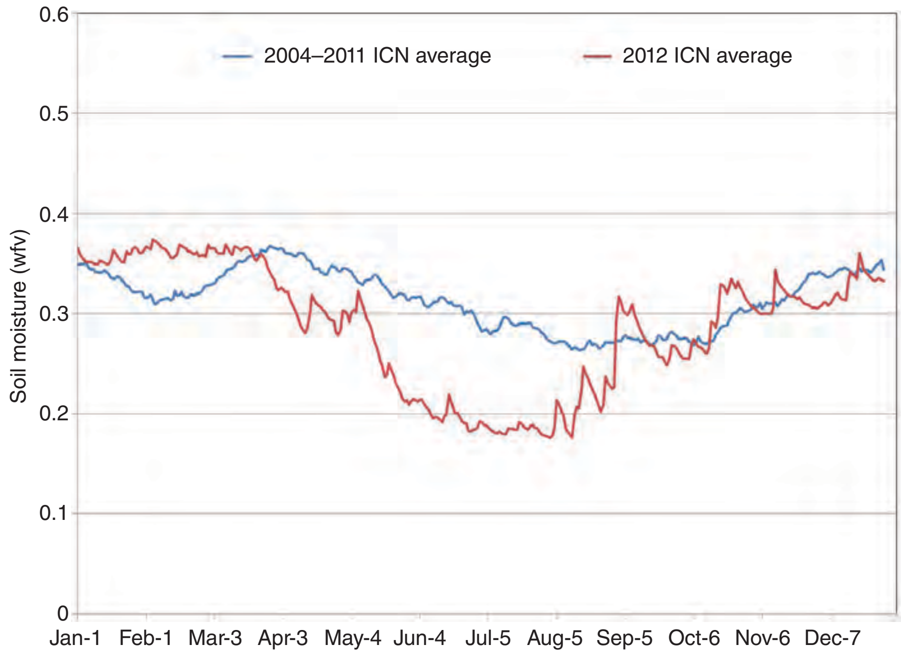


Figure 4.6 Average soil moisture at 8 inches; comparison of 2012 with the eight previous years

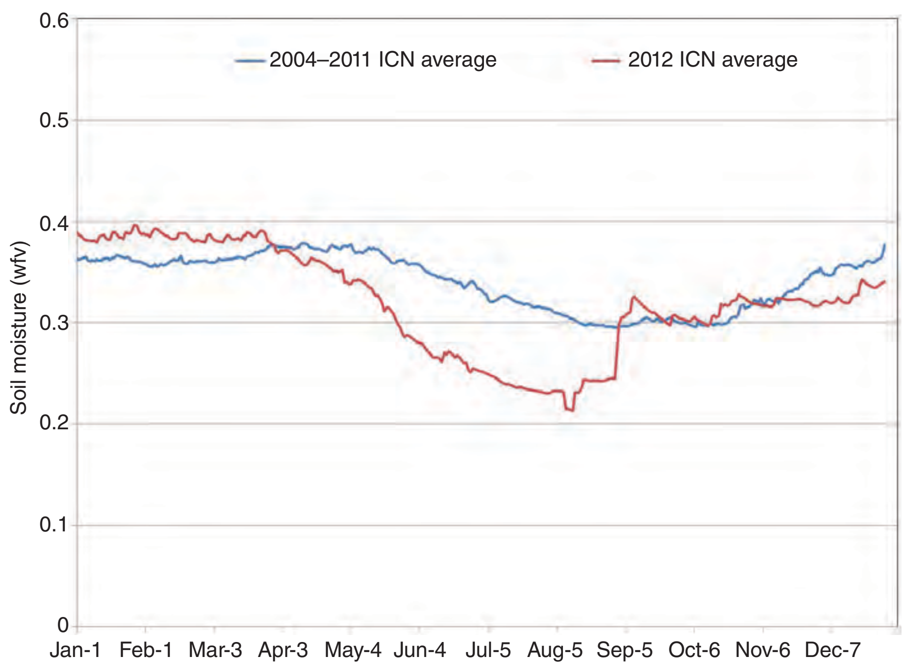


Figure 4.7 Average soil moisture at 20 inches; comparison of 2012 with the eight previous years

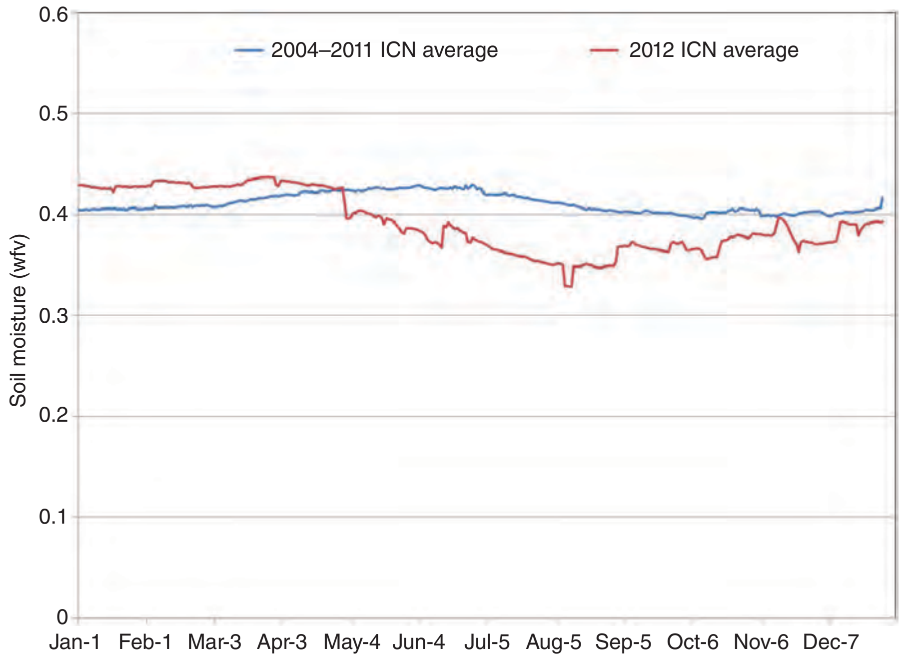


Figure 4.8 Average soil moisture at 39 inches; comparison of 2012 with the eight previous years

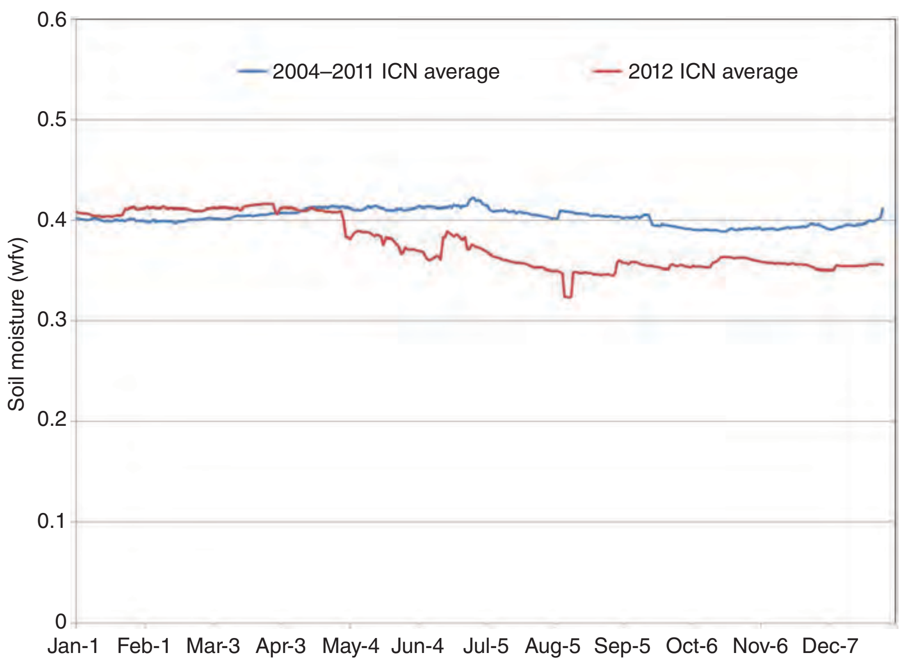


Figure 4.9 Average soil moisture at 59 inches; comparison of 2012 with the eight previous years

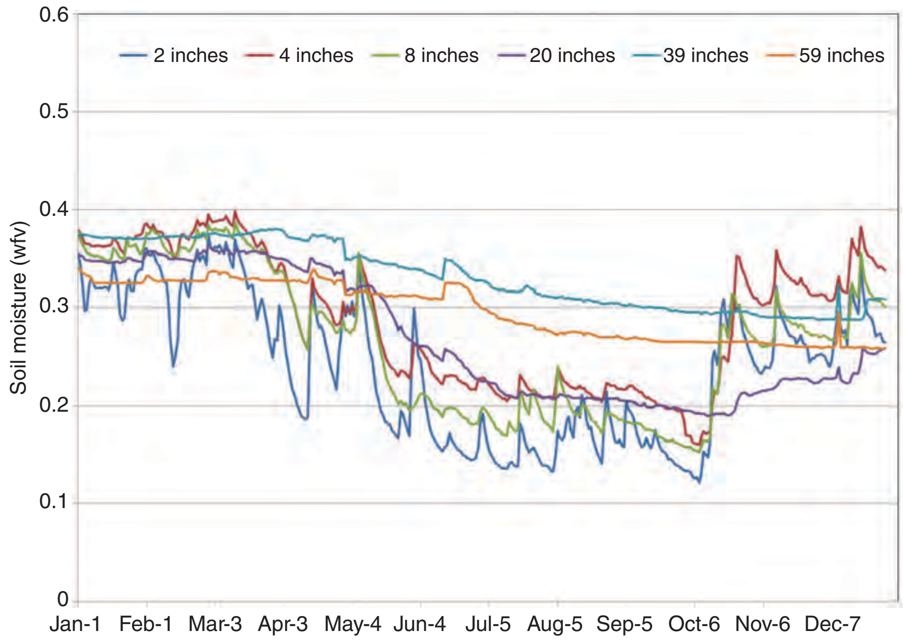


Figure 4.10 Average soil moisture for the ICN northern stations at six separate depths

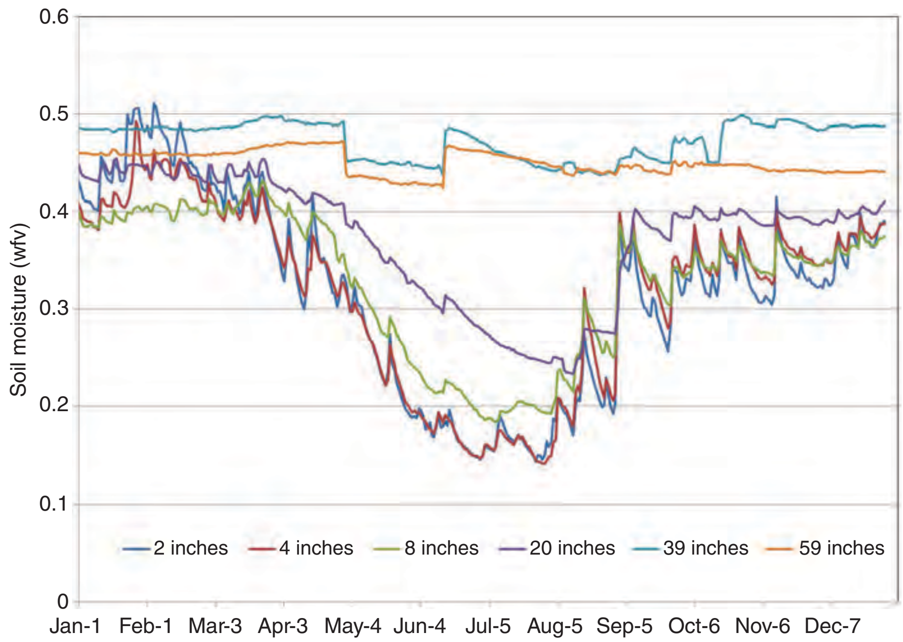


Figure 4.11 Average soil moisture for the ICN southern stations at six separate depths

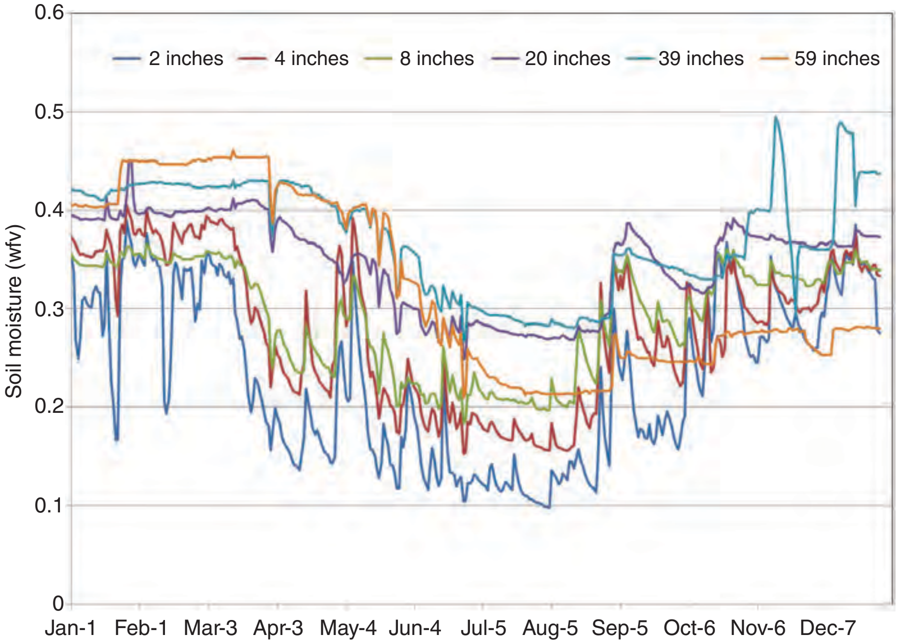


Figure 4.12 Average soil moisture for the ICN east-central stations at six separate depths

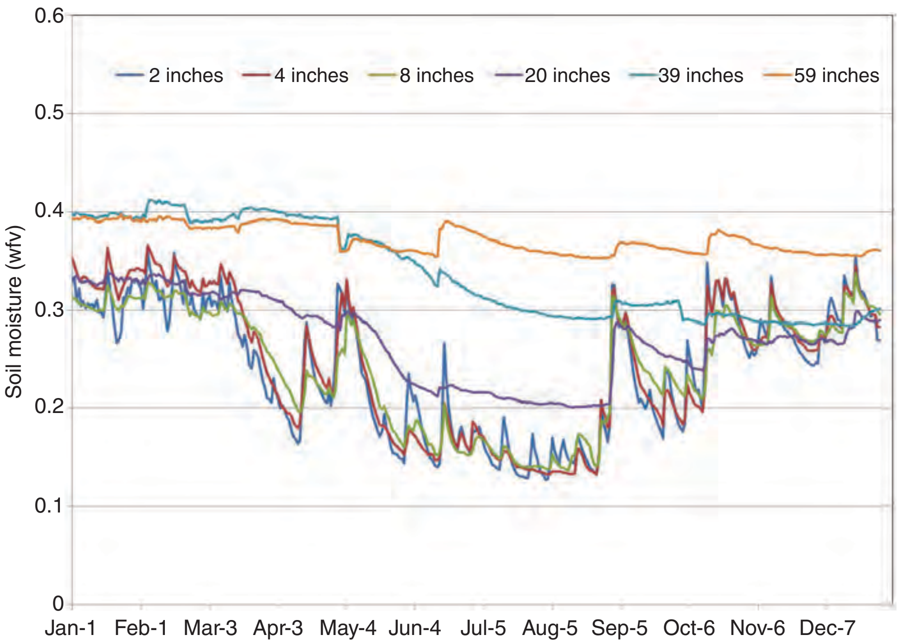


Figure 4.13 Average soil moisture for the ICN west-central stations at six separate depths

January–July 2012

Conditions in early 2012 began with higher-than-average soil moisture levels. At depths of 2 inches, moisture levels averaged 0.37 water fraction by volume (wfv) in January and February. The field capacity for silt-loam soils, the type found most regularly at ICN stations, is 0.36 wfv. The highest levels were measured in southern Illinois with a high of 0.51 wfv at the beginning of February.

Statewide, moisture levels began to decline as air and soil temperatures rose in March, first at the 2- and 4-inch depths, then followed one to two weeks later by declines at the 8- and 20-inch depths. Soil moisture levels at 39 and 50 inches began to decline in late April.

Soils continued to dry through spring and early summer 2012, reaching minimums in late July. Statewide moisture levels averaged 0.15 wfv at 2 inches in July, just at the wilting point for silt loam soils. Dry conditions extended through the 4- and 8-inch depths. However, significant amounts of water were still present at depths of 20 inches and greater. Moisture levels averaged 0.24 wfv at 20 inches and 0.36 wfv at 39 and 59 inches for July. Soil moisture in southern Illinois began to increase at the 2- to 20-inch depths in early August as precipitation levels rose. Slight increases occurred in the levels in central and northern Illinois.

Hurricane Isaac and Recovery

At the end of August, soil moisture levels at the shallower depths were already increasing in most of Illinois due to increased precipitation earlier in the month. ICN stations averaged 3.40 inches of rain between August 1 and 30, with the largest totals in southern and east-central Illinois. On August 30, soil moisture levels at 2 inches averaged 0.17 wfv. Conditions were wetter at deeper depths with moisture levels at 59 inches, averaging 0.35 wfv statewide.

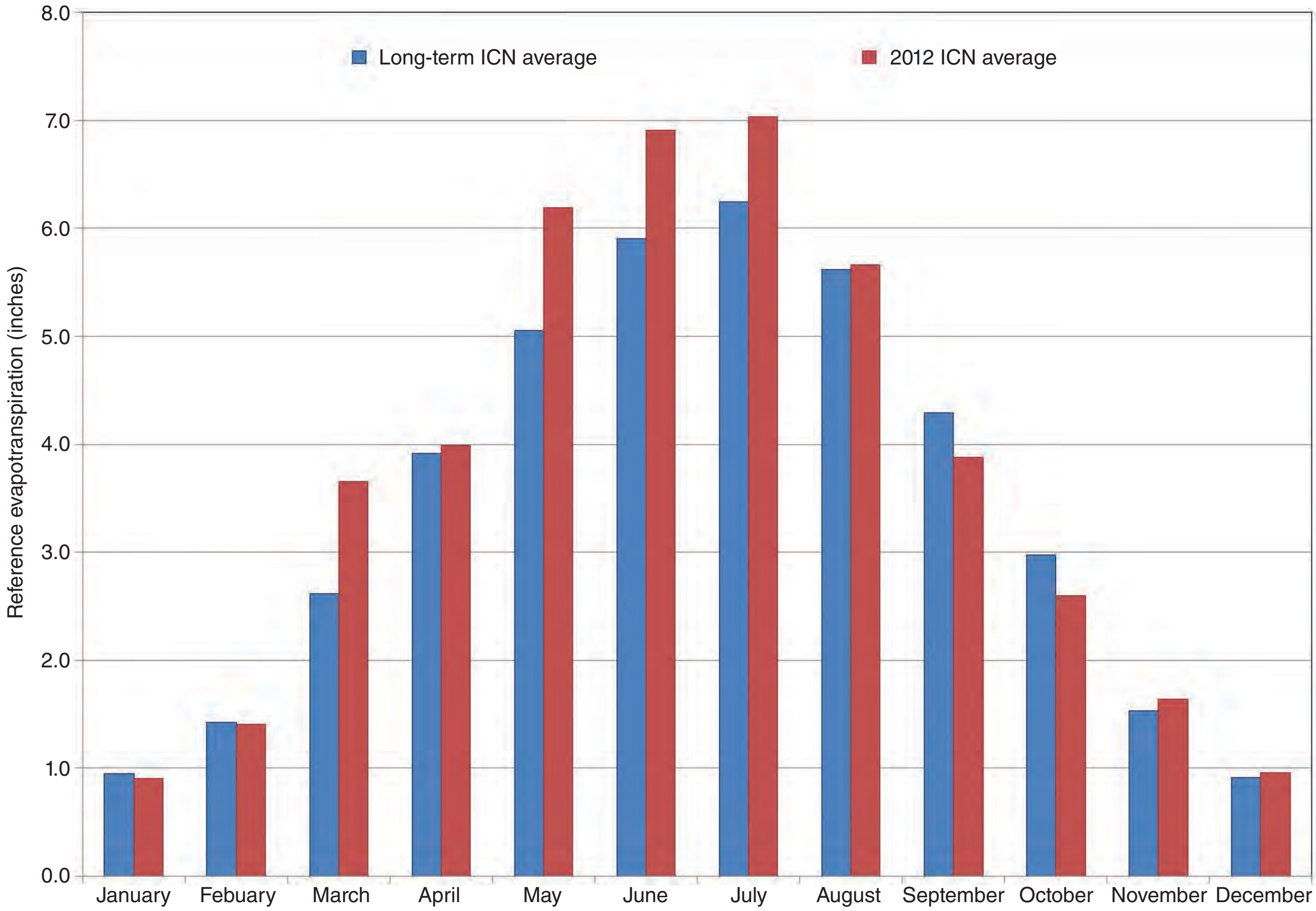


Figure 4.14 Average monthly reference evaporation; comparison of 2012 to 1989–2011

The remnants of Hurricane Isaac moved through Illinois on Labor Day weekend (August 31–September 3), bringing rain to most of the state. ICN averaged 3.03 inches of rain over the four-day period. Southern Illinois received the most with 4.34 inches, but the east and west-central regions also received more than 3 inches. Northern stations, however, saw little impact from the storm with a four-day precipitation average of only 0.03 inches.

Soil moisture levels followed similar regional patterns, reflecting the amount of precipitation from Hurricane Isaac. At 2 inches, the statewide average rose 71 percent over the period, from 0.17 wfv on August 30 to 0.29 wfv on September 3. The highest soil moisture increases were observed in southern Illinois where moisture levels at 2 inches rose 95 percent. At the Carbondale station, 2-inch soil moisture increased 190 percent over the course of the storm, from 0.13 wfv on August 30 to 0.38 wfv on September 3. The northern region, in comparison, saw no change in moisture levels. Two-inch soil moisture at the Freeport station measured 0.19 wfv on August 31 and 0.18 wfv on September 3.

The impacts were observed to depths of 20 inches. At the Fairfield station in southern Illinois, soil moisture at 20 inches increased 49 percent over the course of the storm. No significant changes were observed at depths of 39 and 50 inches over the time period, but moisture levels at 39 inches began a slow upward trend after the storm.

After the passage of Hurricane Isaac, moisture levels in September fell quickly as soils drained, with the greatest impacts at the 2- and 4-inch depths. By September 24, the statewide average at 2 inches had dropped 45 percent from the high on September 4. However, with the cooler air and soil temperatures of fall and winter, soil moisture levels at depths of 2 to 8 inches began to slowly increase through the end of 2012, particularly for southern and east-central Illinois. Meanwhile, northern soil moisture levels declined over September and into October. Rains in mid-October led to significant improvement at the 2- to 8-inch depths that continued through the end of 2012.

On average, levels at 39 inches also began a general upward trend after Isaac, slowly increasing over the last four months of the year. However, increases were limited primarily to southern and east-central Illinois. Moisture levels in west-central and northern Illinois continued to decline during the fall and early winter. At 59 inches, soil moisture levels, on average, showed no impact from the storm and remained steady through the end of the year. Full recovery at the lower soil levels did not occur until spring 2013.

Reference Evapotranspiration

Reference evapotranspiration (ET) is a method of estimating the ET demand rate using commonly measured weather parameters such as air temperature, relative humidity, and solar radiation. The ICN has calculated reference ET since its inception in 1989. Currently, ICN uses a modified Penman-Monteith equation for its calculations which assumes the ground is covered by a short crop of clipped grass as is found at most ICN stations.

In 2012, significant differences in reference ET from the long-term average began to appear in March with increasing air and soil temperatures. Statewide values averaged 3.7 inches for March 2012, 40 percent greater than the long-term average for the month. The higher ETs were seen throughout the state. Higher-than-normal ETs were also calculated for the months of May, June, and July 2012. However, the difference between the long-term and 2012 statewide averages decreased over the three-month period, falling from a 22 percent difference in May to a 13 percent difference in July.

Although soil moisture is not used to calculate reference ET, declining moisture levels would affect the processes of both evaporation and transpiration. Evaporation from the soil would decrease as the surface resistance of dry soil increases. Transpiration would also be expected to decrease during such conditions as plants have greater difficulty extracting water from the soil and begin to wilt.

The statewide average reference ET value declined in August to normal levels. The value remained near or below normal levels for the remaining four months of 2012.

Chapter 5. Streamflow Conditions

A low flow rate in rivers and streams is one of the more easily detected symptoms of hydrologic drought. However, low streamflow amounts do not necessarily occur during the drought's period of least rainfall (in contrast to high streamflow amounts that can usually be directly attributed to recent precipitation events). Instead, low streamflow amounts are more often associated with the progressive depletion of water that has been stored in a stream's watershed, particularly in regard to soil moisture and shallow groundwater. The lowest streamflow amounts occur following extended periods of below-normal precipitation, but also typically during the late summer and fall after the growing season has noticeably depleted soil moisture and surface and sub-surface storage. A map of the cumulative precipitation deficit for a region, such as shown for Illinois in Figure 3.9 for the period March 1 to July 31, 2012, identifies stream locations that are likely to experience well below normal flow amounts.

Two aspects of low streamflow are usually examined in regard to drought. The first aspect is the minimum flow level in the stream. Acute minimum streamflows typically produce the greatest environmental concerns, such as excessively high water temperatures and fish kills. Minimum flow rates are also pertinent to water supplies that need a consistent flow amount when withdrawing directly from a stream. For comparative and analytical purposes, the 7-day low flow (the flow rate during the lowest 7-day period during the year) is often used to represent the minimum condition. The second aspect examined is the average or cumulative flow amount that occurs over an extended period, such as a 6-month period during a drought. These average flow amounts are crucial for identifying the ability of a stream to replenish a water supply reservoir.

In this section, statewide streamflow conditions during the 2012 drought are discussed and comparisons are made with historical droughts to provide a perspective on its level of severity. Historical streamflow records are often used to characterize hydrologic droughts. The most extreme hydrologic droughts for most locations in Illinois occurred in the early and mid-20th century, particularly the 1930s and 1950s. In contrast, more recent droughts of 2005, 1999–2000, and 1988–1989 were less severe and affected only some regions and communities of Illinois (Winstanley et al., 2006). A statistical analysis of streamflows was conducted for a selected set of streamgages located throughout Illinois to assess flow conditions during the 2012 drought.

In Illinois, about 200 U.S. Geological Survey (USGS) streamgages have been used to monitor flow conditions statewide, of which 114 stations have more than 30 years of record. Streamgages that represent natural flow or those that exhibit minimal human influence are desirable for the streamflow analysis because they provide the best point of comparison to historical records, helping to identify impacts of climate variability in contrast to changes from anthropogenic activities such as reservoir storages, withdrawals, return flows, and major land use changes (Knapp, 1994). Most streamgages significantly affected by reservoir storages, withdrawals, and return flows were thus excluded from the analysis; however, a few streamgages with moderately altered low flows were included to provide more complete regional coverage in Illinois. In one case, the Sangamon River at Monticello, the low flow conditions represent a unique circumstance of altered flows related to groundwater-surface water interactions, which are discussed in more detail in Chapter 10: *The Decatur Case Study*.

Return flows from wastewater treatment plants are the most common type of human alteration of low streamflows. Wherever applicable, net return flow is computed as effluents to a stream minus withdrawals from the stream. Streamgages that have net return flows greater than 20 percent of their 7-day, 10-year low flows are assumed to exhibit human influences and thus are excluded from the analysis. In addition, only those stations that have at least 30 years of record are included in the streamflow statistical analysis. Consequently, 49 stations that satisfy these criteria were identified, as illustrated in Figure 5.1 and listed in Table 5.1, including their drainage areas and period of records used in the analysis. Streamflow statistics that best describe drought conditions, such as 7-day low flow and 6-month drought flow, were calculated for each of the 49 streamgages to characterize statewide streamflow conditions during the 2012 drought.

Comparison of the 2012 Low Flows to the Long-Term Statistics

Figure 5.2 illustrates the 2012 7-day low flow as compared to the 7-day, 10-year low flow (Q7,10) for the 49 streamgages used in this analysis. Streamgages are categorized into five groups based on the magnitude of the 2012 7-day low flow. Four categories are based on the expected recurrence interval of the 2012 event:

- The 2012 7-day flow is the lowest on record, which implies a recurrence interval of 30 years or greater (most of the 49 gaging records have more than 50 years of record).
- The 2012 7-day low flow is less than or equal to the Q7,10, thus having an associated recurrence interval of greater than 10 years.
- The 2012 7-day low flow is greater than the Q7,10, but less than or equal to the 5-year low flow, thus having an associated recurrence interval of between 5 and 10 years.
- The 2012 7-day low flow is greater than the 5-year low flow, thus having an associated recurrence interval of less than 5 years.

In addition, a separate fifth category is provided when the Q7,10 is zero:

- The 2012 7-day low flow is equal to zero and the Q7,10 is also equal to zero. In these cases, it is not possible from the 7-day flow to estimate a recurrence interval for the 2012 event. For nearly every streamgage

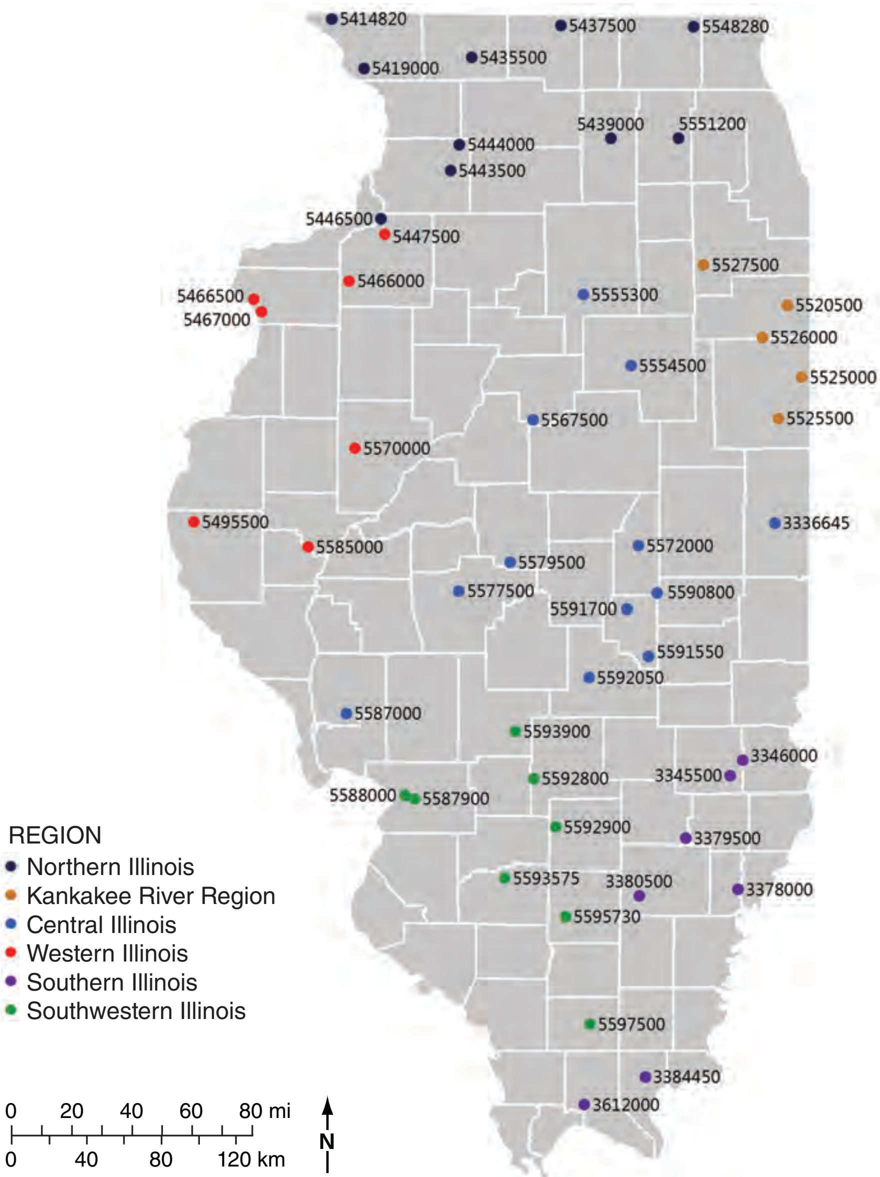


Figure 5.1 Location map of USGS stations used in streamflow analysis

that fits this category, flows in the summer or fall seasons decline to zero every 2 to 3 years. A zero low flow observation is equal to the lowest flow on record, and yet at the same time could be as common as a 2- or 3-year low flow event.

Of the 49, three streamgages located in central Illinois exhibited the lowest 7-day low flow on record. Six streamgages located in the northwestern, western, southwestern, and southeastern regions of the state had 7-day low flows less than their Q7,10. Nine of the streamgages located primarily in the northern half of the state had 7-day low flows less than their 7-day, 5-year low flows. Thirteen of the streamgages located in central, southwestern, and southeastern Illinois were zero and equal to their Q7,10 (i.e., category 5). The remaining 18 streamgages had 7-day low flows less than the Q7,10 but greater than or equal to their 7-day, 5-year low flows.

For each of the 49 streamgages, 6-month drought flows are computed and ranked in order of decreasing flow magnitude. The ranking of the 2012 6-month drought flow is illustrated in Figure 5.3 to provide insight into the severity of the 2012 drought throughout the state.

Streamgages are grouped into four categories based on the ranks of their 2012 6-month drought flow, which are 1 to 5, 6 to 10, 11 to 16, and greater than 16. The 2012 6-month flow is ranked in the lowest five on record for seven of the 49 streamgages used in the analysis, and four of these seven gages are located in central Illinois. The 2012 6-month flow is ranked in the lowest 10 on record in 15 of the 49 streamgages. Although Figure 5.3 does not show recurrence intervals, the respective 2012 6-month drought flow represents a recurrence interval of less than five years for more than half of the selected gages.

Comparison of the 7-day low flows with Q7,10 flows and the ranks of 6-month drought flows for the 49 streamgages used in this analysis suggest that streamflow conditions during the 2012 drought most greatly affected central Illinois. Most streams in southern Illinois became dry (zero flow) in 2012 as they often do during moderate to severe drought conditions; thus the 7-day low flow statistic in southern Illinois does not provide the opportunity in this case to differentiate historical droughts based on relative drought severity. Streamflow conditions during the 2012 drought are further described below for different regions of the state.

Northwestern and Northeastern Illinois

Of the 49 streamgages used in the analysis, 10 are located in northwestern and northeastern Illinois. The 2012 7-day low flow was less than the 7-day, 10-year low flow for two of the streamgages, namely, Apple River near Hanover and South Branch Kishwaukee River at DeKalb (see Figure 5.2), indicating that the 2012 7-day low flow amount is expected to occur less frequently than once in 10 years. For example, the 2012 7-day low flow for Apple River near Hanover is ranked the fifth lowest, having flow equal to 16.7 cubic feet per second (cfs), which is 27 percent less than the streamgage's Q7,10. At one other gage

Table 5.1 USGS Station Records used to Analyze Streamflow Conditions

Region	Station No.	Station Name	Drainage Area (sq. mi.)	Period of Record
Northern Illinois	05414820	Sinsinawa River near Menominee, IL	40	1967–2013
	05419000	Apple River near Hanover, IL	247	1934–2013
	05435500	Pecatonica River at Freeport, IL	1,326	1914–2013
	05437500	Rock River at Rockton, IL	6,363	1903–2013
	05439000	South Branch Kishwaukee River at Dekalb, IL	78	1925–2013
	05443500	Rock River at Como, IL	8,753	1914–2013
	05444000	Elkhorn Creek near Penrose, IL	146	1939–2013
	05446500	Rock River near Joslin, IL	9,549	1939–2013
	05548280	Nippersink Creek near Spring Grove, IL	192	1966–2013
	05551200	Ferson Creek near St. Charles, IL	52	1960–2013
Kankakee River	05520500	Kankakee River at Momence, IL	2,294	1905–2013
	05525000	Iroquois River at Iroquois, IL	686	1944–2013
	05525500	Sugar Creek at Milford, IL	446	1948–2013
	05526000	Iroquois River near Chebanse, IL	2,091	1923–2013
	05527500	Kankakee River near Wilmington, IL	5,150	1914–2013
Western Illinois	05447500	Green River near Geneseo, IL	1,003	1936–2013
	05466000	Edwards River near Orion, IL	155	1940–2013
	05466500	Edwards River near New Boston, IL	445	1934–2013
	05467000	Pope Creek near Keithsburg, IL	174	1934–2013
	05495500	Bear Creek near Marcelline, IL	349	1944–2013
	05570000	Spoon River at Seville, IL	1,636	1914–2013
	05585000	La Moine River at Ripley, IL	1,293	1921–2013
Central Illinois	05554500	Vermilion River at Pontiac, IL	579	1942–2013
	05555300	Vermilion River near Leonore, IL	1,251	1931–2013
	05567500	Mackinaw River near Congerville, IL	767	1944–2013
	05572000	Sangamon River at Monticello, IL	550	1908–2013
	05577500	Spring Creek at Springfield, IL	107	1948–2013
	05579500	Lake Fork near Cornland, IL	214	1948–2013
	05587000	Macoupin Creek near Kane, IL	868	1921–2013
	05590800	Lake Fork at Atwood, IL	149	1972–2013
	05591550	Whitley Creek near Allenville, IL	35	1980–2013
	05591700	West Okaw River near Lovington, IL	112	1980–2013
	05592050	Robinson Creek near Shelbyville, IL	93	1979–2013
	03336645	Middle Fork Vermilion River above Oakwood, IL	432	1979–2013

Continued on next page

Table 5.1 *Continued*

Region	Station No.	Station Name	Drainage Area (sq. mi.)	Period of Record
Southwestern Illinois	05587900	Cahokia Creek at Edwardsville, IL	212	1969–2013
	05588000	Indian Creek at Wanda, IL	37	1940–2013
	05592800	Hurricane Creek near Mulberry Grove, IL	152	1970–2013
	05592900	East Fork Kaskaskia River near Sandoval, IL	113	1979–2013
	05593575	Little Crooked near New Minden, IL	84	1967–2013
	05593900	East Fork Shoal Creek near Coffeen, IL	56	1963–2013
	05595730	Rayse Creek near Waltonville, IL	88	1979–2013
	05597500	Crab Orchard Creek near Marion, IL	32	1951–2013
Southeastern Illinois	03345500	Embarras River at Ste. Marie, IL	1,516	1908–2013
	03346000	North Fork Embarras River near Oblong, IL	318	1940–2013
	03378000	Bonpas Creek at Browns, IL	228	1917–2013
	03379500	Little Wabash River below Clay City, IL	1,131	1914–2013
	03380500	Skillet Fork at Wayne City, IL	464	1908–2013
	03384450	Lusk Creek near Eddyville, IL	43	1967–2013
	03612000	Cache River at Forman, IL	244	1922–2013

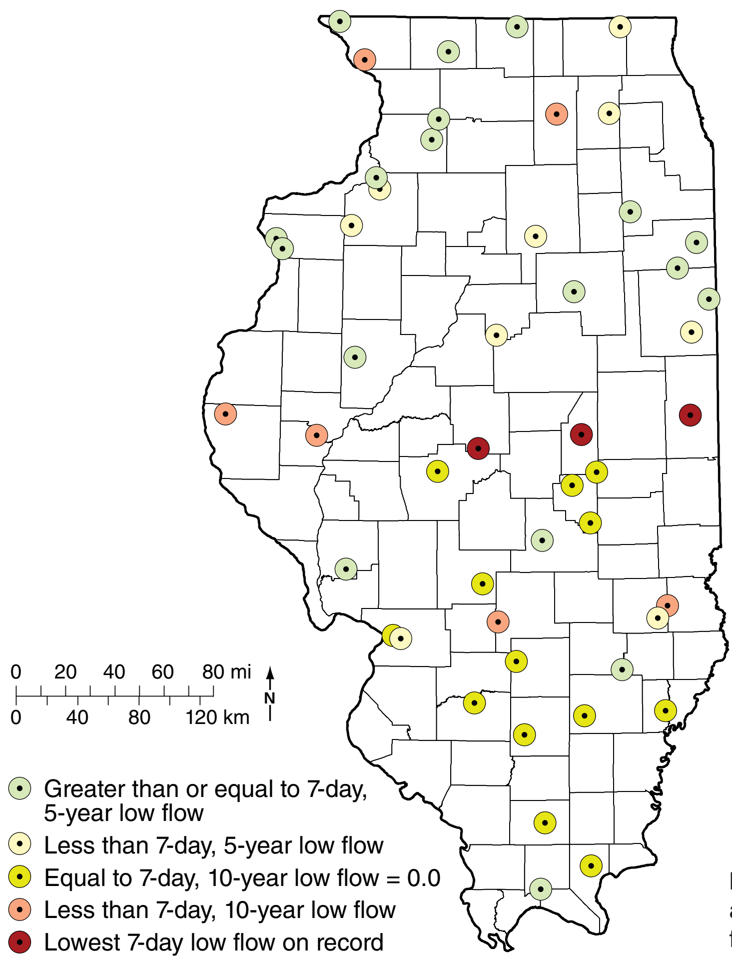


Figure 5.2 2012 7-day low flow as compared to 7-day, 10-year low flow for selected streamgages

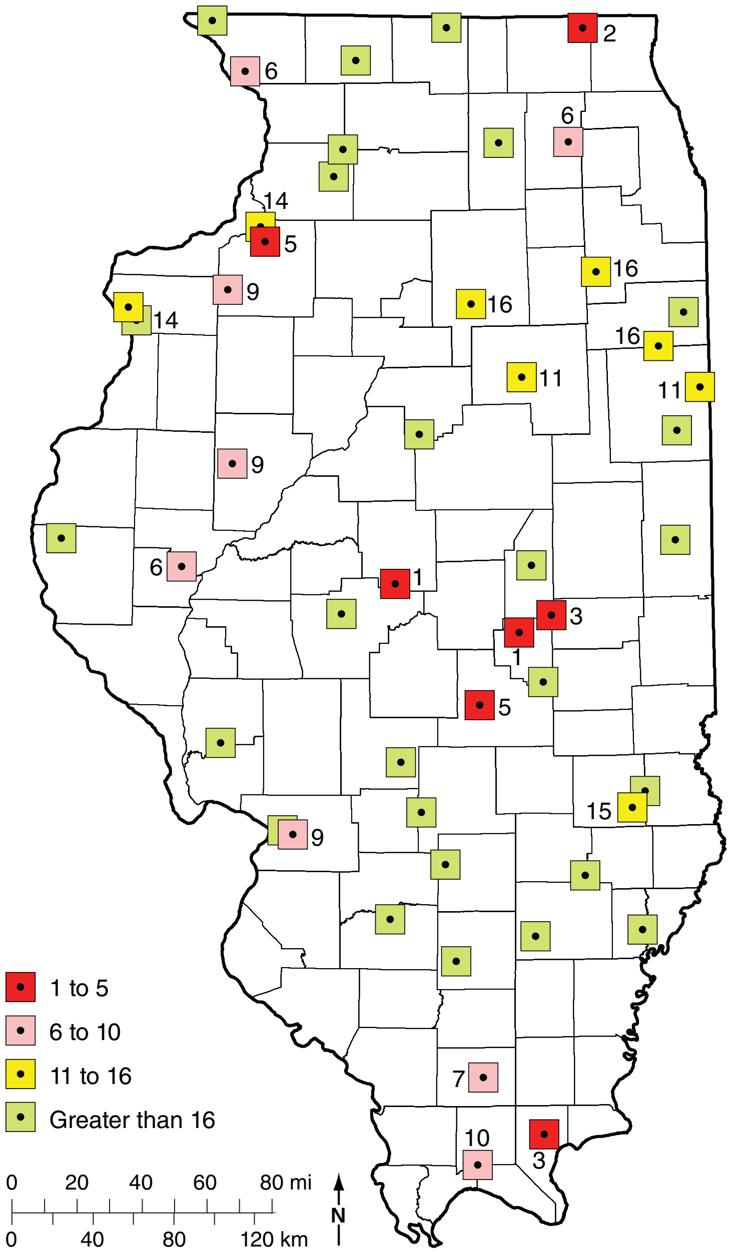


Figure 5.3 Rank of 2012 6-month drought flow for selected streamgages

(Nippersink Creek near Spring Grove), the 2012 7-day low flow was between the estimated 5-year and 10-year low flows. All other streamgages had 7-day low flows that were greater than their 5-year low flow.

In northwestern and northeastern Illinois, the 2012 6-month drought flow is ranked among the top 10 lowest in three of the 11 streamgages. The Nippersink Creek near Spring Grove streamgage had its second lowest 6-month flow on record (see Figure 5.3), equivalent to roughly a 25-year event. This streamgage was not in operation prior to 1966 when many of the region's worst droughts occurred, and its worst 6-month drought flow occurred in 2005. The 6-month flow in the Apple River near Hanover was its sixth lowest on record, roughly computing to a 10- to 15-year event. The 6-month flow in the South Branch Kishwaukee River at DeKalb also had its sixth lowest on record, corresponding to a 5- to 10-year event. All other streamgages experienced flows with recurrence intervals of less than a 5-year event. Thus, in summary, only a relatively small percentage of streamgages in northwestern and northeastern Illinois were appreciably impacted by the drought.

Kankakee River Region

Five streamgages in this region have at least 65 years of flow record with minimal human influences. The 2012 7-day low flow for Sugar Creek at Milford was 3.7 cfs and is ranked sixth on record. For the remaining streamgages, however, the 7-day low flows were above their respective 5-year low flows and not among the lowest 20 on record. Three of the region's gages had 2012 6-month drought flows ranked from 11th to 16th, but no gages were ranked in the lowest 10 on record. More than any other region, the Kankakee River area was least affected by the 2012 drought.

Western Illinois

The western Illinois region is considered herein to be that portion of the state west of the Illinois River and south of the Rock River. Seven streamgages in this region were selected using the criteria described earlier. For two of the gages (La Moine River at Ripley and Bear Creek near Marcelline), the 7-day low flow in 2012 was less than the Q7,10. The 7-day low flow at the Ripley gage, 2.7 cfs, was its second lowest on record. For another two gages (Green River near Geneseo and Edwards River near Orion), the 2012 low flow was less than a 5-year flow and greater than the Q7,10, but also within 20 percent of the Q7,10. Thus, the low flow response in the region was highly variable, but over half of the gages had flows that were approaching a 10-year condition or worse.

Similarly, four of the seven streamgages in the region experienced a 6-month low flow that is within each gage's top 10 on record. The Green River near Geneseo experienced its fifth lowest 6-month flow on record and the La Moine River at Ripley its sixth lowest on record, each with a recurrence interval of greater than 10 years. Both the Spoon River at Seville and Edwards River near Orion experienced their ninth lowest 6-month flows on record; with its longer record, this was also roughly a 10-year event for the Spoon River. The 6-month flows for two of the three remaining gages were within the top 15 on record. In summary, the streamflow statistics suggest that 2012 was roughly a 10-year drought event for western Illinois.

Central Illinois

Based on the criteria described before, 12 streamgages were selected to assess the drought of 2012 in central Illinois. Three of these gages experienced their lowest flows on record. For the Sangamon River near the Monticello streamgage, this was the only 7-day zero flow event in its 100 years of record. For the Lake Fork near Cornland, the 2012 7-day low flow was 0.33 cfs, which is the lowest on record and is only about one-tenth of its Q7,10. For the Middle Fork Vermilion River above Oakwood, the 7-day low flow was 1.76 cfs, which is the lowest on record and 50 percent less than its Q7,10. Four other gages had a zero 7-day low flow in 2012 equal to their Q7,10. All four gages had zero flow lasting at least 22 days, and West Okaw River near Lovington recorded zero flow for 88 days. The duration of zero flow for these four gages suggests associated recurrence intervals of 5 to 15 years. Regarding low flows, these statistics indicate that central Illinois was the region most greatly impacted by the 2012 drought.

The 2012 6-month drought flow was the lowest such event on record for two of the streamgages in the region, namely Lake Fork near Cornland and West Okaw River near Lovington. For the Lake Fork near Atwood and Robinson Creek near Shelbyville, the 6-month flows were the third and fifth ranked events, respectively. Collectively, this response is greater than for any other region in Illinois. For no other streamgages in the region is the 2012 6-month flow ranked as a top 10 event.

Southwestern and Southeastern Illinois

Streamflow analysis was performed for 15 streamgages located in southwestern and southeastern Illinois to assess streamflow conditions during the 2012 drought. In 9 of the 15 streamgages, the 2012 7-day low flow was 0 cfs and is equal to the Q7,10. Again, in these cases the duration of the zero low flow provides the only indication of the relative severity of the low flow condition. For five of the nine gages, the zero flow lasted 15 days or less, representative of a fairly common low flow condition with recurrence intervals of less than 5 years. On the other hand, three of the remaining four gages had zero flow durations of 59 to 74 days; for two gages (Lusk Creek near Eddyville and Rayse Creek near Waltonville) this was the second longest zero flow period on record, and for the East Fork Kaskaskia River near Sandoval it was the longest zero flow period on record. The highly variable rainfall in the region in August 2012 seemed to have a direct influence on the duration of the zero flow events. Locations with little rainfall had extended zero flow periods, whereas the zero flows were abbreviated at locations with sizeable rainfall.

Six of the remaining 15 gages in the region have a Q7,10 greater than zero. For one of these gages, Hurricane Creek near Mulberry, the 7-day low flow in 2012 was zero cfs, only the second time this has happened (the other occurring in 1988). For North Fork Embarras River near Oblong the 7-day low flow in 2012 (0.14 cfs) was also less than its Q7,10.

Figure 5.3 shows that only 4 out of the 15 streamgages in the southwestern and southeastern regions had 6-month drought flows in 2012 that are ranked in their respective 10 lowest events. The 2012 6-month drought flow is the third lowest on record for Lusk Creek near the Eddyville streamgage (roughly a 15-year event). The 6-month flows for Cache River near Forman, Cahokia Creek at Edwardsville, and Crab Orchard Creek near Marion were ranked in the lowest 7 to 10 events for their respective gages, in each case representative of a 5-year to 10-year event.

Comparison of 2012 Low Flows with Previous Droughts at Selected Gages

To showcase the severity level of the 2012 drought as compared with some of the historical droughts, eight streamgages were selected from areas in Illinois that were most greatly impacted by the drought. The historical droughts selected for comparison were the 1953–1955, 1963–1964, 1976–1977, 1980–1981, 1988–1989, and 2005 droughts. The selected streamgages were Green River near Geneseo, Spoon River at Seville, La Moine River at Ripley, Lake Fork near Cornland, Sangamon River at Monticello, Indian Creek near Wanda, Cache River at Forman, and Lusk Creek near Eddyville. All selected streamgages have records of 68 years or longer with the exception of Lusk Creek near Eddyville (1966–present).

For the eight selected streamgages, the 7-day low flows, 61-day low flows, and 6-month drought flows during the 2012 drought are compared with that of historical droughts to provide insight into the severity of the droughts. The comparisons listed in Tables 5.2–5.4 are provided by ranking each drought event within each streamgage's respective historical record. In addition to rank, Table 5.2 first provides the lowest 7-day flow (in cfs) for each drought. For example, the observed 2012 7-day low flow for Green River near Geneseo was 49 cfs, which ranks as the eighth lowest annual low flow in that gage's 80 years of record. Less extreme low flow events for any streamgage are described as having a ranking of greater than 12. Rankings are not provided for the Indian Creek and Lusk Creek 7-day low flows as zero flow (#1 tie) occurs in many years.

The lowest 6-month flow for the Cache River and Lusk Creek occurred from May through October 2012, whereas the lowest 6-month flow for the Lake Fork

Table 5.2 7-day Low Flows (in cfs) for Selected Historical Drought Periods

Stream gages	May 2012–Jan 2013	Jun 2005–Jan 2006	May 1988–Sep 1989	Aug 1980–Mar 1981	Aug 1976–Feb 1977	Jul 1963–Feb 1964	Jul 1953–Sep 1955
Green River near Geneseo	49.0 (#8)	39.0 (#5)	44.6 (#6)	171.0	23.9 (#1)	52.0	29.4 (#3)
Spoon River at Seville	31.9	25.9	6.8 (#2)	109.7	45.1	14.9 (#6)	20.4 (#10)
La Moine River at Ripley	2.7 (#2)	19.0	1.8 (#1)	11.3	10.8 (#12)	9.0 (#8)	10.0 (#11)
Lake Fork near Cornland	0.33 (#1)	3.9 (#12 tie)	0.96 (#2)	4.3	3.9 (#12 tie)	2.0 (#5)	1.3 (#3)
Sangamon River near Monticello	0.0 (#1)	4.0	0.07 (#2)	4.8	3.2	1.6 (#8)	1.0 (#4)
Indian Creek near Wanda	0.0*	0.1	0.0	0.0	0.0	0.0	0.0
Cache River at Forman	0.6	4.2	0.8	0.1	0.1	0.0 (#1tie)	0.2
Lusk Creek near Eddyville	0.0*	0.1	0.0	0.0	0.0	—	—

Table 5.3 Ranks of the 61-day Low Flow for Selected Historical Drought Periods

Stream gages	May 2012–Jan 2013	Jun 2005–Jan 2006	May 1988–Sep 1989	Aug 1980–Mar 1981	Aug 1976–Feb 1977	Jul 1963–Feb 1964	Jul 1953–Sep 1955
Green River near Geneseo	8	3	7	>12	1	>12	4
Spoon River at Seville	>12	8	1	>12	>12	5	>12
La Moine River at Ripley	8	>12	1	>12	10	5	7
Lake Fork near Cornland	1	6	5	>12	7	3	2
Sangamon River near Monticello	2	>12	1	>12	5 (tie)	5 (tie)	4
Indian Creek near Wanda	10	>12	5 (tie)	12	9	5 (tie)	1
Cache River at Forman	11	>12	>12	>12	>12	1	2
Lusk Creek near Eddyville	3	>12	>12	6	8	—	—

occurred from August 2012 through January 2013. Thus, the duration of the 2012 drought, listed in the left column of Table 5.2, is considered to have encompassed the months from May 2012 through January 2013. Similarly, the periods for the other selected historical droughts are July 1953 through September 1955, July 1963 through February 1964, August 1976 through February 1977, August 1980 through March 1981, May 1988 through September 1989, and June 2005 through January 2006.

As shown in Table 5.2, three streamgages in 2012 experienced their first or second lowest 7-day flows on record: the La Moine River at Ripley, Lake Fork near Cornland, and Sangamon River at Monticello. From the small selection of eight gages in Table 5.2 it might be concluded that 2012 low flows are roughly comparable to that of the 1988–1989 drought. However, as mentioned earlier, these eight streamgages were selected from areas in Illinois that were the most greatly impacted by the drought. If the sample selection criteria were reversed, it would show that a substantially larger number of streamgages experienced record low flows during the 1988–1989 drought. In the same manner, if the analysis were instead focused on the 1953–1955 drought, that drought would have been shown to have the overall greatest number of record low flows.

For low flows of longer duration, such as 61 days (Table 5.3) or 6 months (Table 5.4), the relative severity of the 2012 drought is shown to generally decrease. For only three of the selected streamgages is the 61-day low flow in 2012 shown to rank in the top five events on record. In contrast, for both the 1988–1989 and 1953–1955 droughts, low flows for five of the selected streamgages are ranked in the top five. For the 6-month flows, the 1953–1955 drought ranks in the top five for every

Table 5.4 Ranks of the 6-month Drought Flow for Selected Historical Drought Periods

Stream gages	May 2012–Jan 2013	Jun 2005–Jan 2006	May 1988–Sep 1989	Aug 1980–Mar 1981	Aug 1976–Feb 1977	Jul 1963–Feb 1964	Jul 1953–Sep 1955
Green River near Geneseo	5	2	7	>12	4	6	3
Spoon River at Seville	9	2	1	>12	>12	6	4
La Moine River at Ripley	6	8	1	>12	5	4	2
Lake Fork near Cornland	1	>12	7	8	5	3	2
Sangamon River near Monticello	>12	>12	10	>12	4	7	3
Indian Creek near Wanda	12	>12	3	>12	>12	7	1
Cache River at Forman	10	>12	>12	6	>12	1	4
Lusk Creek near Eddyville	3	>12	6	1	2	—	—

selected streamgage (except for the Lusk Creek gage that was not in operation in 1953–1955). Results for a few selected streamgages are described in more detail.

Lake Fork near Cornland

The continuing dry conditions in 2012 arguably affected the flows in Lake Fork more than any other affected gaged stream in Illinois. Its 7-day and 61-day low flows in 2012 were by far the lowest on record. The 6-month flow from August 2012 through January 2013 was also the lowest on record. Of the examined streamgages, only the West Okay Creek near Lovington also experienced its lowest 6-month flow on record, but its gaging record began in 1980 and thus does not include many of the worst droughts as identified in longer flow records. The factor that appears to have made the Lake Fork so dry relative to other locations is the extremely low precipitation (a 5-inch rainfall deficit) that the Logan County vicinity experienced in the latter half of 2011 prior to the onset of the 2012 drought conditions.

Lusk Creek near Eddyville

Southeastern Illinois was the region that experienced the earliest dry conditions and related impacts in 2012. Low flows on Lusk Creek began in late April, an unusual occurrence for the spring season, with its lowest 6-month flow occurring from May through October. Most of the rainfall associated with Hurricane Isaac passed to the west of Lusk Creek, such that at the time there was very little recovery from the zero-flow condition in the creek. The creek continued to have relatively low flow amounts until greater regional rainfalls occurred in January 2013.

Western Illinois Rivers

The La Moine, Spoon, and Green Rivers were subject to roughly similar levels of precipitation throughout the 2012 drought, although dry conditions first affected the southern part of the region (La Moine River) before moving north. The Spoon and Green Rivers also have noticeably higher levels of groundwater flow contribution, which tend to buffer and delay the impacts of dry conditions on flow amounts. Thus, whereas the La Moine River experienced its second lowest 7-day low flow on record, the Green River low flow was its eighth lowest, and the Spoon River its 24th lowest. This is another region where the impacts of Hurricane Isaac rainfall were modest, with low flow conditions continuing into the fall and not fully recovering until January 2013. As a result, the 6-month drought flow for all three gages falls into each streamgage record's top 10 (Table 5.4).

Comparison of 2012 Summer Flows at Selected Gages with Previous Droughts

The average flow for the period June 1 through August 31, 2012 was computed for the same eight selected streamgages. These computed flows were then compared to similarly-computed flows from the June-August period for all years of record at each gage and then ranked from lowest to highest flow. Table 5.5 shows the computed rankings for each gage. The average summer flows are specifically not described herein as low flows because they do not necessarily represent the lowest flow period within the 2012 drought. In a typical year, the lowest flows for many of these streamgage locations would not be expected to occur until the fall months, usually September and October.

When summer flows are examined alone, each of the eight stream locations are shown to have experienced flows that ranked in their respective lowest seven years on record. Furthermore, the five gages in southern and central Illinois all experienced mean summer flows that were either their first or second lowest on record. An examination of many other USGS streamgage records in southern and central Illinois show the same results, i.e., the first or

Table 5.5 Ranks of Summer (June-August) Mean Flows for Selected Historical Drought Periods

Stream gages	May 2012–Jan 2013	Jun 2005–Jan 2006	May 1988–Sep 1989	Aug 1980–Mar 1981	Aug 1976–Feb 1977	Jul 1963–Feb 1964	Jul 1953–Sep 1955
Green River near Geneseo	5	3	4	>10	>10	8	>10
Spoon River at Seville	7	6	1	>10	>10	5	>10
La Moine River at Ripley	3	8	2	>10	10	>10	>10
Lake Fork near Cornland	1	6	3	>10	7	2	5
Sangamon River near Monticello	1	>10	2	>10	>10	6	>10
Indian Creek near Wanda	2	>10	1	>10	>10	4	9
Cache River at Forman	1	>10	4	>10	>10	5	>10
Lusk Creek near Eddyville	1	>10	2	>10	3	—	—

second lowest mean summer flow. These results emphasize: 1) how extremely dry the streamflow conditions were for much of Illinois leading into the fall season; and, consequently, 2) how conditions substantially recovered for many locations immediately following the summer as most greatly influenced by the large amounts of precipitation from Hurricane Isaac. If precipitation amounts had instead remained moderately low leading into September and October (a normal drought progression), it is reasonable to conclude that low flows would have continued to decline into the fall season for most Illinois streams.

Low Flows in Large Rivers

Low flows on the Illinois and Mississippi Rivers also caused water management concerns during the 2012 drought. The primary concern on the Mississippi River was in maintaining water depths along the lower Mississippi River (downstream of St. Louis) as needed to support commercial navigation during the winter months following the drought (December 2012 and January 2013). These concerns are described in more detail in Chapter 11: *Navigation, Water Quality, and Environmental Impacts*.

On the Illinois Waterway (upper Illinois River, lower Des Plaines River, and Chicago Sanitary and Ship Canal) between Starved Rock Lock and Dam and Lockport, low river flow conditions caused several power industries to reduce production. Some of the newer power plants have low flow restrictions that require withdrawals to cease when river flows fall below a specified protected minimum flow. For the second year since the Chicago Sanitary and Ship Canal (CSSC) was constructed in 1900, summer flow in the upper Illinois River (at the USGS gage at Marseilles) fell substantially below 3000 cfs for multiple consecutive days. The other occurrence was during the 2005 drought.

These summer low flows in the Illinois Waterway reflect a substantial reduction in low flows coming from the CSSC, caused by the progressive reduction in Chicago's water use and wastewater effluents since the 1990s. Effluent discharges to the CSSC during the lowest flow periods are now about 40 percent less than they were roughly 20 years ago. With the ongoing reductions in Chicago's water use and effluent discharges, the ISWS estimates that Q7,10 in the Illinois River has been reduced from 3185 cfs to 1670 cfs over this period (see Table 5.6).

Table 5.6 ISWS Estimates of the 7-day, 10-year Low Flow on the Illinois River at Marseilles (cfs)

Year	Flow
1970	3,240
1980	3,200
1990	3,185
2001	1,990
2015*	1,670

*Designates a recent unpublished estimate.
Source: Kelly et al. (2016)

The recent reductions in low flow quantity have exposed another aspect of low flow characteristics in the Illinois Waterway, that being high-frequency flow fluctuations associated with gate operations of the waterway's locks and dams, which to a certain extent are initiated by hydropower operations upstream on the CSSC at the Lockport Dam. As shown in Figure 5.4, flows in the upper Illinois River can rise and fall rapidly in response to gate operations. These flow fluctuations are currently being analyzed by the ISWS (Kelly et al., 2016) to better understand their characteristics and determine: 1) if the fluctuations can be reduced through river management; and 2) if, and to what extent, the fluctuations should influence the manner in which protected minimum flows along the river are managed.

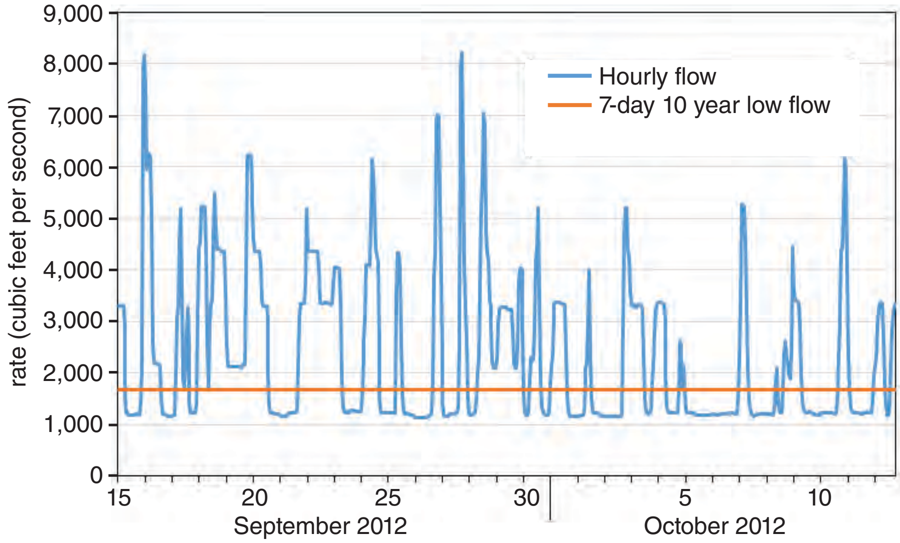


Figure 5.4 Hourly flow rates (cfs) at the USGS streamgage on the Illinois River at Marseilles compared to the 7-day low flow; September 15 through October 14, 2012

Chapter 6. Water Supply Reservoir Levels

Drought Impacts on Reservoir Levels

Reservoir and lake levels are strongly affected by the seasons, which is particularly the case with water supply reservoir levels. Summer is the season of greatest water usage (withdrawals from the reservoir) and highest evaporation. In early fall, stream inflows, which replenish the reservoir, are typically at their lowest. In late fall and winter, the least amount of water is used and stream inflows have typically begun to recover. In spring, stream inflows are typically the greatest and most reliable. Thus, in a normal year, levels in water supply reservoirs would be expected to decline in summer and early fall and begin to recover or fully recover in the fall and winter. The monthly average water levels for Lake Springfield are shown in Figure 6.1 as an example. Reservoirs that are not used for water supply typically have much less drawdown during droughts because there is no withdrawal or water diversion from the reservoir; in many cases such reservoirs have little or no drawdown during normal years.

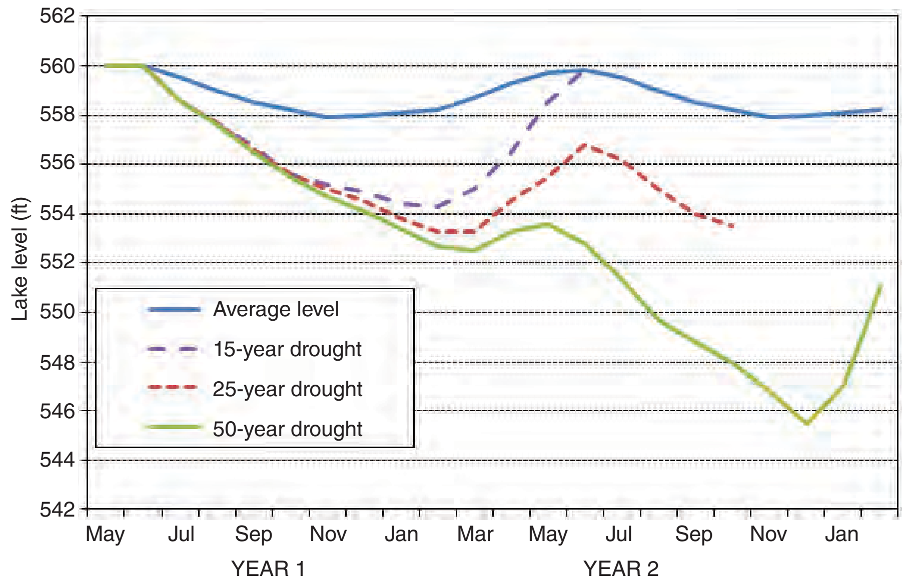


Figure 6.1 Expected water levels on Lake Springfield during an average year and during three drought episodes of various severity. For comparison, the minimum month-end lake level of Lake Springfield during the 2012 drought was roughly 556.2 feet, having occurred at the end of November

In this chapter, the terms lake and reservoir are often used interchangeably. Reservoirs are generally artificial impoundments, which apply to all lakes used for water supply in Illinois except Lake Michigan. The term reservoir is typically used collectively, whereas most individual community water supply reservoirs are commonly referred to as lakes.

Droughts will affect various components of a lake's water budget; for example, drought can result in a noticeable increase in summer water withdrawals and evaporation. But the most substantial and influential impact of drought is reduced stream inflows. Below-normal stream inflows can cause lake levels to start falling sooner than normal in the summer, sometimes as early as June. If precipitation does not recover, low streamflow levels can continue well into the winter and spring following a drought year, delaying or preventing a reservoir from replenishing its storage. In most moderately severe droughts, stream inflows will still be of sufficient quantity for lake levels to replenish in the following winter and spring seasons (such as shown in Figure 6.1 for the 15-year drought). But during more extreme droughts, there may be insufficient inflow in the spring following a drought year to fully replenish the lakes before the next summer begins (see the 25- and 50-year droughts shown in Figure 6.1), with the lowest water levels typically occurring during the second year. In such cases, the drought is characterized as being a multi-year drought, i.e., having entered a second summer or dry season.

Most water supply lakes in Illinois were designed to withstand and provide water throughout a multi-year drought episode, such that the lowest lake levels may be expected to occur at least 18 months following the initial onset of lake drawdown. The Decatur water supply system is one of the few exceptions in Illinois, in that Lake Decatur could potentially experience shortages in as few as eight months following the onset of lake drawdown. The La Harpe off-channel reservoir, also examined in this report, is similarly susceptible to drought events lasting less than 12 months.

2012 Water Supply Lake Level Observations

Near the start of the 2012 drought, the Illinois Environmental Protection Agency (IEPA) began collecting weekly water level readings at many water supply reservoirs (lakes) throughout Illinois, from their regular contacts with water supply operators. In general, water levels were not obtained for systems that were not yet concerned with potential impacts caused by drought. Also, once the worst of the drought had passed, water levels were reported less frequently or, for many lakes, were discontinued entirely. The Illinois State Water Survey (ISWS) also maintains a long-term record of month-end water levels for 35 water supply lakes in Illinois which continued through the drought, and in some cases, those data are used in this report to supplement the IEPA observations.

Table 6.1 represents a composite record of the IEPA weekly readings for selected

Table 6.1 Observed Drawdowns in Water Supply Lakes, Feet Below Full or Target Pool Elevation (Underlined values with bold type identify minimum observed levels for the drought)

Community or System Name	2012 Date										
	6/19	6/26	7/3	7/10	7/17	7/24	7/31	8/7	8/14	8/21	8/28
Altamont	1.0	1.2	1.3	1.6	1.8	2.1	**2.4**	2.0	2.3	2.1	2.3
Bloomington	0.1	0.2	0.7	1.0	1.3	1.6	1.8	2.1	2.4	2.4	2.4
Carlinville	0.2	0.3	0.8	0.8	1.0	1.7	2.1	2.0	2.0	2.1	2.3
Carthage	0.0	0.0	0.5	0.5	2.2	2.8	3.5	3.8	3.9	4.5	3.7
Cedar Lake*	0.6	0.7	1.0	1.0	1.0	1.2	1.4	1.3	1.5	1.7	1.9
Coulterville	—	—	—	1.8	2.0	2.0	2.1	2.5	2.8	2.8	**3.0**
Decatur	0.2	0.5	0.9	1.2	1.7	2.1	2.6	2.9	3.3	3.4	**3.7**
Evergreen Lake*	2.4	2.9	3.2	3.6	4.0	4.5	4.8	5.2	5.3	5.8	**6.2**
Gillespie	0.5	0.5	1.0	1.5	1.7	1.8	2.3	1.7	2.0	2.4	2.2
Hillsboro*	—	—	1.7	2.7	2.9	3.8	4.0	3.7	4.1	4.1	**4.2**
Jacksonville	—	—	0.9	0.9	1.6	**3.0**	2.2	2.2	2.2	2.6	2.8
Kinkaid	—	1.1	1.2	1.3	1.5	1.6	1.8	1.7	1.9	1.9	2.0
La Harpe	0.5	0.5	1.3	1.3	2.0	2.2	2.5	3.1	3.3	3.6	3.8
Lake Lou Yaeger*	0.3	0.3	—	—	0.8	1.2	**1.5**	1.0	1.0	0.8	1.2
Mattoon	0.5	0.8	1.1	1.2	1.5	1.4	1.6	1.8	1.8	2.0	**2.2**
Mauvaise Terre Lake*	—	—	0.5	0.5	1.1	**1.2**	1.0	0.0	—	0.2	0.4
Mount Olive	0.8	—	1.4	1.8	2.0	2.1	2.5	2.7	2.5	2.7	**2.9**
Olney	0.6	—	1.1	1.2	1.3	1.5	1.6	1.8	1.9	2.1	**2.1**
Otter Lake	0.5	—	1.5	1.8	1.8	2.2	2.5	2.0	2.0	2.5	2.7
Palmyra-Modesto	0.7	—	0.7	0.8	1.0	1.0	1.1	0.8	1.3	1.0	1.3
Pana	—	—	1.1	1.1	1.5	1.4	1.6	1.8	1.8	2.0	2.4
Lake Paradise*	0.3	0.4	**0.6**	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.1
Pinckneyville	1.2	1.5	1.6	2.0	2.2	2.5	2.8	2.8	3.1	3.2	3.4
Spring Lake*	0.2	0.2	—	0.3	0.5	0.7	0.8	0.8	0.8	**1.2**	0.8
Springfield	0.2	0.5	0.8	—	1.5	1.9	2.4	2.6	2.9	3.0	3.4
Staunton	—	—	1.0	1.3	1.7	2.0	2.2	1.8	1.8	2.2	2.5
Vermont	—	0.5	0.9	1.1	1.2	1.2	1.0	1.0	1.2	**1.6**	1.5
Vienna Corr. Center	2.4	2.5	3.1	3.3	3.8	4.0	4.2	4.8	4.9	5.1	5.2
Waverly	—	—	—	—	0.8	0.9	—	1.0	1.1	1.2	**1.3**

	9/4	9/11	9/18	9/25	10/2	10/9	10/16	10/30	11/13	11/30	12/31
Altamont	0.6	0.2	0.4	0.6	0.6	0.7	0.8	0.8	—	1.2	1.0
Bloomington	2.0	2.3	2.7	3.2	3.9	**4.3**	—	3.7	—	4.3	4.1
Carlinville	2.2	2.6	2.3	2.2	3.0	—	—	3.5	—	4.0	**4.5**
Carthage	3.5	3.6	3.8	4.0	—	—	—	4.5	—	**5.2**	—
Cedar Lake*	1.3	1.4	1.6	2.0	2.0	2.2	2.3	2.2	2.2	2.5	**2.6**
Coulterville	—	—	—	—	—	—	—	—	—	—	—
Decatur	3.4	3.0	3.1	3.3	3.4	3.6	3.6	1.6	—	0.0	0.0
Evergreen Lake*	5.4	5.4	5.5	5.6	5.7	5.6	—	4.5	—	3.9	2.6
Gillespie	1.7	1.5	1.2	1.7	—	—	—	—	—	3.6	**3.6**

Continued on next page

Table 6.1 *Continued*

Community or System Name	2012 Date										
	9/4	9/11	9/18	9/25	10/2	10/9	10/16	10/30	11/13	11/30	12/31
Hillsboro*	0.0	—	—	—	—	—	—	0.0	—	0.1	0.0
Jacksonville	2.1	—	—	—	2.7	—	—	2.5	—	2.0	—
Kinkaid	1.6	1.7	1.8	1.9	2.0	2.0	2.0	1.8	1.7	2.0	1.6
La Harpe	3.9	4.1	4.2	4.5	4.7	4.8	4.8	4.8	5.0	**5.3**	—
Lake Lou Yaeger*	0.5	—	0.3	0.5	—	—	—	—	—	—	—
Mattoon	1.8	1.6	1.6	1.8	1.7	1.8	—	—	—	1.3	—
Mauvaise Terre Lake*	0.0	—	—	—	0.1	—	—	0.2	—	—	—
Mount Olive	2.5	—	2.7	—	2.3	—	—	1.8		0.9	0.9
Olney	1.8	1.5	1.4	1.8	1.2	1.2	1.3	1.2	1.4	1.5	1.5
Otter Lake	1.0	0.8	0.8	1.2	—	—	—	—	—	**3.2**	—
Palmyra-Modesto	0.8	0.7	0.5	0.8	—	—	—	—	—	**2.5**	—
Pana	2.3	2.2	2.3	—	2.4	—	—	2.8	—	**3.1**	3.0
Lake Paradise*	0.0	0.0	0.2	0.2	0.2	0.3	—	—	—	0.0	—
Pinckneyville	3.4	3.2	3.0	3.1	2.8	—	3.0	3.0	3.3	**3.5**	3.2
Spring Lake*	0.5	0.5	—	—	0.6	—	—	0.3	—	0.3	0.2
Springfield	3.0	3.0	3.1	3.3	3.4	—	—	3.6	—	**3.8**	3.3
Staunton	2.0	2.2	2.0	2.3	2.8	—	—	—	—	**2.8**	—
Vermont	1.2	1.2	1.0	1.3	—	—	—	—	—	—	—
Vienna Corr. Center	5.0	5.0	5.4	5.6	5.7	5.9	6.0	6.2	6.7	6.9	**7.1**
Waverly	0.7	0.7	—	1.0	—	—	—	—	—	—	—

*Cedar Lake is the primary water supply lake for Carbondale. Lake Evergreen is the second lake in the Bloomington water supply system. Lake Hillsboro is a supplemental source for the City of Hillsboro; Lake Glenn Shoals (not included) is the primary supply for that community. Lake Lou Yaeger is the primary water supply lake for Litchfield. Mauvaise Terre Lake is the second lake in the Jacksonville water supply system. Lake Paradise is the second lake in the Mattoon water supply system. Spring Lake is the primary water supply lake for Macomb.

lakes, supplemented when needed with month-end readings from the ISWS records. The locations of these lakes are shown in Figure 6.2. The observation dates shown in Table 6.1 are not exact. In many cases, for example, water levels were observed on the days leading up to the reporting date.

Except where noted by an asterisk, lake names in Table 6.1 are identical to the name of the community or water supply system that the lake serves. But in some cases, the lake levels shown do not fully represent the complete water supply available to that community's water supply system. For example:

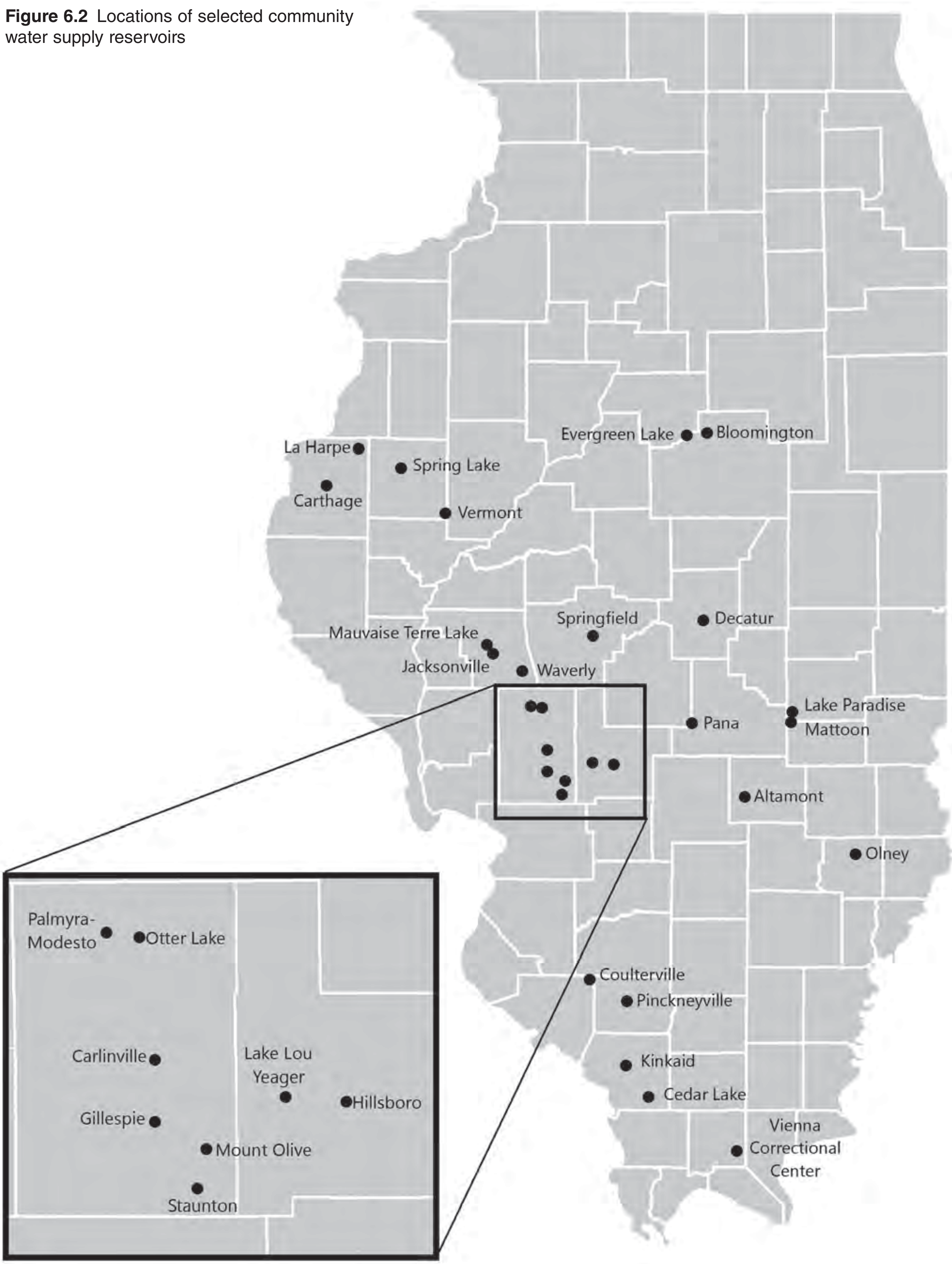
- Lake Hillsboro now serves only as a supplemental source of supply to the City of Hillsboro; lake levels were not available for Lake Glenn Shoals, which is that community's primary supply source.
- Carthage purchases a portion of its water from the Hamilton water supply system.
- Roughly 75 percent of the water supply for the City of Jacksonville comes from a groundwater resource. Thus, low water levels of Lake Jacksonville and Mauvaise Terre Lake (the city's second lake) do not fully represent the potential threat of drought to the Jacksonville water system.

The water depths in Table 6.1 that are highlighted in bold and underlined represent each lake's greatest drawdown during 2012. Roughly half of the water supply lakes experienced their lowest storage levels in summer 2012, either in July or August before the remnants of Hurricane Isaac passed over Illinois. Although water levels in many remaining water supply lakes rebounded with the precipitation brought by Isaac, water levels in these lakes continued to decline later in the fall. Thirteen of the water supply lakes listed in Table 6.1 did not experience their greatest drawdown until the end of November or into December. Thus, the low water levels and water supply condition of many lakes continued to be a concern into January 2013.

Volume of Loss in Water Supply Reservoirs

Because water supply lakes differ in a variety of dimensions, such as maximum depth, usable capacity, and

Figure 6.2 Locations of selected community water supply reservoirs



rate of withdrawal, it is also useful to describe the lake drawdown in terms of the amount of water lost from the lake compared to the total capacity of the lake. Listed in Table 6.2 is the maximum amount of volume lost during the drought for selected water supply lakes, expressed as a percentage of the total capacity of each lake at full pool. These lakes selected generally represent ones for which the ISWS has accurate measurements of lake capacity.

Table 6.2 shows that for most water supply lakes the volume of drawdown in 2012 represented only about 15 to 25 percent of the total lake capacity. These represent the reservoirs that were designed to supply water during multi-year droughts, and as such would not be expected to lose most of their volume during the first year of a drought. Also, for many of these cases, the maximum lake drawdown occurred in late August 2012 (prior to the passage of the remnants of Hurricane Isaac), such that the drawdown represents the impact of only two to three months of drought.

Although the City of Springfield enacted mandatory water restrictions in August 2012, and its lake continued to experience drawdown into the late fall, the volume of water loss (25 percent) never approached a critical condition. Figure 6.3 compares the 2012 water level in Lake Springfield to the 1988–1989 and 1999–2000 droughts as well as to the estimated 100-year drought condition. The initial two-month drawdown in Lake Springfield, from the end of June to the end of August, was as great as for either of the 1988–1989 and 1999–2000 droughts. However, the rate of decline slowed down considerably following the partial replenishment in early September from the remnants of Hurricane Isaac. A comparison of the Lake Springfield water levels in Figure 6.3 indicates that the 2012 lake level was never able to approach the low levels of the 1988–1989 and 1999–2000 droughts, not to mention an extreme water supply drought such as the 100-year drought. Based solely on Lake Springfield's minimum lake level, the 2012 drought would be calculated to have a recurrence interval of only three to four years.

Table 6.2 Maximum 2012 Loss in Volume for Selected Water Supply Lakes (Loss in volume expressed as a percentage of the capacity at full pool)

Community/System Name	
Altamont	35%
Bloomington	30%
Carbondale	15%
Decatur	45%
Gillespie	25%
La Harpe	55%
Litchfield	15%
Macomb	15%
Mattoon	10%
Mount Olive*	40%
Olney	15%
Otter Lake	15%
Palmyra-Modesto	15%
Pana	20%
Springfield	25%
Staunton	20%
Vienna Correctional Center	55%
Waverly	20%

*The value listed is only for the New Lake at Mount Olive for which water levels were reported. No values were reported for Mount Olive's second, older lake, which has a slightly larger capacity. Based on knowledge of the entire system, it is reasonable to conclude that its total 2-lake storage loss may be as little as half of that listed above.

The three water supply lakes that experienced a volume loss of 45 percent or more (Decatur, La Harpe, and the Vienna Correctional Center) are considered the water supply systems most threatened by the 2012 drought. The situations for each of these systems are examined in more detail in Chapter 9: *Water Supply and Water Use Impacts*.

Comparison to Past Droughts

The ISWS collects month-end water level observations for 14 of the lakes listed in Table 6.1. Nine of these water level records date back to the drought of 1988, thus covering at least 25 years of continuous record. The maximum drawdown levels during the 2012 drought were compared to the previous years of record for each of these nine lakes, and Table 6.3 shows the ranking of the 2012 drought within each record and also compares with the previously observed maximum drawdown. For Lake Bloomington and Evergreen Lake, both components of the Bloomington water supply system, a combined drawdown amount was used with a maximum combined amount of 9.9 feet

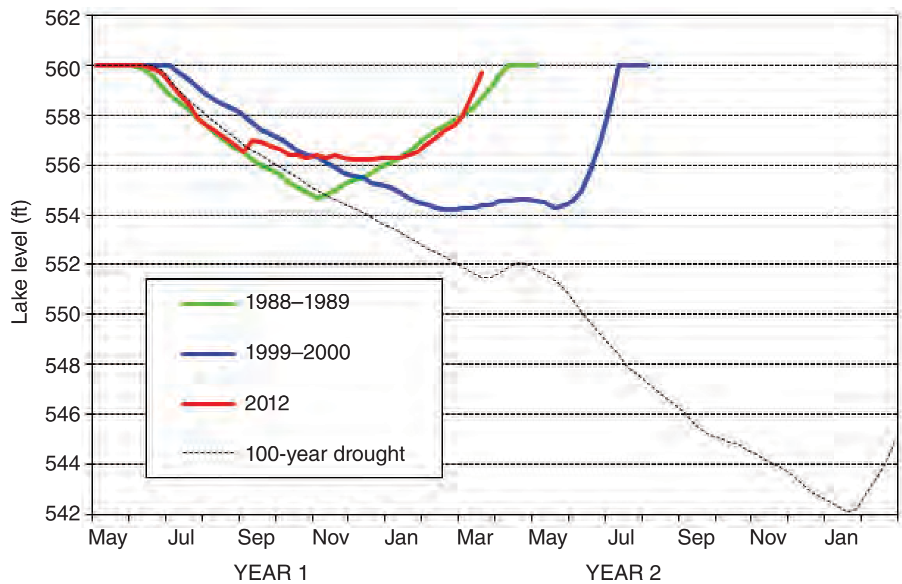


Figure 6.3 Comparison of 2012 lake levels to those of the 1988–1989 and 1999–2000 droughts

Table 6.3 Comparison of 2012 Drought Lake Drawdown to Previous Years of ISWS Records

Lake	Period of record	2012 maximum drawdown (feet)	Rank of 2012 event	Maximum drawdown on record (year)
Altamont	1983–present	2.3	18	6.7 (2006)
Bloomington*	1988–present	9.9	8	35.9 (1989)
Carlinville	1983–present	4.5	3	5.0 (1988 & 2000)
Decatur	1983–present	3.7	3	5.2 (1988)
Kinkaid	1988–present	2.0	3	3.4 (2002)
Mattoon	1983–present	2.2	5	2.8 (1985)*
Spring (Macomb)	1983–present	1.2	9	5.4 (1989)
Springfield	1983–present	3.8	10	5.7 (2000)

*Listed Bloomington drawdown is the combined amount for Lake Bloomington and Evergreen Lake. The water level observations for Lake Mattoon do not include the period from Oct. 1988 to Apr. 1993.

(occurring with the October 9, 2012 lake observations). Also note that the target or operating pool for several of these lakes has changed over their period of record; the drawdown is computed from the designated target pool at the time of the observation.

For three of the lakes listed (Carlinville, Decatur, and Kinkaid), the maximum drawdowns during the 2012 drought rank as the third worst for the respective lake over 25 to 30 years of record. This ranking would correspond to a drought recurrence interval of 8 to 10 years.
For half of the lakes listed (Altamont, Bloomington, Spring, and Springfield) the 2012 maximum drawdowns rank no higher than the eighth worst on record, translating to a drought recurrence interval of no greater than three years. The vicinity of Altamont Lake received copious amounts of rainfall in August and September, thus greatly limiting the overall impact of the drought on that lake.

Lake Michigan

During 2012, the water level in Lake Michigan fell considerably below its normal level, such that by January 2013, the lake reached an elevation of 576 feet above mean sea level, the minimum recorded level since observations began in 1918. The monthly mean water levels for Lake Michigan during the 2012–2013 period are shown in Table 6.4. In March 2012, the lake level was only 1.0 foot below its long-term average for that month. This was not unusual, as Lake Michigan had generally been 1 foot or more below its long-term average for most of the previous decade. However, whereas the lake usually gains about 1 foot in elevation between early spring and mid-summer, in 2012 the lake had risen only 0.3 feet, and by August 2012, was 2.0 feet below its long-term average. By January 2013, when it reached its record low, the lake was 2.4 feet below its long-term average, after which the lake level started to recover.

Regional drought conditions in Illinois have very little influence on Lake Michigan levels, because very little of the water that enters the lake originates from Illinois. Instead, much of the watershed and streams that provide inflows into Lake Michigan and Lake Huron (the two lakes are connected by the Straits of Mackinac and share the same water level) are located in Michigan and the southern part of the Province of Ontario. The lack of precipitation in 2012 over these Great Lakes areas was not as severe as that in Illinois, whereas the unusually warm temperatures during the winter, spring, and summer of 2011–2012 appear to have been a significant factor leading to the low levels on Lake Michigan, influencing the record low ice cover in 2011–2012, record high summer lake temperatures in 2012, and above-normal evaporation rates from the Great Lakes.

Major Federal Reservoirs

Southern Illinois has three very large reservoirs that were constructed and are maintained by the U.S. Army Corps of Engineers (USACE), specifically Rend Lake, Lake Shelbyville, and Carlyle Lake. Although each of these lakes provides a water supply function, their primary operational purpose is for flood management, a function which can delay and alter the impacts of droughts on water levels. One of the additional major purposes of Lake Shelbyville and Carlyle Lake is to provide water for federal operation of the navigation industry on the Mississippi River system.

Table 6.4 lists the month-end reservoir levels for each of these three federal reservoirs. The target water elevation for Rend Lake is 405.0 feet above mean sea level; however, because there are no specific outlet facilities or gates that the USACE uses to regulate the target level, the lake level often remains above the target level following wet conditions until it slowly drains to a lower elevation. During the 2012 drought, Rend Lake did not recede to its target elevation until late July after which it continued to fall until early September (reaching a minimum elevation of 404.4 feet), at which point the remnants of Hurricane Isaac passed over the region and raised the water level. In summary, the overall impact of the drought on the lake was minimal.

Table 6.4 Monthly Elevations of Lake Michigan and the Federal Reservoirs

	Lake Michigan		Rend Lake	
	Monthly average (ft)	Departure from average (ft)	Month-end level (ft)	Departure from target level (ft)
March 2012	577.4	–1.0	408.0	+3.0
April 2012	577.5	–1.2	407.4	+2.4
May 2012	577.6	–1.4	406.6	+1.6
June 2012	577.7	–1.5	405.6	+0.6
July 2012	577.6	–1.7	404.9	–0.1
August 2012	577.3	–2.0	404.4	–0.6
September 2012	577.0	–2.1	404.9	–0.1
October 2012	576.6	–2.3	405.1	+0.1
November 2012	576.4	–2.3	405.0	+0.0
December 2012	576.2	–2.3	405.0	+0.0
January 2013	576.0	–2.4	408.5	+3.5
February 2013	576.1	–2.3	408.6	+3.6
March 2013	576.2	–2.2	410.0	+5.0
April 2013	576.6	–2.1	410.4	+5.4
	Lake Shelbyville		**Carlyle Lake**	
	Month-end level (ft)	Departure from target level (ft)	Month-end level (ft)	Departure from target level (ft)
March 2012	594.4	+0.4	443.4	+0.4
April 2012	596.6	+0.6	445.1	+1.1
May 2012	559.0	–0.7	445.5	+0.5
June 2012	598.8	–0.9	444.9	–0.1
July 2012	598.3	–1.4	443.9	–1.1
August 2012	598.3	–1.4	444.0	–1.0
September 2012	598.5	–1.2	448.3	+3.3
October 2012	599.2	–0.5	447.6	+2.6
November 2012	599.7	+0.0	447.7	+2.7
December 2012	598.9	+4.9	446.4	+3.4
January 2013	597.5	+3.5	447.6	+4.6
February 2013	595.5	+1.5	444.8	+1.8
March 2013	595.3	+1.3	443.9	+0.9
April 2013	608.6	+12.6	452.5	+8.5

For Lake Shelbyville and Carlyle Lake, the USACE has seasonal target water levels and can release or withhold water as needed to meet the multiple objectives of operation for each lake. In March 2012, the levels of both reservoirs were being maintained at the winter target levels, and in April began to increase their water levels to match their normal seasonal operations. Although Carlyle Lake was able to transition to its summer pool elevation (445 feet) by the beginning of May, Lake Shelbyville was unable to rise to its summer pool level (599.7 feet) because of the below-normal streamflow amounts in April, May, and June. The level of Lake Shelbyville remained over 1 foot below its target level throughout much of the duration of the drought, but was able to recover in October and November.

The level of Lake Carlyle also fell to roughly 1.0 foot below its target during

July and August. In early September, however, the path of Isaac was directly over Lake Carlyle and much of its contributing watershed, dropping as much as 10 inches of rain in some locations. Lake Carlyle quickly shifted from below normal to more than 3 feet above normal. After the passage of Hurricane Isaac and the end of the primary portion of the recreational boating season, the USACE decided to retain some of these flood waters (and maintain a higher-than-normal pool level) for possible use later in the year, in particular to supplement low flows in the Mississippi River. The release of water for this purpose later in the drought is described in Chapter 11: *Navigation, Environmental, and Water Quality Impacts*.

Chapter 7. Groundwater Conditions

Of all parts of the hydrologic cycle, groundwater is the least affected by drought. In describing drought impacts to groundwater, it is appropriate to separate shallow groundwater (commonly considered to be within 100 feet of the land surface) from the remaining (deeper) groundwater aquifers. Travel times for deeper groundwater in Illinois range from years to centuries; thus these aquifers, which provide most of the groundwater supply, are typically unaffected by the relatively short duration of droughts. Shallow groundwater levels, however, are depressed during droughts. Because soils are so dry, almost all rainfall will be retained in higher soil layers and evapotranspired, and scant amounts of recharge will reach the water table (the uppermost groundwater layer, which is "open" to the surface). Meanwhile, water tables will progressively drop during a drought as 1) shallow groundwater moves to replenish low flows in streams; 2) vegetation with deep roots induces uptake from groundwater; and 3) water is withdrawn from shallow wells (< 100 feet). Such shallow wells, in turn, can be vulnerable to water shortages.

In Illinois, shallow wells most vulnerable to drought include 1) large-diameter dug and bored wells; 2) sand points; and 3) shallow small-diameter drilled wells, all types typically drawing from shallow groundwater. Large-diameter dug and bored wells are common in rural areas where aquifers are nonexistent, especially in the southern half of Illinois. These wells basically serve as storage reservoirs for shallow groundwater. Even during summers with normal precipitation, they often go dry, and typically well owners must buy and transport water to their wells. Sand points and shallow small-diameter drilled wells are typically finished in shallow alluvial aquifers where water tables may be lowered because recharge is limited due to the lack of precipitation. Low water tables also mean there will be little groundwater discharge to streams and rivers during drought, contributing to abnormally low streamflows and decreased lake levels.

The drop in the water table caused by drought conditions will not in itself affect water availability in confined aquifers in the short-term. In this context, "confined" means where there is a relatively impermeable layer or layers, such as clay or rock, between the water-bearing layer and the land surface. However, increased withdrawals by other wells in the same layer may decrease water levels.

One challenge in determining the effects of drought on groundwater is separating decreasing water levels caused by lower recharge rates from the role of increased demand for groundwater. Increased demand during drought can be manifested in several ways. During the growing season for row crops, especially corn, the lack of rainfall will induce farmers to increase irrigation pumping. Decreasing streamflows during drought may cause some public water suppliers and industries to partially switch from surface water to groundwater sources. Both of these activities increase the amount of groundwater withdrawn during drought.

Groundwater Data Sources

Scientists have been measuring groundwater levels in Illinois for more than a century. However, the collection of groundwater-level data was not systematic or coordinated until the 1950s, following the drought of 1952–1955, when decisions were made to begin long-term collection of groundwater-level data from dedicated monitoring wells. The Illinois State Water Survey (ISWS) and other state agencies currently maintain several monitoring well networks in the state, some of which are described later. Since the last statewide drought in 2005, the number of monitoring wells outfitted with equipment that can collect almost continuous (hourly) groundwater-level measurements has expanded considerably, giving us a richer data set for evaluating the effects of drought on groundwater.

Monitoring Networks and Wells Used in this Report

Water Atmospheric Resource Monitoring Network (WARM)/Illinois Climate Network (ICN) ISWS maintains two networks, WARM and ICN, which monitor the natural short- and long-term fluctuations of shallow groundwater levels (i.e., the water table) across Illinois. Typically, these wells do not extend into highly productive aquifers; rather, they are constructed in fine-grained glacial materials containing thin lenses of sand. These observation wells are generally located in areas remote from pumping centers to minimize the apparent effects of human activities on groundwater levels. In a few cases, wells are located near regional irrigation centers (Snicarte) or suburban areas that use groundwater supplies (St. Charles, Crystal Lake). Nevertheless, the groundwater levels monitored in these observation wells generally represent conditions beneath non-irrigated agricultural land and water levels found in many shallow, rural domestic wells in Illinois.

The WARM network consists of 15 wells (Figure 7.1 and Table 7.1), most of which have been monitored since the early 1960s; four have been measured since the early 1950s. There are 17 ICN observation wells that were established beginning in the mid-1990s at each of the climate site locations (Table 7.2). The locations of the ICN stations are shown in Figure 4.1 (the Big Bend and Champaign ICN stations do not include wells).

McHenry County Network McHenry County in far northern Illinois is completely dependent on groundwater for its drinking water supply, and as such the county government has made a concerted effort to monitor groundwater conditions. Most of the groundwater comes from productive, unconfined glacial sand and gravel aquifers. There are currently 43 dedicated monitoring wells at 27 locations throughout the county, all finished in sand and gravel aquifers (Figure 7.2 and Table 7.3). At 12 of the locations, there are two or three nested wells at different depths.

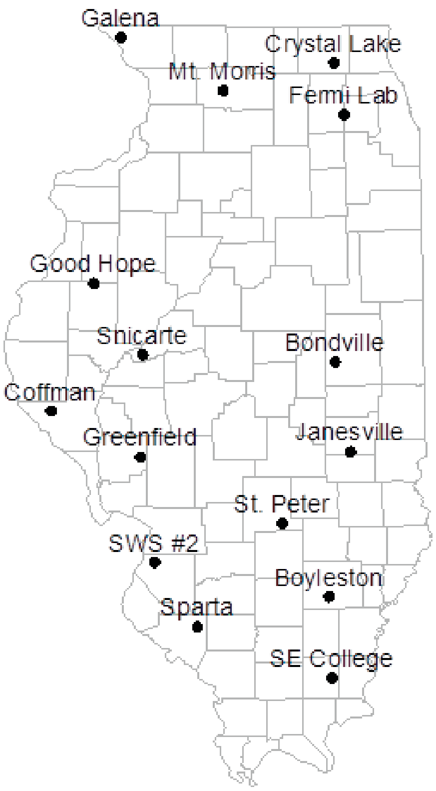


Figure 7.1 WARM network observation well locations

Most of these wells have transducers and data loggers that record water level measurements every 15 minutes, with data records extending back to 2009. The equipment is maintained by the U.S. Geological Survey (USGS), and the data are uploaded to their website in real-time. For this report, daily maximum values were downloaded from the USGS website.

Other Wells Other wells used in this study are shown in Figure 7.3 and Table 7.4. These wells are finished in either glacial sand and gravel aquifers or are water table wells. The water table wells are not part of the WARM or ICN networks, and have a much shorter period of record than wells in those networks. Many of these wells are part of the ISWS groundwater monitoring network for the Mahomet Aquifer. The Mahomet Aquifer is the principal source of water for many communities and irrigated growers in east-central Illinois (see Roadcap et al., 2011). More than 180 observation wells at 140 sites have been constructed

Table 7.1 WARM Network Shallow Observation Well Information. Well depth, case depth, screen length, land surface elevation, and measure point elevation in feet. Well diameter in inches. NS = not screen, i.e., well is a dug or bored well that is brick or tile-lined

ISWS ID	Well Name	Location	Start Date	Hydrologic Unit	Crop Reporting District	Well Depth	Case Depth	Screen Length	Well Diameter	Land Surface Elevation	Measure Point Elevation
21	Galena	08528N01W244H	1963	7060005	NW	25	25	NS	36	730	730.6
31	Mt. Morris	14124N09E341C	1960	7090005	NW	55	55	NS	8	925	925.0
41	Crystal Lake	11143N08E065B	1950	7120006	NE	18	11	7	6	892	895.8
53	Fermi Lab	04339N09E19.6E	1988	7120007	NE	15	10	5	6	762	766.3
61	Coffman	14904S06W265D	1956	7110004	WSW	28	28	NS	36	624	626.0
72	Good Hope	10907N02W068C	1980	7130010	W	30	20	10	4	765	765.0
91	Snicarte	12519N10W118B	1958	7130009	C	42	42	NS	36	485	486.5
132	Greenfield	06111N10W283A	1965	7130012	WSW	22	22	NS	48	610	610.0
143	Janesville	02911N09E182D	1968	5120112	ESE	11	11	NS	36	722	723.5
153	St. Peter	05105N03E171H	1965	7140202	ESE	15	15	NS	60	597	598.0
171	Sparta	15705S05W054F	1960	7140105	SW	27	4	NS	48	511	512.0
181	SWS No.2	16302N09W268F	1952	7140101	SW	80	77	3	6	419	421.1
202	SE IL College	16509S07E094B	1984	5140204	SE	11	11	9	6	380	381.0
221	Boyleston	19102S07E177B	1984	5120115	SE	23	23	NS	36	405	405.5
1120	Bondville	01918N07E023G	1982	7140201	E	21	11	10	6	700	701.8

Table 7.2 ICN Shallow Groundwater Network Well Information. Well depth and land surface elevation in feet

Well Name (ID)	Local Site	Location	Year Drilled	Well Depth	LS Elevation
Belleville (FRM)	SIU Agronomy Farm	16301N07W23	1996	15.0	436
Bondville (CMI)	ISWS BEARS Research Site	01919N07E02	1997	20.0	697
Brownstown (BRW)	UI Brownstown Agronomy Research Center	05106N02E03	1996	15.0	581
Carbondale (SIU)	SIU Ag Research Farm	07709S01W31	1997	25.5	450
DeKalb (DEK)	UI Northern Illinois Ag. Center	03739N03E23	1996	24.5	869
Dixon Springs (DXS)	UI Dixon Springs Ag. Center	15112S05E33	2006	50.0	541
East Peoria (ICC)	Illinois Central College	17926N04W13	2005	41.5	703
Fairfield (FAI)	Frontier Community College	19102S07E02	1997	21.0	446
Freeport (FRE)	Highland Community College	17726N07E03	1996	25.8	869
Ina-Rend Lake (RND)	Rend Lake Community College	08104S03E31	1997	21.0	427
Kilbourne (SFM)	UI River Valley Sand Farm	12520N09W27	1996	47.5	499
Monmouth (MON)	UI Northwestern Ag Research Center	18711N03W27	1996	27.0	751
Perry (ORR)	UI Orr Ag Research Center	14903S04W15	1996	20.0	676
Olney (OLN)	Olney Central College	15904N10E33	1997	19.0	450
St. Charles (STC)	UI St. Charles Horticulture Center	08940N08E31	1996	21.1	742
Springfield (LLC)	Lincolnland Community College	16715N05W26	1997	20.0	581
Stelle (STE)	Village of Stelle	05329N09E35	1997	17.0	699

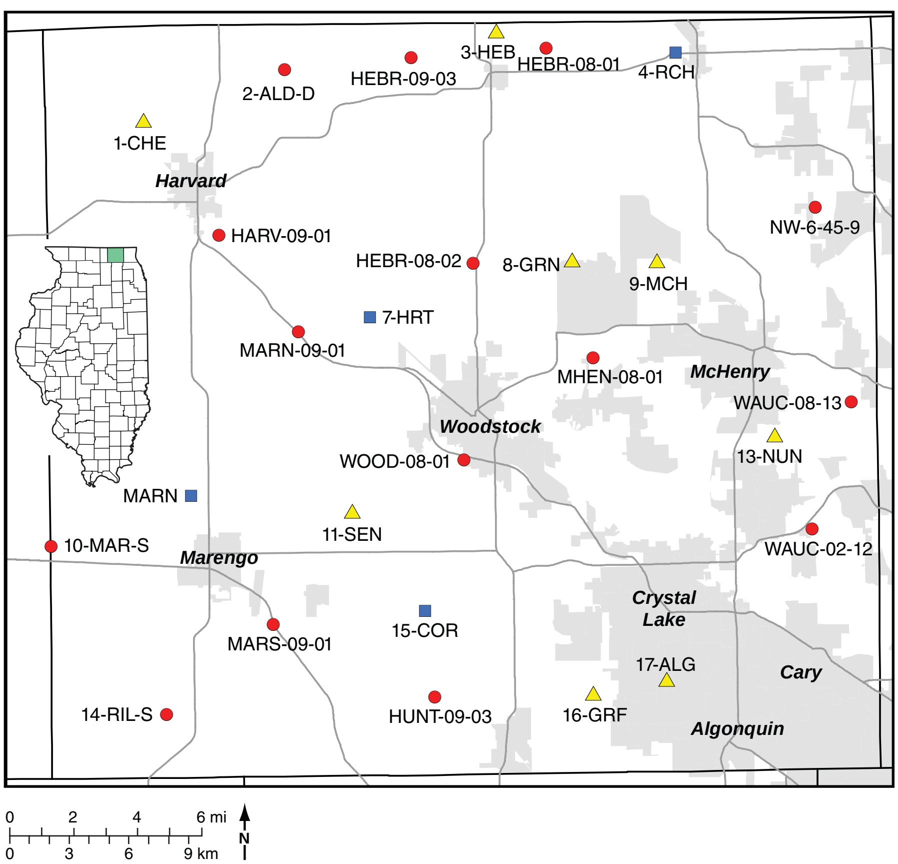


Figure 7.2 Location of monitoring wells with continuous water level data in McHenry County. Red circles indicate locations with single wells, yellow triangles with two nested wells, and blue squares with three nested wells.

across the aquifer as part of numerous hydrogeological investigations, and are measured quarterly by the ISWS except during the drought when extra rounds of water level data were collected at many of the wells. Approximately 25 wells are equipped with transducers and data loggers.

Groundwater Levels during the 2012 Drought

WARM/ICN Historical month-end measurements were used to establish mean monthly groundwater levels for the WARM shallow groundwater network. The long period of record allows a comparison of current water levels to those of past drought periods. Mean monthly water levels were calculated for the period of record (start dates in reported Tables 7.1 and 7.2)

Table 7.3 McHenry County Monitoring Wells. Well depths, water level depths, and difference between minimum and maximum depth in feet over the course of the 2012 drought. Negative depths indicate the water level rises above the land surface, i.e., flowing artesian conditions.

Well ID	Well Depth	Date Minimum	Minimum depth	Date Maximum	Maximum depth	Days Max-Min	Diff Max-Min
1-CHE-D	110.8	3/13/2012	5.56	9/4/2012	9.39	175	3.83
1-CHE-S	40.3	3/13/2012	5.57	9/7/2012	9.53	178	3.96
2-ALD-D	344.4	4/25/2012	218.67	1/24/2013	226.27	274	7.60
3-HEB-D	94.4	4/1/2012	-13.87	2/5/2013	-10.34	310	3.53
3-HEB-I	66.3	4/1/2012	-13.86	1/28/2013	-10.20	302	3.66
4-RCH-D	176.0	4/1/2012	10.35	10/4/2012	15.78	186	5.43
4-RCH-I	98.3	4/2/2012	10.34	9/29/2012	17.92	180	7.58
4-RCH-S	24.0	3/15/2012	4.91	12/5/2012	11.15	265	6.24
7-HRT-D	165.7	4/28/2012	35.39	11/28/2012	45.80	214	10.41
7-HRT-I	114.9	4/25/2012	34.31	1/9/2013	43.18	259	8.87
7-HRT-S	62.3	4/24/2012	33.97	1/9/2013	42.99	260	9.02
8-GRN-D	153.1	3/28/2012	16.63	7/8/2012	22.89	102	6.26
8-GRN-I	70.3	4/24/2012	5.29	1/26/2013	9.46	277	4.17
9-MCH-D	180.0	5/2/2012	52.88	7/8/2012	62.86	67	9.98
9-MCH-S	25.9	3/18/2012	9.53	12/21/2012	15.38	278	5.85
10-MAR-S	20.3	3/13/2012	2.35	9/30/2012	6.99	201	4.64
11-SEN-D	153.2	4/16/2012	3.63	10/9/2012	7.41	176	3.78
11-SEN-I	75.4	4/16/2012	2.58	10/12/2012	6.51	179	3.93
13-NUN-D	152.2	5/7/2012	45.90	7/9/2012	50.38	63	4.48
13-NUN-I	113.0	5/7/2012	46.16	7/9/2012	50.65	63	4.49
14-RIL-S	20.4	3/19/2012	6.25	10/14/2012	10.57	209	4.32
15-COR-D	116.1	3/18/2012	7.65	10/12/2012	12.00	208	4.35
15-COR-I	103.3	3/18/2012	7.92	12/12/2012	12.23	269	4.31
15-COR-S	55.1	3/18/2012	7.64	10/12/2012	12.01	208	4.37
16-GRF-D	139.1	3/16/2012	19.09	10/4/2012	27.86	202	8.77
16-GRF-I	99.0	3/14/2012	12.95	10/5/2012	26.44	205	13.49
17-ALG-D	187.8	2/1/2012	92.46	7/13/2012	119.43	163	26.97
17-ALG-S	47.3	3/1/2012	-1.31	10/13/2012	6.90	226	8.21
HARV-09-01	120.1	3/24/2012	31.23	1/27/2013	36.67	309	5.44
HEBR-08-01	145.3	3/19/2012	27.40	1/28/2013	31.69	315	4.29
HEBR-08-02	100.3	3/14/2012	9.97	10/2/2012	13.58	202	3.61
HEBR-09-03	120.6	4/1/2012	23.63	1/24/2013	30.05	298	6.42
HUNT-09-03	150.7	3/18/2012	23.79	11/14/2012	31.92	241	8.13
MARN-09-01	100.7	4/24/2012	31.66	12/5/2012	38.10	225	6.44
MARN-09-02	110.6	4/20/2012	16.71	1/8/2013	22.92	263	6.21
MARN-10-03	160.0	3/23/2012	26.63	1/24/2013	33.38	307	6.75
MARN-10-04	82.0	4/20/2012	17.03	1/8/2013	23.08	263	6.05
MARS-09-01	190.3	4/20/2012	69.84	10/15/2012	79.93	178	10.09
MHEN-08-01	103.3	5/9/2012	33.59	1/28/2013	36.17	264	2.58
NW-6-45-9	73.0	6/2/2012	32.72	2/20/2013	37.80	263	5.08
WAUC-02-12	192.3	3/28/2012	91.50	7/5/2012	122.89	99	31.39
WAUC-08-13	105.3	5/11/2012	20.81	2/10/2013	24.25	275	3.44
WOOD-08-01	202.3	4/2/2012	77.35	7/13/2012	83.24	102	5.89

through December 2011 at each well, and departures from those means were computed for each month from January 2012 through April 2013. These data were analyzed to show groundwater levels prior to and following the drought period defined by the precipitation data presented in Chapter 3. Because the period of record for the ICN observation well network is relatively short in relation to the WARM network, no analysis was conducted for those data. However, trends observed for those wells are discussed below.

WARM Shallow Groundwater Network, Deviations from Normal Departures of measured groundwater levels from the corresponding mean monthly water levels were calculated for a 16-month period beginning in January 2012.

During drought conditions, the uppermost soils can become so dry that almost all rainfall will be retained in the higher soil levels. Very little precipitation reaches the water table, which continues to decline. In order for rainfall to positively affect the water table (i.e., recharge), the dry pore spaces of the upper soil must become saturated. After the upper soil moisture is replenished, water will then move deeper and

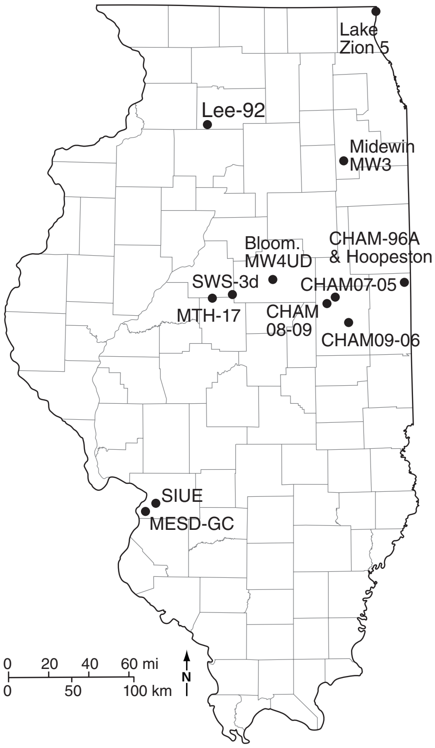


Figure 7.3 Other monitoring wells with continuous water level data shown in this report. There are nested wells at CHAM08-09, Lee-92, MESD-GC, and MTH-17

recharge the water table. This causes a lag in shallow groundwater level increases. For this reason, a 16-month overview of shallow groundwater levels was needed. Table 7.5 lists the mean monthly and statewide deviations from normal for the 15-well WARM network. Figure 7.4 depicts these deviations in graph form. Statewide, below-normal deviations lasted 14 months during the drought of 2012. Above-normal deviations were reported in January 2012 and were not reported again until April 2013.

Statewide monthly deviations from normal are shown in Figures 7.5a-p. These figures indicate the most affected portions of the state during this drought were the west-central and central areas of Illinois. Large below-normal departures began in the west-central part of Illinois at Greenfield in Greene County. These departures spread east across the state and by May 2012, no above-normal departures were reported in Illinois. June, July, and August continued the below-normal trend. The southern part of the state showed some improvement in September and October, but that improvement was short-lived. Below-normal departures engulfed the entire state once again in November and December 2012. January groundwater levels showed improvement in the southwestern and eastern half of Illinois, which continued through April 2013. The northwestern part of Illinois continued to report below-normal deviations in February and March 2013. Deviations below normal were still reported in April at Mt. Morris (Ogle Co.) and Snicarte (Mason Co.), but the overall trend into April 2013 was positive.

WARM Shallow Groundwater Network, Groundwater Levels From January 2012 through April 2013, five wells experienced record low water levels during several months. Three wells, Bondville (Champaign Co.), S.E. College (Saline Co.), and Coffman (Pike Co.), reported record low levels for eight, eight, and six months, respectively. Two other wells, Fermi Lab (DuPage Co.) and Janesville (Cumberland Co.), experienced four and two months of record low groundwater levels, respectively. All totaled, 28 monthly record low water levels were reported during January 2012 through April 2013 among these five stations. Figure 7.6 shows water levels in the Coffman well, one of the five wells that had record low groundwater levels during this period. The hydrographs plot mean levels and monthly highs and lows with the depth to water measurements for January 2012 through April 2013.

Comparison to Past Droughts

Shallow groundwater information was compared to past droughts reported in 1980, 1988, and 2005. The WARM network of observation wells was implemented in response to the drought of 1952. Of the five wells that reported record low water levels in 2012, only two, Coffman and Janesville, have monthly data that span the droughts of 1980, 1988, and 2005. Hydrographs of water levels from these wells are presented in Figures 7.7 and 7.8, respectively. Monitoring at the other three wells began in the 1980s.

The water level information and the hydrographs indicate that the 2012 drought caused more record low monthly water levels than any of the past droughts during which these wells were being monitored. The deviations from normal (Figures 7.5a-p) confirm that the Coffman well area in Pike County was hardest hit in regard to below-normal shallow groundwater levels. Deviations from normal began in January 2012 and lasted into March 2013, a 15-month period. Six record low months were reported for this well from June 2012 through December 2012 (Figure 7.6). The Janesville well located in Coles County had only two record low water levels in June and July, 2012; however, its long period of record (since 1968) suggests that the shallow groundwater levels at that location were the lowest since the 1950s.

The observation well data from the wells with shorter periods of record also indicate that the impact of the 2012 drought was major and felt throughout much of Illinois. Three other WARM network observation wells on the eastern side of the state (Fermi Lab, Bondville, and SE College) reported their lowest water levels during 2012, with records dating back to the 1980s.

A comparison of the deviations from normal for water levels in WARM wells from the three most recent statewide droughts (1980, 1988–1989, 2005) with the 2012 drought is shown in Figure 7.9. A value less than zero indicates a drop in the water table relative to the average level. With respect to the water table, the 2012 drought was of shorter duration than the previous droughts, and the maximum deviation in 2012 (~-3.0 feet) was not as great as for the droughts of 1988–1989 and 2005. The steepness of the decline in the first few months of the 2012 drought, however, was greater than

Table 7.4 Other Monitoring Wells Discussed in this Report. Well depths, water level depths (WL), and difference between minimum and maximum depth in feet over the course of the drought. All wells completed in sand and gravel aquifers.

County	Well Name	Well depth (ft)	Min WL	Min date	Max WL	Max date	WL diff	Days diff
Champaign	CHAM08-09A	265.0	49.34	1/24/2012	59.03	8/1/2012	9.69	190
Champaign	CHAM08-09WT	19.6	7.27	2/6/2012	12.08	8/31/2012	4.81	207
Champaign	CHAM09-06	108.5	29.93	5/9/2012	33.49	8/16/2012	3.56	99
Champaign	CHM-96A	351.0	44.84	3/2/2012	61.43	7/30/2012	16.59	150
Champaign	CHAM07-05	162.0	29.70	5/25/2012	35.92	8/6/2012	6.23	74
Lake	Lake Zion 5	21.8	4.09	5/8/2012	6.50	12/8/2012	2.41	214
Lee	Lee-92E	173.0	22.78	4/12/2012	59.68	8/4/2012	36.9	114
Lee	Lee-92F	22.0	3.01	3/13/2012	10.80	1/28/2013	7.79	321
Madison	MESD-GCD	98.5	13.92	5/2/2012	16.86	1/26/2013	2.94	269
Madison	MESD-GCWT	23.8	13.89	5/2/2012	16.84	1/27/2013	2.95	270
Madison	SIUE	43.5	30.99	5/8/2012	35.85	10/24/2012*	≥4.86	≥169
McLean	Bloomington WL MW4UD	11.5	2.21	5/13/2012	6.58	8/26/2012	4.37	105
Tazewell	MTH-17N	152.0	34.00	1/12/2012	37.18	8/5/2012	3.18	206
Tazewell	MTH-17WT	20.2	10.12	6/12/2012	14.67	1/10/2013	4.55	212
Tazewell	SWS-3d	252.0	33.36	2/4/2012	43.89	8/6/2012	10.53	183
Vermilion	Hoopeston	146.0	22.40	5/24/2012†	29.01	8/8/2012	≥6.61	≥76
Will	Midewin USFS MW3	11.7	0.40	5/7/2012	9.40	10/27/2012	9.00	173

*Record ends on this date
†Records missing prior to this date

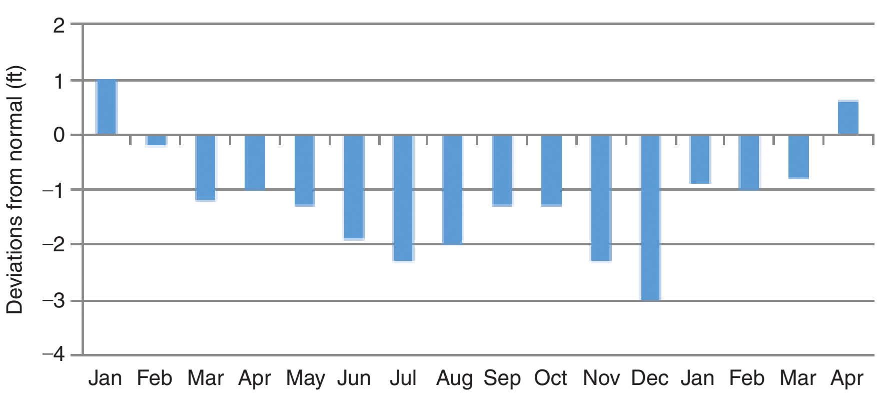


Figure 7.4 2012–2013 average groundwater deviations of water levels from normal for the 15-well WARM Network, January 2012 through April 2013

for the previous droughts and suggests that, without the occurrence of Hurricane Isaac (September 1–2, 2012), this drought was becoming a very serious drought with respect to groundwater levels. But the composite effect shown in Figure 7.9 illustrates that the 1988–1989 drought was the drought with the greatest overall effect on the state in regard to both the maximum average drawdown in the water table and the duration of low water table conditions.

Illinois Climate Network Shallow Groundwater Observation Wells

The water level information for the ICN wells has been grouped into four regional areas that divide Illinois based on the station location (Figure 4.1). Hydrographs for the ICN shallow wells within the west central region are shown in Figure 7.10. Groundwater levels in all wells declined starting around March 2012 and lasted into and beyond December. Dry conditions of the 2012 drought are reflected in all of the water level graphs for this network. The typical recharge season for shallow groundwater is in the fall and spring of each year; however, the drought of 2012 changed this pattern and noticeably pushed it into the early months of 2013. The water level response in the Kilbourne well was more gradual than for the other wells because it is finished in a sand deposit and thus behaves more like an aquifer than a typical water table well.

McHenry County Water levels in all of the monitoring wells in McHenry County declined during 2012 and, for many wells, into 2013. The minimum depth to water (maximum water table elevation) in 2012 occurred between

Table 7.5 WARM Shallow Groundwater Network Deviations of Water Levels from Normal (feet), January 2012 to April 2013

Well	County	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13
Galena	Jo Daviess	1.41	1.21	1.29	0.48	0.02	−0.54	−0.81	−0.46	−0.65	−0.44	−0.59	−0.55	−0.54	−0.48	−0.31	0.81
Mt. Morris	Ogle	4.48	3.36	3.42	1.52	0.32	−0.89	−1.44	−2.39	−3.09	−3.67	−4.57	−5.45	−6.24	−5.61	−6.12	−3.39
Crystal Lake	McHenry	1.82	1.74	1.37	0.72	0.15	−0.74	−0.84	−0.81	−0.94	−1.14	−1.50	−1.74	−1.70	−1.29	−0.97	0.24
Fermi Lab	DuPage	2.38		−2.35	−2.98	−2.36	−2.20	−1.65	−1.97	−3.29	−3.94	−4.05	−3.79	1.86	−0.60	−1.65	2.07
Good Hope	McDonough	1.03	0.32		0.47	0.43	−0.33	−2.56	−3.64	−3.94	−3.02	−4.46	−4.87	−0.25	−2.25	0.67	1.23
Snicarte	Mason	−0.89	−1.06	−1.56	−2.17	−1.53	−4.28							−3.29	−4.57	−3.81	−2.84
Coffman	Pike	−2.95	−5.37	−7.53	−6.77	−5.65	−5.95	−5.72	−5.24	−5.08	−4.76	−6.43	−7.10	−4.15	−5.86	−3.13	1.04
Greenfield	Greene	−5.2	−5.83	−5.66	−2.74	−1.83	−2.46	−3.29	−2.68	−2.27	−2.76	−3.92	−5.91	−6.23	−5.60	−2.49	0.58
Janesville	Cumberland	1.49	−0.31	−0.74	−0.7	−0.73	−1.78	−2.36	−1.38	0.46	0.94	−0.31	−0.05	0.38	2.15	−0.29	1.50
St. Peter	Fayette	1.10	0.28	0.45	1.03	−0.42	−0.75	−1.43	0.26	2.64	2.57	0.71	0.85	0.82	0.82	0.86	0.97
SWS #2	St. Clair		2.26		2.51	0.57	0.28	−0.95	−0.93	−0.74	0.89	0.35	−0.21	1.79	2.13	2.10	3.35
Boyleston	Wayne	1.59	−0.27	−0.90	−0.39	−0.54	−0.43	−0.75	−1.17	1.75	0.30	−1.73	−3.53	1.37	0.68	0.61	0.59
Sparta	Randolph	5.10	2.02	−0.13	−1.18	−1.95	−2.16	−1.57	−0.56	3.82	2.00	0.57	−0.42	3.91	2.95	1.95	2.51
SE College	Saline	1.48		−2.02	−3.21	−3.59	−3.69	−3.25	−3.11	−2.96			−5.61	−3.03	0.11	−0.21	0.04
Bondville	Champaign	1.37	−0.82	−1.78	−2.18	−2.01	−2.57	−5.46	−4.41	−3.46	−4.08	−4.16	−2.91	1.80	1.80	0.32	0.14
Deviation From Normal		1.02	−0.19	−1.24	−1.04	−1.27	−1.90	−2.29	−2.04	−1.27	−1.32	−2.31	−2.95	−0.90	−1.04	−0.83	0.59

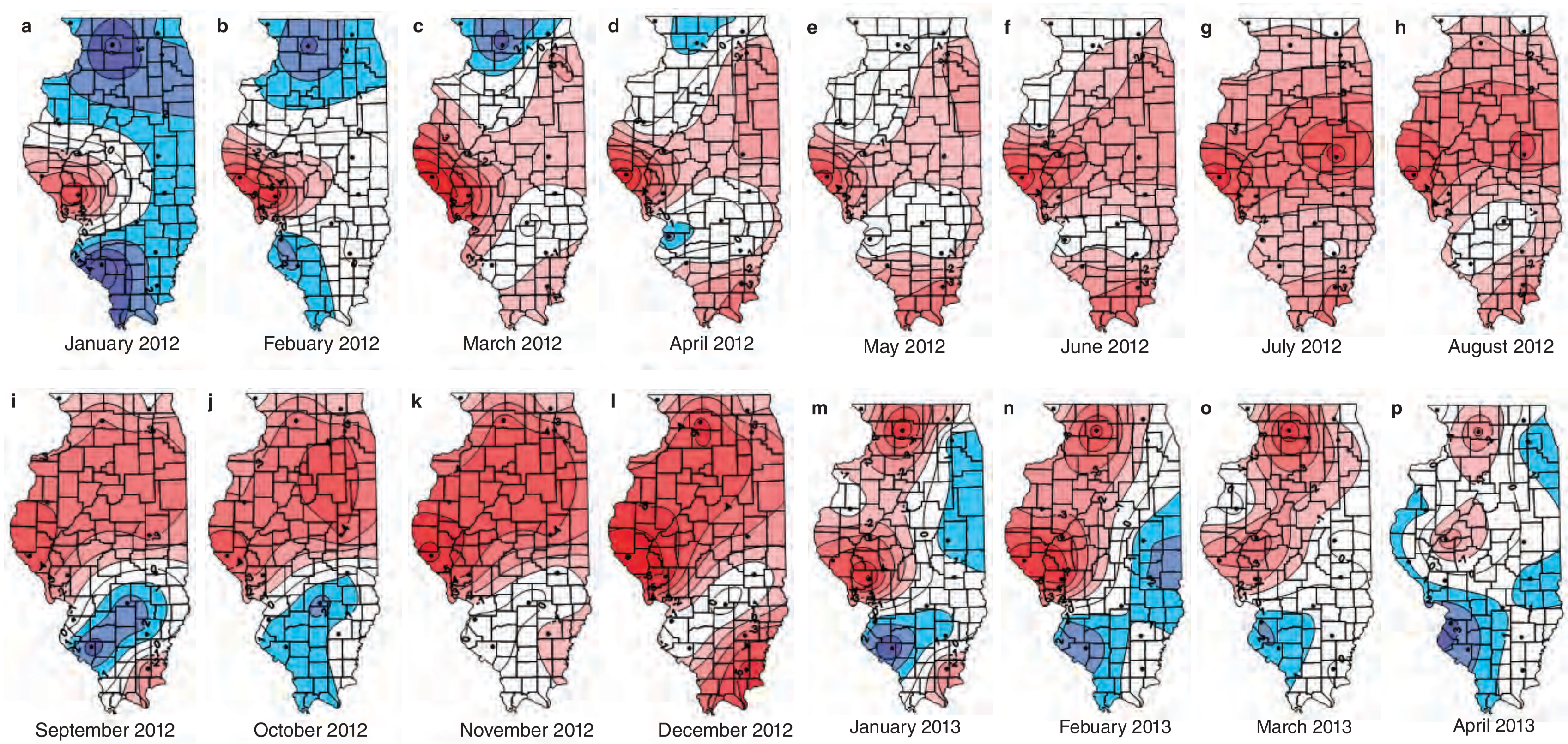


Figure 7. 5a-p Deviations from normal. Contours in feet. Blue indicates above-normal conditions, red indicates below-normal conditions.

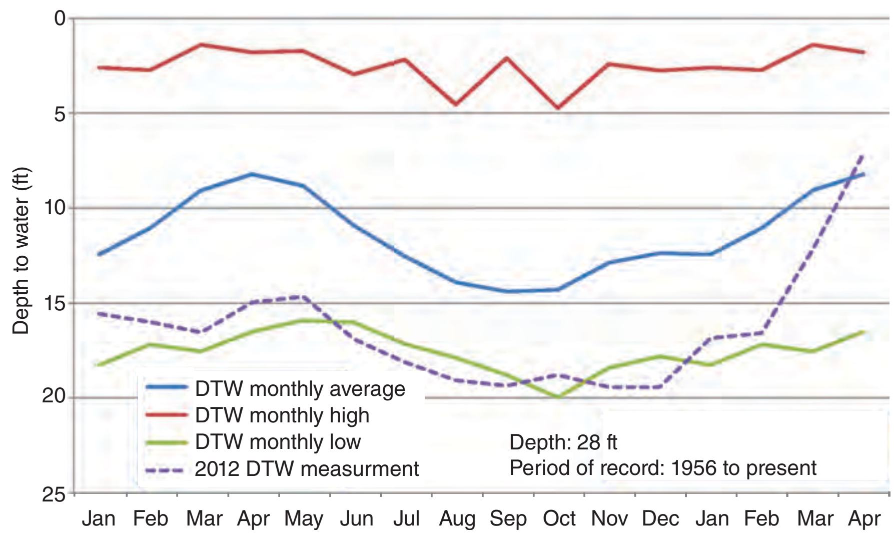


Figure 7.6 Water levels at Coffman observation well, January 2012 through April 2013

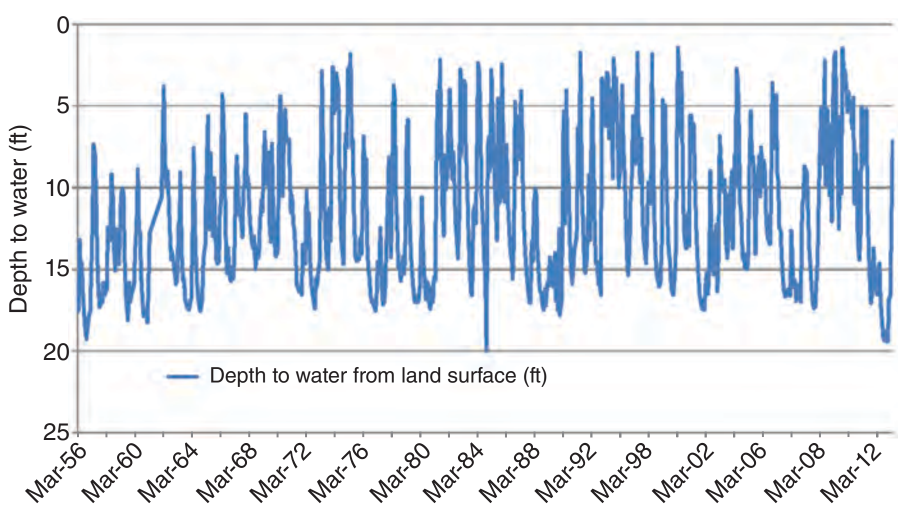


Figure 7.7 Depth to water at Coffman observation well, March 1956 to April 2013

mid-March and early May in all the wells but one (NW-6-45-9), where the minimum occurred in early June. The maximum depth to water, corresponding to the lowest water table, occurred between early July 2012 and early February 2013. The number of days between the minimum and maximum measurement varied from 63 to 315, with a median of 214 days. The difference between the minimum and maximum measurement at an individual well varied from 2.58 to 31.39 feet, with a median value of 5.85 feet. Information for each monitoring well in McHenry County is in Table 7.3.

The hydrograph for monitoring well 15-COR-S is shown in Figure 7.11 for the period of record at the well (2009–2014). The figure shows how much lower groundwater levels were in much of 2012 and the start of 2013 than in non-drought years.

Generally, wells where the maximum depth occurred in August or September 2012 identify as either water table wells or wells influenced by irrigation pumping. Wells with the greatest drop in groundwater levels during 2012 were 17-ALG-D and WAUC-02-12, which are close to municipal and commercial wells in Lake in the Hills, Crystal Lake, and Island Lake.

Other Monitoring Wells Water level information for other monitoring wells in the state with continuous measurements, including the depth and date of minimum water level observations, are included in Table 7.4. The minimum depth to water in 2012 occurred between late January (CHAM08-09A) and mid-June (MTH-17WT). The maximum depth to water occurred between August 2012 and January 2013. The number of days between the minimum and maximum measurement varied from 76 to 321, with a median of 198 days. The difference between the minimum and maximum measurement at an individual well varied from 2.41 to 36.90 feet. The two wells that had the greatest decrease in groundwater levels (Lee 92E and CHAM08-09A) also recovered the most rapidly; these wells were clearly under the influence of nearby irrigation pumping (Figure 7.12).

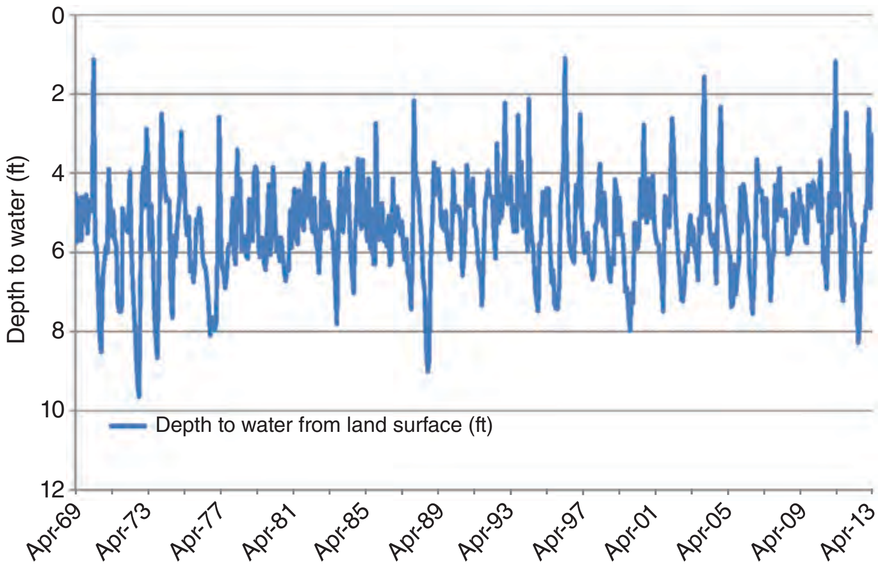


Figure 7.8 Depth to water at Janesville observation well, April 1969 to April 2013

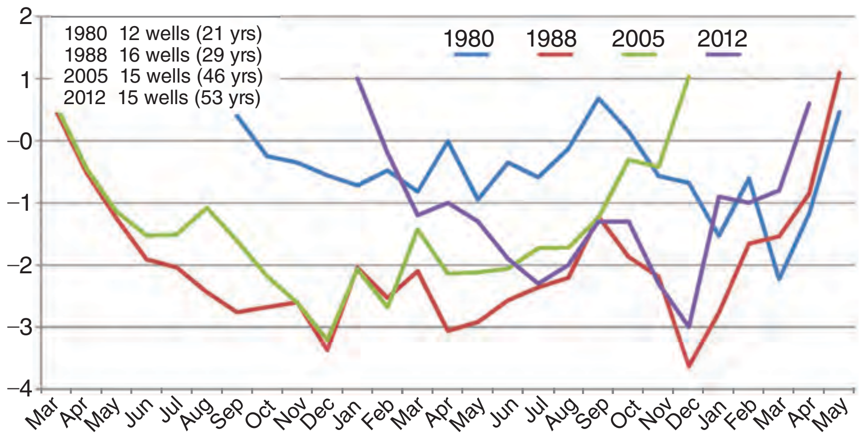


Figure 7.9 Deviations from normal for water levels for WARM wells for the following periods: Sept 1980–May 1982, March 1988–May 1990, March 2005–December 2006, and January 2012–April 2013. Average deviation for all WARM wells in the network for each specific drought.

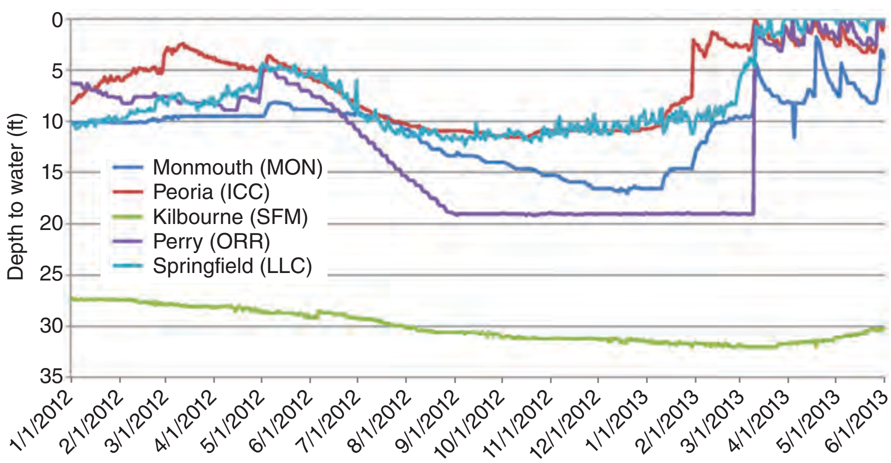


Figure 7.10 ICN Central West Group Observation Wells, January 2012 through June 2013. The flat line for Perry between September and March represents a period when the water table dropped below the sensor height.

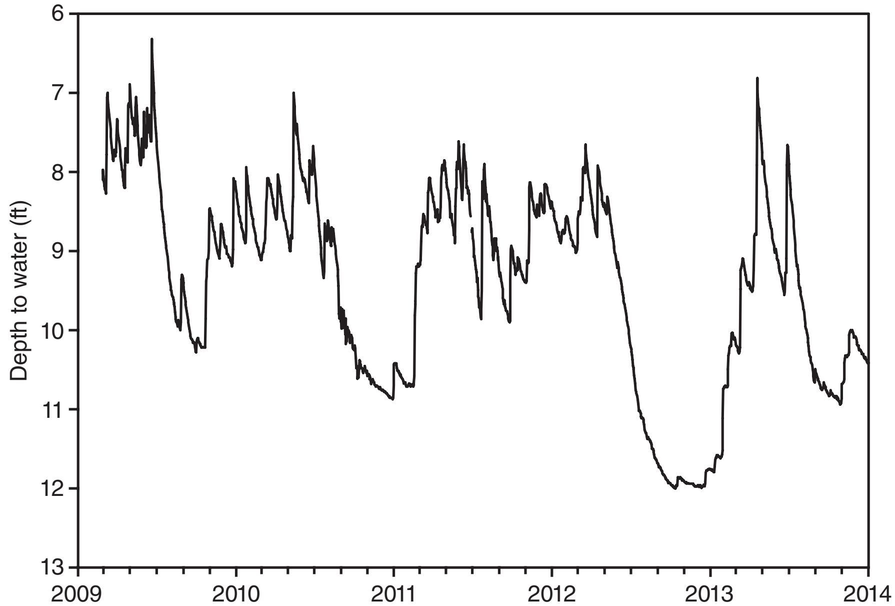


Figure 7.11 Hydrograph for period of record for McHenry County monitoring well 15-COR-S

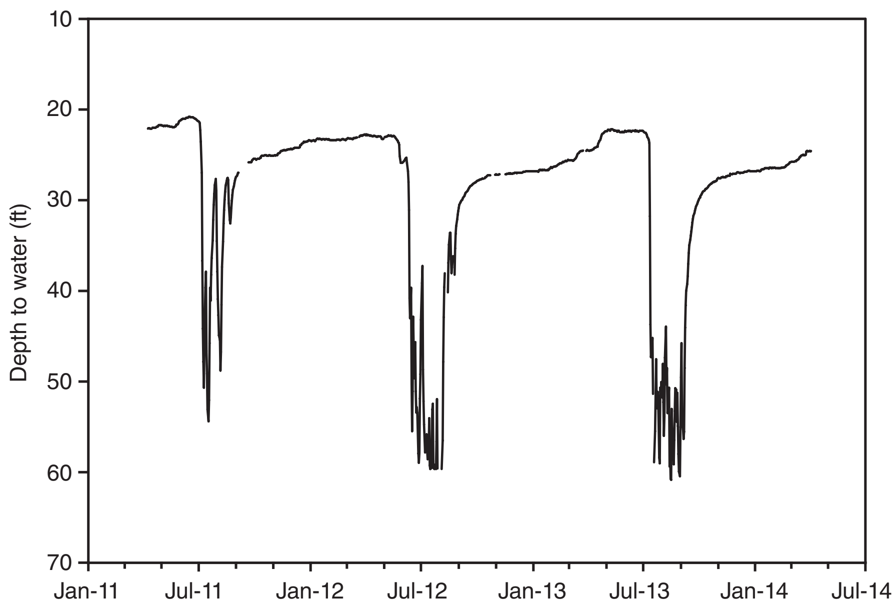


Figure 7.12 Hydrograph between 2011and 2014 for a monitoring well in Lee County showing the effects of irrigation pumping in the summer months. Between July 29 and August 3, 2012, the water level dropped below the transducer on five days, thus the maximum depth to water is unknown; the transducer was lowered in the well prior to 2013.

Electronic Filing: Received, Clerk's Office 05/6/2022

Chapter 8. Agriculture and Irrigation Impacts

Crop Damages

The 2012 drought in Illinois had the most impact on the agricultural sector. These impacts were the most significant since the 1988 drought, and the 2012 precipitation deficits were in many ways similar to the dust bowl drought years of 1934 and 1936. Statewide, corn yields were reduced to an average of 105 bushels per acre (National Agricultural Statistics Service), which is 66 percent of the yield in 2011 and roughly 60 percent of the trend average. The National Agricultural Statistics Service (NASS) calculated the projected trend average using a simple linear regression analysis of yields from previous years. Soybean yields were reduced to 43 bushels per acre, which is 89 percent of the yield in 2011. The number of corn acres cut for silage doubled as it became evident that particular fields would not produce a measurable yield. Hay production was reduced as well. The lower yields and higher hay prices increased costs for livestock producers.

As a result of 2012 crop damages, Illinois farmers received roughly $3.5 billion in crop insurance payouts (September 2013 Report from the U.S. Department of Agriculture [USDA] Risk Management Agency), the greatest portion ($3.2 billion) of which was associated with damages to the corn crop. Farmers in adjacent states of Iowa and Indiana received $2 billion and $1.5 billion, respectively, and the nation's total crop insurance payout for 2012 was $17.4 billion.

Corn

Six states experienced corn crop losses in excess of 30 percent below average based on USDA crop statistics: Illinois, Indiana, Kansas, Kentucky, Missouri, and Tennessee (http://farmdocdaily.illinois.edu/2013/02/locating-the-2012-drought.html). Based strictly on a statewide percentage loss, Kentucky experienced the greatest corn crop damage with an overall 53 percent loss compared to its computed trend average. However, Kentucky has comparatively few acres planted in corn–less than 10 percent of the respective acreage in Illinois. When total production is considered, the loss of the 2012 corn crop in Illinois exceeded that from the other five states combined. Southern Illinois appears to have been the epicenter of the 2012 drought in terms of crop damage.

Figure 8.1 shows the 2012 average corn yields for Illinois by county, illustrating the considerable impact to the crop in southern and south-central Illinois. The average corn yield in the southwest Illinois crop reporting district, for example, was only 43 bushels per acre, equivalent to a 70 percent loss when compared to the trend average of more than 140 bushels per acre. The northwest Illinois crop reporting district had the highest average yields in the state, but the district's average yield of 140 bushels per acre was still roughly 15 percent lower than its trend average.

Figure 8.2 shows the average annual corn yields in Illinois since the late 1960s (National Agricultural Statistics Service [NASS]). Average yields in the state have increased considerably over the years. As such, the severity of a drought to crop yields is normally evaluated by comparing yields to the average trend line. Using this evaluation, the drought years of 1988 and 2012 are considered to have the greatest negative effects on corn yields in the past 50 years, with reductions in yields of 43 and 40 percent, respectively.

The hot, dry summer caused higher-than-normal levels of aflatoxin in the corn crop. Aflatoxins are a group of chemicals produced by a certain family of mold fungi that thrive in hot, dry conditions and can be harmful or fatal to livestock. In addition, they are considered carcinogenic to both animals and humans. As a result, the Illinois Department of Agriculture required extensive oversight in the handling and blending of corn containing aflatoxin to dilute concentrations to acceptable levels.

Soybeans

Into August 2012 it appeared that soybean yields would also be heavily damaged by the drought. However, the higher rainfall amounts that occurred by early September allowed a significant recovery of the crop, such that the statewide average yield of 43 bushels per acre was only about 10 percent below the NASS expected trend average.

The difference in recovery from dry conditions between the soybean and corn crops is related to each crop's growth pattern. The corn crop follows a relatively strict timeline, and lack of moisture at crucial times can heavily damage the crop, whereas soybeans have a greater ability to adjust their growing schedule and fill out if moisture

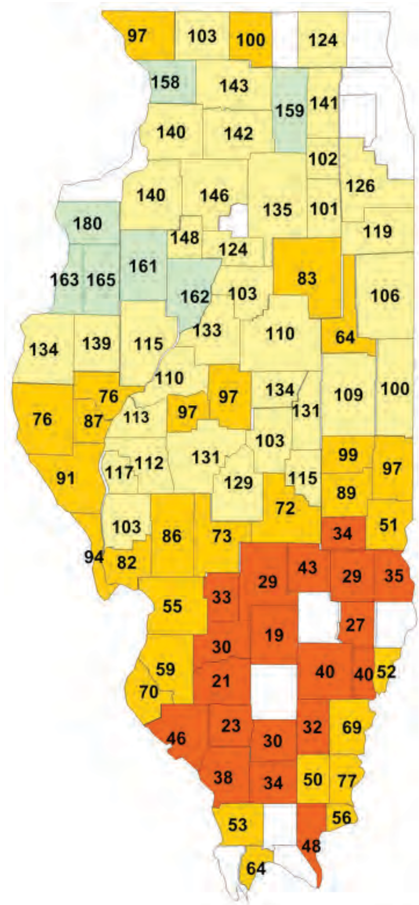


Figure 8.1 Average 2012 corn yield (bushels per acre) for Illinois counties (taken from the FarmDocDaily Newsletter, Dept. of Agricultural and Consumer Economics, University of Illinois)

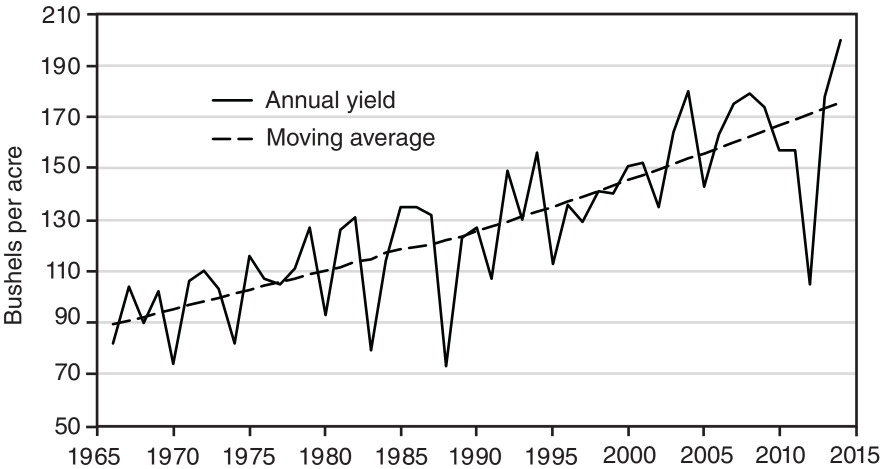


Figure 8.2 Illinois average corn yields, 1966-2014

becomes available at a later date. In contrast to the 2012 drought, the 1988 drought experienced continued dry conditions from early summer through September and early October. Thus, the 1988 soybean crop had no chance to recover and remained damaged, with an average yield in Illinois (27 bushels per acre) that was more than 30 percent below the expected average yield for that year.

Figure 8.3 shows the 2012 average soybean yields for Illinois by county. Many counties in southern and south-central Illinois had average yields below 30 bushels per acre (and a few had less than 25 bushels per acre), roughly associated with a 40 percent reduction from the average trend. In contrast, however, much of the remainder of Illinois had soybean yields that were similar to their expected averages, with a number of counties having yields in excess of 50 bushels per acre.

Other Agricultural Impacts

Livestock

The increase in livestock feed prices, coupled with diminished pasture production and hay shortages, created hardships for hog and cattle producers in Illinois. Many operators were forced to send breeding animals to slaughter to reduce herd sizes. As a result, the subsequent increase in meat supply caused livestock prices to drop. Unlike corn and soybean producers, livestock producers typically do not have access to insurance to protect against financial losses caused by drought.

Transportation of Agriculture Commodities

In Illinois, agriculture relies heavily on the Mississippi and Illinois Rivers as a source of reliable and economic movement of corn, soybeans, fertilizer, and other agricultural commodities. The low river stages on the Mississippi River below St. Louis in the fall and winter months were of special concern, and are addressed in Chapter 11: *Navigation, Environmental, and Water Quality Impacts*.

Fertilizer Transport

The reduced uptake of nutrients by crops, especially nitrogen, is one of the secondary impacts of the 2012 drought. Poor crop growth, and in some cases total crop failure, resulted in the reduced uptake of nutrients from soils. The primary concern was that these extra nitrates would make it into the rivers and streams the following spring. On the other hand, more carryover of nitrates through the winter and following spring could potentially reduce the need for applications in the following growing season. Unfortunately, field measurements in spring 2013 indicated that although the drought-related residual nitrates had stayed in the field, they had moved deeper into the soil, becoming unavailable for crops. As those nitrates moved out of the soil and into field tiles, nitrate levels on the Illinois River rose in March 2013 and remained high through June.

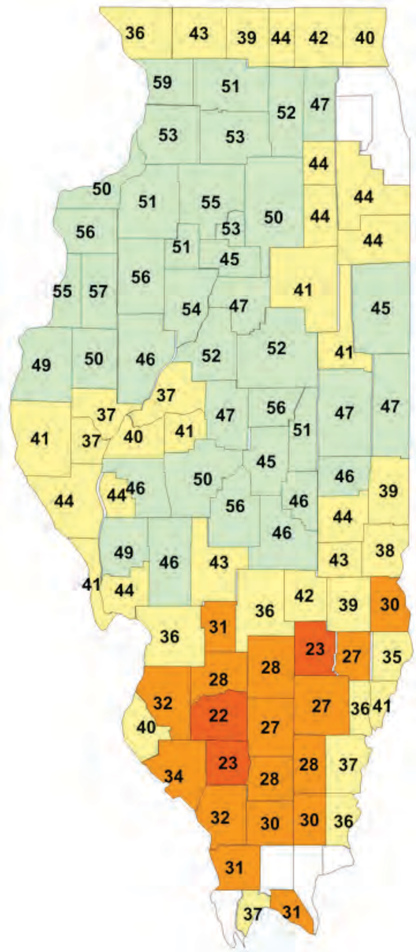


Figure 8.3 Average 2012 soybean yields (bushels per acre) for Illinois counties (taken from the FarmDocDaily Newsletter, Dept. of Agricultural and Consumer Economics, University of Illinois)

Rural Wells

Several agriculture-related water issues arose during the 2012 drought. One of the earliest impacts at the farm level was the drawdown of shallow groundwater wells (typically less than 50 feet below the land surface). As a result, many farmers resorted to hauling water from nearby municipalities at great expense. As the drought progressed, many municipalities restricted bulk water sales over concerns of their own water supplies. There were several complaints of deeper high-capacity wells, associated with irrigation operations, pumping hard enough to drop neighboring farms' well levels.

Expansion of Irrigation

Agricultural water shortages and diminished crop yields experienced during recent droughts such as in 2005 and 2012 have become a driving force in the continuing increase in the number of irrigators in Illinois, typically leading to the development of new irrigation sites in the years following a drought. Additional driving factors related to the increase in irrigated acres are 1) commodity prices, mainly for corn, making irrigation more cost-effective when prices are higher; and 2) requirements by seed corn companies that there be guaranteed yields in seed corn contracts. The combination of the drought and high commodity prices in 2012 triggered a significant expansion of irrigated acres across Illinois that continued in 2013. The trend in expanding irrigation acreage was at least temporarily halted by 2016 as a result of a drop in corn prices.

Historically, Illinois has not been considered a major irrigation state because of its typically abundant rainfall (36–49 in/yr) and organic-rich soils which hold moisture well. However, there are certain regions of the state where irrigation has been historically present and concentrated, most notably in the glacial and alluvial river valleys along the major rivers in Illinois (Mississippi, Illinois, Wabash, Ohio, Kankakee, and Rock Rivers). These regions have sandy soils that do not hold moisture well and thus require supplemental irrigation for adequate crop yields. In recent years, however, there has been an increase in irrigated acres for other areas in Illinois, including areas with more organic-rich soils where one would not expect much irrigation.

A survey of center pivot irrigation completed by the ISWS in 2012 determined that there are approximately 540,000 irrigated acres in Illinois and approximately 6,000 center pivot irrigation systems. The distribution of center pivot irrigation by county is shown in Figure 8.4. Data for the 10 counties with the largest numbers of acres under center pivot irrigation in 2012 are shown in Table 8.1. As noted earlier, most of the heavily irrigated areas are those along river valleys where sandy soils are common and groundwater is the predominant source of water. Other forms of irrigation, such as ditch, subsurface, and lateral line irrigation, do exist in Illinois, but are limited, and data on acreages are not readily available.

Impacts of Irrigation on Water Resources

During abnormally dry years, there is always a substantial increase in the frequency and amount of water applied to crops at existing irrigation facilities. In some cases the increased use of irrigation water during a drought can overuse and negatively affect the availability of the water resource from which the pumping occurs. The effect of irrigation on water supply availability is a common drought concern, particularly with groundwater sources. Ad hoc irrigation from surface sources, such as a farmer temporarily pumping from a hose or pipe dropped into a nearby river, also occurs during a drought and can cause noticeable reductions in low streams, but is rarely documented, and thus in many situations can only be inferred.

During the drought of 2012, irrigation pumping appeared to be the cause of interrupted service to private well owners and other groundwater users in several counties, including reports from Champaign, Iroquois, Lee, and Whiteside Counties. An extensive cone of depression associated with irrigation pumping was reported near the junction of Lee, Whiteside, and Bureau Counties, which may also have affected low flows in the nearby Green River. A case study on such impacts in Champaign and McLean Counties is presented in this chapter.

Among the few regulations of irrigation in Illinois is the Water Use Act of 1983 (amended; Public Act 096-0222). Controls on irrigation are limited to four counties in east-central Illinois, those "through which the Iroquois River flows" and those "with a population in excess of 100,000 through which the Mackinaw River flows." The affected counties are Iroquois, Kankakee, McLean, and Tazewell. If a well owner in these counties has an interruption in service due to pumping by a high-capacity well (>100,000 gallons per day), they may file a complaint with the local Soil and Water Conservation District. The Soil and Water Conservation District, with the assistance of the ISWS and Illinois State Geological Survey, are authorized to determine impacts of withdrawals on other water users. After such an investigation, the Soil and Water Conservation District "may recommend to the [Illinois] Department of Agriculture that the Department restrict

Table 8.1 Ten Highest Ranked Counties Irrigated by Center Pivot in 2012

County	Acres Irrigated by Center Pivot	County's Crop Acreage (%)
Mason	135,684	49.60%
Whiteside	60,122	14.80%
Tazewell	42,250	12.80%
Lee	26,476	6.70%
Cass	25,852	14.90%
White	22,469	7.60%
Lawrence	20,100	10.40%
Gallatin	19,381	10.40%
Henderson	17,569	10.30%
Kankakee	13,842	3.60%

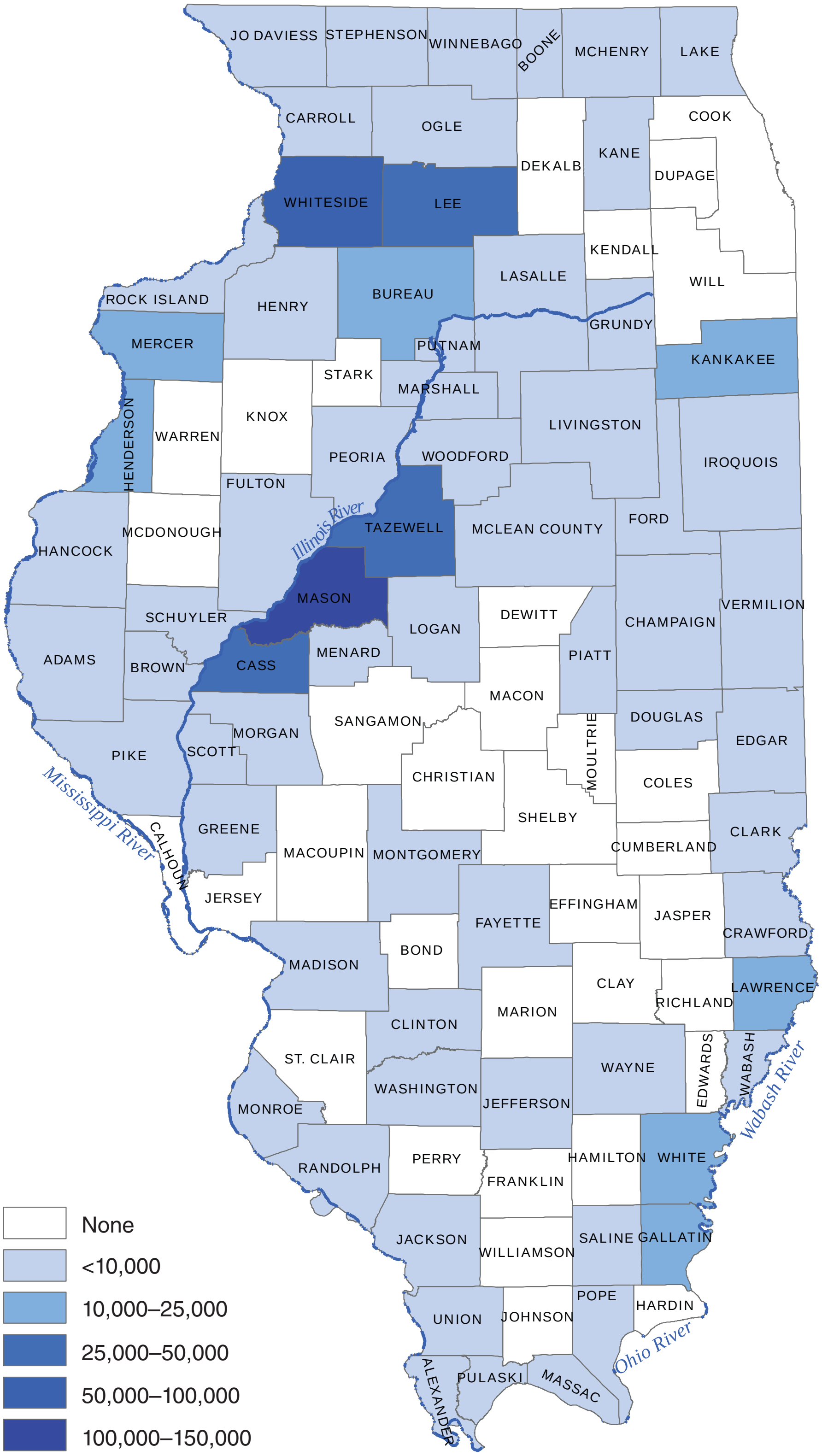


Figure 8.4 Amount of center pivot irrigated acres in Illinois in 2012 per county

the quantity of water that a person may extract from any high-capacity well within the District's boundaries," until conditions return to normal. It should be noted that the legislation refers to any high-capacity well, not only to irrigation wells, although in practice, irrigation wells are the most likely source of conflicts in these regions. As far as we know, the Department of Agriculture has never used their authority to restrict any high-capacity wells in Illinois.

Case Study: Irrigation in Champaign and McLean Counties Although Champaign and McLean Counties have organic-rich soils and are not among the top irrigation counties in Illinois, they have seen a significant increase in irrigation over the past 10 years. This increase is largely attributed to more irrigation requirements by seed corn companies that want a guaranteed crop in a dry year. Irrigation has also been observed on some soybean fields.

In northern Champaign County, over 50 irrigation pivots were identified in 2012 in the Rantoul area, many of which had been constructed since 2007. According to the well records, some of these wells were test pumped at rates of between 1.4 and 3.6 million gallons per day (mgd). Assuming the irrigation systems are pumping 1.4 mgd, the collective pumping rate for all systems in Champaign County is on the order of 70 mgd, or twice the rate of the public and industrial users in the county. The irrigation pumping differs, however, in that it is not operated on a continuous basis (24/7) and occurs only seasonally. Thus, the overall annual volume of irrigation pumping is comparatively less, with drawdown recovery occurring in the off-season. Although the irrigation growth in McLean County is not as pronounced, a cluster has developed in the southwestern part of the county near the village of McLean.

Most of the irrigation water in Champaign and McLean Counties comes from wells that draw from the Mahomet Aquifer. Sharp drops in summer water levels are shown in the hydrographs of observation wells in Champaign County (Figure 8.5). The irrigation systems near these observation wells were heavily used during the dry periods in

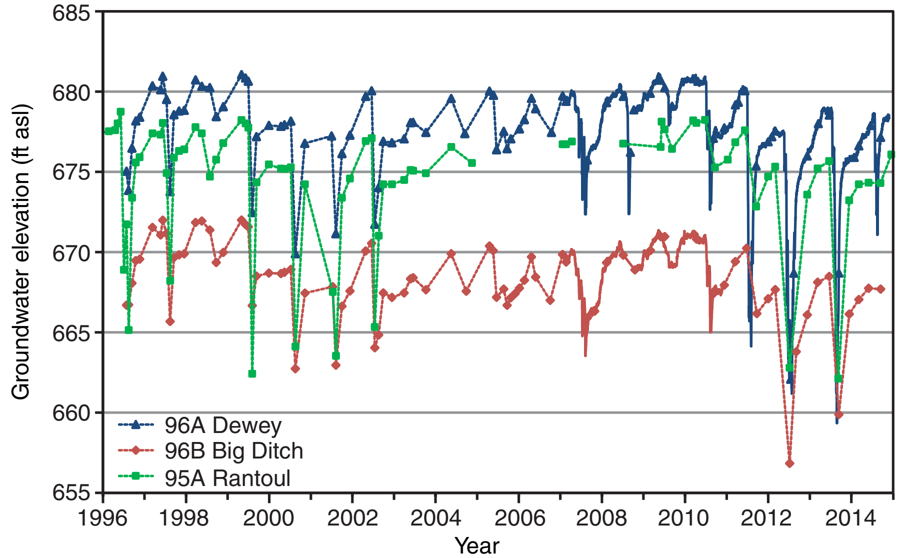


Figure 8.5 Hydrographs from wells CHM-95A, CHM-96A, and CHM-96B

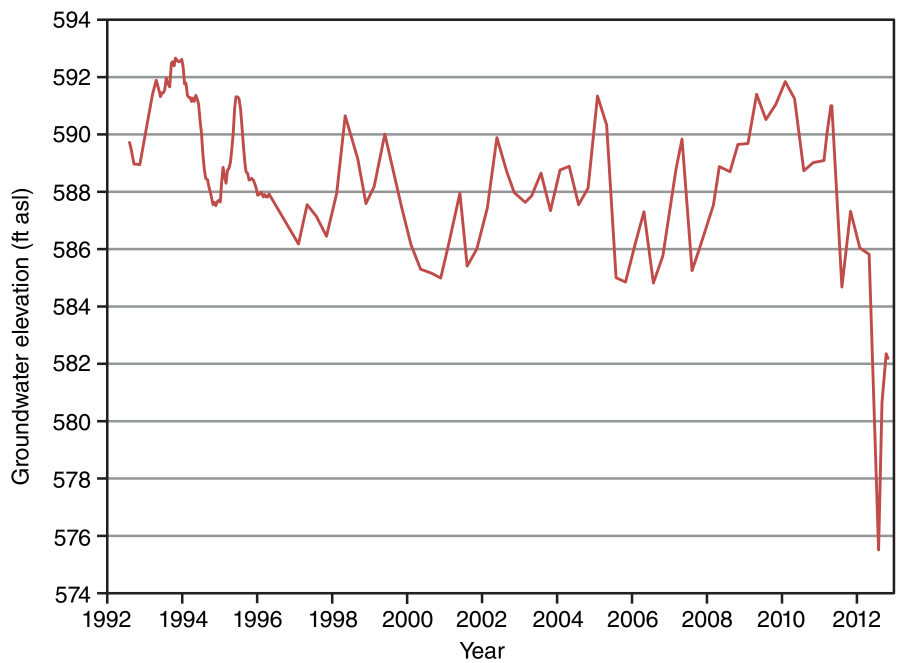


Figure 8.6 Hydrograph between 1992 and 2013 for monitoring well SWS-3d in McLean County

the summers of 2011 and 2013, but not during the relatively wet summers of 2009, 2010, and 2014. In 2012, the sharp water level decreases and increases in well CHM-96A at Dewey indicate that the nearby pumping wells were started between May 25 and June 25 and were shut off between August 1 and August 24. A sharp drop in water levels was also observed around the Village of McLean where several irrigation systems have been installed since 2009. In the quarterly measurements from a nearby monitoring well (Figure 8.6), the summer of 2012 was the first time a significant amount of drawdown had been observed in this portion of the aquifer.

Figures 8.7 and 8.8 show changes in drawdown in the Mahomet Aquifer during two time periods in the 2012 drought 1) from March through July; and 2) from late July through September. The impact of the 2012 drought on water levels in the Mahomet Aquifer from March through July was largely a response to changes in demand from irrigation in the central and eastern portion of the aquifer.

The summer drawdown was widespread throughout the northern half of Champaign County and into Ford and Vermilion Counties with the greatest drawdowns of more than 12 feet occurring immediately north and west of Rantoul. The summer drawdown in southwestern McLean County was less widespread but also had a maximum amount exceeding 12 feet. The irrigation systems were not used after the rainfall associated with Hurricane Isaac (which provided roughly 3 inches of rainfall to this portion of Illinois), so a sharp water level recovery was observed in the September 2012 measurements (Figure 8.8).

Other Regional Impacts to the Mahomet Aquifer In the heavily irrigated Imperial Valley region in Mason and Tazewell Counties, water levels did not drop by more than 4 feet during the growing season. The Mahomet Aquifer in this region is near the surface and is unconfined. Whereas drawdown in confined conditions is related to the reduction of pressure in a fully saturated aquifer, drawdown in unconfined aquifers is related to active dewatering and a drop in the water table. For the same volume of withdrawal, drawdown is generally much less in unconfined aquifers. Furthermore, when rain does occur, there is a much more immediate recharge with a near-surface unconfined aquifer.

The Imperial Valley Water Authority, which covers all of Mason County and about six townships in Tazewell County, has been estimating their irrigation pumping for the past 10 years using estimation methods that rely on electric power consumption. Figure 8.9 shows the amount of irrigation in the Imperial Valley region between 2004 and 2013. Almost 100 billion gallons of groundwater were estimated to have been used for irrigation during 2012 because of the

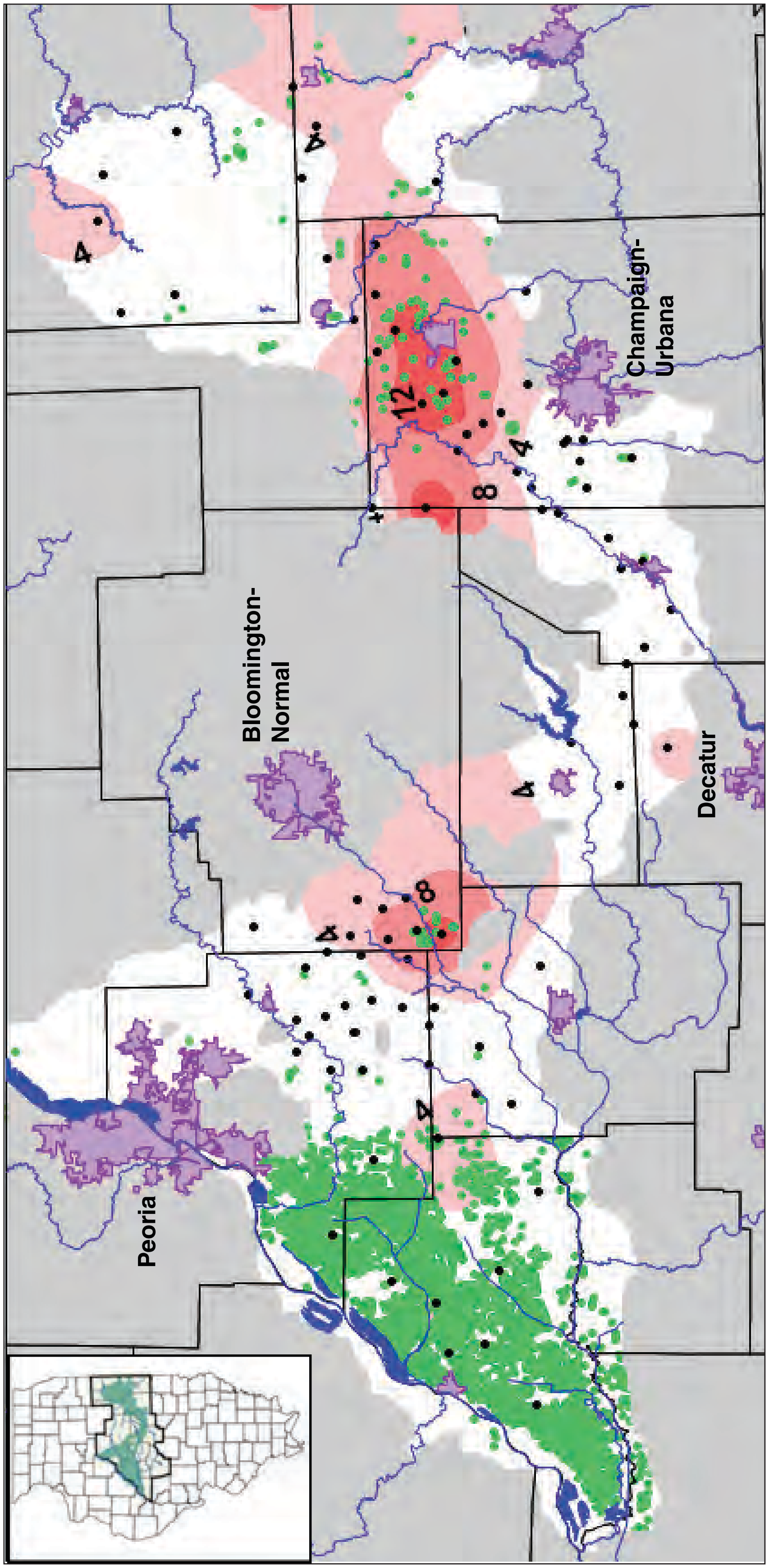


Figure 8.7 Drawdown (ft) in groundwater levels in the Mahomet Aquifer from March to July 2012. Observation wells are represente d with black dots and irrigation wells are represented with green dots.

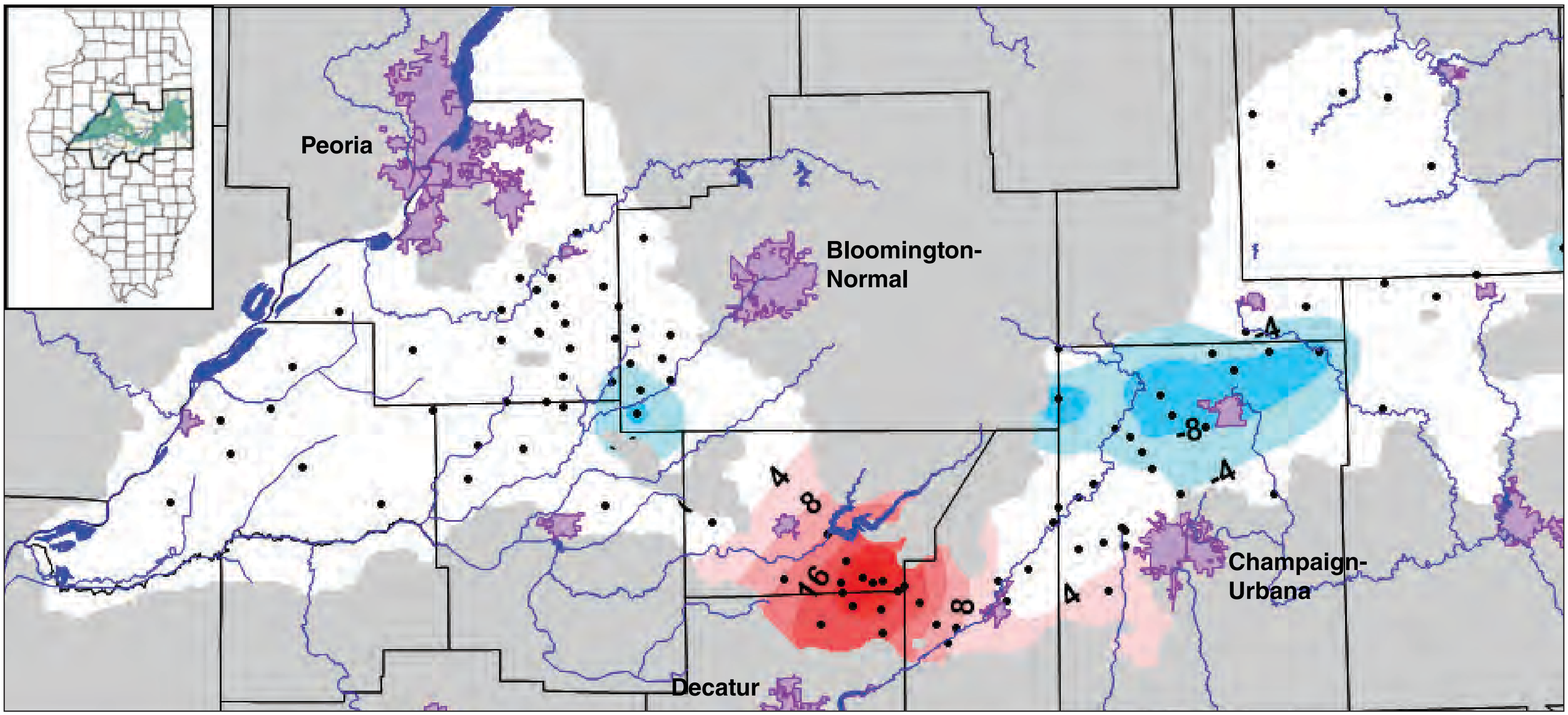


Figure 8.8 Drawdown (ft) in groundwater levels in the Mahomet Aquifer from July to September 2012. Observation wells are represented with black dots. Blue regions are where water levels have recovered.

drought conditions, almost twice the median amount pumped during this period (51 billion gallons).

From late July through September, additional drawdown in the Mahomet Aquifer was mostly in response to the operation of the Decatur emergency wellfield (Figure 8.8). The influence of this drawdown to the water availability to Decatur is addressed in the upcoming Chapter 10: *Water Supply Case Study: The City of Decatur*. Although Champaign-Urbana (Illinois American Water Company) is a large user of the Mahomet Aquifer water, their use is year-round, and groundwater levels in a portion of the aquifer remained relatively static; little additional drawdown occurred during the drought.

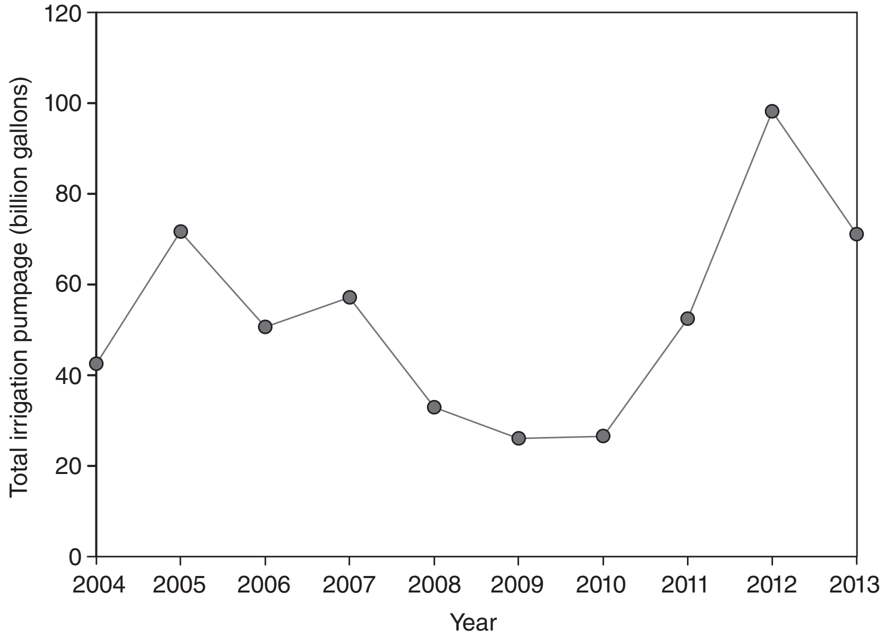


Figure 8.9 Total annual irrigation pumping in the Imperial Valley of Illinois between 2004 and 2013

Chapter 9. Water Supply and Water Use Impacts

Community and Domestic Water Supplies

Community Water Use and Conservation

Table 9.1 lists the monthly amount of water use in 2012 for 22 selected Illinois communities. As with all recent drought events, water use was elevated for most of the communities during the early months of the drought. Water use for both June and July 2012 show this pattern. Most of the increases are associated with outdoor water uses, such as lawn watering. Rates were particularly high in July, even after some communities had enacted voluntary conservation measures because of the high temperatures and low precipitation during that month. In September, much of Illinois experienced substantial recovery in soil moisture as a result of the passage of Hurricane Isaac, thus eliminating the need for lawn watering for most locations in the state. As a result, water use through the remainder of the year dropped to base levels typically experienced during cool seasons.

According to available Illinois Environmental Protection Agency (IEPA) records, at least 11 Illinois community surface water systems (Bloomington, Carlinville, Carthage, Decatur, Gillespie, Hillsboro, Jacksonville, La Harpe, Lake of Egypt Water District, Mt. Olive, and Springfield) enacted either mandatory or voluntary conservation measures during the 2012 drought because of low reservoir levels. The earliest voluntary conservation measures of the year were enacted in early July by Springfield and Hillsboro, with most other communities following suit in mid- to late July. Mandatory conservation was later enacted by roughly half of these communities, most commonly in late July or August. Most of the community conservation measures focused on the restriction of outdoor water uses, and thus were most effective during the summer. As part of the conservation effort, some communities also suspended bulk water sales, in many cases turning away rural residents situated outside of a community's service area who were seeking water because of dwindling well supplies.

Most affected large communities have existing drought action plans that identify triggers (such as specified low reservoir levels) for enacting conservation measures. For example, Decatur initiated voluntary measures on July 17, shortly after Lake Decatur had fallen to an elevation of 613.0 feet. Because their lake level was dropping quickly, only

Table 9.1 Monthly Water Use in 2012 for Selected Illinois Community Systems (Monthly total expressed as an average daily rate in million gallons per day)

Community	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Altamont	0.22	0.20	0.20	0.22	0.25	0.29	0.27	0.25	0.22	0.21	0.22	0.21
Aurora	15.8	15.2	15.1	15.3	17.9	22.3	23.3	20.0	18.1	15.9	14.3	14.8
Batavia	2.7	2.6	2.5	2.7	3.3	4.7	4.6	3.7	2.8	2.8	2.6	2.7
Carlinville	0.85	1.10	1.05	1.11	1.15	1.02	1.16	0.96	0.85	0.83	0.79	0.76
Centralia	3.4	3.3	3.4	3.6	3.8	4.3	4.7	4.0	3.6	3.5	3.4	3.5
Champaign	18.2	18.6	18.7	19.5	22.2	24.3	28.2	23.6	21.1	19.6	18.2	17.9
Danville	7.2	7.1	7.1	6.9	8.0	8.4	9.2	8.3	7.5	7.2	6.8	7.0
Decatur*	34.7	33.3	33.9	35.4	38.0	41.5	42.4	35.5	32.7	32.0	33.5	33.0
Highland	1.0	1.0	1.0	1.0	1.3	1.5	1.9	1.5	1.3	1.3	1.2	1.2
Hillsboro	0.88	0.88	0.91	0.92	1.05	1.24	1.34	1.21	1.10	0.97	0.96	0.85
Kinkaid-Reeds	1.9	1.9	1.8	1.9	2.3	2.4	2.5	2.1	2.0	1.8	1.9	1.8
Marquette Heights	0.16	0.16	0.17	0.17	0.20	0.20	0.22	0.18	0.17	0.17	0.16	0.17
Mattoon	2.1	2.1	2.2	2.1	2.3	2.4	2.7	2.3	2.1	2.0	2.0	2.0
Mt. Olive	0.19	0.20	0.19	0.18	0.24	0.24	0.26	0.24	0.22	0.19	0.18	0.19
Normal	3.5	3.8	3.6	4.0	4.6	4.8	5.4	4.5	4.3	4.2	3.7	3.4
Pontiac	1.7	1.6	1.6	1.7	1.9	2.1	2.1	1.9	1.8	1.7	1.6	1.6
Salem	0.9	0.9	0.9	0.9	1.0	1.2	1.3	1.1	1.0	1.0	0.9	0.9
Springfield	19.7	19.8	19.9	20.8	25.2	29.2	36.3	29.5	23.1	18.8	17.7	18.6
Sterling	1.5	1.5	1.5	1.5	1.6	1.7	1.8	1.6	1.6	1.5	1.5	1.4
Streator	1.7	1.7	1.7	1.8	2.0	2.1	2.4	2.1	1.9	1.9	1.9	2.0
Taylorville	2.0	2.1	2.0	2.0	2.1	2.2	2.4	2.2	2.1	2.1	1.9	1.9
Tuscola	0.32	0.32	0.32	0.33	0.40	0.41	0.49	0.42	0.38	0.37	0.39	0.37

*Includes self-supplied industrial use withdrawn from Lake Decatur.

one week later Decatur enacted mandatory measures in anticipation of the lake falling below an elevation of 612.0 feet. In a similar fashion, Bloomington initiated voluntary measures in mid-August after the combined drawdown of their two reservoirs (Lake Bloomington and Evergreen Lake) exceeded 8 feet. On the other hand, Springfield's conservation responses were enacted well in advance of the trigger levels identified in that city's drought management schedule (with mandatory conservation enacted on August 10), and instead appeared to be associated with a heightened public awareness of the rapidly developing drought conditions in central Illinois.

An examination of water use rates in Table 9.1 shows a reduction in use for all communities between July and August 2012. Some of this reduction can be attributed to conservation measures for those communities that were restricting water use. However, it is also expected that a sizeable amount of the reduction was related to weather conditions. Late June and July were both dry and very hot with average temperatures 8 to 10 degrees F warmer than in August, and thus higher water use rates would be expected. For example, Decatur had 10 days in June and July when the daily water use exceeded 45 million gallons per day (mgd), with a maximum daily use of 47.5 mgd on June 28. On the other hand, Springfield set its record high daily water use of 40.3 mgd on July 26. It is also noted that many of these days of maximum water use occurred after voluntary conservation measures had been enacted by their respective cities, illustrating the strong relationship between water use and the weather, but also bringing into question the overall effectiveness of voluntary measures (as opposed to mandatory measures).

A number of suburbs in the metropolitan Chicago area and outlying communities that use Lake Michigan or groundwater supplies also were enforcing water restrictions, typically in the form of odd-even lawn watering schedules, so that substantial increases in summer water use rates did not 1) surpass the ability of each water system to treat and distribute water; or 2) cause the community to exceed the amount of water allocated to it by Illinois Department of Natural Resources (IDNR) as part of the Lake Michigan diversion process. The Northwest Water Planning Association (NWPA) region, representing most of the five-county region (DeKalb, Kane, Kendall, Lake, and McHenry Counties) to the north and west of Chicago, has developed a model ordinance for outdoor water use restrictions for communities. Some of the communities in the NWPA region and others in the Chicago-Lake Michigan service region have been using such ordinances even in non-drought years, and report generally favorable responses. In fact, several community water suppliers in the NWPA region reported that they did not have a significant increase in water demand during summer 2012, unlike during previous droughts.

Concerns with Adequacy of Supply

Most community water supplies in Illinois have adequate reserves to meet the demands of users during a drought. The public water needs for most of the Chicago metropolitan area, for example, are provided by water taken from Lake Michigan. Although the total amount of water withdrawn from the lake is managed by the State and limited by Supreme Court decree, the availability of that water is essentially unaffected by drought conditions. Much of the remaining northern part of Illinois is supplied by deep groundwater resources; and, although certain locations may have concerns with either infrastructure capacity or sustainability, the available sources are greatly buffered from the impacts of drought. Communities that use a third source of supply, large rivers, usually withdraw only a small portion of the river's minimum flow and thus are able to maintain a reliable supply for users during a drought.

The primary community concerns regarding supply adequacy during a drought involve those systems associated with surface water reservoirs and shallow groundwater sources. About a million residents of Illinois obtain their water from these resources, most of these from surface water reservoirs. Previous studies by the Illinois State Water Survey (ISWS) have identified 25 community reservoir supply systems that are considered susceptible (inadequate or at risk) to shortages during cases of extreme drought, those being droughts that are comparable in magnitude to some of the worst droughts of the past century. These 25 community systems provide water to roughly 400,000 Illinois residents in central and southern Illinois.

Water levels in most Illinois reservoirs dropped rapidly during summer 2012 starting in June, as described in Chapter 6: *Water Supply Reservoir Levels*. In September 2012, reservoir levels rebounded following the passage of Hurricane Isaac. For roughly half of the affected reservoirs, the rebound was sufficient such that water levels did not return to the minimum levels that had been experienced in August; but, for the other half, the reservoirs continued to drop during the fall season such that minimum water levels did not occur until November or December. Even in these latter cases the threat of an extended extreme drought was never again as acute as it was earlier during summer 2012.

The three water systems that experienced the most tangible threats to their adequacy in 2012 were: 1) La Harpe, a small community in western Illinois; 2) the Vienna Correctional Center in southern Illinois; and 3) the City of Decatur in central Illinois. From size alone, problems facing the Decatur system posed the greatest concern as it supplies water to approximately 87,000 people and is the primary source of water for industrial applications including Archer Daniels Midland (ADM). An expanded analysis of the Lake Decatur water supply situation is included in a separate case study in the following chapter. The concerns facing the smaller systems of La Harpe and the Vienna Correctional Center are addressed in the paragraphs below.

La Harpe The City of La Harpe is located in the northeastern corner of Hancock County in western Illinois. Its water system serves about 1400 people, with an average water use of roughly 110,000 gallons per day (gpd). The city's off-channel storage reservoir (La Harpe Lake) typically provides more than half of the water (roughly 65,000 gpd), with the remainder coming from the city's uptown well. During the early part of the 2012 drought, water use had increased to above 120,000 gpd (reportedly peaking at 141,000 gpd), with the lake supplying the increase in demand. In August, after the city called for conservation, the usage was reduced to about 100,000 gpd. Later in the fall when low water levels in the reservoir became a concern, the city increased the proportion of water being supplied by the city well to about 60 percent. IDNR conducted a bathymetric survey of La Harpe Lake in August 2012 to identify the capacity of the lake. The lake's capacity had previously never been measured. Although the IDNR-measured capacity (99.7 acre-feet) is nearly identical to previous estimates of 99 acre-feet, the survey removed an uncertainty in the capacity that had been clouding previous calculations of yield. Another source of uncertainty was the amount of water that could be pumped into the lake during a drought from the South Branch La Moine River (also known as the South Branch Crooked Creek), which is located adjacent to the lake. In December 2012, the ISWS conducted a reconnaissance survey of the South Branch and nearby streams to identify potential alternatives for a stream withdrawal.

By early December, the water level in the reservoir had fallen to 5.4 feet below full pool, corresponding to a 55 percent loss of storage in the lake. At that time, there was roughly 8.5 million gallons of storage available above the water system's intake in the lake, which is situated about 9 feet below the full pool level. Flows in the nearby South Branch La Moine River are usually pumped to replenish the storage in the lake, but the creek had been mostly dry since July. Although the remaining storage above the intake could be calculated to be equivalent to a 5.5-month supply (at an assumed draft of 50,000 gpd), this calculation does not account for evaporation losses or for the incremental recovery of flows in the South Branch La Moine River that undoubtedly would have occurred in spring 2013 even if the drought were to have continued.

At the time, one of the water supply alternatives available to the city was to interconnect with the Dallas Rural Water District (DRWD) on an emergency basis. But as the level of La Harpe Lake began recovering in January 2013, an immediate interconnection became unnecessary. Although the pipeline connection to DRWD was constructed one year later, La Harpe had not been purchasing any water. There appeared to be limitations to the amount of water that can be supplied by the DRWD, suggesting that the connection will not become the primary water source for La Harpe.

An additional solution to lessen La Harpe's vulnerability to drought could be to establish a flow intake on a nearby stream in addition to that already provided by the South Branch La Moine River. In its December survey, the ISWS identified that flow was available in both the main stem of the La Moine River (located roughly 1 mile north of La Harpe Lake) and in La Harpe Creek (located 2 miles south).

Vienna Correctional Center The Vienna Correctional Center (VCC) and its sister facility, the Shawnee Correctional Center, are located 7 miles east of Vienna (Johnson County) in southern Illinois. The water supply for both facilities is provided entirely by the VCC lake, serving roughly 4000 people with a reported average water use of roughly 1 mgd. During the 2012 drought, the facility was able to reduce its average water use to roughly 0.7 mgd.

The IDNR conducted a bathymetric survey of the Correctional Center's lake in September 2012, which measured the capacity of the lake to be 580 acre-feet at an elevation of 375 feet, which is 5 feet below the full pool level. The projected full capacity at 380 feet based on this measurement is 940 acre-feet (306 million gallons). A sedimentation survey conducted by the ISWS in 1996 had previously estimated the lake's capacity to be 1084 acre-feet. After accounting for the rate of sedimentation between the 1996 and 2012 measurements, there is roughly a 10 percent difference between the two surveys because of their different methodologies and instrumentation. The recent IDNR measurement is accepted here as the more accurate estimate of the lake's capacity.

An ISWS water budget model of the VCC lake was used to estimate the response of the lake to varying climate inputs, with particular emphasis on previous historical drought sequences. Figure 9.1 shows the simulated monthly water level for the VCC lake if the 1953–1954 drought of record were to occur today, i.e., using the present-day lake volume and rate of water use. Also shown for comparison are the observed monthly water levels for the 2012 drought. The comparison suggests that until the end of August 2012 (at which time the remnants of Hurricane Isaac passed over the area) the lake drawdown was following a pattern similar to the expected condition during the drought of record. From September through December, the rate of lake drawdown slowed down considerably, reaching its minimum level (7.1 feet below normal) at the end of December. Concerns about low lake levels continued into early winter; however, based on historical streamflow records in the region, some recovery from dry conditions has always occurred in southern Illinois during the winter and spring months. The illustrated lake level response during one of the driest winters on record (1953–1954), shown in Figure 9.1, indicates that replenishment in water levels, provided by watershed and groundwater inflow, could be expected from January to May. As it turned out, with above-normal precipitation, particularly that occurring in January 2013, the lake became fully replenished by March 20, 2013 (IDNR, 2013).

Problems with Water Quality

During a drought, there are often modest changes in the chemistry of the source water that can cause taste and odor issues and occasionally require adjustments in water treatment. Whereas the flow in streams and rivers classically originates from surface runoff, during drought conditions the majority of the flow in natural settings typically comes from shallow groundwater sources instead, and thus has a

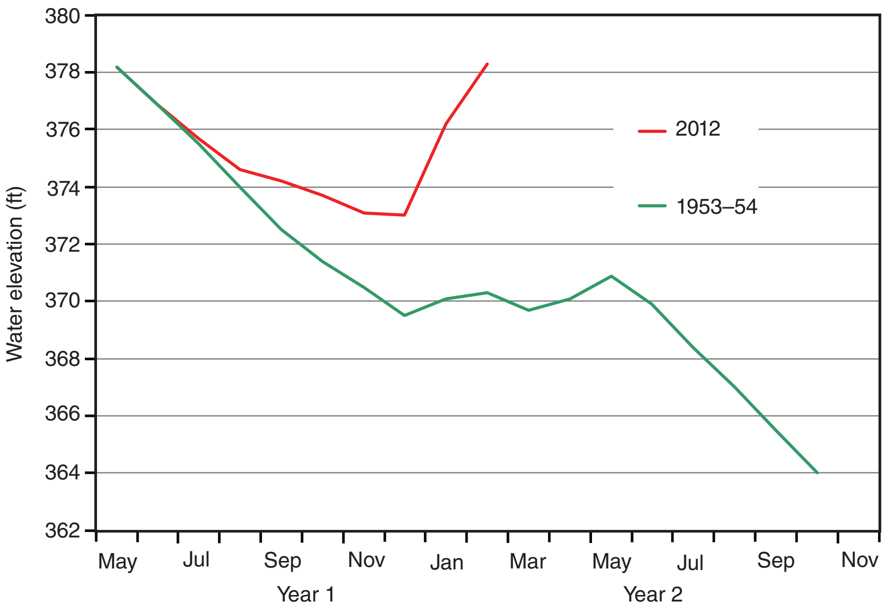


Figure 9.1 Comparison of observed lake levels in the 2012 drought to simulated levels if weather conditions similar to the 1953–1954 drought were to occur with the present water supply system at the Vienna Correctional Center

different quality than normal surface runoff. In Illinois, shallow groundwater generally has very low concentrations of nutrients such as nitrate and phosphate, which are often otherwise elevated in surface waters. On the other hand, groundwater may have higher levels of iron, manganese, and other metals. For certain rivers and streams in Illinois that receive treated wastewaters, the wastewater can become a predominant source of flow during low flow periods, and thus also produce substantially different quality conditions than during normal flows. But such changes tend not to cause water quality concerns of a serious nature, which makes the problem on the Fox River, described below, such a unique circumstance.

In 2012, extensive algal blooms on the Fox River in northeastern Illinois created a highly unusual water treatment problem for the two water supply systems (Elgin and Aurora) that use the river as a water supply source. The amount of algae in the Fox River is typically high during dry periods. Much of the reason for this is because the pools created by the low-head dams along the river provide an ideal environment for algal growth, particularly during low flow (low stream velocity) conditions. But the algal counts in 2012 were exceptionally high, with a reported 1,850,000 cells per milliliter measured in September of that year. Although the Fox Chain of Lakes, located upstream of Elgin and Aurora, is a known source of seed organisms for algae, there is no known analysis that has identified the specific causes of the excessively high amounts of algae during the 2012 drought other than associating it with unseasonably warm temperatures during the preceding winter and spring.

The water treatment problems were particularly challenging for the City of Elgin, for which the Fox River is the predominant source of supply. The City of Aurora was experiencing similar problems, but with less acute concerns because it blends the Fox River water with an equal or greater amount of groundwater. For Elgin, the algal problem began in March 2012 during a period of very warm weather and following one of the warmest winters on record. In June the problem reemerged and became serious enough so that the algae was blocking all of the filters at the Elgin plant. The problem was eventually resolved by significantly increasing the amount of traditional chemicals (alum and soda ash) in the settling (presedimentation) and softening basins, continuous washing of the plant's filters, and also adding high molecular-weight polymers both at the intake to the treatment plant and in the filtering process.

Some potential water quality effects can also lag well beyond the end of a drought. Most fertilizer applied in 2012 was not taken up by crops, thus it may have been available for leaching when wetter conditions returned in the winter and spring. In late spring 2013, the cities of Elgin and Aurora, which both use water from the Fox River, reported unprecedented levels of geosmin, a bacterially derived organic compound with an unpleasant aroma. There was speculation that this occurrence was associated with the drought and dry soil conditions in 2012, although no direct link was ever made.

Rural (Domestic) Groundwater Supplies

In several parts of the state, domestic well owners and smaller rural communities reported interruptions in service for their wells during summer 2012. This is not an uncommon occurrence for dug and bored wells, even in non-drought summers, but in 2012 these wells were running out of water a month or two earlier than usual. For some shallow drilled wells, there were reports of well owners drilling deeper to obtain more water. But in most cases water supplies were typically maintained by purchasing and "hauling" potable water from nearby community water supplies. However, during the height of the drought there were reports of community water systems refusing to sell to water haulers, particularly when that community was restricting water use because of a perceived threat to the adequacy of their own supply.

In other rural regions, irrigation pumping appeared to be the cause of interrupted service. As reported earlier, irrigation appeared to interfere with nearby wells in several counties, specifically Champaign, Iroquois, Lee, and Whiteside. In most cases during the drought of 2012, interrupted service was restored in affected wells by lowering the pump.

Industrial and Power Plant Supplies

The information available on industrial water supplies during the 2012 drought, including impacts on power generation, comes predominantly from the biweekly reports of the Illinois Commerce Commission that were submitted to the Drought Response Task Force during summer 2012. This information was summarized and included in the Illinois Department of Natural Resources report on the 2012 drought (IDNR, 2013). The following material is taken verbatim from that report.

"The coal industry depends on a constant water supply to suppress coal dust as coal is mined. These coal mine operations draw water from numerous sources, including local impoundments, rivers and streams, and federal reservoir allocations. A coal mine in Washington County experienced shortages of available water in August and requested access to water from state park lakes. The mine was able to obtain water to sustain their operations through their own initiatives.

Power plants depend on water supplies to provide cooling water which is essential to the generation of electricity. Closed system plants are those that utilize cooling towers or maintain cooling ponds. Cooling pond plants maintain an adequate water supply to sustain operations for a limited time period. Cooling tower plants still need a small supply of make-up water. Open cycle plants require a continuous supply of cooling water from adjacent waterways, most of which is immediately returned to the water source.

Low flow conditions during 2012 resulted in the need to limit make-up flow and/or to decrease power generation at many power generating facilities in order to stay in regulatory compliance and maintain safe unit operation.

Nuclear power plants such as Braidwood Station that withdraws water from the Kankakee River reached its low flow threshold specified in their DNR Public Water withdrawal permit and withdrawal of water was temporarily suspended. The Kendall 1200-MW combined cycle combustion gas turbine station draws water from the Illinois River, and its withdrawal of that water was severely restricted when the Illinois and Kankakee river flows reached low flow limits set by permit. Three open-cycle fossil fueled plants on the Chicago Sanitary and Ship Canal/Lower Des Plaines River and one on the Mississippi River were required to reduce power production during critical demand periods in response to extremely low river flow conditions, which were further exacerbated by frequent level manipulations by upstream entities.

Low river flows coupled with prolonged periods of above average air and water temperatures also challenged power plants to meet their National Pollutant Discharge Elimination System permits (NPDES) discharge temperature limits. Short-term site-specific thermal variances were granted by the Illinois Environmental Protection Agency, based on the showing of sufficient need by individual entities."

Chapter 10. Water Supply Case Study: The City of Decatur

Of all the community systems in Illinois that depend on a reservoir for their primary water supply, Decatur has the least amount of reservoir storage proportional to its overall water use, with Lake Decatur storing a six to seven-month supply for the city and its industries. Thus, despite the large quantity of water in the lake, it has a "short" supply in terms of the number of months the supply would last during a drought. Dredging in recent years has increased the lake's capacity, but the upper limit of capacity expansion through dredging, if the lake were to approach its original volume, would produce roughly an eight-month supply. Despite this relatively short supply, Decatur is not the most vulnerable of Illinois' community systems in terms of its likelihood of experiencing shortages, although it is clearly one of the most visible.

The Illinois State Water Survey (ISWS) classifies Decatur as an "at risk" water supply system, indicating that the current system has more than a 10 percent computed probability of experiencing shortages if a record drought were to occur. The lake's storage, combined with supplemental sources of supply, has been sufficient to survive extreme and extended droughts for nearly 100 years, primarily because the Sangamon River has dependably provided sufficient inflow in the spring following drought years to fully replenish the lake's storage. But the history of enduring past droughts is not a direct measure of the system's adequacy to face future droughts, in particular because the city's water use is substantially greater today than in the past. It is also possible that a drought worse than the historical droughts of the past 100 years could occur. If the river's flow in the spring following an extreme summer drought were 30 percent less than that of the previous driest spring on record, the river potentially would not fully replenish the lake (given the current level of water use and supplemental sources).

The relatively short amount of supply also puts Decatur in a unique water management situation when compared with other water supply systems in Illinois. During a severe drought, concerns about the water supply and water conservation initiatives typically begin when less than 20 percent of the available lake storage has been used, often no more than six weeks after reservoir drawdown first begins. This nearly guarantees that Decatur will be the first water system in central Illinois to be affected by a drought. Also, because of its prominent size and the large industries that share resources with the City of Decatur, its drought concerns may be expected to receive considerable regional attention. On the other hand, the Decatur system can also recover quickly from a drought. It would take only 0.25 inches of runoff from the Sangamon River watershed to provide enough inflow for Lake Decatur to refill. During the longest, most persistent droughts, it is expected that spring runoff events would refill the lake–removing immediate drought concerns for Decatur–while most other surface water supplies in the region would still be suffering from continuing impacts of drought.

The city's well field in DeWitt County, which pumps water from the Mahomet Aquifer, is the largest supplemental source of water available during a drought. Figure 10.1 shows the location of the well field and other locations along the Sangamon River from Lake Decatur upstream to Monticello, referenced later in this chapter. The DeWitt well field has been a particular source of interest because the Mahomet Aquifer in its vicinity has been determined to be hydrologically connected to the Sangamon River (Roadcap et al., 2011); thus some of the water taken from the aquifer could indirectly reduce the amount of water that the Sangamon River delivers to Lake Decatur. Conversely, flows in the Sangamon River in nearby Piatt County can potentially recharge the aquifer in that vicinity, particularly during high flow conditions. The low flow conditions experienced during the 2012 drought provided ISWS scientists with an opportunity to monitor the Sangamon River and nearby groundwater resources with the intent to characterize the interaction between the two resources. Findings of the ISWS efforts are presented later in this section.

Following the 2012 drought, Archer Daniels Midland Company (ADM)–Decatur's largest industry–constructed two new lateral wells into the shallow groundwater aquifer located underneath Lake Decatur and the Sangamon River. The interactions between this well and the reservoir's water during a drought period are unclear at this time, thus the well's effective yield is yet unknown and has been omitted from ISWS yield assessments. However, the well does provide a more certain supply for ADM when lake levels are low.

2012 Lake Level Conditions Compared to Major Historical Droughts

Figure 10.2 shows observed water levels in Lake Decatur during the 2012 drought. Lake Decatur first started experiencing a drop in water levels in early June. By late August, fewer than 90 days since drawdown began, the lake was drawn down 3.6 feet and had lost roughly half of the water that is considered usable for water supply. In late June and early July, before the drought was considered to pose a serious threat to its water supply, average water use by Decatur and its industries had risen to 43 million gallons per day (mgd)–roughly 20 percent higher than its normal rate of 35 to 36 mgd. On two days (June 28 and July 16) the water use exceeded 47 mgd. An increase in summer water use during the early stages of drought is common in many communities and is primarily related to outdoor uses such as lawn watering.

By August 2012, water levels on the lake were at a critical stage that required mandatory water restrictions, and ADM faced the possibility of curtailing production activities. After the city's stage II mandatory water restrictions were enacted earlier in August, the average water use was lowered to 34 mgd. This rate of use is essentially the amount that the city typically uses during winter

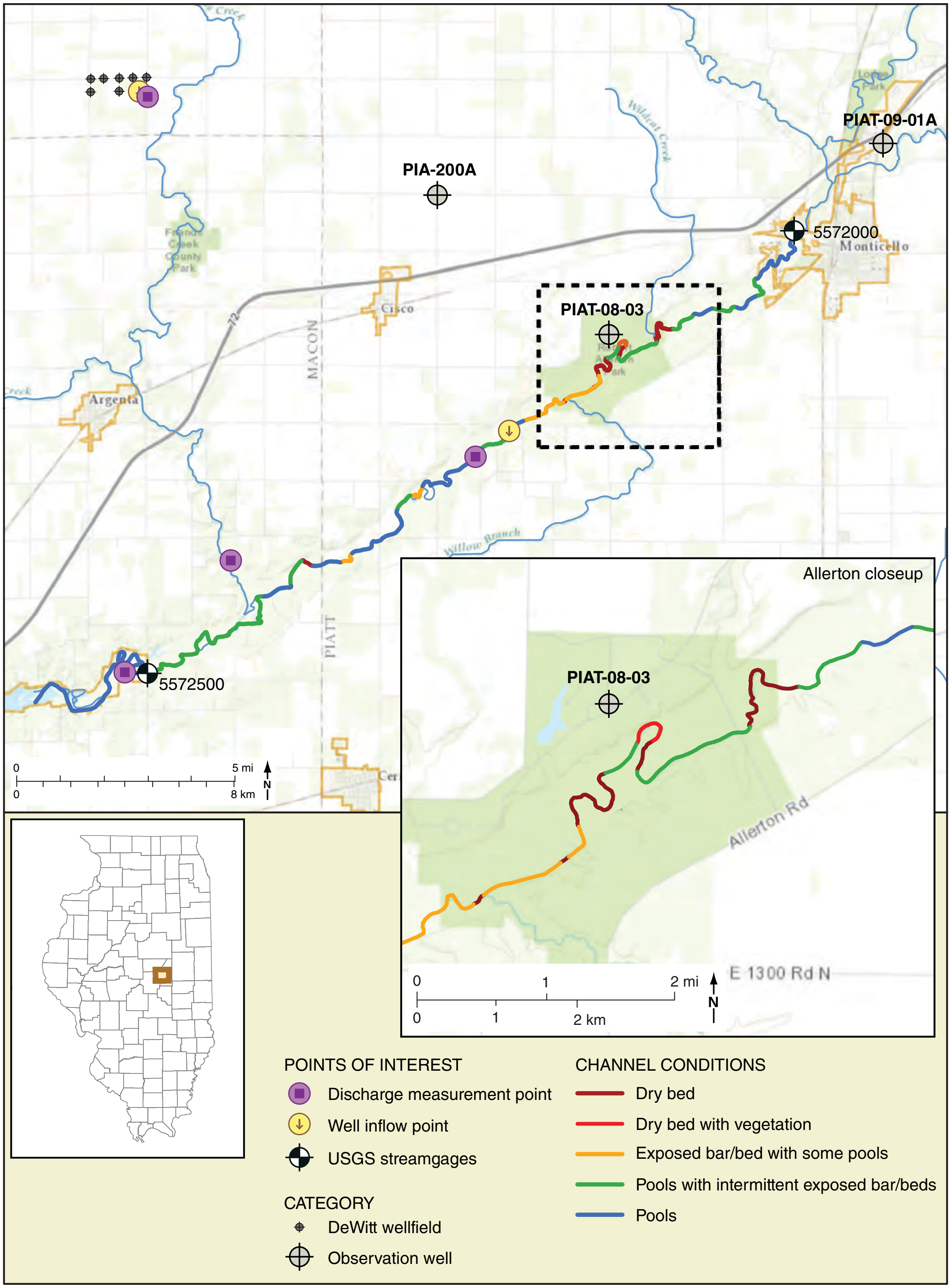


Figure 10.1 Locations of the Mahomet Aquifer, DeWitt well field, observation wells, and streamflow monitoring sites on the Sangamon River and Friends Creek

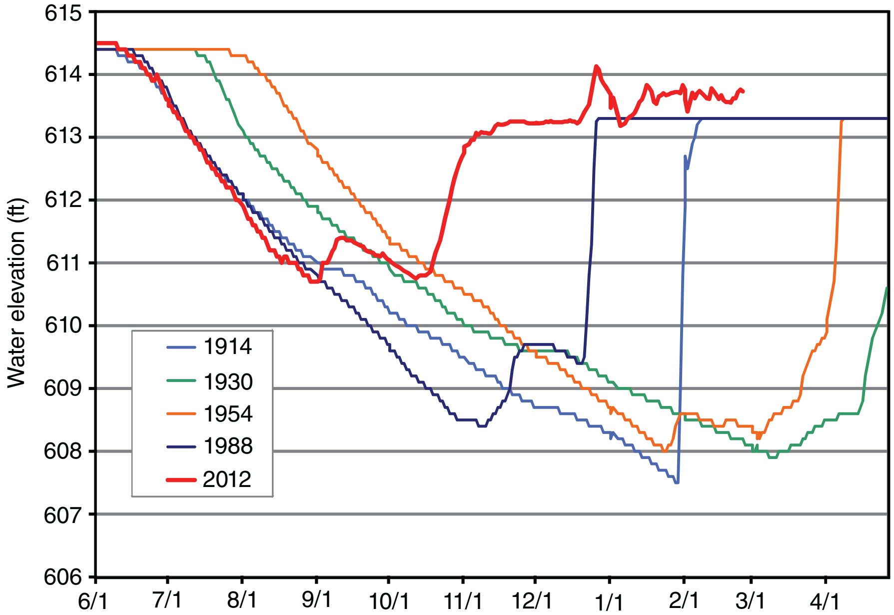


Figure 10.2 Comparison of observed Lake Decatur levels in the 2012 drought to simulate levels if weather conditions similar to four of the worst droughts on record were to occur with the present Decatur water supply system

months when outdoor uses of water are negligible. Rains in early September (the passage of Hurricane Isaac) substantially eased the situation, but water supply concerns continued into early October, after which additional rainfall allowed the lake level to recover.

Also shown in Figure 10.2 for comparison are model-generated lake levels for four of the worst historical drought sequences of the past 100 years, in which a water budget computer model was used to simulate the scenario in which the current water supply system is subjected to the identical hydrologic and climatic conditions that existed during significant drought periods of the past. In this manner, for example, the expected effect of the 1914–1915 drought on the present-day Decatur water supply can be estimated even though that particular drought preceded the construction of Lake Decatur.

An examination of the simulated lake levels for historical drought sequences indicates that there were three past droughts, in 1914–1915, 1930–1931, and 1953–1954, that, for the Decatur system: 1) had the longest durations; and 2) would produce the lowest lake levels (at or below an elevation of 608 feet). The conditions for the 1988 drought produced the fourth lowest simulated lake level in the past 100 years. The 1988 drought had a substantial recovery in November and December of that year and thus, although it was a very threatening drought, with all other factors being equal is not estimated to have had the same potential level of impact as the more severe, extended droughts of 1914–1915, 1930–1931, and 1953–1954.

When the observed 2012 lake levels are compared to simulated levels for historical droughts, two characteristics stand out: 1) the lake drawdown in 2012 began very early in the summer, similar to the onset of the two other early-season droughts of 1988 and 1914–1915; and 2) the lake level decline throughout summer 2012 was as rapid as that during any of the worst droughts on record. If the remnants of Hurricane Isaac had not passed over central Illinois, conceivably, the 2012 lake level decline would have continued to match that of the 1988 drought through the middle of October when other precipitation events would have initiated recovery in the lake level. By the end of August 2012 and before the arrival of Hurricane Isaac, the combination of the rapid decline in Lake Decatur levels and the possibility that dry conditions would persist into the fall and winter posed a genuine impending threat to the community's water supply.

Dry Conditions on the Sangamon River Upstream of Lake Decatur

One of the most notable hydrologic impacts of the drought was the no-flow conditions on the Sangamon River upstream of Lake Decatur, which extended for 26 consecutive days and for 34 of 36 days from July 21 to August 25, 2012, as recorded at the U.S. Geological Survey (USGS) streamgage at Monticello. Since the gaging station was installed in 1911, its flow record shows that the river at this location had experienced zero flow only during the 1988 drought for a total of eight days. At the Monticello gage, August 2012 was the third lowest average monthly flow ever recorded (1.57 cubic feet per second [cfs]) behind September and October 1988 at 0.48 and 1.32 cfs, respectively. The August 2012 total was not the driest because of some significant rainfall on August 16 and August 26. The Sangamon River downstream of Monticello near Allerton Park remained dry throughout the entire month of August 2012 and thus experienced its driest month on record. July 2012 was also very dry with the sixth lowest average monthly flow. Over a longer 12- or 18-month period, only 1930–1931, 1933–1934, and 1953–1954 were as dry or drier. The 2011–2012 period had the longest number of consecutive days with flow below 1000 cfs (604 days), which, as discussed in the next section, could have a significant impact on groundwater recharge. Figure 10.3 illustrates the dry river condition in August as it existed about 1 mile upstream of the USGS gage location.

On August 8, 2012, ISWS staff participated in a helicopter fly-over above the Sangamon River between Monticello and Lake Decatur to identify where the river was flowing and possible locations for flow measurements. Unexpectedly, there were no locations upstream of the lake that appeared to have any river flow. More remarkably, there was

Figure 10.3 Dry conditions on the Sangamon River as viewed from the Old Route 48 Bridge near Monticello

a 4-mile reach of the river near Allerton Park in Piatt County where the river bed was mostly dry, and in some cases completely dry. Figure 10.1 identifies the river bed conditions that existed at the time of the fly-over. In a short stretch in Allerton Park, the river appeared to have cut off a meander, and vegetation was growing in the portion of the channel that carries no flow when the river is low.

Like all natural river beds, this length of the Sangamon River is composed of a series of alternating deep spots (pools) and shallow spots (riffles). When a river initially experiences zero flow, only the riffles are exposed and dry. As dry conditions persist, the water level in the pools will typically slowly fall as the water evaporates or infiltrates into the river bed, thus exposing more of the bed. In this manner, small streams will often become completely dry during extended dry periods if the local groundwater table is below the water level in the stream. But in larger streams and rivers, the groundwater table typically remains close to or elevated above the deeper portions of the pools, in which case the pools usually do not dry up even when there is zero flow. In July and August 2012, however, the Sangamon River in the reach near Allerton Park was dry throughout the deepest pools of the river, not just the more shallow sections. For the pool levels to be this low, there would need to have been an exceptional amount of infiltration over the previous three-week period since the river's flow had fallen to a very low amount. Farther downstream near the Hog Chute Bridge, the river somewhat abruptly returned to a condition in which the pools were mostly wet. This suggests that there was a depression in the shallow groundwater table in the reach near Allerton Park where the stream was dry.

Operation of the DeWitt Well Field and Other Supplemental Sources

Due to the very dry conditions, Decatur turned on their emergency well fields in DeWitt and Piatt Counties on August 6. Water pumped from the DeWitt wells was discharged into Friends Creek, which then flowed into the Sangamon River and downstream to Lake Decatur. The well field was deactivated for five days as Hurricane Isaac passed over Illinois (August 31 to September 5), but then reactivated and operated until October 22 for a total pumping duration of 72 days in 2012. The withdrawal rate from the well field was generally maintained in the range of 10 to 14 mgd.

Decatur's Cisco well is an additional emergency well located next to the Sangamon River at Hog Chute Bridge, 3 miles downstream of Allerton Park and 3 miles southeast of Cisco, IL. The output of the Cisco well is roughly 3.2 mgd. The well is usually operated at approximately the same times as the DeWitt well field, but in 2012 was not activated until August 9 so as not to influence river conditions during the August 8 fly-over.

In late 2011, Decatur had also pumped supplemental water from the Vulcan gravel pit downstream of the Decatur dam, and by summer 2012 the pit was reportedly only about one-third full. Decatur was able to pump 3.5 mgd from the pit between July 31 and August 20, 2012.

Influence of Decatur's Pumping on Nearby Water Levels of the Mahomet Aquifer

Data from Guillou and Associates (Figure 10.4) shows the water levels at an observation well (OW-1) located at the edge of the DeWitt well field. When the well field was operated from August 6 to August 31, the level in the Mahomet Aquifer dropped 36 feet in elevation from 606 to 570 feet. After the well field was reactivated on September 6, the water level continued to fall several feet through the end of September 2012, reaching an elevation of 566 feet and a maximum drop of 40 feet.

Figure 10.4 also shows groundwater levels during the previous dry fall season of 2011. In 2011, the DeWitt well field was operated for a period of 113 days (September 6 to December 27, 2011) and during that time had fallen a maximum of 42 feet. As a result of the prior year's pumping, the static water level at OW-1 was already relatively low leading into the summer of 2012, being 9.15 feet lower than the static water level prior to the 2011 pumping period.

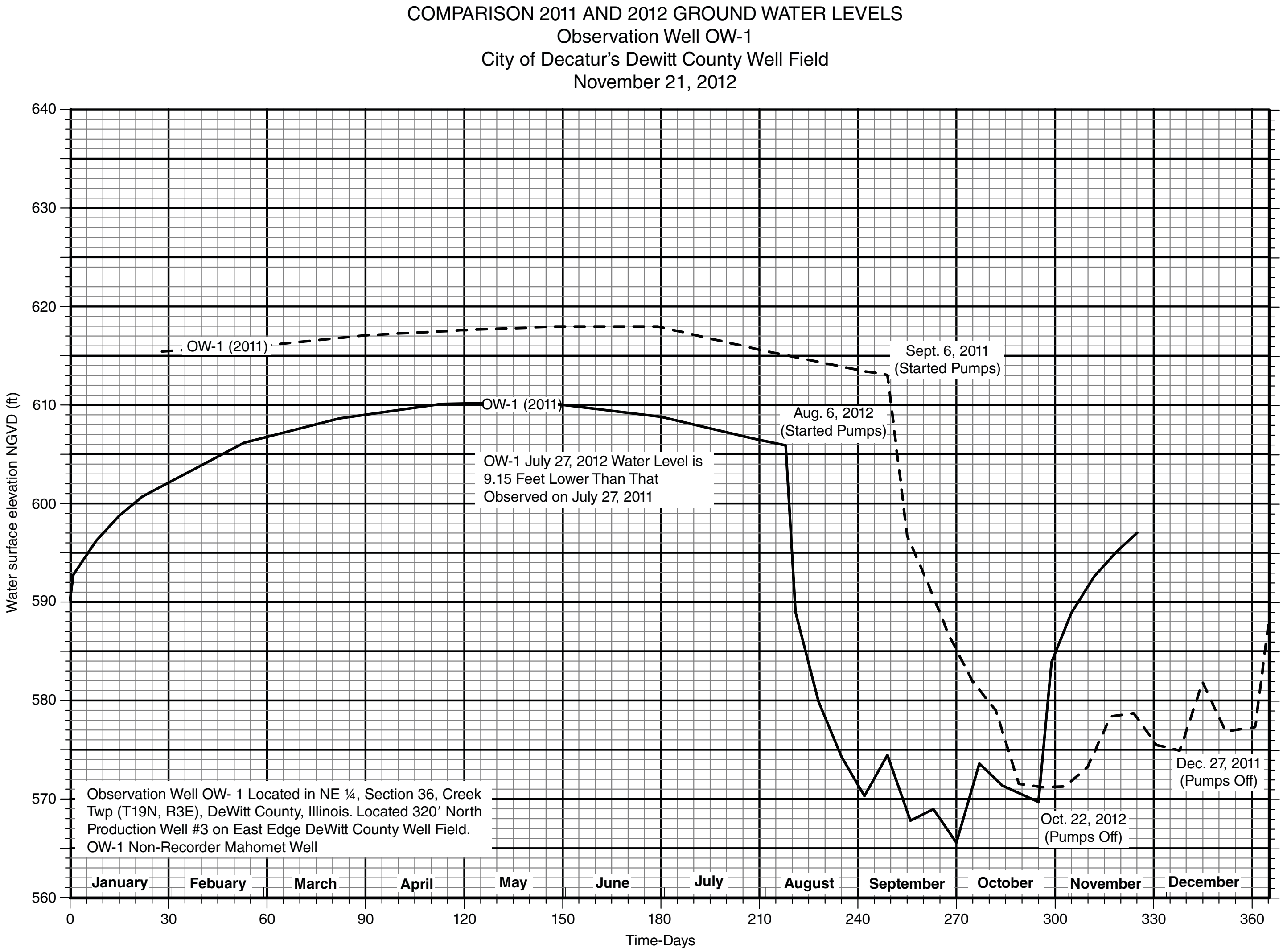


Figure 10.4 Water levels at the DeWitt Well field OW-1 observation well, 2012 (from Guillou and Associates)

The 2011 and 2012 drawdowns from the Decatur wells also extended eastward to observation wells in Piatt County (Figure 10.5). The locations of these observation wells are provided in Figure 10.1. Observation well PIA-2000A, located in the town of Cisco, is roughly 5 miles southeast of the DeWitt well field. Observation wells PIAT-08-03 and PIAT-09-01 are located in Allerton Park and at the railroad museum northeast of Monticello, respectively.

The water level in PIA-2000A fell roughly 17 and 18 feet during the 2011 and 2012 pumping periods, respectively. The PIAT-08-03 well near Allerton Park declined roughly 7 feet during each of the same pumping periods. In contrast, the PIAT-09-01 well northeast of Monticello declined only a few feet in each pumping period, an amount that is considered representative of normal seasonal decline and thus not specifically influenced by pumping from any of Decatur's wells. The hydrographs of all three observation wells (Figure 10.5) show a lack of recovery during winter 2012, indicating that the observed low water levels in spring 2012 were not restricted just to those locations influenced by the 2011 drawdown.

Regional Water Level Response in Summer 2012

The impact of the Decatur well field pumping in August and September 2012 created considerable regional drawdown in the Mahomet Aquifer (Figure 8.8), as estimated using an ISWS groundwater model of the aquifer. The drawdown amounts in Figure 8.8 are directly comparable to the maximum drawdown (40 feet) at OW-1 at the edge of the DeWitt well field (Figure 10.4). Figure 8.8 also shows some recovery in the aquifer levels in northern Champaign County, following the considerable amount of irrigation pumping occurring earlier in the summer in that region. Over the summer of 2012, the combined stress on the aquifer between the irrigation and DeWitt well field pumping was the greatest that the eastern half of the Mahomet Aquifer in Illinois has ever experienced.

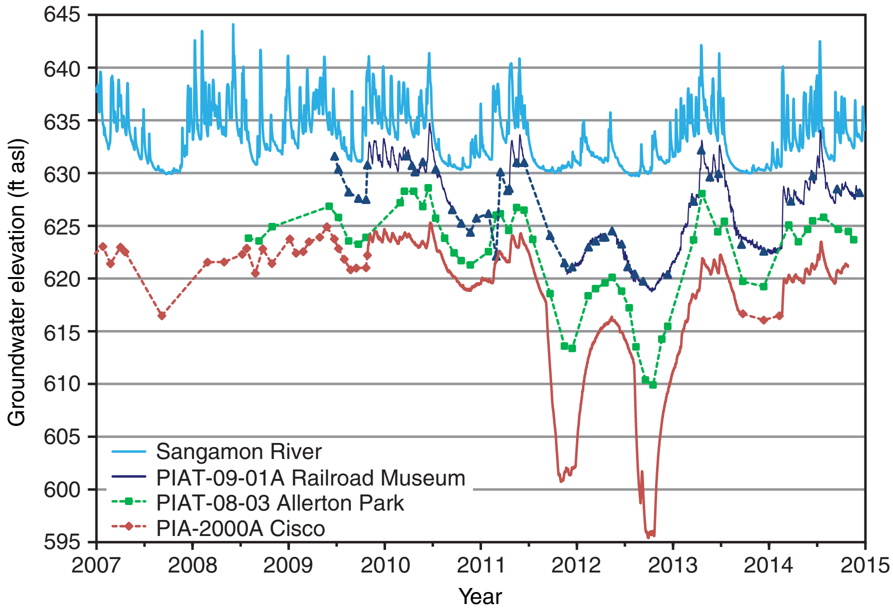


Figure 10.5 Hydrographs of PIA-2000A, PIAT-08-03, PIAT-09-01A, and the USGS gage on the Sangamon River at Monticello

Monitoring of Streamflow Downstream of the DeWitt Well Field

During previous pumping of the DeWitt well field in 2005 and 2007, observations suggested that a noticeable portion of the well water never reached Lake Decatur due to infiltration into the dry channel, thus reducing the overall effectiveness of the well field. The low flow conditions in August 2012 provided the perfect opportunity to examine and quantify the potential losses of water between the well field and the lake, leading ISWS to conduct a series of streamflow measurements. Table 10.1 lists flow measurements taken by ISWS during this period as well as the dates that the DeWitt well field and Cisco well were activated and deactivated. Locations of the ISWS low flow monitoring sites are shown in Figure 10.1. Flow measurements were taken at two locations on Friends Creek: 1) Cemetery Road immediately downstream of the wellfield discharge; and 2) 0.5 miles downstream of Jordan Road near Argenta (roughly 1 mile upstream of the Sangamon River confluence). Flows were also measured at two locations on the Sangamon River: 1) roughly 0.8 miles downstream of Hog Chute Bridge; and 2) roughly 0.4 miles downstream of the Oakley Bridge (3 miles north of Oakley), the latter of which was the most downstream site that could be measured before the river flows into Lake Decatur. Friends Creek flows into the Sangamon River 2.4 miles upstream of the Oakley Bridge. The primary monitoring period of interest occurred August 15–30, 2012. The Sangamon River in September, following the passage of Hurricane Isaac, never returned to the low levels needed to isolate the flow contribution from Decatur's wells. For this reason, the only ISWS flow measurements taken in September were on Friends Creek.

There was no flow in the river at the Hog Chute Bridge during the entire period of monitoring in August 2012. Thus, flow that occurred at the USGS gage in Monticello between August 16 and August 31 did not reach Hog Chute Bridge located 8 miles downstream, and instead was likely filling exposed pools in that reach. In a similar fashion, after the DeWitt well field was activated on August 6, it took roughly a week before its flow had filled the dry bed of Friends Creek and traveled the 15 miles to reach the Sangamon River.

Flow from the Cisco well discharges to the Sangamon River a short distance downstream of the Hog Chute Bridge. The well has a reported average pumping rate of 3.2 mgd or roughly 5 cfs. The two discharge measurements on the Sangamon River downstream of Hog Chute Bridge (on August 15 and 28) are assumed to directly reflect the flow coming from that well, as the river was observed to have no discharge immediately prior to the well being activated. However, the August 15 measurement (6.2 cfs) is 20 percent higher than the reported pumping capacity of the Cisco well.

A comparison of the flow amounts from the two Friends Creek locations indicates that there was little or no flow loss in Friends Creek. In contrast, flows measured on the Sangamon River downstream of the Oakley Bridge suggest that there was a considerable amount of flow loss along the river. If no flow loss had occurred, the flow downstream of the Oakley Bridge would have been expected to be the sum of the flow from the Cisco well (~5 cfs) and the flow from Friends Creek (18–20 cfs); however, the measured flows on August 23 and 29 were much less, 15.5 and 14 cfs, respectively. This indicates that 8–10 cfs, or roughly 40 percent of the water originating from the DeWitt and Cisco wells, was lost from the Sangamon River channel and never reached the Oakley Bridge. If it is assumed that the rate of loss is uniformly distributed along the river's reach between the Cisco well and the Oakley Bridge, this would imply that all of the Cisco well's output and around 30 percent of the DeWitt well's output are being lost in the Sangamon River between Friends Creek and the Oakley Bridge. It is possible that additional channel losses could be occurring downstream of the Oakley Bridge, and this should probably be expected in any conservative estimate of lake inflow; unfortunately, no viable measurement locations were found between the lake and the Oakley Bridge site.

The two August measurements on the mainstem of the Sangamon River represent only a snapshot of the channel's loss rates and the hydrologic interaction between the river and shallow groundwater. The observed characteristics could potentially change as: 1) sustained

Table 10.1 Date and Locations of ISWS Streamflow Measurements to Determine Contribution of Well Pumpage to Lake Decatur, cfs

			Friends Creek		Upstream → Sangamon River → Downstream				
Date	Lake Level (ft)	DeWitt Field Info	Inflow at Cemetery Rd.	Outflow 0.5 mi DS of Jordan Rd.	USGS Monticello station	Observations of Channel DS of HogChute Bridge	Cisco Well Info	Sangamon River 0.8 mi DS HogChute Bridge	Sangamon River 0.4 mi DS Oakley Bridge
8/1/2012	611.79	Off	Dry	No flow	No flow	No Flow	Off (Electrical problems until the 6th)	No Flow	No flow
8/3/2012	611.66				0.01 cfs				
8/6/2012	611.52	Activated 6 wells @ 1850rpm			No flow		Activated on August 9		
8/13/2012	611.18		15 cfs		0.01 cfs	No Flow			
8/15/2012	611.09				No flow			6.2 cfs	
8/20/2012	611.03		15.5 cfs		6 cfs	No Flow			
8/22/2012	610.97	6 wells @ 2050rpm			4.1 cfs				
8/23/2012	610.91			20 cfs	3.6 cfs	No Flow			15.5 cfs
8/28/2012	610.74				15 cfs	No Flow		4.3 cfs	
8/29/2012	610.73		17 cfs	18 cfs	15 cfs	No Flow			14 cfs
8/31/2012	610.62	Deactivated			9.8 cfs		Deactivated		
9/5/2012	611.0	Activated 6 wells @ 1850rmp			174 cfs		Activated		
9/17/2012	611.29		20.5 cfs		9.6 cfs				
10/19/2012	611.16		14.7 cfs		159 cfs				
10/22/2012	611.42	Deactivated							

Primary monitoring period (shaded rows: 8/15/2012–8/29/2012) pumping from the DeWitt well field causes continued water level declines in the Mahomet Aquifer near the river; 2) sustained pumping also results in nearby well interference, forcing a reduction in the pumping rates from the DeWitt field; and 3) cooler conditions occur during the late fall and winter of an extended drought. However, the passage of Hurricane Isaac at the beginning of September substantially diminished the dry streambed conditions, thus removing the feasibility for extended monitoring of low flows in 2012. For future drought events, it is recommended that such a sustained monitoring effort be undertaken.

Flow Losses on the Sangamon River in Previous Droughts

From 1951 to 1956, the USGS operated a second continuous-discharge gage on the Sangamon River at the Oakley Bridge upstream of Lake Decatur. Whereas flow at the Oakley Bridge during normal flow conditions is typically about 40 percent higher than at Monticello (because of the greater contributing watershed area), during the eight-month drought period from August 1953 to March 1954 the total flow amount at Oakley Bridge was only 12 percent higher than at Monticello. During the lowest flow conditions in October 1953, the flow at the Oakley Bridge was less than that at Monticello, essentially the same condition as observed in August 2012. It is possible, perhaps likely, that the flows at the Oakley Bridge would have been even lower in 1953–1954 if the Mahomet Aquifer in the DeWitt-Piatt County region had experienced a large amount of pumping as now occurs in drought periods. The flow losses observed in 2012 corroborate the 1953–1954 observations, and collectively verify that the Sangamon River downstream of Monticello indeed loses flow during extreme drought conditions. In contrast, the lower observed flows at the Oakley Bridge gage in 1953–1954 had been considered a discrepancy associated with measurement error in previous ISWS analyses.

Connection between the Mahomet Aquifer and the Sangamon River

The possible connection between groundwater and the cause and duration of the low flow (and no-flow) conditions on the Sangamon River is difficult to directly quantify. At this time, the interconnection of the river to the Mahomet Aquifer and shallower sands appears to be the most likely mechanism that caused the dry river beds. As shown in Figure 8.8, during the 2012 drought the water level in the Mahomet Aquifer was not significantly lowered west of Champaign where the large-capacity Illinois-American Water Company public water supply well fields are located. Therefore, increased seasonal demand from Champaign-Urbana was probably not an important factor in the river going dry. The new irrigation demands in northern Champaign County could have lessened the flow in the upstream portion of the watershed by inducing water out of the stream at rates that would not have occurred in previous droughts. It can also be speculated that other changes in agricultural practices that have occurred in the watershed since previous droughts may have resulted in lower water tables along riparian areas, including more widespread installation of intensive drainage tile networks, the conversion of many thousands of acres from pastureland to drained row crop fields, and the use of corn and soybean hybrids which use water earlier in the growing season. But none of these other potential influences explain how the pools dried up in the Sangamon River downstream of Monticello.

Roadcap et al. (2011) attributed the sharp rises in groundwater levels in well PIAT-09-01 to storm events on the Sangamon River, indicating a nearby hydraulic interconnection between the river and the aquifer. As hypothesized in that report, water stored in shallow sands near the river likely maintains baseflow in the river during dry periods. The complex geometry of the sands that connect the river to the underlying Mahomet Aquifer is unknown as is the amount of unconfined sand in the system that can store and release water. Leakage from the river through the shallow sands to the aquifer is variable, with a large portion of it appearing to occur during storm events when the downward gradients are the greatest. During dry conditions in the winter of 2011–2012, the water level in PIAT-09-01 (Figure 10.5) did not recover to its normal level following the dry fall season in 2011 (when there was emergency pumping from the DeWitt well field, as shown in Figure 10.4). There were only two small storms during the winter and another event in early May 2012, but none of these produced flows in the river of more than 800 cfs, and they only briefly raised the stream level at the Monticello gage above 640 feet (Figure 10.5). It is possible that these storms were neither big enough nor lasted long enough to refill the water removed from storage in the aquifer during 2011. Although more data are needed, water level data collected between 2011 and 2014 may indicate that the groundwater does not act in tandem until the river stage at Monticello exceeds approximately 635 feet in elevation or a corresponding flow of 600 cfs.

The lack of wintertime recovery in groundwater levels in 2011–2012 is evident throughout the watershed. It is likely that the reduced amount of stored groundwater throughout the watershed contributed to the low flow conditions in summer 2012. In particular, it is possible that the lack of recharge in the shallow sands and the underlying Mahomet Aquifer led directly to the no-flow conditions and dry streambeds downstream of Monticello. The winter-spring seasons of 1930–1931, 1933–1934, and 1953–1954 produced low flow conditions in the Sangamon River similar to that of 2011–2012, and it would be reasonable to expect in those years that there would have been little water replenishment in the aquifer and shallow sands as well. Thus, water supply planning for future droughts should consider such contingencies and the potential for not only flow losses in the Sangamon River but also the possibility of a limited recovery in the Mahomet Aquifer water levels in advance of the worst drought conditions.

Implications to the Yield of the Decatur Water Supply System

In June 2012, the ISWS calculated the yield of the Decatur water system to be 32.2 mgd (http://www.isws.illinois.edu/data/ilcws/addl/DecaturSupplementalMaterial.pdf) at the 90 percent confidence level. That yield was calculated using the climatic and hydrologic conditions measured during the 1914–1915 drought, which is computed to be the drought of record for Lake Decatur. The 90 percent level of confidence indicates that, during such a drought, there is roughly a 10 percent chance that the system could fail to deliver an average water supply rate equal to the computed yield. If a 95 percent level of confidence is used instead, the computed yield is reduced to 30.4 mgd. For these yield estimates, water withdrawn from Lake Decatur by ADM is considered to be a part of the Decatur water system, as the city and ADM share that water source. These yield estimates also assume that only 70 percent of the water that is pumped from the DeWitt well field reaches the lake.

For most historical drought periods, the streamflow measured at the USGS gage on the Sangamon River at Monticello provides the best available information on the amount of inflow into Lake Decatur. The size of the Sangamon River watershed where it flows into Lake Decatur is considerably larger than at Monticello. In past yield analyses, the river downstream of Monticello was previously considered to be a "gaining stream," and the observed flow amounts at Monticello were proportionally increased (scaled up) to represent the total inflow into the lake. However, from ISWS flow measurements taken during the 2012 drought and a renewed analysis of the 1953–1954 low flows at the Oakley Bridge gage, it can be observed that the river instead loses flow downstream of Monticello at certain times. Thus, whereas the collective flow into Lake Decatur is still expected to be higher than that measured at Monticello, the increase in flow amount should no longer be assumed to be directly proportional to the watershed area.

As indicated previously, the combined observed flows at Monticello and the Oakley Bridge gage in 1953–1954 provide data to describe flow losses between those two locations. For computing the water supply yield of Lake Decatur, it is reasonable to assume that similar flow losses occurred with many if not all other historical extreme droughts. In doing so, it can be estimated that the yield associated with the drought of record is reduced by 1.3 to 30.9 mgd (90 percent confidence level).

The assumptions used here in these adjusted yield estimates could be conservative in nature and underestimate flow losses (and overestimate yield) as they do not consider that:

- Additional flow losses may be occurring in the channel downstream of the Oakley Bridge. If channel losses cause an additional 10 percent of reduction in the flows coming from the DeWitt well field, for example, the yield of the system would roughly be reduced by an additional 0.7 mgd.
- External influences from increased regional pumping from the Mahomet Aquifer since the 1950s may have increased the inducement of flow from the river to the shallow sands along the river. The regional pumping effects are assumed to include both the Champaign-Urbana and the DeWitt well fields, the latter of which was first used in 1999.

Chapter 11. Navigation, Environmental, and Water Quality Impacts

Navigation Impacts

Low flow and low stage conditions on the Mississippi River created difficulties for commercial navigation throughout much of 2012 and into early 2013. The 9-foot-deep navigation channel of the Mississippi River, maintained by the U.S. Army Corps of Engineers (USACE), often contains scattered deposits of sediment and debris, particularly following flood conditions such as occurred the previous year in 2011. However, these deposits ordinarily do not affect the passage of tow boats and barges until water levels become low. When the groundings of tows become frequent, such as those which began to occur in summer 2012, the USACE clears and dredges the channel. Dredging on the river began in July 2012 and continued throughout most of the remainder of the drought.

River closures were occasionally needed for channel maintenance (surveying, dredging, and re-marking) or when grounded barges needed to be pulled away from sediment bars and river banks. Because of the low water conditions, the number of barges per tow was reduced, and barges were asked to lighten their loads in an effort to avoid scraping the bottom or sides of the channel. Barges loaded to their full capacity typically have an 11- to 12-foot draft; however, during the drought, drafts were progressively restricted to 9 feet, the specified minimum navigation channel depth. Closures, delays, and draft and tow restrictions can result in substantial economic losses and additional transportation costs. The USACE (2013) estimates that closures and low water conditions during the 2012 drought increased transportation costs by roughly $277 million.

Although much of the Mississippi River navigation system experienced navigation problems such as groundings in 2012, the 180-mile "middle" reach between St. Louis, MO, and Cairo, IL, located in Figure 11.1, was probably one of the most susceptible reaches on the Mississippi River. Lock and Dam 27 (LD27), located near St. Louis, is the last downstream dam on the Mississippi River. Upstream (north) of LD27, river stages and depths are to various degrees controlled by the lock and dam system; downstream of LD27, however, river stages are directly associated with the low flow quantity. Two of the most notable navigation impacts in 2012 occurred along this reach of the Mississippi River: 1) the five-day river closure at LD27 in September 2012 associated with a barge accident; and 2) the low water conditions and channel work needed in December 2012 through February 2013 at the "rock pinnacles" located near Thebes and Grand Tower in southern Illinois.

Lock and Dam 27

By late summer 2012, the low water level at LD27 had exposed a guide cell at the approach to a lock chamber, a structure which is almost always underwater. On September 15, a less-fortified section of the guide cell was struck and ruptured by a tow, causing tons of loose rock to fall into the flow of barge traffic into the lock. A five-day closure of the main lock and auxiliary lock was required to remove the rock and temporarily repair the cell.

Rock Pinnacles at Thebes and Grand Tower

Near both Thebes and Grand Tower, the Mississippi River cuts across thick limestone formations. At low water, the dissected limestone ledges become less submerged and in places can be exposed. The resulting rock outcroppings and pinnacles are a hazard to navigation, and at the lowest water levels, constrict the main channel. As a result, in fall 2012 barge drafts and tow sizes not only were restricted, but also the navigation through a 6-mile stretch near Thebes was limited to one-way traffic.

Throughout much of any drought year, the flows in this middle portion of the Mississippi River are partially sustained by the Missouri River's navigation system. Flow releases from numerous reservoirs in the Missouri River basin are used to supplement flow and maintain navigation. However, at the end of November of every year, the Missouri navigation season comes to an end, and with it comes the scheduled termination of much of the flow supplementation that also benefits the middle Mississippi River. In accordance with the Missouri River Basin Master Manual, on December 1, 2012, the USACE reduced the Missouri reservoir releases from 37,000 to 12,000 cubic feet per second (cfs).

The navigation industry was greatly concerned that the subsequent flow reduction, beginning in December 2012 and lasting throughout the winter, might cause sufficiently low water levels at Thebes to force a navigation shut-down on the Mississippi River. To compound the concern, it was also expected that flows from the upper reaches of the Mississippi River might be sharply diminished by early January as winter weather caused that portion of the river to freeze. Although requests were made for the USACE to reopen the Missouri River reservoirs to help maintain navigation on the middle Mississippi River, such an action conflicts with the Missouri River Master Manual which binds the USACE's operations.

Supplementing Mississippi River Flows Using Kaskaskia Reservoir Storage

The only USACE reservoir storage available to supplement the Mississippi River flow near Thebes was that in the Kaskaskia River basin in Illinois (Carlyle Lake and Lake Shelbyville). The maximum navigation release from those reservoirs, roughly 3700 to 4000 cfs, is sufficient to increase the water level at Thebes by roughly 6 inches.

Although navigation is one of the primary functions of the joint-use storage in Carlyle Lake and Lake Shelbyville, in over 40 years of operation there has yet to be a designated navigation release from these reservoirs. But in the fall of 2012 the USACE was fully prepared to use the storages of these reservoirs for this purpose. As it turned out, the remnants of Hurricane Isaac passed over the Carlyle Lake region earlier in

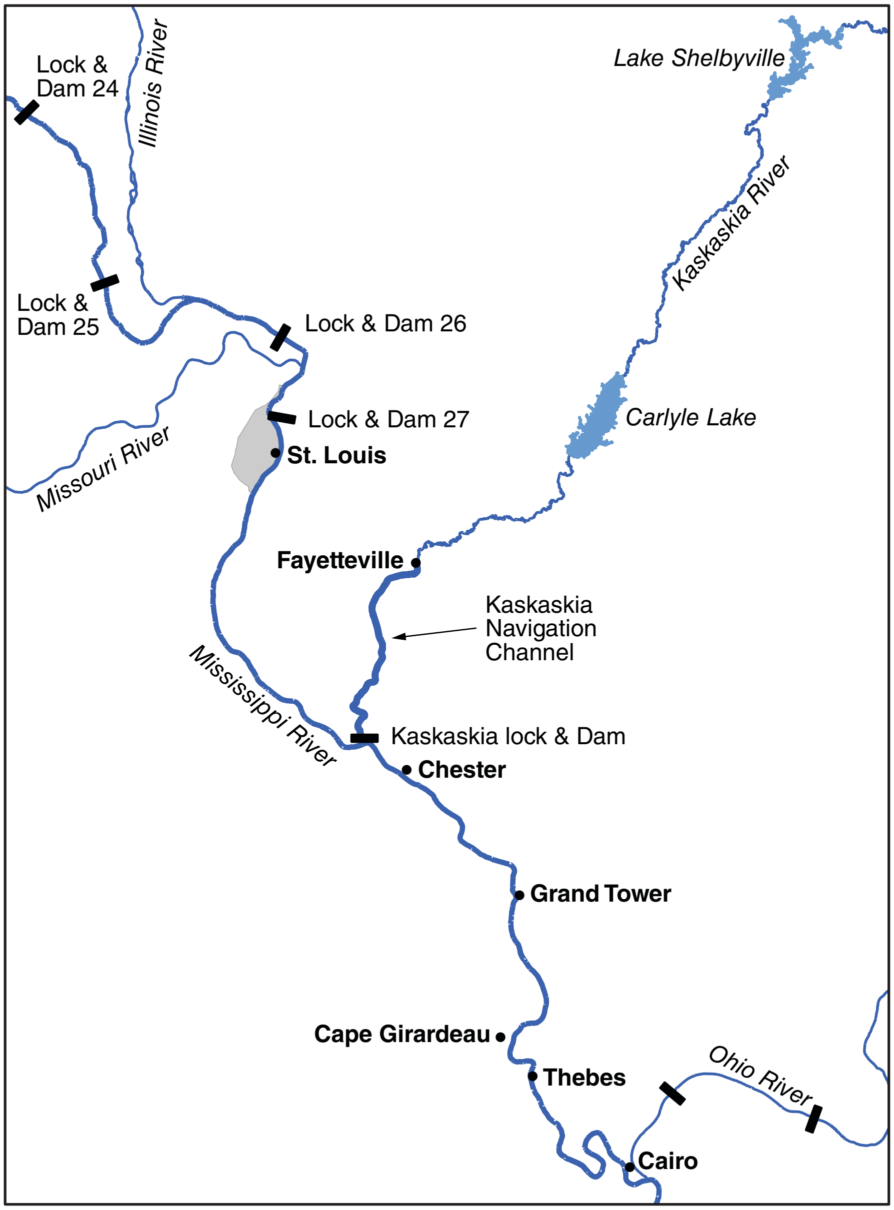


Figure 11.1 Location of the Middle Mississippi River and Kaskaskia River navigation systems

the fall, such that the storage of Carlyle Lake had not merely recovered from the drought, but was in the flood control pool as much as 3 feet above the normal pool level (Table 6.4). The USACE began releasing water from Carlyle Lake on December 15, 2012 to supplement flows on the Mississippi River. But with wet conditions in January 2013, the water level in Carlyle Lake never fell back to its normal winter pool level. Because the joint-use storage in Carlyle Lake was not accessed during this time, its December–January flow releases were never officially designated as a navigation release. By late January 2013, flow levels in the Mississippi River had recovered sufficiently that navigation restrictions were no longer a concern.

In December 2012, contractors for the USACE began blasting and removing rock near Thebes to maintain the 9-foot navigation channel during low water periods. In late January, that work moved from Thebes to Grand Tower, and by the end of February the rock removal effort had been completed.

Environmental and Water Quality Impacts

Surface Water Quality

Although there is no known specific analysis of water quality conditions during the 2012 drought, certain general impacts can be inferred. During droughts, streams and rivers typically have low flows, with the majority of the flow in natural settings coming from shallow groundwater. Thus, for many constituents, surface water quality can become atypical and more similar to groundwater quality, with lower concentrations of nutrients such as nitrate and phosphate, and higher levels of iron, manganese, and other constituents. On the other hand, the water quality of streams that receive substantial amounts of wastewater (for example, portions of the Fox and Illinois Rivers) may be more likely to take on characteristics of that wastewater if the shallow groundwater contribution is limited.

As flows and water levels in the streams and rivers of Illinois decreased during the drought, water temperatures rose and dissolved oxygen levels fell. Low dissolved oxygen conditions result from the accumulation of oxygen-consuming substances under prolonged low flow stagnant conditions and because warmer waters hold less dissolved oxygen. High temperatures and less water also mean an increase in evaporation, which increases the concentrations of many solutes. Some of these solutes, such as ammonia and nitrite, can be toxic at certain levels.

Algal blooms can also increase during droughts, further robbing the water of oxygen and possibly producing cyanotoxins such as microcystin, which is toxic to humans. In response to several reports of harmful algal blooms, the Illinois Environmental Protection Agency (IEPA) and the U.S. Geological Survey (USGS) sampled 13 lake and stream sites during August–October 2012. Three sites contained high to very high levels of microcystin, with a highest recorded value of 4,800 micrograms per liter (μg/L) (IDNR, 2013). The World Health Organization standard for microcystin is 20 μg/L.

Fish Kills and Other Environmental Damages

Low dissolved oxygen levels and increased water temperatures in streams, lakes, and ponds stressed fish, as well as other aquatic organisms and biota, sometimes leading to fish kills. Fish kills have various causes, but during droughts a primary cause is low dissolved oxygen levels. The Illinois Department of Natural Resources (IDNR) Division of Fisheries reported more than 80 fish kills in rivers, streams, lakes, and ponds in Illinois between July and September 2012 (tabulated in IDNR, 2013). Twelve of the kills were described as “major,” most of those with a loss of life numbering in the thousands. The greatest frequency of reported fish kills occurred during the week of July 9–15, 2012. High losses were specifically reported on the Illinois River and one of its tributaries, the Vermilion River; however, fish kills were observed on almost all the major rivers in the state.

Some of the largest fish kills occurred in lakes used for cooling purposes. Some power plants were permitted under an IEPA variance to discharge water at temperatures in excess of 120 degrees into their cooling lakes. Heated water discharges have multiple adverse effects on fish and other aquatic organisms including direct lethality, increased metabolism and oxygen consumption, and increased toxicity of certain chemicals (Madden et al., 2013).

Additionally, several mussel beds dried up, leaving the mussels exposed to high temperatures and predators. Mussel die-off was reported along the Embarras, Fox, and Kankakee Rivers in 2012. Although wildlife are ordinarily stressed during drought, the dry conditions also indirectly caused the death of roughly 700 deer in the state when they contracted Hemorrhagic Disease. The spread of the disease is worse during droughts because deer are forced to seek limited water sources that harbor the insects carrying the disease. The number of deer lost, however, was not enough to noticeably affect either the overall population or the hunting season. The drought had both positive and negative effects on Illinois birds. Wetland vegetation flourished on the banks of the receded Illinois River, creating a dense cover of vegetation on any bare ground. On one hand, this has made life for shorebirds very difficult, as there is no exposed mud for them to probe for food. On the other hand, however, ducks and other water birds will have a huge amount of food to feast on when water returns to the area.

Groundwater Quality

Illinois currently does not have sufficient ongoing groundwater quality monitoring that might pick up variations in quality during a drought. Recently, McHenry County, with the assistance of the USGS, has installed specific conductance probes into a few of their monitoring wells, which might indicate water quality variations during a drought. However, these probes were not installed until after the 2012 drought. The relatively short duration of the 2012 drought means that there are insufficient data from monitoring programs, such as the IEPA’s ambient water quality programs for public supply wells, to statistically validate possible drought-induced water quality changes.

Groundwater quality is generally a function of several processes, including 1) the quality of surface recharge entering aquifers; 2) the quality of recharge from subsurface sources entering aquifers, such as bedrock discharge entering the Mahomet Aquifer (Panno et al., 1994); 3) water-rock-microbial interactions within an aquifer, such as the dissolution of minerals and ion exchange reactions; 4) the effects of high-capacity well pumping which may draw waters of differing qualities into the aquifer or well bore; and 5) groundwater-surface water interactions.

The effects of drought on groundwater quality are difficult to quantify. Probably the primary mechanism for altering water quality in an aquifer is a reduction of natural recharge. Reduction in recharge can either improve or degrade groundwater quality, depending on the quality of the recharge water. Recharge water can either bring in surface-derived contaminants, dilute contaminants already in the aquifer, or both. An example of decreased recharge degrading groundwater quality would be if septic system discharge becomes a greater percentage of recharge water due to less dilution. This kind of relative increase in a contamination source during drought is often observed in surface waters. For example, during the 2005 drought, the water quality of the Illinois River was altered when there was a significant decrease in natural groundwater discharge, but the amount of wastewater effluent discharged to the river, especially in the Chicago region, did not decrease (Kelly et al., 2010). Thus chemical markers of wastewater from Chicago were observed hundreds of miles downstream of the city.

Whittemore et al. (1989) found a relationship between groundwater quality variations in public supply wells in Kansas and the Palmer Drought Index. The predominant effect they observed was that total dissolved solid (TDS) concentrations, primarily sulfate, chloride, calcium, and sodium, slowly increased during droughts due to a lack of diluting recharge. This correlation between drought and groundwater quality was significant only for aquifers with relatively shallow water tables (< 10 meters). Kampbell et al. (2003) reported increased levels of several dissolved constituents, including nitrate, chloride, sulfate, and orthophosphate, in shallow wells surrounding Lake Texoma (on the Red River border between Texas and Oklahoma) during a short-term drought in 2000.

Another potential mechanism that can affect groundwater quality during drought is if lowered water tables expose reducing zones to atmospheric oxygen, leading to the oxidation of reduced minerals or aqueous species. For example, if a pyritic zone is exposed, the oxidation of pyrite can lead to decreases in pH, increases in sulfate, and increases in arsenic (Appleyard et al., 2006). Exposing a reduced zone that had not previously been exposed to oxygen would generally require a significant decrease in the water table and would probably be due to increased groundwater extraction as is typical during droughts.

It should be noted that these potential groundwater quality effects are reported only for unconfined, i.e., water table, aquifers. One would not expect deep aquifers, such as the deep sandstone aquifers in northeastern Illinois, to exhibit any direct effects from drought. Groundwater travel times in these aquifers are measured in decades to hundreds of years, thus the relatively short-term duration of droughts is too short to materially affect them.

Chapter 12. Conclusions

On June 19, 2012, the Illinois Drought Response Task Force (DRTF) was activated with Governor Quinn's approval in response to emerging drought conditions and drought impacts in Illinois. With this action, Illinois became the first Midwestern state to officially designate drought conditions in 2012, with most nearby states following suit in late June and July. Official drought proclamations such as this are expected to occur in Illinois on average once in seven to eight years. They are based on identification of impending drought impacts, or threat thereof, that necessitate a concerted response from relevant state agencies. As with past droughts, the Illinois State Water Survey (ISWS) played a key role for the state in identifying emerging impacts in the early stages of drought development and recommending, by way of the State Water Plan Task Force, a suitable threshold for convening the DRTF.

On July 16, 2012, the National Climatic Data Center prepared a national drought overview indicating that a greater percentage of the conterminous United States was in moderate to exceptional drought (using the Palmer Z short-term index) than in any time since 1956. A substantial portion of the affected United States was located in the Mountain West, Southwest, and High Great Plains, a large region that was geographically separate from the pocket of drought that was affecting Illinois and nearby states. Nevertheless, the "largest drought" soon was translated by many to be the "worst drought since the 1950s," a label that stuck throughout the course of the 2012 drought, regardless of locations affected and extent of impacts. Whereas the "worst drought since the 1950s" classification eventually turned out to be accurate for the epicenter of the western drought (Colorado, Nebraska, and Kansas), where precipitation deficits continued into summer 2013, such a designation was not applicable to Illinois and neighboring states.

Agricultural Impacts

The 2012 drought in Illinois will be primarily identified by its agricultural losses. As reported in Chapter 8, the average corn yield in Illinois was roughly 40 percent below the expected normal, the lowest relative yield since the 1988 drought and the second lowest in the past 50 years. The corn crop was also tainted with high levels of aflatoxins, often requiring blending of the harvest with corn from other regions to dilute concentrations to acceptable levels. The soybean crop fared better, with average yields roughly 10 percent below the expected normal. Although the soybean crop was in poor shape in early August, sufficient precipitation in late August and early September, including that from Hurricane Isaac, provided for substantial recovery of the soybean crop.

Water Resource Condition

The severity of the 2012 drought's impact to Illinois' surface water and groundwater resources varied substantially by location. Central Illinois was most greatly affected, on average representative of a 10-year drought but with several streams and shallow observation wells experiencing their lowest levels on record, most often referring to the past 30 to 50 years. The lowest 2012 water level in Lake Decatur, one of the water supplies most significantly affected by the drought, is representative of a drought event with a 10- to 12-year recurrence. The southern and western Illinois regions also had a few hydrologic observations that were at or near their historical minimums, but on average the regions experienced drought measurements suggestive of a 7- to 10-year event. Water resources in the remaining northern regions of Illinois were generally lightly affected, with a less than 5-year event. All of these observations taken in hindsight, however, belie the seriousness of the drought threat posed to water resources and related impacts (water supplies, environment, and navigation) during the summer of 2012.

Gravity of the Drought During Summer 2012

Through July and August 2012, streams and water supply reservoirs across substantial portions of central and southern Illinois were experiencing conditions that were comparable, at the same stage of development, to the worst water resource droughts of the past 100 years. It is reasonable to assume that historical minimum streamflows, typically associated with the fall season, may have occurred in a widespread manner across Illinois in September or October 2012 had precipitation continued to remain below normal. Lake Decatur, in particular, was on pace and would have been expected to reach low levels similar to what was experienced in 1988. Most reservoir and shallow groundwater levels, on the other hand, would generally not have been expected to reach noteworthy minimum levels unless and until conditions remained relatively dry well into 2013. There are important exceptions, as noted in this report, particularly regarding the reservoir supplies for Decatur, La Harpe, and the Vienna Correctional Center.

The Role of Hurricane Isaac in Truncating the Drought

November turned out to be the driest month of 2012 in Illinois. Furthermore, from September 1 to December 31, 2012, the average observed precipitation in Illinois (12.4 inches) was only 0.2 inches above normal. Without the 3 to 5 inches of precipitation that occurred in central and southern Illinois during the first four days of September, when the remnants of Hurricane Isaac passed over the region, much of those regions would have continued to suffer through a cumulative increase in precipitation deficits through the remainder of the year. Thus, it is contended herein that Hurricane Isaac effectively truncated the drought, singularly bringing about a drought recovery from a water resource condition in which streams, reservoirs, and shallow groundwater would likely have continued to decline through the fall or early winter. Under such a hypothetical scenario (assuming that all continuing climate events were unaffected), the drought would instead likely not have ended until April–June 2013. Given the rarity of tropical storms in Illinois, Hurricane Isaac provided a unique ending to a potentially severe and threatening drought situation.

Detecting Future Droughts and Usefulness of Available Drought Indexes

The U.S. Drought Monitor (USDM) is a highly visible drought index that many agencies and the public access for information to track drought conditions, and the USDM will likely continue to provide a primary information resource for future drought episodes. The Palmer Drought Severity Index (PDSI) is a second drought index, most typically used by climatologists, that is particularly useful for providing historical perspectives regarding drought severity. The two indexes use similar qualitative adjectives in describing drought severity, those being moderate, severe, and extreme drought. The USDM also has a more severe category, that being exceptional drought. Although the two indexes are developed in noticeably different ways, their categorizations are roughly similar; that is to say the USDM "severe drought" and PDSI "severe drought" categories roughly represent events of similar severity and frequencies of occurrence.

In the authors' judgement regarding applications to Illinois drought events, the USDM qualitative categories often appear to convey a shifted perception regarding drought impacts and the associated need for response. For example, one might expect that a USDM "severe drought" would be causing tangible water resource or agricultural impacts to an extent that would demand attention from state authorities. However, in the first chapter of this report it is shown that a USDM "severe drought" instead represents roughly a once in four year event with, at most, isolated impacts; furthermore, at least one region of Illinois has been classified in the USDM "severe drought" category in 10 out of the past 16 years. Instead, events classified by the USDM (or PDSI) within the "extreme drought" category are more closely associated with perceptible impacts and official drought designations in Illinois. Although the USDM "extreme drought" classification could in concept be used as an indicator of official drought in Illinois, its use as such in most cases would result in delayed identification of emerging drought conditions.

The ISWS and Illinois' State Water Plan Task Force have established a reliable record regarding identification of emerging drought conditions in the state leading to official drought designation. Droughts are identified by their specific impacts, not by any given climatic measure or index. Whenever drought conditions begin to emerge in Illinois, the ISWS assesses the potential for tangible impacts to agriculture and water supplies. Such assessments: 1) use near-future projections of hydrologic and agricultural conditions based on the 14-day weather forecast; 2) anticipate drought impacts and specific concerns based on knowledge from prior drought episodes; and 3) incorporate an understanding of seasonal patterns regarding hydrologic response and agricultural growth into longer range projections of associated impacts.

References

Appleyard, S. J., J. Angeloni, and R. Watkins. 2006. Arsenic-rich groundwater in an urban area experiencing drought and increasing population density, Perth, Australia. *Applied Geochemistry* 21(1):83–97. doi:10.1016/j.apgeochem.2005.09.008.

Changnon, S. A., Jr. 1987. *Detecting Drought Conditions in Illinois*. Illinois State Water Survey Circular 169, Champaign, IL, 36 pp.

Changnon, S. A., Jr., F. A. Huff, and K. E. Kunkel. 1996. *Dry Periods in Illinois: A Climatological and Meteorological Analysis*. Illinois State Water Survey Contract Report 599, Champaign, IL.

Easterling, W. E. and S. A. Changnon, Jr. 1987. Precipitation Drought. In *Droughts in Illinois: Their Physical and Social Dimensions*. Illinois State Water Survey unpublished manuscript, S. A. Changnon, Jr.

Fuchs, B. A., N. A. Umphlett, M. S. Timlin, W. Ryan, N. Doesken, J. Angel, O. Kellner, H. J. Hillaker, M. Knapp, S. F. Xiamao Lin, J. Andresen, A. Pollyea, G. Spoden, P. Guinan, A. Akyuz, J. C. Rogers, L. M. Edwards, D. Todey, and T. Bergantino. T. 2014. *From too much to too little: How the central U.S. drought of 2012 evolved out of one of the most devasting floods on record in 2011*. Brian A. Fuchs, Deborah A. Wood, Dee Ebbeka (Ed.), 105 pp. http://drought.unl.edu/Portals/0/docs/CentralUSDroughtAssessment2012.pdf

Hoerling, M., J. Eischeid, A. Kumar, R. Leung, A. Mariotti, K. Mo, S. Schubert, and R. Seager. 2014. Causes and predictability of the 2012 Great Plains drought. *Bull. Amer. Meteor. Soc.* 95:269–282. doi:10.1175/BAMS-D-13-00055.1.

Illinois Department of Natural Resources (IDNR). 2013. The Drought of 2012: A Report of the Governor's Drought Response Task Force. http://www.isws.illinois.edu/hilites/drought/archive/2012/docs/TheDroughtOf2012.pdf

Kampbell, D. H., Y. J. An, K. P. Jewell, and J. R. Masoner. 2003. Groundwater quality surrounding Lake Texoma during short-term drought conditions. *Environmental Pollution* 125(2):183–191. doi:10.1016/S0269-7491(03)00072-1.

Kelly, W. R., S. V. Panno, K. C. Hackley, H. H. Hwang, A. T. Martinsek, and M. Markus. 2010. Using chloride and other ions to trace sewage and road salt in the Illinois waterway. *Applied Geochemistry* 25(5):661–673. doi:10.1016/j.apgeochem.2010.01.020.

Kelly, W., D. Abrams, V. Knapp, S. Meyer, Z. Zhang, B. Dziegielewski, D. Hadley, G. Roadcap, D. Mannix, and Y. Lian. 2016. *Water Supply Planning: Middle Illinois Progress Report*. Illinois State Water Survey Contract Report 2016-02, Champaign, IL.

Knapp, H. V. 1994. Streamflow conditions, flooding, and low flows. In *The Changing Illinois Environment: Critical Trends, Volume 2: Water Resources*. Illinois Department of Energy and Natural Resources, Report ILENR/RE-EA-94/05(2): 113-144.

Madden, N., A. Lewis, and M. Davis. 2013. Thermal effluent from the power sector: An analysis of once-through cooling system impacts on surface water temperature. *Environmental Research Letters* 8:1–8. doi:10.1088/1748-9326/8/3/035006.

National Centers for Environmental Information. 2016. Billion Dollar Disasters in the United States. https://www.ncdc.noaa.gov/billions/events.pdf (accessed July 18, 2016).

Panno, S. V., K. C. Hackley, K. Cartwright, and C. L. Liu. 1994. Hydrochemistry of the Mahomet Bedrock Valley Aquifer, east-central Illinois: indicators of recharge and groundwater flow. *Ground Water* 32(4):591–604.

Roadcap, G. S., H. V. Knapp, H. A. Wehrmann, and D. R. Larson. 2011. *Meeting East-Central Illinois Water Needs to 2050: Potential Impacts on the Mahomet Aquifer and Surface Reservoirs*. Illinois State Water Survey Contract Report 2011-08, Champaign, IL.

Svoboda, M., D. LeConte, M. Hayes, R. Heim, K. Gleason, J. Angel, B. Rippey, R. Tinker, M. Palecki, D. Stooksbury, D. Miskus, and S. Stephens. 2002. The Drought Monitor. *Bulletin of the American Meteorological Society* 83:1181–1190.

U.S. Army Corps of Engineers (USACE). 2013. *Event Study: 2012 Low Water and Mississippi River Lock 27 closures*. August 2013 Report prepared by the USACE Planning Center for Inland Navigation in collaboration with the USACE Institute for Water Resources, Washington, D.C.

Whittemore, D. O., K. M. McGregor, and G. A. Marotz. 1989. Effects of variations in recharge on groundwater quality. *Journal of Hydrology* 106(1-2):131–145. doi:10.1016/0022-1694(89)90170-4.

Willeke, G., J. R. M. Hosking, J. R. Wallis, and N. B. Guttman. 1994. *The National Drought Atlas. Institute for Water Resources*. Report 94–NDS–4, U.S. Army Corps of Engineers, Washington, D.C.

Winstanley, D., J. R. Angel, S. A. Changnon, H. V. Knapp, K. E. Kunkel, M. A. Palecki, R.W. Scott, and H. A. Wehrmann. 2006. *The Water Cycle and Water Budgets in Illinois: A Framework for Drought and Water-Supply Planning*. Illinois State Water Survey Information/Educational Materials 2006-02, Champaign, IL. http://www.isws.illinois.edu/pubdoc/IEM/ISWSIEM2006-02.pdf

Attachment

7

ISWS Map Series 2015-03
Published November 2015

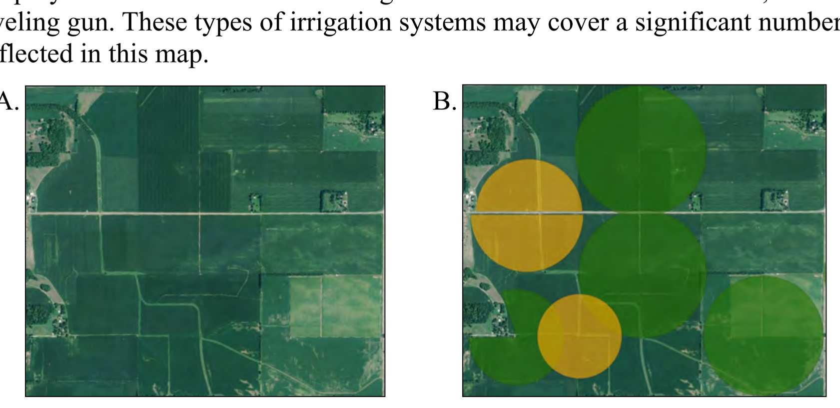
Center Pivot Irrigation in Illinois
2012 and 2014

Illinois State Water Survey

This map displays center pivot irrigation systems in use in Illinois during the 2012 and 2014 growing seasons. There was a significant increase in irrigation use during 2013 and 2014, likely due to the drought in 2012. The saturated hydraulic conductivity layer represents soils with a value of ≥10 micrometers per second (3.6 centimeters per hour) in the upper 30 inches of soil, a value typical of sandy soils in Illinois. Saturated hydraulic conductivity is a measure of the ease with which water will move through a soil, and values typically increase with the sand content. Traditionally, irrigation is needed where sandy soils are present due to their low water-holding capacity and high hydraulic conductivity. This layer provides a general location for areas that are more likely to require irrigation for a successful crop. The majority of center pivot systems in Illinois are located in alluvial valleys where soils are sandy and where shallow aquifers are available to sustain high capacity wells. In recent years, seed corn contracts that require a guaranteed crop, as well as the positive return on investment for crops under irrigation, have expanded the use of center pivot irrigation to areas that have not historically required irrigation, such as northern Champaign and southern Ford counties. Irrigation will likely continue to expand in Illinois as concerns over drought increase and farming practices change to ensure crop yields meet expectations.

A. Center pivot irrigation imprints identifiable circular patterns on the landscape which can be visible in aerial images. The USDA collects aerial images during the crop growing season through the National Agricultural Imagery Program (NAIP) and makes them available through the USDA Geospatial Data Gateway. Images collected by the USDA during the 2012 and 2014 growing seasons were used to develop this map. In reviewing the USDA 2014 data, a QA/QC check indicated a few pivots were omitted from the 2012 map. This revision includes those additional pivots identified from USDA images collected during the 2014 growing season. Using aerial photography to identify irrigation systems is limited by the resolution and timing of the photography, and in some cases a system was not discernable and may have been missed.

B. The NAIP images were examined for irrigation patterns, and field boundaries were traced to create an ArcGIS map layer. A total of 5,829 center pivot irrigation systems were identified in Illinois during the summer of 2012, representing approximately 553,000 acres of farmland. An additional 826 pivots were in use during the 2014 growing season, bringing the statewide total to 6,656 center pivot systems irrigating approximately 625,000 acres of farmland in 2014. This map does not include all forms of irrigation employed in Illinois. Alternative irrigation methods include subsurface, lateral-move, solid-set, and traveling gun. These types of irrigation systems may cover a significant number of irrigated acres not reflected in this map.

A. B.


Karen Bridges, Steve Wilson, and Rebecca Perry
Groundwater Science Section, Illinois State Water Survey

Funding was provided in part by Illinois Department of Natural Resources. The technical content of the map is the responsibility of the authors. The user assumes all liability for the interpretation and use of the map. Map compiled by Karen Bridges. Projection: Lambert Conformal Conic.

Sources:

National Agricultural Imagery Program (NAIP) and Soil Survey Geographic Database (SSURGO 2.2) from the USDA Geospatial Gateway, http://datagateway.nrcs.usda.gov
Bridges, et al. 2014. 2012 Center Pivot Irrigation in Illinois. ISWS Map Series 2014-03.

www.isws.illinois.edu, 217-333-6800
University of Illinois, www.illinois.edu

ILLINOIS STATE WATER SURVEY
PRAIRIE RESEARCH INSTITUTE

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Attachment

8

WATER SURVEY ARCHIVED CONTENT

Home
General Information
Methods
Quick Guide
Select Crop
Map Search
Crop List
County Search
Disclaimer
Citations
Site Map

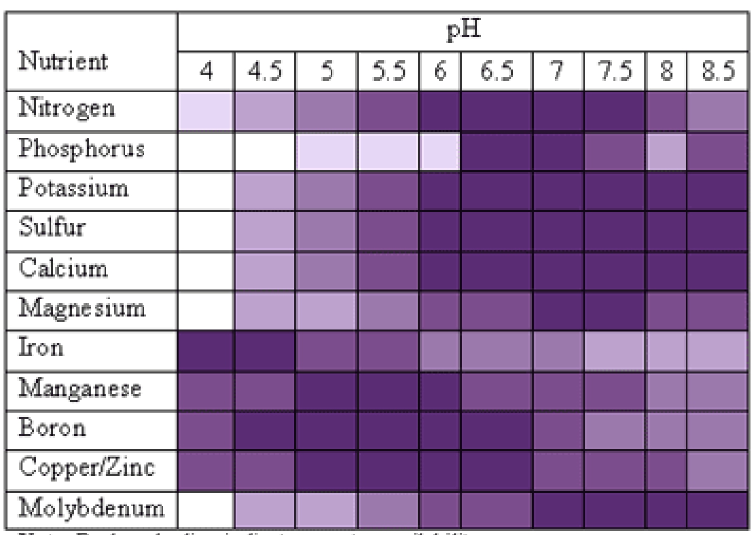
1. Soils – 2. Climate – 3. Other – General Information

Soil

The most detailed Illinois GIS soil descriptions are STATSGO soil map units composed of similar soil types. Each map unit may include up to 21 individual soil types. Soil values used in this Web page are the weighted average values of the soil types contained within the STATSGO map unit; soil pH and texture are weighted averages of the surface soil layer only. The STATSGO map unit soil pH, texture, and drainage values are compared to crop requirements to obtain suitability scores for each soil characteristic.

Soil pH is a measure of acidity (hydrogen ion concentration). The pH values range from 0 to 14: 0 is most acidic, 7 is neutral, and 14 is most basic (lowest hydrogen ion concentration). Soil pH values range from ~3 to 10. Forest and bog soils of the humid east tend to be acidic and grassland and desert soils of the west tend to be basic.

Effect of pH on nutrient availability



Note: Darker shading indicates greater availability.

Extremes of soil pH release substances from soils in amounts that can be toxic to plants. Acid soils may dissolve toxic amounts of metals (such as aluminum and manganese). Alkaline soils may accumulate salts and sodium carbonates in toxic concentrations that can alter soil structure, thereby making it difficult for roots to grow. Stunted root systems have trouble taking up adequate water and nutrients. Toxic metals in acid soils, subsoil nutrient depletion, and subsoil clay pans also stunt root growth.

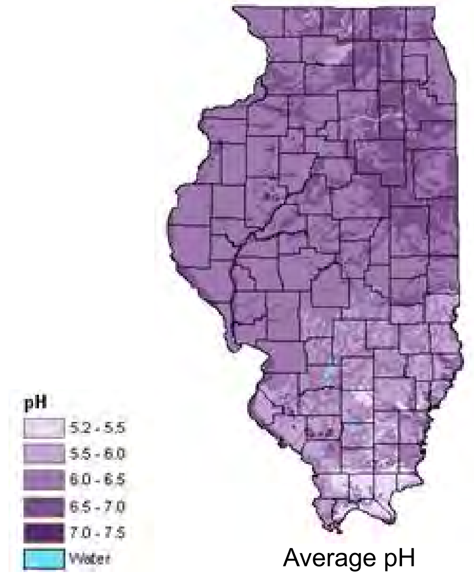
Slightly acidic soils (pH ~6.5) are considered most favorable for overall nutrient uptake. Such soils are also optimal for nitrogen-fixing legumes and nitrogen-fixing soil bacteria. Some plants are adapted to acidic or basic soils due to natural selection of species in these conditions. Potatoes grow well in soils with pH <5.5. Blueberries and cranberries grow well in even more acidic soils (<4.5) . Sugar beets, cotton, kale, garden pea, and many grasses grow well in alkaline soil (>7.5).

Soil pH also affects the soil in other ways. For example, soil microbe activity, particularly nitrogen-fixing bacteria may be reduced in acid soil.

Agricultural soils of Illinois tend to acidify to pH values more acidic than 6.5. This acidity is managed by adding lime (carbonates of calcium and magnesium). Average soil pH values vary from mildly alkaline (7.0-7.5) to strongly acid (5.2-5.5) in extreme southern Illinois.

The Natural Resources Conservation Service has set standard soil pH classifications.

pH classifications	*pH values*
Extremely acid	< 4.5
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Medium acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3
Mildly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline	> 9.0



Average pH

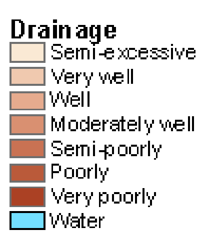
DRAINAGE rate refers to the rapidity and extent that water is removed from a soil by surface runoff, underground flow through the soil, and evaporative loss. Drainage also refers to soil drainage status — the frequency and duration with which soil is waterlogged. In Illinois' climate, the drainage rate coincides with soil drainage status. If drainage is very rapid, the soil is excessively drained. If drainage is very slow, the soil suffers from excessive waterlogging and is very poorly drained.

Soil drainage extremes present the same types of problems for crops that extremes of soil pH do. Excessively drained soils do not provide most crops with adequate water and nutrients, and the structure of the soil limits root growth. Additionally, excessively drained soils tend to warm early and generally undergo marked temperature fluctuations. Water and nutrient availability are also limited in poorly drained soils because oxygen deficiency limits the ability of roots to take up adequate water and nutrients. With waterlogging, putrefaction sets in. Putrefaction occurs when partially decomposed organic matter accumulates, clogging soil pores and blocking root growth and the drainage of water through soil. Putrefaction produces toxic substances: reduced nitrogen, sulfur, metals, and organic fermentation products. Furthermore, it produces methane, a gas that attacks the atmosphere's self-cleansing system. Additionally, poorly drained soils tend to warm up slowly in the spring and reduce the length of crop growing seasons.

Illinois' drainage problems are principally those of poor drainage. Ditching and subsurface tiling typically improve drainage. With improved drainage, excessive organic matter is destroyed due to decomposition by oxidation rather than putrefaction. Root and soil fauna penetration of subsoil improves soil drainage and structure. The soil's large store of organic nitrogen undergoes oxidation to water-soluble nitrate. With good drainage, nitrate may drain into groundwater and surface water at rates detrimental to water quality. The map below depicts average drainage for Illinois soils. The sandy soils in Mason and Will counties are unlike the majority of Illinois soils, which are moderately well to poorly drained.

The NRCS assigns soils to one of the following eight drainage classes:

Excessively drained
Semi-excessively drained
Very well drained
Well drained
Moderately well drained
Semi-poorly drained
Very poorly drained
Poorly drained



Texture describes the proportion of sand, silt, and clay in a soil. The relative proportion and physical properties of these separates (i.e., particles) affect drainage, water storage capacity, aeration, permeability, and other soil properties.

Average Drainage

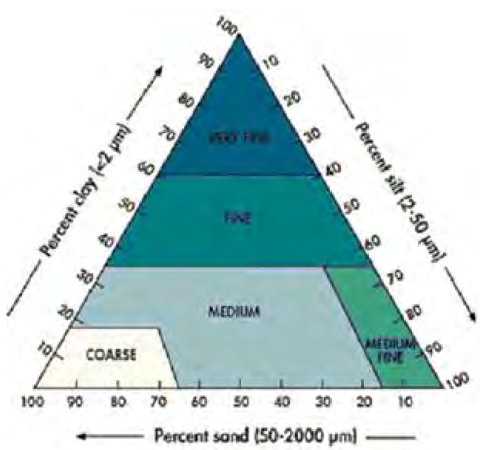
Sand, the largest sized particle (> 0.5 millimeters or mm), has small surface area for its mass. This, in turn, prevents sand from holding significant water or nutrients. Sand, therefore, reduces the amount of a soil's physical and chemical activity. Sand increases the spaces between particles, letting air and water readily enter and exit the soil.

Clay, the smallest sized particle (< 0.002 mm), has the greatest surface area. Clay particles have a millionfold more surface area per mass than silt. Clay is capable of holding large amounts of water and nutrients but may prevent the release of water for plant use.

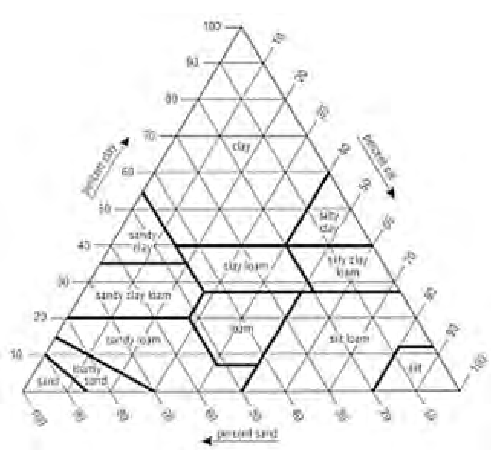
Silt is intermediary between sand and clay in size, water and nutrient retention, and chemical and physical activity. It has approximately four times the surface area of sand. Soils with large proportions of silt provide greater amounts of water for plant use than other soils.

In addition to sand, silt, and clay, soil is made up of water, air, organic matter, and other larger mineral matter. The coarse fragments of mineral matter are named by their size, shape, and composition. Examples of these coarse fragments are gravel, stones, flagstone, and chert. The amount of organic matter varies. As a general rule, the darker the soil, the higher the organic matter (and productivity). Mucks and peat soils are examples of soils extremely high in organic matter.

Any separate alone would not be a desirable soil. Blends of these separates form soil textures, and some are ideal for plant growth. The soil texture triangle is a method of simultaneously representing the percentage of each separate in a soil. The first soil texture triangle is labeled with general texture class names. The second soil texture triangle is labeled with the soil texture class names used by the United States Department of Agriculture-Natural Resource Conservation Service.



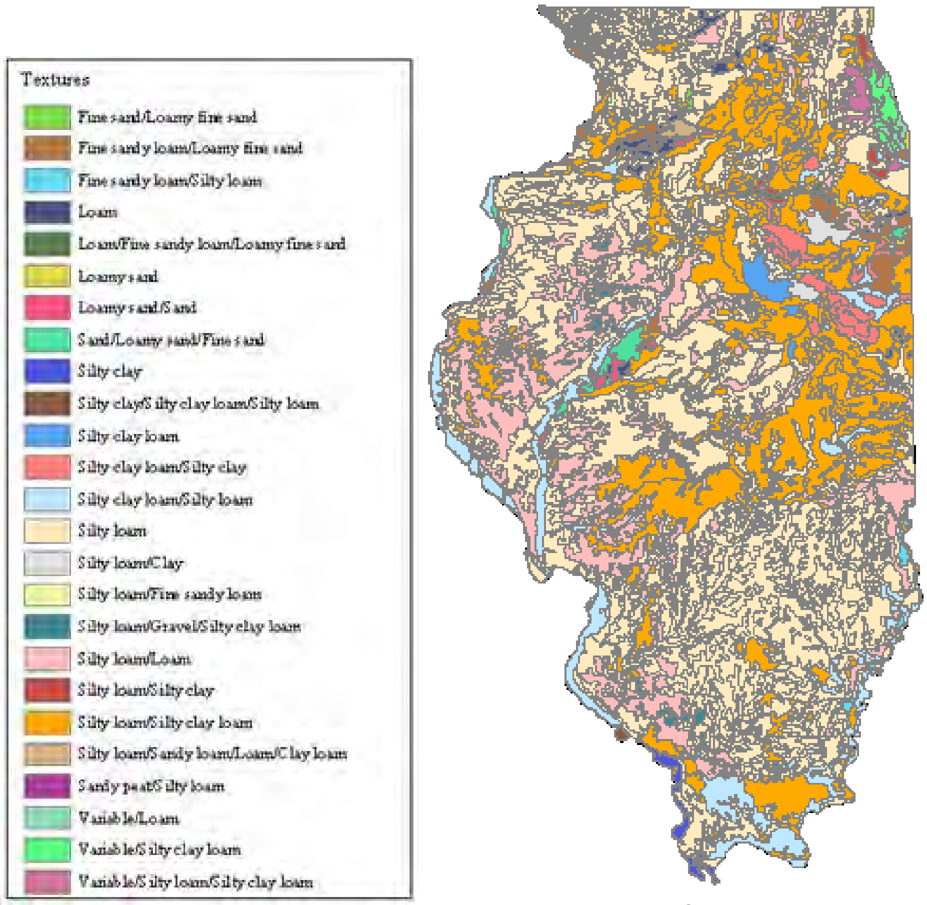
Soil texture triangle with general texture classes



[Soil Survey Manual -United States Department of Agriculture]

USDA-NRCS soil texture triangle

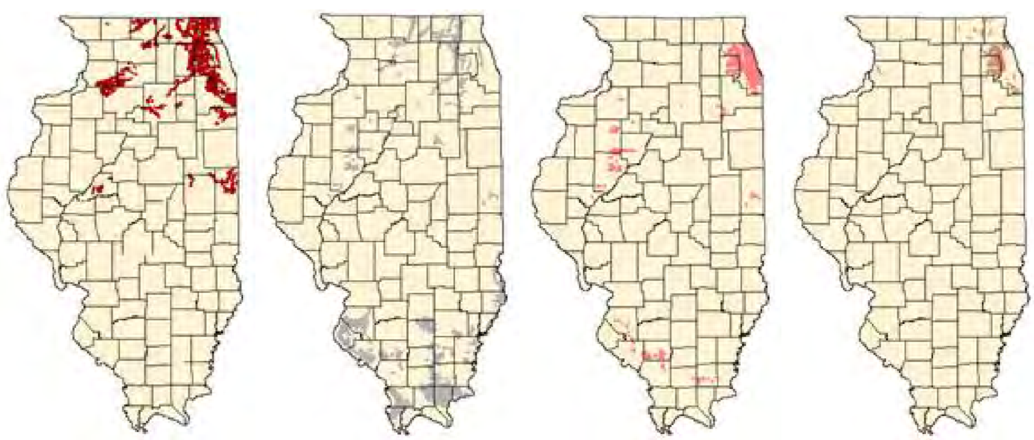
Electronic Filing: Received, Clerk's Office 05/6/2022



Predominate Soil Textures

The map above identifies the predominant (>16% area) soil textures within STATSGO map units.

Disturbed soils, such as urban areas and reclaimed stripmines, occur in Illinois. These soils are the result of removal and/or addition of soil or other materials. The maps below highlight map units that contain atypical soil types.



Muck Coarse Fragment Disturbed Soils Sandy Peat

Soil pH, drainage, and texture requirements are available for many crops and were therefore used to create suitability maps. Other soil properties with impacts on crop growth and development are soil depth, organic matter content, permeability, cation exchange capacity, salinity, and fertility. Information on the plant requirement for these soil characteristics was limited to a few crops and therefore were not included in this discussion.

1. Soils – 2. Climate – 3. Other – General Information

NEXT

| Alternative Crops Home | General Information | Methods | Quick Guide | Select Crop |
| Map Search | Crop List | County Search | Disclaimer | Citations | Site Map |

| Home | Staff Directory | Data | Research |

Illinois State Water Survey, Contact Information
University of Illinois at Urbana-Champaign

Email the Web Administrator with questions or comments.
Last Modified: March 15, 2021

Attachment

9

ASSISTANT SECRETARY OF DEFENSE
3500 DEFENSE PENTAGON
WASHINGTON, DC 20301-3500

SUSTAINMENT

NOV 22 2019

MEMORANDUM FOR ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, ENERGY AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE NAVY (ENERGY, INSTALLATIONS AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND ENERGY)
DIRECTOR, NATIONAL GUARD BUREAU (JOINT STAFF, J8)
DIRECTOR, DEFENSE LOGISTICS AGENCY (INSTALLATION SUPPORT)

SUBJECT: Establishing a Consistent Methodology for the Analysis of Per- and Polyfluoroalkyl Substances in Media Other than Drinking Water

The Secretary of Defense created the Per- and Polyfluoroalkyl Substances (PFAS) Task Force to manage growing health concerns over releases of these substances and the effects on military installations and their surrounding communities. To support the PFAS Task Force's efforts, we need to ensure appropriate levels of quality assurance and quality control (QA/QC) are incorporated into the sampling and analysis for PFAS in various media. The Department of Defense (DoD) will need to conduct sampling and analysis of environmental media to meet requirements under various laws such as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Clean Water Act (CWA), and Resource Conservation and Recovery Act (RCRA).

To date, the Environmental Protection Agency (EPA) has not published methods for analyzing media other than drinking water that are capable of achieving the precision, accuracy, and limits of quantitation needed to support decision making. Therefore, the DoD Components will test media other than drinking water using the PFAS analytical methods that meet the preparation and analysis criteria contained in the DoD/Department of Energy Quality Systems Manual (QSM) for Environmental Laboratories (current version 5.3), Appendix B, Table B-15 (www.denix.osd.mil/edqw/documents/). Laboratories capable of meeting the Table B-15 criteria can be found at www.denix.osd.mil/edqw/accreditation/accreditedlabs, and by choosing "PFAS by LCMSMS Compliant with Table B-15 of QSM Version 5.1 or Latest Version" from the Method dropdown box.

The DoD Environmental Data Quality Workgroup (EDQW) has determined that EPA Draft Method 8327 will not meet DoD's needs to support decision making for the DoD's PFAS efforts. The DoD is currently working with the EPA on the development of a different method for the analysis of PFAS in various media. Once this method has been published, updated guidance will be issued.

My point of contact for this matter is Dr. Jordan Adelson, chair of the EDQW, at 843-794-7270 or jordan.adelson@navy.mil.

Robert H. McMahon

Attachment

10

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
3500 DEFENSE PENTAGON
WASHINGTON, DC 20301-3500

SUSTAINMENT

12/7/21

MEMORANDUM FOR ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, ENERGY AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE NAVY (ENERGY, INSTALLATIONS AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND ENERGY)
DIRECTOR, NATIONAL GUARD BUREAU (JOINT STAFF, J8)
DIRECTOR, DEFENSE LOGISTICS AGENCY (INSTALLATION MANAGEMENT)

SUBJECT: Update for Establishing a Consistent Methodology for the Analysis of Per- and Polyfluoroalkyl Substances in Media Other than Drinking Water

The Department of Defense's (DoD) Strategic Environmental Research and Development Program, in partnership with the Environmental Protection Agency (EPA), has recently produced Draft Method 1633 "*Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS,"* a single-laboratory validated method to test for 40 PFAS compounds in wastewater, surface water, groundwater, soil, biosolids, sediment, landfill leachate, and fish tissue. EPA and DoD will continue to collaborate to complete a multi-laboratory validation study of the method in 2022.

This memorandum is an update to the Assistant Secretary of Defense for Sustainment memorandum, "*Establishing a Consistent Methodology for the Analysis of Per- and Polyfluoroalkyl Substances in Media Other than Drinking Water*," dated November 22, 2019, and provides guidance on the use of Draft Method 1633 for analysis of PFAS in matrices other than drinking water.

The DoD Environmental Data Quality Workgroup has determined that draft method 1633 meets the precision, accuracy, and limits of quantitation needed to support sound decision-making. All new contracts and task orders after December 31, 2021, shall require the use of Draft Method 1633 for the analysis for PFAS in matrices other than drinking water using a laboratory accredited to the method/matrix/analyte by the DoD Environmental Laboratory Accreditation program (ELAP). All existing projects are encouraged to use Draft Method 1633 for PFAS analysis in matrices other than drinking water when ELAP-accredited laboratories become available.

Laboratories capable of meeting the DoD ELAP requirements applicable to this method can be found at www.denix.osd.mil/edqw/accreditation/accreditedlabs, and by choosing "Draft EPA Method 1633" from the Method dropdown box. Table B- 24 has been added to the DoD/Department of Energy Consolidated Quality Systems Manual (QSM) for Environmental Laboratories, version 5.4 to address this new method.

The point of contact for this matter is Dr. Jordan Adelson, Chair of the EDQW, at 843-794-7270 or jordan.adelson@navy.mil.

MORANI.STEVEN.J.1174632444 Digitally signed by MORANI.STEVEN.J.1174632444 Date: 2021.12.07 16:51:43 -05'00'

Steven J. Morani
Principal Deputy Assistant Secretary of Defense for Sustainment (Logistics)
Acting Assistant Secretary of Defense for Sustainment

Attachment 11

Carcinogen Classifications for Proposed Part 620 Constituents

CASRN	Constituent	IRIS	IARC	NTP
Inorganics				
7429-90-5	Aluminum	Not Assessed	Not Assessed	Not Listed
7440-48-4	Cobalt	Not Assessed	2B (Possible - inhalation only)	Anticipated (inhalation only)
7439-93-2	Lithium	Not Assessed	Not Assessed	Not Listed
7439-98-7	Molybdenum	Not Assessed	Not Assessed	Not Listed
7440-02-0	Nickel	A (Known - inhalation only)	2A (Probable - inhalation only)	Known (inhalation only)
14797-73-0	Perchlorate	D (Not Likely)	Not Assessed	Not Listed
7440-22-4	Silver	D (Not Likely)	Not Assessed	Not Listed
7440-62-2	Vanadium	Not Assessed	Not Assessed	Not Listed
7440-66-6	Zinc	D (Not Likely)	Not Assessed	Not Listed
Organics				
83-32-9	Acenaphthene	Not Assessed	3 (Not Classifiable)	Not Listed
67-64-1	Acetone	Inadequate Information	Not Assessed	Not Listed
120-12-7	Anthracene	D (Not Likely)	3 (Not Classifiable)	Not Listed
319-84-6	*alpha*-BHC (*alpha*-benzene hexachloride)	B2 (Likely)	Not Assessed	Anticipated
56-55-3	Benzo(a)anthracene	B2 (Likely)	2B (Possible)	Anticipated
205-99-2	Benzo(b)fluoranthene	B2 (Likely)	2B (Possible)	Anticipated
207-08-9	Benzo(k)fluoranthene	B2 (Likely)	2B (Possible)	Anticipated
65-85-0	Benzoic acid	D (Not Likely)	Not Assessed	Not Listed
78-93-3	2-Butanone (methyl ethyl ketone)	Inadequate Information	Not Assessed	Not Listed
75-15-0	Carbon disulfide	Not Assessed	Not Assessed	Not Listed
218-01-9	Chrysene	B2	2B (Possible)	Anticipated
53-70-3	Dibenzo(a,h)anthracene	B2	2A (Probable)	Anticipated
1918-00-9	Dicamba	Not Assessed	Not Assessed	Not Listed
75-71-8	Dichlorodifluoromethane	Not Assessed	Not Assessed	Not Listed
75-34-3	1,1-Dichloroethane	C (Suggestive)	Not Classified	Not Listed

CASRN	**Constituent**	**IRIS**	**IARC**	**NTP**
84-66-2	Diethyl phthalate	D (Not Likely)	Not Assessed	Not Listed
84-74-2	Di-*n*-butyl phthalate	D (Not Likely)	Not Assessed	Not Listed
99-65-0	1,3-Dinitrobenzene	D (Not Likely)	Not Assessed	Not Listed
121-14-2	2,4-Dinitrotoluene	B2 (Likely)	2B (Possible - oral only)	Not Listed
606-20-2	2,6-Dinitrotoluene	B2 (Likely)	2B (Possible - oral only)	Not Listed
123-91-1	1,4-Dioxane (*p*-dioxane)	B2 (Likely)	2B (Possible)	Anticipated
206-44-0	Fluoranthene	D (Not Likely)	3 (Not Classifiable)	Not Listed
86-73-7	Fluorene	D (Not Likely)	3 (Not Classifiable)	Not Listed
13252-13-6	HFPO-DA (hexafluoropropylene oxide dimer acid, GenX)	Not Assessed	Not Assessed	Not Listed
2691-41-0	HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	D (Not Likely)	Not Assessed	Not Listed
193-39-5	Indeno(1,2,3-c,d)pyrene	B2 (Likely)	2B (Possible)	Anticipated
98-82-8	Isopropylbenzene (cumene)	D (Not Likely)	2B (Possible - inhalation only)	Anticipated
93-65-2	MCPP (mecoprop)	Not Assessed	Not Assessed	Not Listed
1634-04-4	MTBE (methyl tertiary-butyl ether)	Not Assessed	3 (Not Classifiable)	Not Listed
90-12-0	1-Methylnaphthalene	Not Assessed	Not Assessed	Not Listed
91-57-6	2-Methylnaphthalene	Inadequate Information	Not Assessed	Not Listed
95-48-7	2-Methylphenol (*o*-cresol)	C (Suggestive)	Not Assessed	Not Listed
91-20-3	Naphthalene	C (Suggestive)	2B (Possible - inhalation only)	Anticipated (inhalation only)
98-95-3	Nitrobenzene	B2 (Likely)	2B (Possible)	Anticipated
375-73-5	PFBS (perfluorobutanesulfonic acid)	Not Assessed	Not Classified	Not Listed
355-46-4	PFHxS (perfluorohexanesulfonic acid)	Not Assessed	Not Classified	Not Listed
375-95-1	PFNA (perfluorononanoic acid)	Not Assessed	Not Classified	Not Listed
335-67-1	PFOA (perfluorooctanoic acid)	Not Assessed	2B (Possible - oral only)	Not Listed

CASRN	Constituent	IRIS	IARC	NTP
1763-23-1	PFOS (perfluorooctanesulfonic acid)	Not Assessed	Not Assessed	Not Listed
129-00-0	Pyrene	D (Not Likely)	3 (Not Classifiable)	Not Listed
121-82-4	RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine)	C (Suggestive)	Not Assessed	Not Listed
118-96-7	TNT (2,4,6-trinitrotoluene)	C (Suggestive)	3 (Not Classifiable)	Not Listed
99-35-4	1,3,5-Trinitrobenzene	Not Assessed	Not Assessed	Not Listed

Sources:
IRIS: U.S. EPA Integrated Risk Information System, available at: https://www.epa.gov/iris
IARC: World Health Organization International Agency for Research on Cancer, available at: https://monographs.iarc.who.int/list-of-classifications
NTP: U.S. Department of Health and Human Services National Toxicology Program 15th Report on Carcinogens, 2021, available at: https://ntp.niehs.nih.gov/

Attachment

12

Additional Performance Data Associated with Multi-Laboratory Validation of SW-846 Methods 3512 and 8327

Date: 07-15-2021
Author: United States Environmental Protection Agency
Docket No. EPA-HQ-OLEM-2018-0846

Groundwater % Recovery statistics, 200 ng/L (nom.) concentration[1]

Target Analyte	Lab 2 (n=5) % Recovery		Lab 4 (n=5) % Recovery		Lab 5 (n=5) % Recovery		Lab 6 (n=5) % Recovery		Lab 10 (n=5) % Recovery		Lab 11 (n=5) % Recovery		Lab 12 (n=5) % Recovery		Lab 16 (n=5) % Recovery		Summary Statistics All Labs		
	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}$[2] (%)	S_w[3] (%)	S_b[4] (%)
PFBA	90.7	2.3	110	6.7	108	4.3	91.7	2.6	82.3	10.0	93.9	2.3	89.8	5.5	112	7.6	97.2	5.8	11.0
PFPeA	107	7.3	109	8.2	113	8.0	96.8	1.6	81.8	2.0	91.6	2.1	91.9	2.9	111	3.9	100	5.2	11.3
PFHxA	89.0	7.5	104	17.1	103	10.6	97.4	1.7	93.7	2.6	93.3	1.7	91.0	2.9	104	14.0	96.9	9.2	6.1
PFHpA	93.0	3.7	105	9.0	106	6.6	96.8	3.3	95.3	5.1	97.4	3.2	91.9	5.5	104	13.7	98.8	7.1	5.7
PFOA	98.8	12.3	107	5.5	111	9.0	97.3	2.4	93.4	3.9	107	2.7	91.2	5.9	111	21.0	102	9.8	7.8
PFNA	93.4	5.9	107	13.5	115	10.3	98.6	1.1	94.8	2.1	106	3.5	90.9	6.2	99.3	11.8	101	8.1	8.1
PFDA	95.7	4.4	104	17.2	109	5.7	95.4	2.7	95.6	5.5	111	7.1	95.3	8.1	110	14.4	102	9.4	7.2
PFUnA	87.0	12.4	101	6.9	115	6.2	100	2.4	89.7	4.0	107	6.0	89.7	7.3	136	15.4	103	8.6	16.4
PFDoA	83.0	3.9	101	3.6	106	5.3	97.4	2.1	91.4	4.0	99.9	5.4	93.5	5.9	150	10.7	103	5.6	20.4
PFTriA	73.2	6.7	103	5.5	124	8.3	95.7	3.0	91.7	4.4	99.6	4.1	87.4	14.7	120	12.4	99.3	8.4	16.6
PFTreA	76.1	6.7	90.3	9.9	99.5	11.0	89.3	4.0	87.8	4.5	100	3.0	83.0	15.2	117	24.7	92.9	12.0	12.6
PFBS	93.1	4.5	108	11.9	109	13.0	98.3	2.7	101	1.7	95.7	2.0	92.3	2.8	107	15.1	101	8.5	6.7
PFPeS	88.9	6.5	108	6.1	103	4.3	102	1.3	98.1	1.0	94.9	2.1	91.0	3.7	109	7.3	99.2	4.7	7.4
PFHxS	98.6	6.8	96.8	6.5	105	5.7	101	1.3	99.4	2.1	98.8	7.8	92.2	3.6	113	7.3	101	5.6	6.0
PFHpS	89.2	5.5	105	9.2	106	4.6	101	2.2	94.9	2.4	110	5.2	92.1	4.6	114	1.6	102	5.0	8.9
PFOS	95.9	8.5	108	11.7	116	7.1	99.8	2.4	99.5	2.0	107	3.8	90.7	5.5	125	5.6	105	6.6	11.1
PFNS	92.3	9.0	106	5.3	121	5.0	103	1.2	92.4	2.8	114	6.7	91.4	5.5	130	7.1	106	5.8	14.3
PFDS	88.0	3.6	100	9.4	121	9.1	97.8	2.0	85.8	2.1	107	4.3	88.2	5.6	130	9.3	102	6.4	16.1
PFOSA	90.8	3.0	99.5	5.4	111	7.1	96.8	1.3	90.0	3.4	93.4	2.7	84.5	2.2	112	3.8	97.3	4.0	10.0
FtS 4:2	91.3	7.7	106	9.0	111	6.6	93.3	2.0	79.4	4.0	92.8	3.4	93.9	7.3	113	6.9	97.6	6.3	11.4
FtS 6:2	94.4	20.4	103	9.1	112	15.7	102	2.8	188	217	38.1	2.8	84.6	7.5	54.4	3.5	97.1	77.4	44.8
FtS 8:2	88.5	13.5	109	16.7	119	10.0	107	3.2	101	8.6	115	4.6	93.0	8.9	109	10.0	105	10.3	10.5
NMeFOSAA	91.7	12.5	104	10.1	133	30.5	94.7	1.4	92.8	3.5	105	3.5	93.0	7.6	112	7.1	103	12.9	14.1
NEtFOSAA	91.3	10.2	111	16.8	155	24.7	96.2	1.7	93.9	4.4	102	3.5	92.7	6.6	120	5.7	108	11.8	21.4

[1]% Recovery of each replicate sample was calculated after subtracting the mean unspiked concentration (n=5) by matrix determined at each laboratory

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Groundwater % Recovery statistics, 60 ng/L (nom.) concentration[1]

Target Analyte	Lab 2 (n=5) % Recovery		Lab 4 (n=5) % Recovery		Lab 5 (n=5) % Recovery		Lab 6 (n=5) % Recovery		Lab 10 (n=5) % Recovery		Lab 11 (n=5) % Recovery		Lab 12 (n=5) % Recovery		Lab 16 (n=5) % Recovery		Summary Statistics All Labs		
	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}^2$ (%)	$S_w{}^3$ (%)	$S_b{}^4$ (%)
PFBA	88.0	13.7	124	6.7	95.9	11.6	74.7	14.9	87.2	9.3	102	7.7	87.6	7.1	124	34.0	98.0	15.6	17.9
PFPeA	97.6	13.1	124	5.5	109	9.5	89.5	4.5	83.5	5.5	98.5	9.5	106	6.9	194	84.1	113	30.7	34.9
PFHxA	85.9	13.4	106	11.3	99.0	13.2	86.5	7.8	99.5	4.1	99.6	7.9	91.0	8.4	92.4	28.3	95.0	13.7	7.1
PFHpA	89.3	15.5	108	8.7	100	7.9	85.7	3.3	94.1	7.2	105	15.4	87.8	6.8	99.7	16.7	96.2	11.2	8.3
PFOA	88.4	21.4	109	6.5	91.6	13.8	91.9	4.4	96.5	5.4	111	12.8	92.1	6.5	111	10.0	98.8	11.4	9.6
PFNA	87.8	12.8	105	12.5	100	10.1	84.9	4.7	90.1	5.6	114	16.8	84.2	8.0	105	21.7	96.5	12.7	11.2
PFDA	85.3	14.6	98.4	13.5	109	11.7	82.7	4.6	96.6	4.8	112	14.2	82.8	11.6	118	35.1	98.2	16.4	14.0
PFUnA	84.7	14.6	91.0	17.6	107	9.2	86.7	4.6	86.5	4.1	104	12.3	87.1	8.1	121	18.7	96.0	12.3	13.2
PFDoA	87.2	19.2	72.6	7.2	106	9.8	84.5	3.3	91.4	4.0	110	16.3	86.2	12.7	146	30.4	98.0	15.4	22.7
PFTriA	75.1	8.6	73.0	7.5	133	13.1	84.6	4.2	91.6	6.6	110	11.4	76.8	5.7	122	24.3	95.8	11.8	23.1
PFTreA	72.8	8.3	68.2	14.4	103	9.1	78.9	7.1	87.6	4.8	123	17.0	74.3	16.9	98.2	23.5	88.2	13.9	18.6
PFBS	92.8	15.4	108	22.2	99.4	13.2	87.9	2.1	104.8	10.2	96.0	8.7	104	21.9	99.0	21.0	99.1	15.9	6.8
PFPeS	81.4	12.3	105	7.6	101	4.8	90.8	2.8	95.5	4.7	101	4.6	90.7	2.5	102	10.9	95.8	7.1	7.8
PFHxS	88.5	15.1	66.8	10.5	103	9.7	93.2	3.4	99.3	7.6	102	23.2	89.7	2.0	117	12.9	94.9	12.3	14.5
PFHpS	82.1	21.9	98.7	15.4	98.7	9.3	90.9	5.3	94.6	5.7	110	12.8	89.8	3.7	116	8.6	97.5	11.8	10.9
PFOS	82.6	13.4	110	21.5	116	10.5	91.7	5.3	98.7	8.9	111	19.7	88.1	4.3	122	14.7	103	13.6	14.3
PFNS	81.4	19.5	87.0	8.3	118	5.2	92.1	5.0	92.8	7.6	126	9.5	86.3	5.9	115	12.2	99.8	10.2	17.0
PFDS	70.1	16.3	86.2	11.1	118	8.9	90.0	5.6	86.5	3.3	114	10.3	82.1	5.4	118	6.1	95.6	9.2	18.3
PFOSA	77.2	10.6	80.0	7.0	93.2	12.0	84.8	5.5	91.0	5.7	100	8.0	81.6	3.5	109	5.6	89.6	7.7	10.9
FtS 4:2	73.1	14.5	97.3	33.6	106	20.8	84.6	4.4	72.5	9.7	95.1	8.2	93.3	4.7	107	15.3	91.0	16.6	13.2
FtS 6:2	80.5	9.2	87.8	19.3	96.6	11.6	90.5	4.5	77.2	42.4	39.6	5.2	86.8	7.1	45.8	6.8	75.6	17.8	21.2
FtS 8:2	82.7	29.4	99.1	7.6	115	29.2	93.6	4.3	98.7	8.8	119	11.3	92.1	11.4	108	30.0	101	19.4	12.1
NMeFOSAA	79.6	17.0	116	29.9	91.7	16.2	83.8	4.3	94.8	5.1	107	19.0	85.2	8.8	110	11.7	96.0	16.1	13.4
NEtFOSAA	72.8	37.1	77.6	18.9	136	36.1	86.4	4.2	97.5	4.5	104	13.4	83.3	7.1	124	14.2	97.6	20.9	22.4

[1]% Recovery of each replicate sample was calculated after subtracting the mean unspiked concentration (n=5) by matrix determined at each laboratory

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Reagent water % Recovery statistics, 200 ng/L (nom.) concentration[1]

Target Analyte	Lab 2 (n=5) % Recovery		Lab 4 (n=5) % Recovery		Lab 5 (n=5) % Recovery		Lab 6 (n=5) % Recovery		Lab 10 (n=5) % Recovery		Lab 11 (n=5) % Recovery		Lab 12 (n=5) % Recovery		Lab 16 (n=5) % Recovery		Summary Statistics All Labs		
	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}^2$ (%)	S_w [3] (%)	S_b [4] (%)
PFBA	110	8.0	111	7.2	109	8.7	88.4	10.6	65.1	10.5	94.9	4.5	86.3	7.7	107	20.1	96.4	10.6	16.1
PFPeA	118	4.5	112	7.1	112	4.4	90.2	4.9	85.4	3.0	86.7	4.9	90.8	3.7	107	2.1	100	4.6	13.1
PFHxA	104	4.7	116	5.4	104	8.7	91.1	5.6	94.2	1.7	92.1	3.0	93.1	6.4	102	18.2	99.5	8.2	8.5
PFHpA	108	4.8	110	7.7	110	3.6	94.5	1.7	97.2	3.0	97.0	3.3	87.4	4.4	107	13.9	101	6.4	8.4
PFOA	111	9.3	110	7.8	115	7.9	93.6	1.7	94.5	1.5	102	5.3	94.4	6.1	114	14.6	104	7.9	9.3
PFNA	106	2.3	113	3.8	118	1.8	95.7	2.0	90.9	3.2	104	3.9	91.0	5.3	110	17.6	104	7.0	10.1
PFDA	106	10.8	116	35.8	119	10.6	98.0	1.6	94.9	3.0	101	2.5	97.1	7.3	111	7.5	106	14.3	9.3
PFUnA	96.9	15.6	107	8.8	119	4.1	99.1	1.9	93.8	3.0	97.5	4.9	89.5	9.9	134	8.9	105	8.3	14.8
PFDoA	90.5	10.0	101	7.3	110	7.5	99.3	3.3	95.6	1.8	100	3.8	93.4	7.0	134	13.6	103	7.7	13.9
PFTriA	85.5	5.6	97.5	21.2	130	12.0	104	3.5	97.8	2.8	101	9.2	84.7	11.3	121	12.2	103	11.2	15.7
PFTreA	84.5	9.7	83.8	21.1	115	12.9	104	3.9	96.5	3.0	111	11.3	88.1	8.6	127	18.5	101	12.6	15.7
PFBS	106	4.9	114	17.1	112	5.2	92.2	4.0	93.4	10.3	90.6	4.3	91.3	2.7	102	14.0	100	9.3	9.4
PFPeS	101	4.4	109	8.2	98.5	8.5	92.1	3.1	97.4	2.1	91.4	3.8	92.5	4.5	110	9.8	99.0	6.2	7.4
PFHxS	106	11.5	97.0	4.1	112	3.2	95.4	0.9	98.9	2.4	94.6	9.7	91.8	3.1	114	10.4	101	6.9	8.3
PFHpS	95.4	7.9	110	3.2	113	5.0	98.4	0.8	95.7	3.9	104	1.7	93.0	5.0	121	7.0	104	4.9	10.1
PFOS	96.8	4.8	113	11.5	118	3.4	98.2	2.3	99.0	2.9	102	4.1	87.3	5.6	119	6.3	104	5.8	11.2
PFNS	104	15.4	102	7.2	126	9.5	98.5	0.9	94.3	1.3	105	3.9	90.8	3.5	129	7.6	106	7.6	13.9
PFDS	96.8	11.8	98.9	5.3	127	13.0	100	2.2	87.6	4.6	102	4.1	89.4	3.9	127	4.4	104	7.2	15.2
PFOSA	88.8	5.0	96.2	7.3	106	1.8	94.3	1.5	87.0	3.0	90.8	4.2	72.9	2.4	101	5.1	92.1	4.2	10.0
FtS 4:2	109	9.0	115	6.1	108	8.1	92.9	4.3	105	4.0	94.0	3.0	96.9	7.9	111	7.3	104	6.5	8.3
FtS 6:2	105	7.3	105	9.4	112	9.6	104	5.2	113	27.7	53.3	34.3	85.3	8.6	60.6	4.7	92.3	17.0	23.5
FtS 8:2	99.7	13.1	109	8.4	126	12.4	105	2.2	111	9.7	111	4.1	90.0	10.1	120	19.2	109	11.1	11.1
NMeFOSAA	102	11.9	98.5	10.8	111	23.6	98.8	1.3	97.2	4.1	92.3	4.9	88.0	4.3	116	14.0	100	11.6	9.2
NEtFOSAA	89.5	11.4	103	30.7	141	23.7	98.9	1.9	99.5	2.4	89.6	3.2	89.6	7.3	121	16.2	104	15.7	18.3

[1]% Recovery of each replicate sample was calculated after subtracting the mean unspiked concentration (n=5) by matrix determined at each laboratory

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Reagent water % Recovery statistics, 60 ng/L (nom.) concentration[1]

Target Analyte	Lab 2 (n=5) % Recovery		Lab 4 (n=5) % Recovery		Lab 5 (n=5) % Recovery		Lab 6 (n=5) % Recovery		Lab 10 (n=5) % Recovery		Lab 11 (n=5) % Recovery		Lab 12 (n=5) % Recovery		Lab 16 (n=5) % Recovery		Summary Statistics All Labs		
	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}$[2] (%)	S_w[3] (%)	S_b[4] (%)
PFBA	103	13.6	119	10.7	112	16.7	85.4	3.3	58.5	17.0	96.3	5.8	75.5	4.7	96.4	20.8	93.1	13.1	19.6
PFPeA	104	6.0	120	18.1	111	12.2	87.5	3.5	88.4	9.3	115	16.7	89.3	2.1	117	23.7	104	13.5	13.7
PFHxA	99.8	10.2	111	15.9	105	14.2	90.2	5.2	97.8	12.7	99.2	6.2	87.2	6.9	89.2	16.1	97.4	11.7	8.2
PFHpA	101	8.6	111	8.0	113	4.5	87.8	5.5	94.7	9.1	104	6.0	83.5	5.6	92.6	15.9	98.5	8.6	10.7
PFOA	105	15.0	108	10.2	106	10.8	88.8	2.8	93.8	13.3	110	7.0	84.1	11.9	104	14.9	100	11.4	9.7
PFNA	97.0	9.9	103	5.6	111	9.8	90.0	4.9	93.7	12.9	105	9.2	83.5	7.1	92.6	13.8	97.0	9.6	8.9
PFDA	88.6	7.1	126	31.0	111	22.0	92.6	5.4	97.8	11.6	108	10.2	82.1	9.7	110	19.0	102	16.6	14.4
PFUnA	87.8	9.7	87.2	15.4	123	15.5	92.7	3.9	93.5	11.9	106	3.4	83.9	10.2	118	23.5	98.9	13.2	14.7
PFDoA	81.2	19.0	73.0	15.1	106	19.1	91.7	5.8	95.9	10.5	103	12.2	85.3	13.0	131	32.3	95.8	17.5	17.9
PFTriA	77.9	12.4	78.8	18.0	120	19.2	93.6	5.5	100	11.1	111	11.0	76.0	14.1	125	15.6	97.7	14.0	19.3
PFTreA	66.3	12.7	73.3	26.3	108	22.5	92.4	8.7	97.9	11.0	111	7.7	80.4	11.5	135	9.2	95.5	15.1	22.6
PFBS	94.6	11.6	102	16.4	96.5	9.7	87.0	5.4	91.7	16.1	92.4	8.9	89.1	3.0	88.6	11.7	92.7	11.3	4.9
PFPeS	98.4	11.5	107	8.9	99.4	6.0	88.3	3.4	96.6	11.0	95.6	4.9	88.6	4.2	100	11.3	96.8	8.3	6.2
PFHxS	99.3	11.2	68.2	13.6	111	14.5	92.9	5.8	100	12.4	99.3	9.1	87.9	4.4	104	10.8	95.3	10.8	12.9
PFHpS	95.7	16.5	104	10.4	107	13.0	92.8	5.8	95.4	9.1	112	8.9	88.4	4.9	115	16.8	101	11.5	9.5
PFOS	90.5	5.0	112	35.3	113	11.6	92.8	3.5	98.0	9.1	102	15.9	74.9	5.0	117	14.7	100	15.8	14.0
PFNS	80.4	10.2	103	4.5	121	13.4	92.9	4.9	97.2	4.8	113	8.1	87.4	3.0	119	18.9	102	9.9	14.9
PFDS	84.5	9.7	84.0	11.4	117	22.0	94.9	6.9	91.4	9.7	106	6.8	84.4	5.0	119	16.3	97.7	12.2	14.6
PFOSA	78.6	6.1	88.5	12.7	96.0	7.0	83.8	3.5	86.9	7.0	97.3	7.7	74.7	3.0	95.7	12.7	87.7	8.2	8.4
FtS 4:2	93.7	18.5	110	31.2	103	14.1	90.4	6.5	97.0	10.7	100	9.6	91.8	7.1	102	14.8	98.5	15.9	6.5
FtS 6:2	100	20.0	98.2	16.0	99.3	17.8	96.2	7.0	128	84.3	39.2	6.0	87.9	6.6	35.0	21.0	85.5	32.9	32.0
FtS 8:2	96.3	9.3	95.6	17.0	109	12.9	103	6.5	119	15.4	115	10.5	92.7	8.4	110	16.6	105	12.6	9.6
NMeFOSAA	100	15.3	92.3	29.3	120	25.6	93.0	3.1	101	11.6	95.4	10.0	84.6	10.1	103	12.6	98.6	16.8	10.5
NEtFOSAA	88.6	9.1	71.7	19.6	127	39.9	94.0	5.4	102	14.0	94.7	8.8	82.3	12.5	112	12.3	96.5	18.3	17.2

[1]% Recovery of each replicate sample was calculated after subtracting the mean unspiked concentration (n=5) by matrix determined at each laboratory

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Surface water % Recovery statistics, 200 ng/L (nom.) concentration[1]

Target Analyte	Lab 2 (n=5) % Recovery		Lab 4 (n=5) % Recovery		Lab 5 (n=5) % Recovery		Lab 6 (n=5) % Recovery		Lab 10 (n=5) % Recovery		Lab 11 (n=5) % Recovery		Lab 12 (n=5) % Recovery		Lab 16 (n=5) % Recovery		Summary Statistics All Labs		
	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}^2$ (%)	S_w [3] (%)	S_b [4] (%)
PFBA	85.0	6.8	109	7.3	113	5.7	76.4	14.0	64.2	5.8	93.6	2.8	87.4	6.4	93.3	18.3	90.2	9.7	16.0
PFPeA	98.6	3.7	115	3.6	113	4.9	109	1.6	83.7	4.1	88.3	4.5	88.7	3.1	100	4.0	99.5	3.8	11.9
PFHxA	91.9	3.4	109	8.0	111	10.7	102	2.5	92.4	2.7	95.4	3.3	94.4	8.4	95.6	13.2	98.9	7.6	7.4
PFHpA	98.8	4.0	108	7.1	110	4.0	102	3.2	96.3	4.6	99.0	5.1	90.7	1.9	95.1	11.6	100	5.9	6.4
PFOA	98.6	10.7	110	7.4	111	5.1	103	4.0	92.8	1.6	107	4.5	89.1	8.8	109	6.8	103	6.7	8.3
PFNA	95.0	9.7	110	9.0	117	5.9	108	3.4	92.3	2.9	107	7.1	83.1	8.4	95.4	12.9	101	8.1	11.2
PFDA	91.7	8.3	108	16.4	116	2.1	107	5.3	96.2	4.9	108	6.9	90.8	7.9	109	16.2	104	9.8	9.3
PFUnA	94.1	10.5	106	6.7	123	2.8	105	5.0	90.6	2.8	99.1	4.6	88.7	7.7	118	13.9	103	7.7	12.4
PFDoA	74.6	5.7	105	7.4	118	5.3	105	2.7	91.7	4.0	102	3.5	83.0	7.9	131	21.9	101	9.3	18.3
PFTriA	75.4	7.9	110	3.5	128	8.5	100	3.0	92.6	2.7	102	1.9	78.4	10.9	109	12.8	99.4	7.5	17.2
PFTreA	73.7	8.3	102	13.7	114	5.8	90.4	4.2	90.3	2.1	111	2.8	74.6	10.0	97.3	8.8	94.1	7.9	14.9
PFBS	93.8	3.7	115	13.7	112	7.6	96.6	2.7	98.2	1.3	94.6	5.7	89.8	2.0	94.1	11.2	99.2	7.3	9.0
PFPeS	86.4	6.4	111	4.8	106	3.5	99.1	1.9	95.1	1.9	96.7	3.5	89.8	1.0	105	6.5	98.7	4.2	8.4
PFHxS	99.7	7.2	104	9.6	110	7.1	99.1	1.0	96.3	2.3	101	5.5	90.8	2.9	109	7.0	101	6.0	6.5
PFHpS	86.1	7.7	103	5.3	112	2.8	101	1.4	93.3	2.4	106	3.0	91.2	2.6	109	15.3	100	6.6	9.1
PFOS	94.2	4.0	103	12.7	119	5.6	101	2.0	98.3	1.5	108	4.1	90.7	3.7	112	9.2	103	6.4	9.4
PFNS	99.1	15.6	109	9.9	125	5.2	101	0.9	93.2	2.7	112	3.1	88.6	1.6	117	8.0	106	7.5	12.2
PFDS	80.0	11.0	103	3.3	126	9.0	99.2	1.8	85.7	1.8	107	2.7	85.3	3.0	115	8.0	100	6.1	15.9
PFOSA	90.4	3.4	95.1	5.6	104	5.1	93.9	1.1	88.9	3.1	93.6	2.9	84.0	2.3	103	5.9	94.2	4.0	6.9
FtS 4:2	83.3	10.7	107	10.6	113	3.2	118	22.2	93.6	6.8	95.1	3.4	94.7	6.4	104	6.1	101	10.4	11.5
FtS 6:2	106	12.6	102	5.6	103	4.7	125	26.6	74.8	10.1	39.8	2.3	84.8	10.0	54.4	3.2	86.2	11.9	28.6
FtS 8:2	95.7	13.6	103	20.9	130	14.0	118	13.6	105	9.8	107	4.4	93.1	9.3	103	10.4	107	12.8	12.1
NMeFOSAA	89.7	11.6	106	21.3	135	23.2	101	2.4	95.4	3.3	101	4.2	87.3	8.0	109	13.3	103	13.2	14.9
NEtFOSAA	92.5	11.8	108	9.6	149	12.2	102	3.3	97.2	4.4	97.2	3.1	88.2	7.1	110	11.9	105	8.7	19.1

[1]% Recovery of each replicate sample was calculated after subtracting the mean unspiked concentration (n=5) by matrix determined at each laboratory

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Surface water % Recovery statistics, 60 ng/L (nom.) concentration[1]

Target Analyte	Lab 2 (n=5) % Recovery		Lab 4 (n=5) % Recovery		Lab 5 (n=5) % Recovery		Lab 6 (n=5) % Recovery		Lab 10 (n=5) % Recovery		Lab 11 (n=5) % Recovery		Lab 12 (n=5) % Recovery		Lab 16 (n=5) % Recovery		Summary Statistics All Labs		
	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}$[2] (%)	S_w[3] (%)	S_b[4] (%)
PFBA	78.9	12.9	124	9.2	111	10.7	76.5	24.5	54.2	9.0	85.0	4.1	84.0	12.6	80.8	30.3	86.7	16.4	21.4
PFPeA	84.8	13.2	130	7.7	104	9.2	114	8.3	76.4	6.7	101	16.8	101	8.4	109	6.6	103	10.2	16.6
PFHxA	84.2	11.9	131	24.3	114	28.3	97.4	9.3	89.5	6.1	93.8	6.8	93.7	10.1	82.0	21.6	98.2	16.9	16.6
PFHpA	86.1	13.4	114	15.7	107	12.9	96.8	2.3	84.5	3.6	96.2	6.4	91.4	9.9	88.5	22.3	95.6	12.5	10.4
PFOA	95.7	27.7	111	10.4	113	18.6	104	4.8	84.7	5.3	103	10.9	90.0	9.2	103	11.3	101	14.2	9.8
PFNA	80.7	12.9	105	17.7	109	12.5	104	3.7	82.9	6.5	104	8.0	86.8	6.6	88.5	12.7	95.1	10.9	11.4
PFDA	82.5	8.9	101	31.0	113	10.2	102	5.5	88.1	5.9	104	2.9	82.5	12.9	104	13.8	97.2	14.0	11.3
PFUnA	80.6	15.4	95.3	13.0	104	24.7	104	4.7	80.2	4.8	102	4.1	86.7	13.2	117	29.9	96.3	16.4	13.1
PFDoA	76.7	18.4	76.5	8.0	108	12.9	103	5.6	83.0	2.1	96.7	5.9	83.6	21.8	125	9.5	93.9	12.3	17.0
PFTriA	62.7	16.0	77.7	21.7	124	24.9	98.6	4.7	89.6	6.9	101	4.2	76.9	11.8	108	9.9	92.3	14.4	19.7
PFTreA	52.4	16.5	85.5	13.7	98.5	13.1	84.5	10.3	90.6	5.8	105	6.2	74.1	18.3	79.6	17.9	83.8	13.5	16.1
PFBS	90.5	14.8	110	13.5	99.4	16.6	97.5	4.8	87.8	3.3	90.8	4.8	99.3	12.8	84.3	22.8	94.9	13.3	8.2
PFPeS	77.3	14.8	109	11.2	102	14.0	97.9	3.7	87.2	5.1	94.5	2.9	93.4	8.0	101	15.2	95.3	10.5	9.8
PFHxS	84.6	15.6	114	11.1	108	9.0	95.5	4.0	88.1	4.1	84.3	6.5	94.3	9.0	107	7.1	96.9	9.0	11.4
PFHpS	82.3	20.5	96.4	12.5	102	14.5	99.9	4.9	82.7	3.6	107	4.6	91.2	7.6	111	6.4	96.5	10.9	10.5
PFOS	95.5	18.6	107	26.4	119	14.5	101	3.5	89.2	2.3	101	6.4	97.5	11.1	119	10.1	104	13.8	10.8
PFNS	67.4	5.9	98.4	15.2	119	15.7	99.6	2.4	87.0	4.2	114	8.2	89.2	8.9	120	9.2	99.4	9.8	18.2
PFDS	70.2	11.8	77.6	24.6	116	17.7	101	4.4	82.3	3.1	104	10.1	87.1	10.2	117	15.5	94.4	13.8	17.6
PFOSA	67.0	9.0	68.7	6.3	94.7	9.1	88.6	3.4	76.5	6.1	98.6	22.8	85.6	6.8	101	3.7	85.2	10.2	13.2
FtS 4:2	72.0	17.9	89.2	17.0	113	18.7	106	6.5	79.0	6.4	86.1	6.2	91.9	8.6	101	9.0	92.2	12.4	13.7
FtS 6:2	93.1	15.8	102	28.0	119	12.4	113	10.0	-4.3	18.5	494	1030	85.5	6.9	41.2	6.5	130	363	153
FtS 8:2	75.6	10.3	104	22.3	92.9	26.5	118	12.1	88.4	6.6	104	9.0	83.5	12.0	84.8	7.3	93.9	14.9	13.8
NMeFOSAA	74.0	21.2	94.0	14.3	143	53.7	97.8	1.8	85.5	3.9	92.4	3.6	89.8	8.3	111	21.0	98.5	22.6	20.9
NEtFOSAA	75.3	25.7	88.8	37.5	137	20.4	105	2.9	87.1	6.0	91.9	7.4	86.0	9.1	121	12.8	99.0	18.8	20.7

[1]% Recovery of each replicate sample was calculated after subtracting the mean unspiked concentration (n=5) by matrix determined at each laboratory

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Wastewater % Recovery statistics, 200 ng/L (nom.) concentration[1]

	Lab 2 (n=5) % Recovery		Lab 4 (n=5) % Recovery		Lab 5 (n=5) % Recovery		Lab 6 (n=5) % Recovery		Lab 10 (n=5) % Recovery		Lab 11 (n=5) % Recovery		Lab 12 (n=5) % Recovery		Lab 16 (n=5) % Recovery		Summary Statistics All Labs		
Target Analyte	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}^2$ (%)	S_w [3] (%)	S_b [4] (%)
PFBA	82.0	6.6	110	8.2	109	9.0	77.8	18.3	80.7	9.9	96.4	3.5	92.0	5.2	115	25.0	95.4	12.7	14.7
PFPeA	100	6.5	118	4.9	115	6.3	103	6.1	81.3	3.8	86.2	2.0	93.6	3.6	115	10.5	102	6.0	13.8
PFHxA	95.4	3.8	110	9.1	109	9.6	100	6.6	91.1	6.0	95.6	3.7	98.8	5.9	90.0	30.7	98.7	12.5	7.3
PFHpA	95.7	3.4	108	10.3	110	6.0	103	5.0	92.1	4.0	98.4	2.8	94.6	3.7	98.7	21.9	100	9.3	6.4
PFOA	99.6	10.9	107	6.6	114	10.2	107	4.5	89.1	5.2	109	4.6	93.4	6.4	111	11.8	104	8.0	8.8
PFNA	97.3	5.0	107	7.1	115	8.8	106	3.7	90.8	3.9	110	4.7	91.4	10.2	109	18.1	103	8.9	9.0
PFDA	99.3	8.7	113	21.7	119	1.3	112	4.4	93.4	4.0	111	9.7	97.7	15.0	105	13.5	106	11.6	8.9
PFUnA	87.7	8.9	103	11.8	125	3.8	109	6.5	88.2	4.6	103	3.8	91.5	10.8	141	19.4	106	10.0	18.7
PFDoA	81.3	5.3	103	7.3	101	17.5	108	5.8	88.8	4.8	98.5	3.6	88.9	15.0	140	15.0	101	10.7	17.8
PFTriA	69.1	11.3	109	11.4	109	26.4	106	5.4	92.6	5.3	100	4.1	81.8	10.0	119	21.5	98.2	14.1	16.2
PFTreA	69.7	11.0	99.6	15.3	83.6	18.3	89.8	10.1	88.2	4.5	107	6.5	84.5	13.7	113	18.2	91.8	13.1	13.9
PFBS	95.4	7.4	109	7.4	113	7.7	103	5.9	96.8	3.1	92.2	6.7	96.2	2.2	91.2	23.2	99.5	10.0	7.8
PFPeS	93.0	4.4	110	4.7	101	3.3	102	4.7	95.2	3.3	97.6	2.6	93.4	2.8	109	18.0	100	7.3	6.7
PFHxS	101	4.1	115	36.6	115	2.7	103	4.2	97.2	2.4	97.6	4.1	97.3	3.4	119	10.1	106	13.8	9.0
PFHpS	91.9	9.0	107	6.3	115	6.2	102	5.2	95.3	5.9	109	4.0	93.1	5.4	118	7.9	104	6.4	10.1
PFOS	102	10.6	113	6.7	120	4.3	101	15.1	194	145	111	11.8	92.3	7.3	124	7.0	120	51.9	31.8
PFNS	85.5	9.0	106	10.5	112	17.3	103	5.3	92.4	3.0	116	3.2	90.9	5.5	130	11.7	104	9.4	14.7
PFDS	66.7	10.9	101	6.5	92.4	35.6	95.8	3.7	85.8	3.0	107	5.5	89.0	8.2	128	16.2	95.5	15.1	17.5
PFOSA	91.5	2.1	100	3.8	115	1.7	99.2	4.8	88.7	4.0	94.4	1.5	85.8	4.4	114	10.6	98.6	4.9	10.9
FtS 4:2	88.2	5.1	118	10.0	118	8.6	134	16.1	78.7	6.6	99.2	3.2	93.9	5.5	115	16.0	106	10.0	18.6
FtS 6:2	104	8.2	111	12.7	118	13.3	141	18.6	89.5	7.4	41.8	2.5	83.0	9.8	63.4	7.4	93.9	11.0	31.5
FtS 8:2	149	23.5	116	9.7	112	11.0	144	12.3	95.3	11.7	117	1.5	94.0	11.5	120	15.8	118	13.4	19.7
NMeFOSAA	85.1	11.8	110	15.4	110	35.6	101	5.0	90.8	6.2	99.2	3.3	88.0	9.5	116	9.9	100	15.4	11.4
NEtFOSAA	101	6.2	103	10.1	152	16.0	117	5.4	92.0	3.9	96.8	5.7	92.0	7.3	122	13.0	109	9.3	20.2

[1]% Recovery of each replicate sample was calculated after subtracting the mean unspiked concentration (n=5) by matrix determined at each laboratory

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Wastewater % Recovery statistics, 60 ng/L (nom.) concentration[1]

Target Analyte	Lab 2 (n=5) % Recovery		Lab 4 (n=5) % Recovery		Lab 5 (n=5) % Recovery		Lab 6 (n=5) % Recovery		Lab 10 (n=4) % Recovery		Lab 11 (n=5) % Recovery		Lab 12 (n=5) % Recovery		Lab 16 (n=5) % Recovery		Summary Statistics All Labs		
	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}$[2] (%)	S_w[3] (%)	S_b[4] (%)
PFBA	82.8	7.7	123	11.0	115	17.0	84.5	9.5	76.0	19.8	92.9	11.0	98.4	8.9	96.8	23.3	96.1	14.6	15.9
PFPeA	99.6	6.6	122	7.5	124	11.6	99.9	10.9	90.8	15.7	112	15.8	103	13.8	101	9.0	107	11.8	11.6
PFHxA	101	10.0	131	21.9	116	15.2	91.8	9.5	85.8	9.6	90.0	12.0	90.3	12.9	78.4	21.2	97.9	14.8	17.3
PFHpA	98.4	7.3	114	7.5	112	13.1	101	6.9	91.8	2.0	91.6	10.6	97.9	4.7	102	4.0	101	7.8	8.4
PFOA	110	21.4	104	7.9	107	5.8	99.8	6.3	84.5	4.7	95.9	15.5	97.1	8.0	101	10.0	99.8	11.3	7.7
PFNA	91.3	10.3	103	10.1	110	10.1	96.4	8.1	90.2	3.8	104	18.0	92.7	9.6	98.9	18.6	98.3	12.0	6.9
PFDA	97.5	10.2	92.4	24.9	117	17.7	103	9.6	89.5	8.6	96.2	15.1	96.7	21.2	106	24.1	99.8	17.5	8.8
PFUnA	86.3	11.4	83.8	12.3	123	11.3	101	9.2	86.3	7.3	98.6	17.1	89.8	11.2	115	29.2	97.9	15.1	14.3
PFDoA	83.2	9.1	57.4	9.3	97.7	20.0	99.3	7.5	87.8	8.8	98.1	19.7	90.5	10.1	149	24.0	95.4	14.9	25.6
PFTriA	75.9	11.3	75.9	10.3	98.7	29.5	99.8	8.7	93.7	7.0	100	13.1	88.8	14.9	144	39.6	97.1	20.0	21.3
PFTreA	66.0	18.3	58.2	20.7	90.7	26.0	91.0	8.1	90.2	4.4	104	14.3	82.7	15.1	143	21.4	90.7	17.4	25.7
PFBS	105	8.7	110	24.4	111	9.4	97.3	8.5	93.5	1.7	87.4	6.6	102	3.0	92.4	9.5	99.8	11.1	8.6
PFPeS	93.6	11.6	96.6	12.1	100	7.6	100	8.7	90.7	6.8	95.4	2.7	93.0	4.7	99.3	8.4	96.1	8.4	3.6
PFHxS	96.5	10.9	102	5.5	115	12.3	101	10.7	95.8	4.1	81.8	15.5	102	3.3	120	8.4	102	9.7	11.7
PFHpS	95.4	18.0	94.8	15.6	107	11.8	100	8.3	88.9	3.2	101	9.5	94.1	4.8	118	11.0	100	11.3	9.2
PFOS	116	16.4	130	17.2	108	6.0	92.9	10.4	93.9	4.1	95.9	28.5	96.9	6.2	128	7.2	108	14.3	15.2
PFNS	80.8	14.0	90.1	12.0	110	13.3	100	8.0	90.0	2.0	117	2.1	93.5	7.2	121	21.2	100	11.7	14.2
PFDS	80.9	11.5	76.5	10.3	98.9	32.8	93.4	8.9	83.7	5.8	106	7.6	91.0	5.3	128	13.1	94.8	14.5	16.5
PFOSA	88.2	5.2	85.1	7.4	98.5	7.8	91.9	5.4	85.0	5.9	90.5	1.7	88.7	3.1	109	9.2	92.2	6.2	8.2
FtS 4:2	84.9	10.4	98.7	32.3	132	24.8	102	14.7	81.2	3.7	90.4	10.3	93.8	10.0	104	9.0	98.3	16.9	15.7
FtS 6:2	109	6.1	110	18.2	115	24.1	94.3	10.9	107	54.9	39.2	6.5	76.7	11.7	59.6	7.1	88.8	23.2	27.7
FtS 8:2	124	22.5	102	24.5	151	26.6	112	10.5	95.0	14.7	106	4.6	94.0	8.7	98.8	13.8	110	17.4	19.1
NMeFOSAA	93.8	29.1	115	14.0	124	42.6	89.9	6.7	89.3	5.9	87.2	10.8	94.4	7.2	103	12.6	99.5	20.2	13.3
NEtFOSAA	93.9	22.2	74.2	17.1	159	17.6	107	8.2	93.1	7.3	93.6	10.2	95.5	9.4	117	10.4	104	13.8	25.4

[1]% Recovery of each replicate sample was calculated after subtracting the mean unspiked concentration (n=5) by matrix determined at each laboratory

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Lowest Acceptable LLOQ Verification QC Sample Concentrations by Laboratory and Sample Preparation Batch, in ng/L[1]

Lab	Lab 2			Lab 4			Lab 5			Lab 6			Lab 10			Lab 11			Lab 12			Lab 16			Median LLOQ (ng/L); n=24	Median 95% low CI	Median 95% high CI
Batch #	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3			
PFBA	10	10	10	80	80	40	10	20	20	10	10	10	10	20	10	20	20	20	10	10	10	10	10	10	10	10	20
PFPeA	10	10	10	80	80	40	10	20	10	10	10	10	10	20	20	20	20	20	10	10	10	10	10	10	10	10	20
PFHxA	10	10	20	80	80	40	20	10	20	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	20
PFHpA	10	10	10	80	80	40	10	10	10	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	10
PFOA	20	10	20	80	80	40	10	10	20	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	20
PFNA	10	10	10	80	80	40	10	10	10	10	10	10	20	20	10	20	20	20	10	10	10	10	10	10	10	10	20
PFDA	20	10	***160***	80	80	40	10	10	10	10	10	10	10	10	10	20	20	20	20	10	10	10	10	10	10	10	20
PFUnA	10	20	20	80	80	40	10	10	20	10	10	10	10	20	10	20	20	20	10	10	10	10	10	10	10	10	20
PFDoDA	20	20	***160***	80	80	40	10	20	10	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	20
PFTrDA	10	20	20	80	80	40	***160***	40	40	10	10	10	10	20	10	20	20	20	10	10	10	10	10	10	15	10	20
PFTeDA	20	20	20	80	80	40	10	10	10	10	10	10	10	10	10	20	20	20	10	10	10	10	20	10	10	10	20
PFBS	20	10	10	80	80	40	10	10	10	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	20
PFPeS	10	10	10	80	80	40	10	10	10	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	10
PFHxS	10	10	10	80	80	40	10	10	10	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	10
PFHpS	10	10	10	80	80	40	10	10	10	10	10	10	10	10	10	20	20	20	10	10	10	10	20	20	10	10	20
PFOS	20	10	20	80	80	40	10	10	20	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	20
PFNS	10	20	10	80	80	40	10	10	10	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	20
PFDS	10	20	20	80	80	40	20	10	10	10	10	10	10	10	10	20	20	20	10	10	10	10	20	10	10	10	20
PFOSA	10	10	10	80	80	40	10	10	10	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	10
4:2 FTS	10	10	20	80	80	40	10	10	20	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	10	10	20
6:2 FTS	20	10	10	80	80	40	20	10	10	10	10	***160***	***160***	***160***	***160***	**none**	**none**	**none**	20	20	20	***160***	***160***	***160***	60	20	160
8:2 FTS	10	10	20	80	80	40	40	40	40	10	10	10	10	***160***	10	20	20	20	10	10	10	***160***	10	10	15	10	40
NMeFOSAA	20	***160***	***160***	80	80	40	40	20	20	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	15	10	20
NEtFOSAA	***160***	20	***160***	80	80	40	20	20	40	10	10	10	10	10	10	20	20	20	10	10	10	10	10	10	15	10	20

[1]NOTES:

Lower Limits of Quantitation (LLOQs) in the table above are nominal; Preliminary acceptance criterion for LLOQ Verification was 50-150% recovery

95% Confidence Interval (CI) of median is calculated as described in Section 1.3.1 of the Method 8327 Statistical Report; the 95% low and high CI are equivalent to the 7th and 18th ranked values sorted from low to high, respectively.

Values in bold did not meet preliminary LLOQ verification acceptance criteria (50-150% recovery) except at the LCS level (160 ng/L, nominal)

Values in red did not meet preliminary LLOQ verification acceptance criteria (50-150% recovery) at any concentration; These values were considered to be >160 ng/L for determination of median LLOQ and 95% CI

Labs 2, 10, 12, and 16 included LLOQ verifications at 10 and 20 ng/L in each preparation batch

Lab 4 included LLOQ verifications at 80 ng/L in preparation batches 1 and 2 and at 40 ng/L in preparation batch 3

Lab 5 included LLOQ verifications at 10, 20 and 40 ng/L in each preparation batch

Lab 6 included two replicate LLOQ verifications at 10 ng/L in each preparation batch

Lab 11 included LLOQ verifications at 20 ng/L in each preparation batch

LCS % Recovery statistics by Laboratory, 160 ng/L (nom.) concentration

Target Analyte	Lab 2 (n=6) % Recovery		Lab 4 (n=6) % Recovery		Lab 5 (n=6) % Recovery		Lab 6 (n=6) % Recovery		Lab 10 (n=6) % Recovery		Lab 11 (n=6) % Recovery		Lab 12 (n=6) % Recovery		Lab 16 (n=6) % Recovery		Summary Statistics All Labs		
	Mean (%)	Std dev (%)	Mean (%)	Std dev (%)	Mean (%)	Std dev (%)	Mean (%)	Std dev (%)	Mean (%)	Std dev (%)	Mean (%)	Std dev (%)	Mean (%)	Std dev (%)	Mean (%)	Std dev (%)	$\bar{X}$ (%)[2]	S_w (%)[3]	S_b (%)[4]
PFBA	101	5.6	98.1	6.5	100	5.3	86.3	4.5	59.3	2.5	94.3	1.6	85.5	5.1	107	10.9	91.5	2.8	14.9
PFPeA	102	7.8	99.3	5.0	106	4.7	88.5	6.8	76.8	2.0	91.3	2.8	90.7	3.6	98.5	8.6	94.1	2.4	9.2
PFHxA	100	9.4	98.8	4.5	104	11.5	86.4	4.8	98.9	3.1	97.1	2.7	91.5	6.8	89.2	19.6	95.8	5.7	6.2
PFHpA	94.8	8.6	99.0	4.0	105	6.6	90.7	4.8	98.9	2.2	98.7	2.8	91.3	5.2	93.2	18.3	96.4	5.2	4.7
PFOA	94.9	12.8	94.1	7.5	116	9.6	92.1	7.1	95.0	2.7	110	4.5	92.7	7.1	109	12.2	101	3.5	9.6
PFNA	101	15.7	101	4.6	125	6.0	92.2	6.6	96.9	5.1	111	4.7	96.5	5.1	98.8	9.6	103	3.8	10.4
PFDA	95.7	13.8	111	16.4	113	7.4	91.8	6.3	102	4.0	107	7.6	95.0	9.2	100	7.6	102	4.1	7.5
PFUnA	90.8	11.1	98.3	7.9	115	9.1	95.5	7.3	95.6	2.7	104	4.8	93.2	10.7	113	15.2	101	3.9	9.1
PFDoA	86.5	12.9	95.9	6.2	121	9.2	94.7	5.7	100	3.1	104	7.3	100.9	10.0	129	21.7	104	5.7	14.1
PFTriA	82.9	9.8	101	8.5	153	21.2	96.7	5.3	103	3.6	111	3.9	98.1	16.2	113	17.8	107	6.8	20.7
PFTreA	73.6	8.3	110	9.9	121	15.3	99.1	7.0	103	4.9	120	7.6	102.0	15.3	99.0	27.2	103	7.2	14.8
PFBS	91.1	7.5	105	10.1	95.5	6.0	90.2	5.9	90.3	4.1	92.6	1.6	91.4	2.6	89.8	20.0	93.2	5.8	5.1
PFPeS	93.9	7.9	99.9	5.2	105	1.7	90.8	4.6	102	2.5	98.5	3.4	93.1	4.7	101	11.6	98.0	3.2	4.9
PFHxS	90.6	4.4	91.9	4.4	110	5.2	92.4	4.7	103	4.2	102	3.8	92.7	3.9	101	8.7	97.9	1.6	6.9
PFHpS	92.7	8.5	98.9	9.3	109	7.4	93.4	5.8	98.6	3.0	112	3.3	93.6	2.2	106	6.3	101	2.6	7.5
PFOS	89.9	5.1	103	8.7	104	7.7	91.8	3.4	105	2.6	107	3.9	91.3	5.7	108	6.8	99.9	2.1	7.5
PFNS	99.8	16.6	103	8.8	126	1.1	95.3	5.3	101	3.1	110	3.2	92.9	5.2	112	11.1	105	5.1	10.6
PFDS	92.0	10.5	97.1	7.1	115	2.8	94.9	3.8	94.8	1.3	104	2.6	92.6	4.5	111	10.5	100	3.6	8.8
PFOSA	92.4	6.0	101	4.9	114	6.3	93.5	4.1	97.1	3.3	98.5	1.9	90.4	3.3	103	4.7	98.7	1.5	7.4
FtS 4:2	100	14.6	88.7	12.1	98.6	9.4	97.7	20.2	103	10.7	95.6	2.2	94.3	6.0	105	11.2	98.0	5.4	5.2
FtS 6:2	99.9	3.8	90.2	11.8	105	6.0	118	26.1	135	31.1	40.0	1.5	85.0	8.1	55.1	8.2	91.1	10.7	31.3
FtS 8:2	90.1	8.6	103	5.2	105	22.5	110	19.3	117	11.9	111	4.8	93.3	9.7	105	14.6	104	6.4	8.9
NMeFOSAA	87.2	7.4	104	12.1	132	11.8	95.6	6.2	107	3.7	98.4	5.1	91.5	9.1	101	10.8	102	3.2	13.6
NEtFOSAA	93.5	7.4	92.2	17.5	129	22.1	98.9	8.0	109	3.8	94.8	2.3	92.7	4.1	106	4.9	102	7.2	12.5

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Surrogate % Recovery statistics across study sample matrices by Laboratory, 160 ng/L (nom.) concentration

	Lab 2 (n=60) % Recovery		Lab 4 (n=59)[1] % Recovery		Lab 5 (n=60) % Recovery		Lab 6 (n=59)[1] % Recovery		Lab 10 (n=59)[1] % Recovery		Lab 11 (n=60) % Recovery		Lab 12 (n=60) % Recovery		Lab 16 (n=60) % Recovery		Summary Statistics All Labs		
Target Analyte	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}$[2] (%)	S_w[3] (%)	S_b[4] (%)
MPFBA	89.3	6.4	105	6.7	106	5.5	91.1	6.2	87.3	11.9	99.1	5.2	91.2	6.9	96.4	15.7	95.6	3.7	7.1
M5PFPeA	94.7	8.1	108	4.4	105	5.8	95.3	5.0	97.7	7.1	92.8	3.3	95.7	3.6	100	5.6	98.6	1.7	5.3
M5PFHxA	87.8	10.8	110	9.6	103	11.8	95.4	4.4	102	4.4	100	3.2	96.6	4.2	84.6	15.1	97.3	4.5	8.2
M4PFHpA	92.4	9.0	110	11.7	104	5.4	96.3	4.5	104	5.8	104	3.4	93.6	4.9	86.1	13.2	98.7	3.6	7.9
M8PFOA	94.5	10.5	107	8.3	106	7.1	97.6	4.5	102	4.6	110	4.4	94.9	7.4	95.1	10.6	101	2.6	6.2
M9PFNA	87.4	10.8	109	9.1	107	4.9	97.8	5.0	102	5.3	118	4.5	94.2	5.7	102	12.0	102	3.0	9.4
M6PFDA	89.2	9.5	109	8.0	110	7.3	99.8	5.7	104	5.9	120	6.8	99.3	10.3	104	12.9	104	2.5	9.0
M7PFUnDA	92.4	13.1	106	7.2	113	9.0	101	5.4	102	5.6	111	6.8	94.1	8.9	108	14.6	103	3.4	7.5
MPFDoDA	83.6	10.3	98.7	6.9	110	6.3	99.5	5.4	99.7	5.6	109	5.8	89.2	11.9	116	21.7	101	5.6	10.8
M2PFTeDA	75.9	10.3	84.2	14.7	105	16	92.2	9.4	101	5.8	120	7.0	89.2	11.8	107	23.7	96.8	5.8	14.2
M3PFBS	84.6	8.6	108	10.3	105	6.8	96.8	4.4	98.2	15.5	98.0	4.7	97.4	2.7	86.2	13.9	96.8	4.6	8.1
M3PFHxS	92.4	8.7	103	9.0	105	4.9	98.6	3.6	105	4.0	110	6.9	96.8	3.1	103	6.2	102	2.3	5.5
M8PFOS	92.3	11.5	103	9.7	113	7.0	99.1	3.6	103	3.6	119	6.9	95.3	4.6	108	8.0	104	2.9	9.0
M8PFOSA	90.6	5.9	98.3	5.4	113	12.2	99.2	3.7	102	4.6	101	3.6	95.2	3.0	105	7.4	101	3.0	6.7
M2-4:2FTS	89.4	11.4	102	46.2	103	8.4	102	18.9	96.9	11.7	94.7	5.9	97.3	4.7	96.9	7.9	97.8	13.6	4.5
M2-6:2FTS	93.2	11.3	105	10.9	105	11.7	108	19	108	12.0	93.1	25.1	95.1	5.7	96.6	8.0	100	6.2	6.5
M2-8:2FTS	95.3	18.0	105	13.2	111	12.4	111	14.8	108	13.0	112	9.9	98.0	7.7	106	9.3	106	3.3	6.2
d3-N-MeFOSAA	83.1	11.0	106	17.2	125	20.6	96.3	5.0	102	5.4	109	11.2	97.4	4.8	102	7.4	103	5.9	12.0
d5-N-EtFOSAA	91.3	16.2	98.6	16.1	130	16.3	102	7.7	103	6.1	104	9.7	95.3	5.2	108	8.6	104	4.7	11.7

[1] A study sample from labs 4 and 6 with recovery near 200% for all surrogates and a study sample from lab 10 with no recovery of target analytes or surrogates were excluded from this summary; a preparation error was presumed for these samples

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of "Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA's Alternate Test Procedure Program, February 2018", available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Surrogate % Recovery statistics across method blank, LCS, and LLOQ verification quality control samples by Laboratory, 160 ng/L (nom.) concentration

	Lab 2 (n=18) % Recovery		Lab 4 (n=15) % Recovery		Lab 5 (n=21) % Recovery		Lab 6 (n=18) % Recovery		Lab 10 (n=18) % Recovery		Lab 11 (n=15) % Recovery		Lab 12 (n=17) % Recovery		Lab 16 (n=18) % Recovery		Summary Statistics All Labs		
Target Analyte	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	Avg (%)	Std dev (%)	$\bar{X}$[2] (%)	S_w[3] (%)	S_b[4] (%)
MPFBA	97.9	3.4	98.6	4.5	101	5.7	92.4	5.1	71.9	4.7	95.4	3.3	86.4	5.7	102	12.7	93.3	3.0	10.0
M5PFPeA	103	6.8	100	4.2	102	6.5	91.2	5.3	87.8	5.7	91.9	3.9	92.3	4.5	94.8	9.4	95.5	1.8	5.6
M5PFHxA	102	10.7	102	3.8	92.6	12.0	91.2	3.9	101	3.4	97.5	2.1	94.8	5.6	82.1	15.4	95.2	4.9	6.8
M4PFHpA	97.6	8.8	102	7.5	103	4.9	93.6	5.1	103	4.9	102	2.2	91.1	7.0	84.3	15.6	97.0	4.0	6.9
M8PFOA	103	10.8	99.2	4.6	105	7.8	94.2	4.5	103	4.4	106	3.4	94.9	7.4	92.1	13.1	99.7	3.5	5.4
M9PFNA	93.8	10.7	100	5.8	104	5.7	94.5	5.1	101	4.4	113	4.7	93.6	4.8	97.3	13.4	99.5	3.3	6.6
M6PFDA	95.5	6.5	99.2	7.4	114	9.2	95.7	5.6	104	4.4	111	4.0	97.9	11.9	97.7	11.5	102	3.0	7.1
M7PFUnDA	97.0	11.2	101	6.9	112	10.7	98.0	6.4	103	3.3	104	4.6	93.9	7.7	98.1	14.1	101	3.6	5.6
MPFDoDA	88.2	10.0	101	7.1	113	13.7	97.6	6.0	102	4.6	106	3.4	94.4	9.7	109	20.2	102	5.5	8.0
M2PFTeDA	73.5	10.8	105	7.6	110	23.9	98.6	6.8	104	5.8	124	3.9	101	13.2	91.8	19.3	101	7.0	14.5
M3PFBS	93.5	6.4	103	6.1	99.7	4.7	92.4	4.7	92.1	7.6	96.4	4.7	95.0	8.4	84.5	15.7	94.5	3.7	5.5
M3PFHxS	97.6	6.2	96.1	8.5	100	4.0	94.6	3.6	104	2.8	110	6.9	93.7	4.5	97.5	9.0	99.1	2.3	5.4
M8PFOS	98.4	10.4	98.7	7.6	106	6.4	96.0	3.7	103	3.9	117	5.5	93.5	3.0	103	10.0	102	2.8	7.3
M8PFOSA	97.0	4.8	101	6.9	111	13.7	97.0	4.1	102	4.5	101	3.5	92.1	4.5	97.2	6.7	100	3.3	5.5
M2-4:2FTS	101	10.2	105	46.6	95.4	7.5	103	18.0	105	8.2	92.0	4.9	92.4	4.2	93.3	12.9	98.4	13.9	5.7
M2-6:2FTS	99.8	11.6	99.4	11.6	105	10.8	114	22.2	121	18.2	85.6	5.9	92.9	5.8	94.5	14.0	102	5.6	11.5
M2-8:2FTS	94.3	12.3	96	13.7	105	14.1	109	13.9	116	13.9	104	6.8	95.5	7.4	98.5	13.7	103	3.1	7.6
d3-N-MeFOSAA	95.6	9.3	100	16.7	115	22.6	98.1	5.8	105	5.0	99.5	6.3	94.8	4.5	93.8	11.4	101	6.5	7.0
d5-N-EtFOSAA	95.0	13.7	108	14.6	119	18.1	99.9	6.0	110	4.5	96.6	8.2	94.0	4.6	104	9.6	104	5.1	8.7

[1] One QC sample with recovery near 200% for all surrogates was excluded from this summary; a preparation error was presumed for these samples

[2] Pooled mean % recovery across 8 laboratories; For calculation refer to Appendix G Section 3.2.4 (1) of “Protocol for Review and Validation of New Methods for Regulated Organic and Inorganic Analytes in Wastewater Under EPA’s Alternate Test Procedure Program, February 2018”, available at: https://www.epa.gov/sites/production/files/2018-03/documents/chemical-new-method-protocol_feb-2018.pdf. Individual % recoveries were calculated after subtracting the average concentration across unspiked replicates by matrix and laboratory.

[3] Within-laboratory standard deviation of % recovery (n= 8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above

[4] Between-laboratory standard deviation of % recovery (n=8 laboratories); Refer to calculation in Appendix G Section 3.2.4 (1) in the reference above.

Attachment 13

Non-Hazardous Solid Waste Landfills with GMZs

PART 813 PERMITTED OPERATING MUNICIPAL SOLID WASTE LANDFILLS

SiteID	SiteName	County	Date Established (Approved)
0378020001	DeKalb County Landfill - West Unt	DeKalb	7/28/2000
0770200002	Southern Illinois Regional Landfill Inc.	Jackson	3/27/1998
1098100003	Envirofil of Illinois Inc.	McDonough	9/18/1997, 5/30/2000
1158040008	Advanced Disposal Services Valley View Landfill Inc.	Macon	9/10/2003
1190900002	Roxana Landfill Inc.	Madison	4/3/2009
1418030020	Rochelle Municipal Landfill No. 2	Ogle	1/13/2005
1630450001	Milam Recycling and Disposal Facility	St. Clair	8/30/1995
1678220037	Sangamon Valley Landfill Inc.	Sangamon	10/24/2002
1830450009	Illinois Landfill	Vermilion	8/23/2011, 2/27/2015

PART 813 PERMITTED OPERATING SOLID WASTE LANDFILLS

SiteID	SiteName	County	Date Established (Approved)
0570255197	Duck Creek Station Ash LF	Fulton	12/11/2015

PART 813 PERMITTED MUNICIPAL SOLID WASTE LANDFILLS IN POST CLOSURE

SiteID	SiteName	County	Date Established (Approved)
0910550006	Kankakee RDF	Kankakee	3/21/2012
1638140001	Belleville Landfill Inc	St. Clair	10/6/2017
2018080001	Winnebago Landfill - Northern and Southern Unit	Winnebago	5/16/2008

PART 813 PERMITTED AND CLOSED, BUT NOT CERTIFIED CLOSED, SOLID WASTE LANDFILLS

SiteID	SiteName	County	Date Established (Approved)
1978090001	Lincoln Stone Quarry	Will	7/1/2020

PART 813 PERMITTED SOLID WASTE LANDFILLS IN POST CLOSURE

SiteID	SiteName	County	Date Established (Approved)
0018010001	Quincy Municipal 4	Adams	6/20/1997
0313330001	Winnetka Municipal	Cook	11/6/2008
0798080002	Newton Power Station LF Phase 1	Jasper	9/14/2004

PART 807 PERMITTED SOLID WASTE LANDFILLS PERMITTED, IN POST CLOSURE

SiteID	SiteName	County	Date Established (Approved)
0070050006	Belvidere Municipal 2	Boone	7/30/2004
0110850001	Princton Muncipal Landfill	Bureau	5/15/2000
0310630001	Des Plaines Landfill	Cook	10/27/2003
0418080002	Equistar Chemicals	Douglas	6/23/2006
0678150001	Carthage Muni	Hancock	4/13/2004
0838000001	Principia College	Jersey	9/26/2008
1958140003	Whiteside County Landfill 2	Whiteside	2/7/1997

PART 807 PERMITTED SOLID WASTE LANDFILLS PERMITTED, IN POST CLOSURE

SiteID	SiteName	County	Date Established (Approved)
1618100004	East Moline Municipal	Rock Island	1/9/2009
1770200002	Freeport Municipal 2 & 3	Stephenson	3/27/2000
0958160002	Knox County Landfill Phase I/II	Knox	11/30/2016

Part 724 Hazardous Waste Landfills/Sites with GMZs

SiteID	SiteName	County	Date Established (Approved)
0310390001	CID Recycling and Disposal Facility	Cook	6/11/2008
0311860003	Trex Corporation LLC	Cook	10/9/2003
0316000037	Honeywell Cicero fka Baron-Blakeslee	Cook	1/24/2014
0438020002	Argonne National Laboratory	DuPage	11/27/2000
1190400006	Vertellus Specialties Environmental Response Trust	Madison	3/13/2007
1190650001	Greenfield Environmental Multistate Trust LLC	Madison	3/29/1994
1191150001	BP Products/Main Plant fka Dome Petroleum Corp	Madison	4/6/1994
1191155009	BP Products/Riverfront	Madison	4/6/1994
1430050001	Keystone Steel and Wire Company	Peoria	6/30/1992
1770200010	Modern Plating Corp	Stephenson	5/17/2007
1970450002	Laraway Recycling and Disposal Facility	Will	8/12/1999
1970500012	Chevron Environmental Services	Will	2/14/2003
1978030001	Citgo Lemont Refinery	Will	5/7/2009
2018000002	Clean Harbors Pecatonica	Winnebago	1/25/2007

Last updated 4/8/2022