STORMWATER MANAGEMENT
POST CONSTRUCTION REQUIREMENTS
POLICY & PROCEDURES

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SUMMARY:

Construction and redevelopment projects on EMU property are regulated under the National Pollutant Discharge Elimination System (NPDES) Permit #MIG610000 for storm water discharges, as issued by the Michigan Department of Environmental Quality (MDEQ). The Storm Water Management Post-Construction Requirements Policy has been developed to provide guidance regarding responsibilities and actions to meet the permit conditions for construction and renovation projects on EMU property.

The post-construction storm water policy for regulated projects is required to include:
1. A minimum treatment volume standard to address water quality impacts;
2. Channel protection criteria to address resource impairment resulting from flow volumes and rates;
3. Operation and Maintenance Plan s

REFERENCE REGULATIONS:
1. Federal Water Pollution Control Act, as amended (33 U.S.C. 1251 et seq.)
2. Michigan Act 451, Public Acts 1994, as amended, Part 31.
3. Michigan Executive Orders 1991-31, 1995-4, and 1995-18.

SCOPE:

As required by the NPDES permit for EMU, the scope of this Policy includes all construction and renovation projects on EMU property that involve either:

a. earth disturbance of one (1) acre or greater,

OR

b. earth disturbance of less than one (1) acre, but which are part of a larger common plan of development or sale that would disturb one (1) acre or more.

Note: "Regulated site" in this policy refers to projects meeting a. or b. above.

ACRONYMS:

BMPs – Best Management Practices
CSO – EMU Certified Stormwater Operator
EHS – Environmental Health & Safety
EMU – Eastern Michigan University
MDEQ – Michigan Department of Environmental Quality
NOAA – National Oceanic & Atmospheric Administration
NPDES – National Pollutant Discharge Elimination System
O&M – Operation & Maintenance
SOP – Standard Operating Procedure
TSS – Total Suspended Solids
UAs – Urbanized Areas

RESPONSIBLITY:

This Policy applies only to units involved in construction or renovation activities meeting one of the scope criteria. These responsibilities do not apply to units not involved in construction or renovation activities.

<u>Physical Plant Chief of Operations</u>

- Promote an environment where EMU staff and other personnel are directed and encouraged to follow this policy.

<u>Directors, Facility Managers, and Supervisors</u>

- Provide support to units/staff with responsibilities for storm water management, including ensuring appropriate notifications, information, data, etc. are provided to collaborating university departments (i.e., EHS, DPS, Communications & Marketing)

- Assure that staff and contractors are aware of the requirements outlined in this policy and instructed on the details of implementation in accordance with the NPDES permit.
- Provide Facilities Planning and Construction with advance notification of regulated projects.
- Maintain documentation on all of the above and/or provide CSO with data for tracking these activities.

Facilities Planning and Construction and Project Managers

- Work with the Project Developers and Contractors to ensure that the project prepares and implements site plans which incorporate the post-construction storm water requirements of the NPDES permit for EMU (#MIG610000, May 2008), including the minimum treatment volume standard, channel protection criteria and operation & maintenance plan requirements.
- Work with the Project Developers & Contractors to provide the documentation, certifications and plans to EMU Certified Stormwater Operator for the post-construction storm water controls.
- Initiate enforcement of the post-construction storm water control requirements, with EMU CSO support.

Program Managers and Supervisors

- Assure that staff and contractors are aware of the requirements outlined in this policy and instructed on the details of implementation in accordance with the NPDES permit. This includes providing information developed by Physical Plant to personnel regarding the importance of storm water management planning and controls.

Project Developers & Contractors

- Submit the post-construction storm water control plan with supporting documentation to Facilities Planning and Construction and EMU CSO for review, comment and recordkeeping.
- Provide EMU CSO with certification that the design complies with the post-construction storm water control requirements.
- Prepare and implement site plans which incorporate the post-construction storm water requirements of the NPDES permit for EMU #MIG610000, May 2008), including the minimum treatment volume standard, channel protection criteria and operation and maintenance plan requirements.
- Provide EMU Facilities Maintenance and Operations with certification that the construction of the post-construction storm water controls meets the required volume and treatment standards identified in the permit.

EMU Certified Stormwater Operator

- Review and revise the Policy in collaboration with Facilities Planning and Construction.
- Coordinate the storm water management program for EMU and act as primary contact with MDEQ. Administer and enforce (with the support and participation of Physical Plant and other EMU Project Managers) the storm water management program for EMU, including developing and maintaining procedures, guidance, information, etc. to aid EMU staff and contractors in complying with the post-construction requirements for storm water management on regulated sites.
- Develop, track and enforce (with the support and participation of Grounds, Facilities, and other EMU Project Managers) a program to ensure long-term O&M plans for the water quality treatment and channel protection controls installed as a requirement under this policy.
- Maintain and retain records on post-construction storm water management for all regulated sites, in accordance with NPDES permit #MIG610000.

PROCEDURES:

1. **The post-construction plan for storm water management on regulated sites shall include:**
    - A minimum treatment volume standard to address water quality impacts;
    - Channel protection criteria to address resource impairment resulting from flow volumes and rates;
    - Operation and Maintenance requirements.
      Refer to EMU NPDES permit #MIG610000 and the Post-Construction Storm Water Worksheet for additional details on these requirements.

The project team (Project Manager, Project Developer and/or Contractors) shall develop the post-construction storm water management plan in accordance with this policy and the NPDES permit #MIG610000. Preferred design elements are identified in the Post-Construction Storm Water Worksheet.

1.1 Minimum Treatment Volume Standard

The minimum treatment volume standard shall be either:

a. One (1) inch of runoff from the entire site,

OR

b. The calculated site runoff from the *90 Percent Annual Non-Exceedance Storms*, as summarized in MDEQ's memo dated March 24, 2006.

1.2 Minimum Treatment Volume Standard – TSS Removal

The treatment methods shall be designed on a site-specific basis to achieve the following:

a. A minimum of 80 percent removal of total suspended solids (TSS), as compared with uncontrolled runoff,

OR

b. Discharge concentrations of TSS not to exceed 80 milligrams per liter (mg/l).

Note: A minimum treatment volume standard is not required where site conditions are such that TSS concentrations in storm water discharges will not exceed 80 mg/l.

2.0 Channel Protection Criteria

The channel protection criteria must maintain post-development site runoff volume and peak flow rate at or below existing levels for all storms up to the 2-year, 24-hour event. “Existing levels” means the runoff volume and peak flow rate for the last land use prior to the planned new development or redevelopment. More restrictive channel protection criteria may be utilized by EMU on a case-by-case basis, as appropriate.

2.1 Rainfall data

The rainfall data for calculating runoff volume and peak flow rate shall be the *Rainfall Frequency Atlas of the Midwest*,, 1992 (NOAA - Huff & Angel).

2.2 Methods for estimating pre- and post-development runoff

The methods used for estimating pre- and post development runoff shall follow curve number evaluations as described in MDEQ’s *Computing Flood Discharges from Small Ungaged Watersheds,* June 2008.

3.0 Operation & Maintenance Plans

All structural and vegetative BMPs installed as a requirement under this section of the permit shall include a plan for maintaining maximum design performance through long-term operation and maintenance.

EMU CSO will oversee annual inspections of the BMPs, and report the findings to the facility manager(s) for remedy.

More frequent inspections of BMPs may be required, based on the O&M plan. All inspections, other than the annual inspection by EMU CSO, shall be the responsibility of the facility manager. A copy of all inspection reports shall be forwarded to EMU CSO, for recordkeeping.

4.0 Project Submittals

The project team (EMU Project Manager, developer and/or contractors) shall submit the post-construction storm water management plan, all calculations, and BMP details, including TSS designed removal rates and the O&M plan to EMU CSO for review and comment.
The project team must ensure that the storm water control plan and all supporting information are deemed acceptable by EMU CSO prior to beginning any earth disturbance.

A statement is required to be signed by a Professional Engineer familiar with the project, certifying that the design meets the minimum treatment volume standard and channel protection criteria.

A second certification from the engineer is required after construction has been completed, stating that the as-built conditions meet the post-construction storm water requirements required in the permit.

5.0 Enforcement

Facilities Maintenance will administer and enforce the storm water management program for EMU, including developing and maintaining procedures, guidance, information, etc. to aid EMU staff and contractors in complying with the post-construction requirements for storm water management on regulated sites. Enforcement may include, but is not limited to, letters of warning, stop work orders, withholding SESC permits, withholding payment to the contractor, etc. and shall be implemented with the participation of Project Managers at EMU and Environmental Health and Safety.

TECHNICAL

All referenced regulations and other documents are available through the EMU Physical Plant web site.

SUPPORT:

Kevin Abbasse, EMU Structural and Life Safety Manager, (734-487-3426) or John Foley, EMU Certified Stormwater Operator, (248-820-7509)

APPENDICES:

Due to the volume of these documents, Appendices B, C, D, and G remain online accessible by links and through EMU Physical Plant web site

A. EMU Storm Water Permit – NPDES #MIG610000, May 2008
B. 90 Percent Annual Non-Exceedance Storms, March 2006 – MDEQ
http://www.michigan.gov/documents/deq/lwm-hsu-nps-ninety-percent_198401_7.pdf
C. Rainfall Frequency Atlas of the Midwest, 1992 – NOAA
http://www.isws.illinois.edu/pubdoc/B/ISWSB-71.pdf
D. Computing Flood Discharges for Small Ungaged Watersheds, June 2008 - MDEQ
http://www.michigan.gov/documents/deq/lwm-scs_198408_7.pdf
E. Post-Construction Storm Water Worksheet
F. Rules of the Washtenaw County Drain Commissioner: Procedures and Design Criteria for Storm Water Management Systems May 2000
G. Low Impact Development Manual for Michigan, 2008 – SEMCOG
http://www.semcog.org/LowImpactDevelopment.aspx

PERMIT NO. MIG610000

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
WASTEWATER DISCHARGE GENERAL PERMIT

Storm Water Discharges from
Municipal Separate Storm Sewer Systems (MS4s) – Watershed General Permit

In compliance with the provisions of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251 et seq; the "Federal Act"), Michigan Act 451, Public Acts of 1994, as amended (the "Michigan Act"), Parts 31 and 41, and Michigan Executive Orders 1991-31, 1995-4, and 1995-18, storm water is authorized to be discharged from the Municipal Separate Storm Sewer Systems (MS4s) of those permittees specified in individual "certificates of coverage" in accordance with the conditions set forth in this general National Pollutant Discharge Elimination System (NPDES) permit (the "permit").

The applicability of this permit shall be for point source discharges of storm water from MS4 owners or operators that have submitted complete applications for coverage under this permit. Discharges that have been determined by the Michigan Department of Environmental Quality (the "Department") to need an individual NPDES permit or coverage under the NPDES general permit "Storm Water Discharges from MS4s – Jurisdictional Permit," are not authorized by this permit.

In order to constitute a valid authorization to discharge, this permit must be complemented by a Certificate of Coverage (COC) issued by the Department. The items to be listed in the COC are identified on the following page.

Unless specified otherwise, all contact with the Department required by this permit shall be to the position indicated in the COC.

This permit shall take effect upon issuance.

The provisions of this permit are severable. After notice and opportunity for a hearing, this permit may be modified, suspended, or revoked in whole or in part during its term in accordance with the applicable laws and rules.

This permit shall expire at midnight, **April 1, 2013**.

Issued May 22, 2008.

Original Permit Signed by William Creal
William Creal, Chief
Permits Section
Water Bureau

PERMIT FEE REQUIREMENTS

In accordance with Section 324.3118 of the Michigan Act, the permittee shall make payment of an annual storm water fee to the Department for each January 1 the permit is in effect, regardless of the occurrence of a discharge. The permittee shall submit the fee in response to the Department's annual notice. The fee shall be postmarked by March 15 for notices mailed by February 1. The fee is due no later than 45 days after receiving the notice for notices mailed after February 1.

CONTESTED CASE INFORMATION

The terms and conditions of this permit shall apply to an individual permittee on the effective date of a COC for the permittee. The Department of Labor and Economic Growth may grant a contested case hearing on this permit in accordance with the Michigan Act. Any person who is aggrieved by this permit may file a sworn petition with the State Office of Administrative Hearings and Rules of the Michigan Department of Labor and Economic Growth, setting forth the conditions of the permit which are being challenged and specifying the grounds for the challenge. The Department of Labor and Economic Growth may grant a contested case hearing on the COC issued to an individual permittee under this permit in accordance with Rule 2192(c) (Rule 323.2192 of the Michigan Administrative Code).

ITEMS TO BE IDENTIFIED IN THE COC

The following will be identified in the COC:

- The watershed boundaries that are to be covered by a Watershed Management Plan (WMP), referred to as “regulated watersheds”
- Receiving waters to which the permittee discharges
- Approved Total Maximum Daily Loads (TMDLs) applicable to the receiving waters and storm water discharges
- The submittal date for the process or revised/updated process to facilitate the involvement of the watershed jurisdictions and the public [i.e., the Public Participation Process (PPP)] in the development and implementation of a WMP or revised/updated WMP
- The submittal date for the WMP or revised/updated WMP
- The submittal date for the Storm Water Pollution Prevention Initiative (SWPPI), which includes the Illicit Discharge Elimination Plan (IDEP), the Public Education Plan (PEP), and an implementation schedule or revisions/updates of the SWPPI and implementation schedule
- Any nested jurisdictions for which the permittee is assuming responsibility for permit requirements
- Any deferred areas for a portion of a permittee’s urbanized area
- The submittal date for joint reporting requirements and progress reports.

PUBLIC PARTICIPATION IN A PROPOSED COC

Proposed COCs, their applications, and other documents related to requests for coverage under this permit will be posted on the Department Web site for a period of 14 days prior to the issuance of each COC. Any person may file comments with the Department on these documents. Any person may request a public hearing on a proposed COC. The Department may reject as untimely any comments or public hearing requests filed after the 14-day public notice period.

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Section A. Effluent Limits and Monitoring

1. Authorized Discharges

a. Eligible Permittees
Except as excluded below, any public body that owns or operates an MS4 may be eligible for coverage under this permit.

The Department will determine eligibility for coverage under this permit on a case-by-case basis. Coverage will be granted only if the Department determines there is a sufficient number of participating watershed partners to develop an effective WMP.

A permittee may have, within its political or territorial boundaries, "nested" MS4s owned or operated by public bodies that include, but are not limited to, public school districts; public universities; or county, state, or federal agencies. If the permittee assumes responsibility for the permit requirements where a nested jurisdiction owns or operates an MS4, including identification of the discharge points for the nested jurisdiction's MS4, then the nested jurisdiction does not need to apply for an MS4 permit and the permittee is authorized for the MS4 discharges from the nested jurisdiction. Otherwise, the nested jurisdiction shall apply for a permit.

b. Storm Water Discharges by the Permittee
This permit authorizes the discharge of storm water from MS4s to the surface waters of the state only from those discharge points identified in the application submitted by the permittee for coverage under this permit. The discharge points authorized include those identified as a set of discharge points by category in the application. The permittee may obtain authorization for additional discharge points by providing an updated list of discharge points to the Department's Water Bureau, Permits Section.

c. Discharges Authorized under Other NPDES Permits
This permit does not prohibit the use of the MS4 for discharges authorized under other NPDES permits or equivalent Department approval under the Michigan Act or the Federal Act.

2. Discharge Point Location

a. The permittee shall identify the location of each storm water discharge point (i.e., points discharging directly to the surface waters of the state or to any other entity's separate storm sewer system) from the MS4 it owns or operates, as follows:

1) For discharge points identified after submittal of the application, except for those belonging to categories identified under 2), below, the permittee shall provide an updated map which clearly shows the discharge point, the unique identification code or number assigned to the discharge point, and the receiving surface waters of the state. It is highly recommended that the permittee also establish the latitude and longitude of these discharge points.

2) Permittees that have identified a set of discharge points by category related to their MS4s in their permit applications shall identify the location of each discharge point for which specific location information has not yet been determined as follows:

a) For permittees with less than 1,500 estimated discharge points to identify, this requirement shall be completed by the due date for discharge point locations in the permittee's COC issued under this permit. For each discharge point identified, the permittee shall include in the progress report at Part I.B.1.b.1., a specific discharge location, a unique identification code or number, and the receiving surface water of the state.

b) For permittees with more than 1,500 estimated discharge points to identify, this requirement shall be completed within this and the next permit cycle by the due date for discharge point locations in the permittee's COC issued under this permit. For each discharge point identified, the permittee shall include in the progress report at Part I.B.1.b.1., a specific discharge location, a unique identification code or number, and the receiving surface water of the state.

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In both cases, reasonable and regular progress shall be made in the identification of discharge points. Such progress shall be documented in the progress reports.

3) For discharge points constructed or installed after submittal of the application, the permittee shall provide an updated map clearly showing the location of the discharge point, the unique identification code or number assigned to the discharge point, the latitude and longitude of the discharge point, and the receiving surface waters of the state.

b. All discharge point locations shall be submitted to the Chief of the Permits Section, Water Bureau, Michigan Department of Environmental Quality, P.O. Box 30273, Lansing, Michigan 48909-7773.

c. Submittals of discharge point information under Parts I.A.2.a.1 and I.A.2.a.3 are required in order for the permittee to obtain authorization from the Department to discharge from those discharge points.

3. Public Participation Process (PPP) and Watershed Management Plan (WMP)

The permittee shall participate in the development and implementation of a joint Watershed Management Plan (WMP). The purpose of the WMP is to identify and execute the actions needed to resolve water quality and quantity concerns by fostering cooperation among the various public and private entities in the watershed.

a. PPP
People most affected by watershed management decisions should participate in the development and implementation of the WMP and shape key decisions. <u>By the date specified in the COC</u>, the process to facilitate the involvement of the watershed jurisdictions and the public (i.e., "the Public Participation Process") in the development of the WMP shall be submitted to the Department. A person, group, or agency responsible for coordinating the development of the WMP shall be identified. Where multiple permittees are responsible for submittal of a WMP for the same watershed, there shall be one coordinated public participation process, which shall be described in a joint submittal or separately by each permittee. (See also Part I.A.3.c.)

Where a WMP and PPP already have been developed, in lieu of preparing a PPP, the existing PPP shall be revised and submitted as a joint plan to the Department <u>by the date specified in the COC</u>. The revision shall:

- Focus on methods of educating the public on the needs and goals of the WMP and involving them in its update and implementation.
- Ensure that all stakeholders are invited.
- Include an updated timeline that reflects public involvement in revising and implementing the WMP.
- Include any additional changes reflective of current conditions (e.g., responsible parties, contact information, communication mechanisms, etc.).

The permittees shall participate in the implementation of the PPP or revisions to the PPP upon submittal.

b. WMP
The WMP shall cover the watershed(s) identified in the COC. <u>By the date specified in the COC</u>, the permittee shall submit the WMP or revised/updated WMP to the Department. Where multiple permittees are responsible for submittal of a WMP for the same watershed, one WMP shall be submitted on behalf of all the permittees. The permittees may submit a demonstration that no revision is needed, if the demonstration is based on the “Methods for evaluation of effectiveness,” in Part I.A.3.b.7. of this permit, and the triggers for revision in Part I.A.3.b.9. of this permit. (Note: The WMP requirement may be deferred until a later time for a portion of the permittee’s jurisdiction. The WMP shall not be deferred for the permittee’s entire urbanized area. Any portion of the jurisdiction that is deferred will be indicated in the COC.)

The permittee may choose to demonstrate that a watershed other than that specified in the COC is appropriate. This demonstration shall be submitted to the Department for approval.

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The Department's "Developing a Watershed Management Plan for Water Quality: An Introductory Guide" (February 2000) should be used as a guide in establishing a framework for the WMP. It is available on the Web at www.michigan.gov/deqnps, then select "Developing an Approvable Watershed Management Plan" under the Information and Education heading.

The WMP, or revised WMP, as specified by the COC, should contain the following components:

1) A summary of the PPP
- A description of how public input and comment were solicited.
- The roles and responsibilities of the partners involved in the development and implementation of the WMP.

2) An assessment of the nature and status of the watershed
- A watershed map that clearly shows the watershed boundaries, the location of surface waters, and a description of the watershed, including such information as land use, predominant soil types, significant natural features, and hydrology
- A list of the designated uses and whether or not they are being met
- A description of the water quality threats and water quality impairments, if applicable, as they pertain to the designated uses.
- A list of the desired uses for the watershed which are not directly tied to the designated uses or water quality; for example, installing a recreational trail along a river
- A description of the local programs, projects, and ordinances that currently improve or degrade water quality
- Beneficial and/or impaired uses identified in the Area of Concern (AOC) or Remedial Action Plan (RAP) documents, where applicable

3) Identification of priority problems and opportunities
- Waterways included on the 303(d) list
- TMDLs established for a pollutant within the watershed
- A description of the known or suspected cause of each threat or impaired use, including specific pollutants
- A description of the sources of the pollutants causing the impairments or threats, and those that are critical to control in order to meet water quality standards or other water quality goals (including a description of the source inventory and prioritization process)

Note: Information on approved TMDLs is available on the Internet at: www.michigan.gov/deqwater; on the right side under "Quick Links" click on "Total Maximum Daily Load (TMDL) Assessment." Other identified use impairments are available on the Web at: www.michigan.gov/deqnps. Follow the Quick Link to Nonpoint Source Monitoring and Assessment, then Assessment of Michigan Waters, and then "Water Quality and Pollution Control in Michigan 2006 Sections 303(d), 305(b), and 314 Integrated Reports" under the Information banner.

4) Identification of the goals and environmental objectives based on the condition or vulnerability of resources, the needs of the aquatic ecosystem, and the people within the community
- A description of the long-term goals for the watershed, which should include the protection of the designated uses of the receiving waters as defined in Michigan's Water Quality Standards
- A description of the measurable objectives for the watershed that will work toward meeting the long-term goals

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5) Specific management options and action plans

- A description of the actions needed to achieve the measurable objectives and long-term goals for the watershed, including one or more of the following:
  - Best management practices needed, including physical improvements
  - Land use management tools
  - Information and educational activities
  - Activities needed to institutionalize watershed protection
- A timeline for the actions identified above

6) Commitments to implement the action plan

- Identification of responsibilities to implement actions by the specified dates necessary to initiate achievement of the measurable objectives and long-term goals
- Specific commitments by the permittee to meet the requirements of the SWPPI shall be included in the SWPPI

7) Methods for evaluation of effectiveness

Identification of methods for the evaluation of progress, which may include:

- Chemical water quality monitoring, such as nutrients.
- Physical water quality monitoring, such as temperature, habitat, erosion indices, or streamflow.
- Biological indicators, such as insects and fish.
- Photographic or visual evidence, such as before and after photos.
- Compilation of the number and location of the Best Management Practices (BMP) implemented.
- Pollutant loading reduction measurements.
- Public surveys, such as baseline and follow-up surveys, to evaluate changes in knowledge and behavior.
- Focus groups, to determine the effectiveness of project activities.

Permittees may meet this component by working collaboratively with their watershed partners to develop and implement a watershed-wide effectiveness program. This may include watershed-wide monitoring that can be used to evaluate the effectiveness of the overall activities in meeting the public education objectives, water quality standards, and determining the priority areas for future implementation activities.

8) Identifying disagreements

- Significant components of the WMP that do not have the complete agreement of the participants shall be detailed in an appendix to the WMP [including a description of the WMP component, identification of participants who disagreed with the component, the reasons for the disagreement, and suggested or planned alternatives (if appropriate)].
- A permittee who receives a COC under this permit after the WMP is completed shall document any disagreements in a letter to the person, group, or agency coordinating the development/oversight of the WMP, which shall be included in an appendix to the WMP.

9) Plan revision or update

Description of the procedures that will be used to revise/update the WMP that, at a minimum, should consider:

- Identifying the party(ies) responsible for revising/updating the WMP.
- Delineating a schedule of events needed to revise/update the WMP in accordance with the due date specified in the COC.
- Identifying the triggers for revision, such as:
  - The WMP does not meet the criteria for the WMP detailed in Part I.A.3.b.1-8.
  - Permittee-specific commitments in the WMP have expired.
  - Evaluation of the WMP indicates that modifications are needed to achieve goals, objectives, etc.

A WMP developed under the Watershed General Permit should include the identification of any undesirable impacts on the receiving water caused by wet weather discharges from the MS4s and the measures necessary to mitigate the impacts. Because these are also goals of a SWPPI (see Part I.A.4. of this permit), permittees are encouraged to draw upon applicable WMP actions to fulfill SWPPI requirements.

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Section A. Effluent Limits and Monitoring

c. Joint Requirements

Watershed planning requires permittees to work jointly on the following requirements of this permit:

- Developing a comprehensive WMP that includes the information identified in this Part.
- Maintaining a Public Participation Process throughout the development and implementation of the WMP.
- Updating/revising the WMP as necessary.

Failure to complete the joint requirements could result in the Department requiring the permittee to get discharge authorization under a jurisdictional general permit or an individual permit. With the exception of the discharge point requirements in Part I.A.2. of this permit and the SWPPI requirements in Part I.A.4. of this permit, the Department will rely upon and encourage voluntary and collaborative efforts of the watershed stakeholders for implementation of the WMP.

d. Multiple Watershed Plans

The term “Watershed Management Plan” or “WMP,” as used in this permit, may refer to a single plan, or multiple plans for the permittee that has more than one.

Where full participation in multiple watershed (or subwatershed) advisory groups by one permittee may be difficult because of limitations on staff and resources, the permittee may identify a “primary watershed” and concentrate its efforts there. For the remaining “secondary” watershed(s), the permittee shall, at a minimum:

1) Be involved in the Public Participation Process.
2) Share the necessary information regarding the assessment of the watershed in its jurisdiction.
3) Review actions in the WMPs and consider them for implementation.
4) Certify in the progress reports that the permittee reviewed the WMPs.
5) If applicable, include details of disagreements to WMP components, to be included in an appendix to the WMP.

For the “primary watershed,” the permittee shall perform all activities required in the WMP, as detailed in Part I.A.3.b.1-8., and actively participate in watershed or subwatershed meetings.

If a permittee’s jurisdiction spans multiple watersheds, but it does not own or operate MS4s in all of those watersheds, then the watersheds where the permittee owns or operates MS4s within an urbanized area shall be identified in the COC as its “regulated watersheds,” unless the permittee and the Department agree to have other watersheds identified. The Department encourages the permittee to be involved in watershed activities within its jurisdiction for watersheds that are not listed in the COC.

4. Storm Water Pollution Prevention Initiative (SWPPI)

a. SWPPI Submission

1) Standard Requirements

By the date specified in the COC, the permittee shall submit a SWPPI or revised/updated SWPPI to the Department. The permittee shall implement the SWPPI upon submittal. The permittee is encouraged to collaborate with the Department on major SWPPI components and review those items that would require major local government resources in order to secure Department agreement prior to SWPPI submittal. A SWPPI shall be considered complete and approved upon submittal if it meets the requirements in Part I.A.4.b. of this permit

For the convenience of a single implementation document, the permittee may wish to list all WMP actions in the SWPPI document. Any WMP actions included in the SWPPI that are not necessary to meet the requirements in Part I.A.4.b. of this permit must be clearly denoted as "voluntary WMP actions" and placed in an appendix to the SWPPI. Otherwise, these actions will be considered enforceable effluent limitations.

2) Alternative Approaches

Permittees that are interested in alternative approaches are strongly encouraged to collaborate with their watershed partners to seek innovative watershed-based alternatives for meeting SWPPI requirements, where allowed in the permit.

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Alternative approaches are allowed for any of the standard SWPPI requirements in Part I.A.4.b. of this permit, except where restricted by the permit. Requests for alternative approaches, along with details of the alternatives, shall be submitted with the SWPPI, by the SWPPI submittal date identified in the COC. The permittee is encouraged to collaborate with the Department on alternative approaches prior to SWPPI submittal.

The permittee shall implement alternative approaches upon approval from the Department. The Department may deny an alternative approach or request that it be modified before approval. If the permittee is notified that an alternative approach is denied, or the requested modifications to the alternative are not completed satisfactorily within six (6) months of SWPPI submittal, or some other date set by the Department, then the permittee shall revise the SWPPI to replace the alternative with the applicable standard permit requirement(s) and begin implementation of those standard requirements within 90 days of notification from the Department.

Alternative approach submittals shall include clearly-defined methods for evaluating their effectiveness and a description of why the alternative approach will be at least as effective as the standard permit requirement.

Approved alternative approaches become part of the SWPPI. Failure to comply with an approved alternative approach, or to implement the alternative by the expiration of the COC issued under this permit, is a violation of this permit.

3) Reopener
The Department may notify the permittee that the SWPPI is deficient in meeting the permit requirements and request modification of the SWPPI to address specific permit requirements. The permittee shall be given 90 days to address the specific concerns, unless a longer timeframe is agreed to by the Department.

The Department may, after notice and opportunity for hearing, modify permit coverage for the permittee, including requiring a jurisdictional general permit or an individual permit, pursuant to Part I.B.4. of this permit.

b. SWPPI Contents
The submitted SWPPI shall, at a minimum, include actions to address the standard requirements in this section (Part I.A.4.b).

Where WMPs are developed under the Watershed General Permit, the SWPPI shall address actions as follows:

- The Public Education Plan (Part I.A.4.b.2.) and Post-Construction Storm Water Control for New Developments and Redevelopment Projects (Part I.A.4.b.4.) shall be designed and implemented to carry out actions across the regulated area.
- All other requirements of Part I.A.4.b. of this permit shall be designed and implemented to carry out actions where the permittee owns and operates MS4s in the regulated area.

1) Total Maximum Daily Load (TMDL)

In order for the SWPPI to be consistent with the requirements and assumptions of the TMDL approved by the United States Environmental Protection Agency (USEPA), as identified in the COC issued under this permit, the SWPPI shall identify and prioritize actions to reduce pollutants in storm water discharges from the MS4 to make progress in meeting Water Quality Standards.

In addition, except as provided under Subsection c) below, the following specific actions shall be taken by the permittee:

a) E. coli: For MS4 discharges to waterbodies that are covered by a TMDL for the pollutant E. coli, the permittee shall conduct the following activities:

(1) Within three years of COC issuance, the permittee shall take at least one representative sample of a storm water discharge from at least 50 percent of the major discharge points discharging directly to surface waters of the state within the portion of the TMDL watershed in the urbanized area. A major discharge point is a pipe or open conveyance measuring 36 inches or more at its widest cross section. At a minimum, the sample shall be analyzed for E coli.

(2) The permittee shall retain these results and report them in the second progress report.

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(3) The permittee shall use these results and other available information to develop and prioritize actions to reduce the discharge of E coli to be consistent with the TMDL. These prioritized actions shall be reported to the Department in the second progress report, with implementation targeted during the five-year permit cycle that begins in 2013.

b) Total Phosphorus: For MS4 discharges to waterbodies that are covered by a TMDL for the pollutant Total Phosphorus, the permittee shall conduct the following activities:

(1) Within three years of COC issuance, the permittee shall take at least one representative sample of a storm water discharge from at least 50 percent of the major discharge points that discharge directly to surface waters of the state within the portion of the TMDL watershed in the urbanized area. A major discharge point is a pipe or open conveyance measuring 36 inches or more at its widest cross section. At a minimum, the sample shall be analyzed for Total Phosphorus.

(2) The permittee shall retain these results and report them in the second progress report.

(3) The permittee shall use these results and other available information to develop and prioritize actions to reduce the discharge of Total Phosphorus to be consistent with the TMDL. These prioritized actions shall be reported to the Department in the second progress report, with implementation targeted during the five-year permit cycle that begins in 2013.

c) Elective Option: Permittees subject to monitoring requirements under Parts I.A.4.b.1.a. (E. coli) or b. (Total Phosphorus) above, may elect to meet these requirements by working collaboratively with their watershed partners to implement a monitoring program within three years of COC issuance to evaluate the effectiveness of the overall activities in meeting water quality standards and determine priority areas for future implementation activities. The monitoring program shall be detailed in the SWPPI and assess the portion of the TMDL watershed in the urbanized area, as listed in the COC, and be based on:

(1) Known water quality deficiencies (use of existing data is encouraged) that are identified as priorities in the watershed plan and incorporated into the SWPPI.

(2) Applicable approved TMDLs listed in the COC.

The design of the monitoring program shall be based on such factors as:

- Applicable approved TMDLs listed in the COC.
- 303(d) listed waters.
- TMDL findings.
- Priorities in the watershed plan.
- Results from the IDEP.
- The availability of existing monitoring data.

(3) The permittee shall keep a record of the monitoring results and submit them in the permittee's progress reports. The results of the monitoring program shall be used to determine which activities are needed to be consistent with E. coli or phosphorus TMDLs identified in the permittee's COC. These activities shall be reported in the second progress report, with implementation targeted during the five-year permit cycle that begins in 2013.

d) In the event that the permittee already has information and a plan for prioritizing and controlling the discharge of E. coli or Total Phosphorus consistent with the TMDL, that plan may be submitted as an alternative approach to Part I.A.4.b.1.a. (E. coli) or b. (Total Phosphorus) above, as applicable.

2) Public Education Plan (PEP)

The permittee shall submit a PEP or updates to an existing PEP to comply with these permit requirements. The PEP shall promote, publicize, and facilitate watershed education for the purpose of encouraging the public to reduce the discharge of pollutants in storm water to the maximum extent practicable. Pollution prevention shall be encouraged.

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Permittees may elect to meet the PEP requirements by working collaboratively with watershed or regional partners to develop, submit, and implement a watershed-wide or regional PEP. A collaborative PEP shall demonstrate that the audiences of all permittees will be targeted. The PEP shall be submitted with the SWPPI.

Whether using an individual or collaborative PEP approach, an individual permittee shall document in its progress report the status of the public education activities targeted at audiences in its jurisdiction, as well as its participation and contribution.

To assist permittees with the PEP requirement, the Department has developed a "Public Education Plan (PEP) Guidance" document. It is available on the internet at www.michigan.gov/deqstormwater; under Information; select "Municipal Program / MS4 Permit Guidance."

a) An adequate PEP will implement a sufficient amount of educational activities to ensure that the targeted audiences are reached with the appropriate message(s) for the following topics:

(1) Responsibility and stewardship in their watershed

(2) The connection of MS4 catch basins, storm drains, and ditches to area waterways, and the potential impacts these could have on the surface waters of the state

(3) Public reporting of illicit discharges or improper disposal of materials into MS4s

(4) The effects and need to minimize the amount of residential or noncommercial wastes discharged into MS4s, including:

- Preferred cleaning materials and procedures for car, pavement, and power washing
- Acceptable application and disposal of pesticides, herbicides, and fertilizers
- Proper disposal practices for grass clippings, leaf litter, and animal wastes that get flushed into MS4s and the surface waters of the state

(5) The availability, location, and requirements of facilities for disposal or drop-off of household hazardous wastes, travel trailer sanitary wastes, chemicals, yard wastes, and motor vehicle fluids

(6) For property owners with septic systems, the proper septic system care and maintenance, and how to recognize system failure

(7) The benefits of using native vegetation instead of non-native vegetation

(8) For permittees with riparian land owners, methods for managing riparian lands to protect water quality

(9) Additional pollutants unique to commercial, industrial, and institutional entities as the need is identified.

b) For all applicable topics, the PEP shall identify the:
(1) Target audience(s).
(2) Key message(s).
(3) Delivery mechanism(s).
(4) Timetable.
(5) Responsible party (or parties).

c) The PEP shall describe a method for determining the effectiveness of the public education program. Permittees may meet this requirement by working collaboratively with their watershed partners to develop and implement a watershed-wide effectiveness program. This may include watershed-wide social monitoring that can be used to evaluate the effectiveness of overall activities in meeting public education objectives and changing social behaviors. These results can be used to determine priority areas for future implementation activities.

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3) Illicit Discharge Elimination Plan (IDEP)

The permittee shall submit an IDEP or updates to an existing IDEP to comply with these permit requirements. The permittee shall develop, implement, and enforce a program to detect and eliminate illicit connections and discharges to MS4s. Illicit discharges are not authorized by this permit.

The IDEP shall include the following general requirements:

- An ordinance or other regulatory method for controlling discharges in the MS4 (Part I.A.4.b.3.a. of this permit)
- Identification of areas prioritized for field screening or other investigation methods (Part I.A.4.b.3.b.2. of this permit)
- Procedures for eliminating illicit discharges, pursuing enforcement action, and the development of a system to track the elimination status of illicit discharges and enforcement actions (Part I.A.4.b.3.b.5. of this permit)
- A program to train staff (Part I.A.4.b.3.c. of this permit)
- A method for determining the effectiveness of the illicit discharge elimination program (Part I.A.4.b.3.d. of this permit)

At a minimum, the IDEP program shall include the requirements of Parts I.A.4.b.3.a-d. of this permit, unless an alternative approach is approved by the Department:

a) An ordinance, or other regulatory mechanism where an ordinance is not feasible or appropriate, to effectively prohibit illicit discharges into the MS4 owned or operated by the permittee, and to implement appropriate enforcement actions. At a minimum, the ordinance or other regulatory mechanism shall:

(1) Regulate the contribution of pollutants to the MS4 owned or operated by the permittee.

(2) Prohibit illicit discharges, including the direct dumping or disposal of materials into the MS4 owned or operated by the permittee.

(3) Establish the authority to investigate, inspect, and monitor suspected illicit discharges into the MS4 owned or operated by the permittee.

(4) Require and enforce elimination of illicit discharges and connections into the MS4 owned or operated by the permittee.

Non-Storm Water Discharges

The following non-storm water discharges are not authorized in this document, but do not need to be prohibited by the permittee in accordance with Part I.A.4.b.3.a.2. of this permit, unless the permittee identifies them as significant contributors of pollutants to the regulated separate storm water drainage system:

- Water line flushing and discharges from potable water sources
- Landscape irrigation runoff, lawn watering runoff, and irrigation waters
- Diverted stream flows and flows from riparian habitats and wetlands
- Rising groundwaters and springs
- Uncontaminated groundwater infiltration [as defined by 40 CFR 35.2005(20)]
- Pumped groundwaters (except for groundwater cleanups not specifically authorized by NPDES permits), foundation drains, water from crawl space pumps, footing drains, and basement sump pumps
- Air conditioning condensates
- Waters from non-commercial car washing
- Residual street wash waters
- Discharges or flows from emergency fire fighting activities
- Dechlorinated swimming pool waters from single, two, or three family residences. A swimming pool operated by the permittee shall not be discharged to a separate storm sewer or to the surface waters of the State without specific NPDES permit authorization from the Department.

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b) A program to find and eliminate illicit connections and discharges to the MS4 from commercial, industrial, private educational, public, and residential sources. Unless the Department approves an alternative approach, the program to find and eliminate illicit discharges and connections shall include:

(1) A storm sewer system map, showing the location of all discharge points the permittee owns or operates, and the names and location of all the surface waters of the state that receive discharges from the permittee's MS4. A separate storm sewer system includes: roads, catch basins, curbs, gutters, parking lots, ditches, conduits, pumping devices, and man-made channels. Maps may include available diagrams, such as certification maps, road maps showing rights-of-way, as-built drawings, diagrams, or other hard copy or digital representation of the storm sewer system. Maps may be accompanied by narrative descriptions for portions of the system.

<u>By the date identified in the COC for the first progress report</u>, or another date as agreed to by the Department for a portion of the storm sewer system, the permittee shall have the above information. This information shall be retained by the permittee and made available to the Department upon request. System information shall be maintained and updated as discharge points are identified or added.

(2) Identification of areas prioritized by the permittee for field screening or other investigation methods for the purpose of maximizing the detection and elimination of illicit discharges. Prioritization shall consider the criteria in Table 1. Highest priority criteria are generally listed toward the top of the table, but a permittee's priority order may vary and some criteria may not be applicable.

Table 1

Prioritization Criteria	Key Characteristics to Consider for Prioritization
Poor Dry Weather Water Quality	Areas where TMDLs have been developed to address pollutants that could originate from illicit discharges or where the available data shows dry-weather water quality criteria are exceeded two or more times in a year are high priorities.
Density of Aging On-Site Disposal Systems (OSDS)	Older septic systems that have exceeded their design life may have failure rates of 25 to 30 percent or more. Areas where the OSDS designs would not be permitted today because of poor soils or small lot sizes, but where older OSDS are still in operation, have a high illicit discharge potential.
Aging or Failing Sewer Infrastructure	Areas where sewer age exceeds its design life; and where clusters of pipe breaks, spills, overflows, or infiltration and inflow are known problems should be given a high priority.
Discharge Complaints and Reports	Any MS4s owned or operated by the permittee with a history of discharge complaints should be given a high priority.
Age and Density of Industrial Operations	Older industrial operations often have floor drains, waste handling areas, gray water, and sanitary facilities connected to storm sewers. Industrial areas also commonly have storm water pollutants related to poor housekeeping practices, so a higher density of industrial operations increases the likelihood of contaminated discharges.
Age of Development	Areas where the average age of the majority of the development exceeds 50 years should be given a higher priority.
Sewer Conversion Areas	Areas where sanitary sewers were added in the last 30 years, and people switched from septic systems, have a high potential for illicit taps of sanitary water to MS4s.
Historic Combined Sewer Systems	Sewer systems that were once combined, but were subsequently separated, have a high illicit discharge potential if oversight of the projects was not documented.
Type of Commercial Activity	Businesses not regulated by industrial storm water permits, especially those that handle liquids, including oils and greases (e.g., auto maintenance, food service, and carpet cleaners) may remain unaware of storm water pollution concerns from improper waste disposal and "hopper juice" from the trash bins and compactors they operate.
Other Potential Pollutant Generating Sites	Conditions unique to the permittee's jurisdiction should be considered.

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(3) A plan and procedures to perform dry-weather screening of each MS4 discharge point at a minimum of every five (5) years, beginning on the due date for the IDEP submittal, unless the Department approves an alternative plan or the permittee chooses to use the Elective Option as provided below. Alternatives should be based on the identification of priority areas in Table 1, and shall demonstrate that other methods for identifying illicit connections and discharges will be at least as effective as dry-weather screening every five years.

(a) At a minimum, dry-weather screening shall include observations of MS4 discharge point flows and receiving water characteristics, including: water clarity, color, and odor; the presence of suds, oil sheens, sewage, floatable materials, bacterial sheens, algae, and slimes; staining of the banks and unusual vegetative growth. MS4 discharge structures shall be observed for unusual vegetative growth, staining, undocumented connections, and integrity of the structure.

(b) If flow is observed from the MS4 discharge point, then the permittee shall do one of the following:

- Where an illicit discharge and its source are obvious, it shall be eliminated. Additional analysis or sampling is not required.
- Conduct a field assessment of the dry-weather flow to analyze, at a minimum: pH, ammonia, surfactants, and temperature. The analysis may be conducted using a field kit.

Elective Option: Permittees may elect to meet the dry-weather screening requirement by working collaboratively with the MS4 permittees in a jointly-operated MS4 and performing dry-weather screening on the MS4 at the discharge points that directly discharge to surface waters of the state. Discharge points at surface waters shall have dry-weather screening performed a minimum of once every five years, beginning on the due date for the SWPPI submittal as identified in the COC, and shall follow the requirements of (a) and (b), unless an alternative is approved. Under the elective option, the permittee shall include a statement in the SWPPI that includes the names and commitments from all permittees in the jointly-operated MS4 certifying participation in this elective option. The SWPPI shall include a method for sampling the discharge points to a surface water of the state and a process for notifying the other participating MS4 operators within one month of detection of an illicit discharge, identifying the date and location where the illicit discharge was detected, and any other information about the discharge that will assist with the identification of its source. All participating operators of an MS4 where an illicit discharge has been detected shall perform dry-weather screening of their discharge points in that MS4 within 13 months of detection, unless the illicit discharge is eliminated or is identified in a portion of the MS4 not influenced by discharges from the permittee's discharge points.

(4) If an illicit discharge is detected, but the source has not been identified, the source shall be confirmed by one or more of the following methods, unless the Department approves an alternative plan: indicator parameter sampling, which may include chemical and bacterial sampling; dye testing; video testing; smoke testing; documented visual observation or physical indicators; homeowner surveys and surface condition inspections for on-site sewage disposal systems; and drainage area investigations. The discharge of tracer dyes shall be authorized in accordance with Part 1.A.5.a. of this permit.

(5) Procedures for eliminating illicit discharges and pursuing enforcement action, including responding to spills and emergency situations. The procedure shall specify measures for expeditious response to, and elimination of, each identified illicit discharge, spill, and emergency situation. If not already existing, the permittee shall develop a system to track the elimination status of illicit discharges and enforcement actions. The system shall also track confirmation that illicit connections are removed and the discharge permanently ceased. The permittee shall make records associated with this activity available to the Department upon request.

c) A program to train staff employed by the permittee who are involved in illicit discharge-related activities, or who have field jobs with the potential for witnessing illicit discharges and connections. The training shall be implemented according to the program and include the following:

(1) The definition of illicit discharges and connections

(2) Techniques for finding illicit discharges, including field screening, source identification, and recognizing illicit discharges and connections

(3) Methods for eliminating illicit discharges and the proper enforcement response

(4) A training schedule and requirement for training during the term of the permit

d) The IDEP shall describe a method for determining the effectiveness of the illicit discharge elimination program.

4) Post-Construction Storm Water Control for New Developments and Redevelopment Projects

The permittee shall develop, implement, and enforce a program through an ordinance or other regulatory mechanism to address post-construction storm water runoff from all new and redevelopment projects that disturb one (1) acre or more, including projects less than one (1) acre that are part of a larger common plan of development or sale that would disturb one (1) acre or more. The program shall include the following general requirements:

- A *minimum treatment volume standard* to minimize water quality impacts
- *Channel protection criteria* to prevent resource impairment resulting from flow volumes and rates
- Operation and maintenance requirements
- Enforcement mechanisms with recordkeeping procedures
- A requirement for the project developer to write and implement site plans, which shall incorporate the requirements of this section of the permit

The permittee shall retain the records associated with this activity in accordance with Part II.C.3. of this permit.

The permittee shall establish structural storm water BMP design standards by meeting any of the following:

- The permittee identified in its application a schedule to develop and place in effect an ordinance or other regulatory mechanism that incorporates the *minimum treatment volume standard* and the *channel protection criteria* listed in a) and b) below.
- The permittee identified in its application for coverage under this general permit its applicable local ordinance or regulatory mechanisms that implement a standard for storm water treatment and criteria for channel protection that existed before the permittee submitted its application.
- The permittee identified in its application for coverage under this general permit the applicable local procedures that implement a standard for storm water treatment and criteria for channel protection that existed before submittal of its application, and these local procedures will be converted into an ordinance or other regulatory mechanism by the date specified in the COC for SWPPI submittal.
- The permittee submits with the SWPPI an alternative approach, such as design criteria based on low-impact development (LID), that provides at least the same level of water quality treatment and channel protection as a) and b) below, and the alternative is approved by the Department.
- Elective Option: The permittee identified in the application for coverage under this general permit that it will develop an ordinance or other regulatory mechanism to meet the following outcomes:
    - A methodology and standard for treating water quality based on watershed priorities identified in the WMP
    - Criteria for channel protection based on scientifically accepted morphological concepts
    - The requirements of Part I.A.4.b.4.c.

  The permittee shall submit its standards and criteria proposed under the elective option as a request for permit modification by the date specified in the COC to the Chief of the Permits Section, Water Bureau, Michigan Department of Environmental Quality, P.O. Box 30273, Lansing, Michigan 48909-7773.

Any combination of existing regulatory mechanism or procedure, approved alternative approach, elective option, or adoption of an ordinance or regulatory mechanism in accordance with the requirements of a) and b) below, may be used to establish the necessary minimum treatment volume standard and channel protection criteria, provided that they are applied to all new developments and redevelopment projects as described at the beginning of this section. Amendments made to ordinances or other regulatory mechanisms do not have to be submitted to the Department if the amendments do not reduce the level of channel protection or water quality treatment that were provided prior to the amendment.

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a) The *minimum treatment volume standard* shall be either:

(1) One inch of runoff from the entire site, or ½ inch of runoff from the entire site if the permittee demonstrates technical support for it in the WMP, or

(2) The calculated site runoff is from the 90 percent annual non-exceedance storm for the region or locality, according to (a) or (b) below, respectively.

(a) The statewide analysis by region for the 90 Percent Annual Non-Exceedance Storms is summarized in a Department memo dated March 24, 2006, which is available on the Internet at: www.michigan.gov/deqstormwater; under Information, select "Municipal Program/MS4 Permit Guidance," then go to the Storm Water Control Resources heading.

(b) The analysis of at least ten years of local published rain gauge data following the method in the memo "90 Percent Annual Non-Exceedance Storms" cited above. This approach is subject to approval by the Department.

Treatment methods shall be **designed** on a site-specific basis to achieve the following:

- A minimum of 80 percent removal of total suspended solids (TSS), as compared with uncontrolled runoff, or
- discharge concentrations of TSS not to exceed 80 milligrams per liter (mg/l).

A minimum treatment volume standard is not required where site conditions are such that TSS concentrations in storm water discharges will not exceed 80 mg/l.

b) The *channel protection criteria* established in this permit is necessary to maintain post-development site runoff volume and peak flow rate at or below existing levels for all storms up to the 2-year, 24-hour event. "Existing levels" means the runoff flow volume and rate for the last land use prior to the planned new development or redevelopment. Where more restrictive channel protection criteria already exists or is needed to meet the goals of reducing runoff volume and peak flows to less than existing levels on lands being developed or redeveloped, permittees are encouraged to use the more restrictive criteria than the standard permit requirements.

(1) An acceptable source of rainfall data for calculating runoff volume and peak flow rate is: *Rainfall Frequency Atlas of the Midwest*, Huff & Angel, NOAA Midwest Climate Center and Illinois State Water Survey, 1992.

(2) Methods for estimating pre- and post-development runoff shall follow curve number evaluations as described in Computing Flood Discharges for Small Ungaged Watersheds, dated July 2003, which is available on the Internet at: www.michigan.gov/deqstormwater; under Information, select "Municipal Program/MS4 Permit Guidance," then under "Storm Water Control Resources" select "Guidance for Calculating Runoff Volume and Peak Flow Rate."

(3) The permittee shall request approval from the Department to use other rainfall data sources and runoff models.

(4) Channel protection criteria shall not be required for the following water bodies:

(a) The Great Lakes or connecting channels of the Great Lakes
(b) The Rouge River downstream of the Turning Basin
(c) The Saginaw River
(d) Mona Lake and Muskegon Lake in Muskegon County
(e) Lake Macatawa and Spring Lake in Ottawa County

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c) All structural and vegetative BMPs installed as a requirement under this section of the permit shall include a plan for maintaining maximum design performance through long-term operation and maintenance (O & M). The permittee shall develop, track, and enforce a program, through an ordinance or other regulatory mechanism, to ensure long-term O & M plans for the *water quality treatment* and *channel protection* controls the permittee requires.

5) Construction Storm Water Runoff Control

The Department has determined that Part 91 of the Michigan Act and Michigan's Permit by Rule (Rule 323.2190) are qualifying local programs for the control of wet weather discharges from construction activities that result in a land disturbance of greater than or equal to one (1) acre, or disturb less than one (1) acre that is part of a larger common plan of development or sale. A qualifying local program provides control for soil erosion, off-site sedimentation, and other construction-related wastes, consistent with Federal Phase 2 storm water control requirements for MS4 permittees.

To ensure adequate protection of the MS4, the permittee shall develop and implement the following:

a) A procedure to provide notice as follows when pollutants are discharged from construction activity in violation of Section 9116 of Part 91 of the Michigan Act, Michigan's Permit by Rule at R 323.2190(2)(a), or the prohibition of non-storm water discharges in Part I.A.4.b.3.a. of this permit, and the pollutants enter the MS4 owned or operated by the permittee:

(1) Notify the Part 91 permitting entity and the Department when soil and sediment are discharged.
(2) Notify the Department when other wastes are discharged.

If the permittee suspects the discharge may endanger public health or the environment, the violations shall be reported in accordance with Part I.B.2.a. of this permit.

b) A procedure to ensure adequate allowance for soil erosion and sedimentation controls on preliminary site plans, as applicable

c) A procedure for the receipt and consideration of complaints or other information submitted by the public regarding construction activities discharging wastes to the MS4

6) Pollution Prevention and Good Housekeeping Activities for Municipal Operations

Municipal operations cover a wide variety of activities and land uses that are potential sources of storm water pollutants. These include, but are not limited to, roadways; parking lots; transportation and equipment garages; fueling areas, warehouses; stockpiles of salt and other raw materials; open ditches and storm sewers; turf and landscaping for all municipal properties, including parks; and waste handling and disposal areas.

The permittee shall develop, implement, and ensure compliance with a program of operation and maintenance of BMPs, with the ultimate goal of minimizing pollutant runoff to the maximum extent practicable from municipal operations that discharge storm water to the surface waters of the state. The permittee is encouraged to use BMP guidance and training materials that are available from federal, state, or local agencies, or other organizations. The SWPPI shall include specific actions and implementation schedules for the BMP operation and maintenance program.

The program shall meet the following requirements:

a) Employee/Contractor Training Related to Storm Water Management Activities
The permittee shall ensure there is training for staff and contractors associated with potential storm water pollutant sources on topics that affect the water quality entering the MS4, such as park and open space maintenance, fleet and building maintenance, new construction and land disturbances, storm water system maintenance, and any other activity included in the standard requirements of Part I.A.4.b.6.b-e. Training topics shall be determined by the permittee, working with the watershed partners. Timing for training shall include the following:

- For existing employees, one (1) training session prior to the expiration of this permit
- For new employees, one (1) training session during the first year of employment

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- For contractors, the permittee shall ensure that they are trained before they perform the contract work. Permittees may conduct the training or provide training materials relating to storm water management activities, which may include local pollution control specifications and standards for bid specifications.

b) Structural Storm Water Control Effectiveness
Structural storm water controls include, but are not limited to, vegetated swales; infiltration, sedimentation, and bioretention facilities; storm water devices (e.g., catch basins and oil/water separators); and any controls installed or operated by the permittee to remove pollutants from storm water. Routine maintenance shall be provided, and maintenance schedules shall be developed and implemented that are adequate to maintain pollution removal effectiveness at design performance, and to ensure that the controls are maintained in a condition (e.g., adequately stabilized, seeded, functional) to reduce, to the maximum extent practicable, the contribution of pollutants to the surface waters of the state.

(1) The permittee shall inspect all structural storm water controls at a frequency appropriate for the BMP design and site conditions. Inspection frequencies shall be identified in the SWPPI.

(2) The permittee shall include in the SWPPI a summary list of the municipal properties and an estimate of the structural storm water controls owned or operated by the permittee. The list shall include the type and number of municipal properties and structural storm water controls. The permittee shall have location information for all municipal properties and structural storm water controls <u>by the date specified in the COC for the submittal of the first progress report</u>. The information may be included on the maps maintained for the IDEP (Part. I.A.4.b.3.b.1. of this permit). The location information shall be updated whenever new municipal properties and structural storm water controls are added. The location information shall be retained by the permittee and, upon advance notice, provided to the Department for review.

The following are examples of municipal properties: police or fire station(s), library(ies), administration building(s) (e.g., city or township hall), public works facility(ies), such as maintenance garages or storage yards, park(s), cemetery(ies), waste disposal areas or unregulated landfills/dumps, open or vacant land, or any other type (describe) of property maintained by the permittee.

(3) The permittee shall describe and implement procedures to dispose of the following materials in accordance with Part 111 (hazardous waste), Part 115 (solid waste), and Part 121 (liquid industrial waste) of the Michigan Act: operation and maintenance waste, such as dredge spoil, accumulated sediments, floatables, and other debris the permittee removes from the MS4. Options for the disposal of wastes removed from catch basin sumps or other parts of an MS4 are included in the Department publication entitled "Guidance for Catchbasin Cleaning Activities," which is available on the Internet at: <u>www.michigan.gov/deqstormwater</u>, under the information link named "Municipal Program/MS4 Permit Guidance."

(4) When the permittee adds facilities or structural controls for water quantity or pollution treatment or removal, it shall design and install the controls based on the treatment volume standard, channel protection criteria, and requirements for operation and maintenance established under Part I.A.4.b.4. Permittees are encouraged to upgrade and rehabilitate existing facilities or structural controls based on the treatment volume standard, channel protection criteria, and requirements for operation and maintenance in Part I.A.4.b.4.

c) Roadways, Parking Lots, and Bridges

(1) The permittee shall construct, operate, and maintain its streets, roads, highways, parking lots, and other permittee-owned or operated impervious infrastructure in a manner so as to reduce the discharge of pollutants into the MS4 and the surface waters of the state, including pollutants resulting from snow removal practices.

(2) The permittee shall reduce the runoff of total suspended solids (TSS) from all of its paved surfaces to the maximum extent practicable.

TSS reductions may be achieved by any combination of pollution prevention (e.g., improved materials handling, or altered land uses or traffic patterns), removal (cleaning streets and catch basins), or treatment (settling filtration or infiltration). Permittees are encouraged to collaborate with their watershed partners to seek watershed-based alternative approaches for meeting the TSS reduction.

Reductions of sediment from activities otherwise regulated or prohibited, such as sediment track-out or runoff from construction sites, shall not be counted toward the TSS load reduction achieved. As a method of assessing progress in storm water pollution prevention, the permittee's progress reports shall provide an estimate of the TSS loading reduction achieved.

(3) Salt and sand applied for improved traction shall be prevented from entering MS4s and receiving streams to the maximum extent practicable. Good housekeeping shall be required at salt and sand storage facilities to prevent the discharge of salt and sand from these areas. The permittee shall also comply with the salt storage requirements of the Part 5 Rules (Rules 324.2001 to 324.2009 of the Michigan Administrative Code).

(4) The permittee shall implement the appropriate BMPs to control dust and suspended solids in runoff from unpaved roads and parking lots.

(5) The permittee shall not use coal tar emulsions to seal asphalt surfaces.

d) Fleet Maintenance and Storage Yards

(1) A Storm Water Pollution Prevention Plan (SWPPP) shall be implemented for all municipal fleet maintenance and storage yards that are not regulated as industrial activities. The SWPPP shall be developed in accordance with the Appendix to this permit.

The permittee shall have a certified storm water operator in accordance with Part II.D.2 of this MS4 permit to oversee storm water controls at all facilities with SWPPPs. To meet the SWPPP and the certified storm water operator requirements, the permittee may opt to incorporate the requirements identified in the Department's industrial storm water permit program into the SWPPI, to be overseen by the Storm Water Program Manager.

(2) The permittee's SWPPI shall identify its fleet maintenance and storage yard facilities (including those for nested jurisdictions, if applicable), and shall indicate if a SWPPP has been developed for each facility and if it has been implemented under the supervision of a certified storm water operator.

(3) The completed SWPPP shall be signed by the facility manager and certified storm water operator or Storm Water Program Manager, as applicable, and retained on-site at the facility that generates the storm water discharge. The permittee shall retain the SWPPP, reports, log books, storm water discharge sampling data (if collected), and supporting documents in accordance with Part II.C.3. of this MS4 permit.

(4) Fleet maintenance activities include, but are not limited to, adding or changing vehicle fluids, including fuel, lubrication, mechanical repairs, parts degreasing, and vehicle or equipment washing. Storage yards include, but are not limited to, areas where vehicles are stored or impounded, and where vehicle and road maintenance materials and other chemicals in bulk are stored and handled. The discharge of vehicle or maintenance facility wash water is not authorized by this MS4 permit. Vehicles and equipment shall be maintained for clean and effective operation to prevent impacts on storm water quality.

(5) The permittee shall also investigate, select or design, and implement appropriate BMPs to prevent the discharge of pollutants to the MS4 from the storage, collection, transport, and disposal of refuse by the permittee or for the permittee under contract.

e) Managing Vegetated Properties
The permittee shall minimize the discharge of pollutants related to the management of vegetation on land that the permittee owns or operates. BMPs required under this measure include:

PART I

Section A. Effluent Limits and Monitoring

(1) A process to train employees and contractors on the proper storage, handling, and use of pesticides, herbicides, and fertilizers before they handle or apply them.

(2) Use of only phosphorus-free fertilizers for turfgrass. Phosphorus may be added to turfgrass only if soils are tested for nutrients (nitrogen/phosphorus/potassium) every four years and a need for phosphorus is demonstrated. Phosphorus fertilizers shall be applied to lands that the permittee owns or operates only as prescribed in the soil test results.

(3) A program to minimize storm water impacts from all of the permittee's managed vegetated properties.

7) Program Assessment

The SWPPI shall identify methods for determining the effectiveness of the SWPPI actions to be implemented. Evaluation of the effectiveness at the watershed level is encouraged.

8) Implementation Schedule

Provide a detailed implementation schedule, identifying the years and frequency, if applicable, that the permittee will implement the actions to which they have committed. All actions shall be implemented (i.e., put into action, operation, service, or practice) over the term of this permit, unless the permittee has a shortened permit term and the Department agrees to another schedule.

9) SWPPI Coverage in Areas with Deferred WMPs

Where the WMP has been deferred for urbanized areas, as indicated in the COC, the requirements of Part I.A.4.b. of this permit shall be designed and implemented to carry out actions where the permittee owns and operates MS4s in the regulated area.

c. Facility Contact Person

The permittee shall identify a facility contact person to act as a storm water program manager responsible for overseeing compliance with the requirements of this permit. The facility contact person may be replaced at any time, and the permittee shall notify the Department within ten days after the replacement.

d. Retention of Records

The latest approved version of the SWPPI shall be retained until at least three years after coverage under this permit terminates. All records and information resulting from the assessment of SWPPI effectiveness shall be retained for a minimum of three years or longer if requested by the Department or the Regional Administrator.

5. Discharges Requiring Separate Authorizations

a. Tracer Dye Discharges

This permit does not authorize the discharge of tracer dyes without approval from the Department. Requests to discharge tracer dyes shall be submitted to the Department.

b. Water Treatment Additives

This permit does not authorize the discharge of water additives without approval from the Department. Water additives include any material that is added to water discharged through the MS4 to condition or treat the water.

In the event a permittee proposes to discharge water additives, the permittee shall submit a request to discharge water additives to the Department for approval. Such requests shall be sent to the Surface Water Assessment Section, Water Bureau, Department of Environmental Quality, P.O. Box 30273, Lansing, Michigan 48909-7773, with a copy to the Department. Instructions to submit a request electronically may be obtained via the Internet (http://www.michigan.gov/deq and on the left side of the screen click on Water, Water Quality Monitoring, and Assessment of Michigan Waters; then click on the Water Treatment Additive List which is under the Information banner). Written approval from the Department to discharge such additives at specified levels shall be obtained prior to discharge by the permittee. Additional monitoring and reporting may be required as a condition for the approval to discharge the additive.

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Section A. Effluent Limits and Monitoring

A request to discharge water additives shall include all of the following water additive usage and discharge information:

1) Material Safety Data Sheets

2) The proposed water additive discharge concentration

3) The discharge frequency (i.e., the number of hours per day and the number of days per year)

4) The monitoring point from which the product is to be discharged

5) The type of removal treatment, if any, that the water additive receives prior to discharge

6) Product function (i.e., microbiocide, flocculant, etc.)

7) A 48-hour LC50 or EC50 for a North American freshwater planktonic crustacean (either *Ceriodaphnia sp*., *Daphnia sp*., or *Simocephalus sp*.)

8) The results of a toxicity test for one other North American freshwater aquatic species (other than a planktonic crustacean) that meets a minimum requirement of Rule 323.1057(2) of the Water Quality Standards

Prior to submitting the request, the permittee may contact the Surface Water Assessment Section by telephone at 517-335-4184 or via the Internet at the address given above to determine if the Department has the product toxicity data required by items 7) and 8) above. If the Department has the data, the permittee will not need to submit product toxicity data.

c. Wastewater Associated with Concrete
The permittee shall not discharge to the surface waters of the state any wastewater generated from cutting, grinding, drilling, or hydrodemolition of concrete without authorization under an NPDES wastewater discharge permit.

PART I

Section B. Program Assessment and Reporting

1. Progress Reports

By the dates indicated on the COC, progress reports shall be submitted to the Department on the implementation status of this permit and the progress of the permittee's pollution prevention program. The progress reports shall cover all of the decisions, actions, and results performed as part of this permit during the period since the last report, or since the effective date of the permit if no report was previously submitted.

At a minimum, the progress reports shall cover the following subjects:

a. Joint Reporting Requirements
Where permittees are responsible for submittal of a joint WMP for the same watershed, joint reports shall be submitted on behalf of all the permittees, by the date specified on the COC for the first and second progress reports, and will include the following information about joint activities conducted by all permittees for that watershed's WMP and PPP:

1) WMP

a) Permittees who developed a joint WMP under a former general permit with Watershed Planning shall:
- In the first report, identify what is necessary to revise/update the existing joint WMP to meet the requirements of Part I.A.3.b. of this permit.
- In the second progress report, provide the implementation status of the existing joint WMP.

b) Permittees required to develop a new joint WMP under this permit shall submit the WMP with the first progress report.

2) PPP
Describe the PPP activities that have occurred in support of WMP development and/or implementation since the previous progress report. The description shall include an evaluation of the plan's effectiveness and steps needed to remedy inadequate public participation (if identified).

3) Watershed-Wide Activities
In the first and second progress reports, describe the status of the plan to make progress towards meeting the Water Quality Standards through joint watershed-wide activities, with particular emphasis on waterbodies listed on the 303(d) list and those waterbodies for which a TMDL has been completed.

4) Watershed-Wide Alternative Approaches
An alternative approach implemented on a watershed basis may be accompanied by a joint report of its effectiveness in the second progress report.

b. Permittee-Specific Reporting Requirements
The permittee shall provide progress reports with the following information:

1) Discharge Point Location
Provide updated information in accordance with Part I.A.2.a. of this permit that was not previously submitted for newly identified, constructed, or installed MS4 discharge points.

2) SWPPI

a) Describe the status of the SWPPI actions and implementation schedules for the permittee's regulated areas. This review shall cover all of the permittee's commitments under the SWPPI (including the PEP and the IDEP).

b) Provide monitoring data and describe the actions prioritized to minimize pollutants consistent with a TMDL within the permittee's area of permit coverage, if applicable, under Part I.A.4.b.1. of this permit.

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Section B. Program Assessment and Reporting

c) Provide schedules for the elimination of illicit connections that have been identified but have yet to be eliminated.

d) If the SWPPI has been revised, submit the revised SWPPI with the revisions identified.

e) Provide contact information for any certified storm water operators or Storm Water Program Manager added under Part I.A.4.b.6.d. of this permit since the last report or SWPPI submittal.

f) If there are urbanized areas with a deferred WMP, describe the status of any additional SWPPI actions for any areas with a deferred WMP. If necessary, update both the characterization of the watershed(s) in the deferred area and the comparison to the watershed(s) covered by the WMP. The permittee shall update any additional actions that have been included in the SWPPI as a result of any significant discrepancy between deferred watersheds and watersheds with WMPs.

4) Evaluation of Effectiveness
Describe the effectiveness of all of the actions implemented under the SWPPI and the methods for these determinations. Specific evaluation criteria for the PEP, the IDEP, and TSS reduction are as follows:

a) For the PEP, provide a summary of the evaluation of the PEP's overall effectiveness, using the evaluation methods prescribed in the PEP.

b) For the IDEP, in addition to evaluating its effectiveness, provide documentation of the actions taken to eliminate illicit discharges. For identified illicit discharges, the permittee shall summarize the total estimated volume and pollutant load eliminated for the main pollutant(s) of concern, and the location(s) of the discharge(s) into both the permittee's MS4 and the receiving water. For illicit discharges identified under the elective option coming from other participating operators of the MS4, the permittee performing dryweather screening at the discharge points to the surface waters of the state shall provide documentation of the notifications to the other participating operators and the information given to them with the notifications.

c) Assess TSS reduction in accordance with Part I.A.4.b.6.c.2. of this permit by reporting the following:
- Describe the current level of control related to TSS discharges from paved surfaces
- Estimate the load reduction from existing controls
- In the second annual report, evaluate the effectiveness of current TSS control practices and identify the methods for improving this effectiveness, to be implemented beginning in 2013

5) WMP Implementation
The permittee may report any voluntary actions that contributed to the implementation of the WMP or progress toward meeting measurable objectives in the WMP.

6) Other Actions
The permittee shall submit information for any other actions taken to reduce the discharge of pollutants in storm water.

7) Nested MS4 Agreements
If applicable, the permittee shall identify any nested jurisdictional agreements that were not identified in previous progress reports or permit applications.

c. Phase I Annual Reporting Requirements (Phase I Permittees Only)
The operator of a large or medium separate storm sewer system who was permitted under Phase 1 of the Federal storm water regulations shall also submit the following information annually, on or before the anniversary date of the COC's issuance:

1) Implementation Status [40 CFR 122.42(c)(1)]
The permittee shall describe the status of implementing the components of the SWPPI.

PART I

Section B. Program Assessment and Reporting

2) Environmental Impacts [40 CFR 122.42(c)(7)]
The permittee shall provide an assessment of the pollution reduction and probable receiving water quality impacts associated with the program's implementation. When applicable, a statement shall be included regarding any negative water quality impacts that may have occurred as a result of any illicit discharges or accidental spills during the report cycle.

3) Revised Fiscal Analysis [40 CFR 122.42(c)(3)]
The permittee shall provide a summary of revisions, if necessary, to the fiscal analysis reported during the previous permit. Permit application requirements at 40 CFR 122.26(d)(2)(vi) may be used to guide reporting.

4) Data Summary [40 CFR 122.42(c)(4)]
The permittee shall provide a summary of data, including monitoring data, that is accumulated throughout the reporting year.

5) Annual Budget [40 CFR 122.42(c)(5)]
The permittee shall provide the previous reporting cycle's expenditures and proposed budget for the reporting cycle following the report.

6) PEP Reporting and Program Enforcement [40 CFR 122.42(c)(6)]
The permittee shall provide a summary describing the number and nature of enforcement actions, inspections, and public education programs.

2. Notification Requirements

The permittee shall verbally notify the Department within 24 hours of becoming aware of any discharges to or from the MS4 that the permittee suspects may endanger public health or the environment.

Notification should include (if known) the name of the person responsible for the discharge, the location of the discharge into the MS4, the location where the MS4 discharges to the surface waters, the nature of the discharge and the pollutants, and clean-up and recovery measures taken or planned. If the notice is provided after regular working hours, call the Department of Environmental Quality's 24-Hour Pollution Emergency Alerting System telephone number: 1-800-292-4706.

3. Expiration and Reissuance

On or before October 1, 2012, a permittee seeking continued authorization to discharge under this permit beyond the permit's expiration date shall submit to the Department a written request containing such information, forms, and fees as required by the Department. Without an adequate request, a permittee's authorization to discharge will expire on April 1, 2013. With an adequate request, a permittee shall continue to be subject to the terms and conditions of the expired permit until the Department takes action on the request, unless this permit is terminated or revoked.

If this permit is terminated or revoked, all authorizations to discharge under the permit shall expire on the date of termination or revocation.

If this permit is modified, the Department will notify the permittee of any required action. Without an adequate response, a permittee's authorization to discharge will terminate on the effective date of the modified permit. With an adequate response, a permittee shall be subject to the terms and conditions of the modified permit on the effective date of the modified permit, unless the Department notifies the permittee otherwise.

PART I

Section B. Program Assessment and Reporting

4. Requirement to Obtain an Individual Permit

The Department may require any permittee that is authorized to discharge due to possessing a valid COC under this general permit to apply for and obtain an individual NPDES permit if any of the following circumstances apply:

a. The discharge is a significant contributor to pollution as determined by the Department on a case-by-case basis.

b. The discharger is not complying with, or has not complied with, the conditions of the permit.

c. A change has occurred in the availability of a demonstrated technology or the practices for the control or abatement of waste applicable to the point source discharge.

d. Effluent standards and limitations are promulgated for point source discharges subject to this permit.

e. The Department determines that the criteria under which the permit was issued no longer apply.

Any person may request the Department to take action pursuant to the provisions of Rule 2191 (Rule 323.2191 of the Michigan Administrative Code).

PART I

Section C. Compliance Schedule Summary

Table 2 summarizes the compliance schedules for this permit. The permit is designed to follow the schedules shown, but actual compliance schedules may vary, and are listed in the permittee's COC issued under this permit.

TABLE 2: Approximate Compliance Schedule for the Certificate of Coverage (COC)

PERMIT REQUIREMENT	SUBMITTAL	DUE TO MDEQ	IMPLEMENTATION
Joint Public Participation Plan (PPP) revision/update submittal (by group or each permittee)	Six (6) months after the effective date of the certificate of coverage (COC)	Revised/Updated Joint PPP (Part I.A.3.a.)	Upon submittal
SWPPI Revision/Update submittal (including IDEP and PEP)	One (1) year after the effective date of the COC	SWPPI revisions/updates that include all requirements from Part I.A.4., including proposed alternatives	Implement standard requirements upon submittal, or alternatives upon approval
Joint report on WMP updates/revisions needed, PPP activities, and status of watershed-wide activities (not by each permittee)	Two (2) years after the effective date of the COC	Report on activities, progress, and plan revision needs related to the WMP and PPP (Parts I.B.1.a.1.a and I.B.1.a.2.-3.)	Begin revisions/updates of the WMP based on the needs identified Implement ways to improve public participation, if necessary
Progress Reports	Two (2) years and four (4) years after the effective date of the COC	Permittee's progress made since last report (Part I.B.1.b.)	
Report newly discovered or constructed discharge point locations	Upon discovery/construction, to provide authorization to discharge	Location of discharge points submitted to Permits Section - Lansing (Part I.A.2.)	
Joint report on the implementation status of the WMP and watershed-wide activities, and PPP activities (not by each permittee)	Four (4) years after the effective date of the COC	Summary of all actions carried out under the WMP developed under the last permit (Parts I.B.1.a.1.a. and I.B.1.a.2.-3.)	SWPPI Revision/Update submittal Implement ways to improve public participation, if necessary
Joint WMP revision/update submittal (not by each permittee)	Four (4) years after the effective date of the COC Include with the second progress reports	Revised/Updated Joint WMP according to Part I.A.3.b.	As determined by the watershed partners
Where a new WMP is initiated under this permit, the first-time WMP submittal shall be approximately two (2) years after the effective date of the COC. The schedules for first-time submittal and implementation of all other plans shall be the same as the schedules for revised or updated plans (above).			

PART II

Section A. Definitions

This list of definitions may include terms not applicable to this permit.

Acute toxic unit (TU_A) means $100/LC_{50}$, where the LC_{50} is determined from a whole effluent toxicity (WET) test which produces a result that is statistically or graphically estimated to be lethal to 50 percent of the test organisms.

Best management practices (BMPs) means structural devices or nonstructural practices that are designed to prevent pollutants from entering into storm water flows, to direct the flow of storm water, or to treat polluted storm water flows.

Bioaccumulative chemical of concern (BCC) means a chemical which, upon entering the surface waters, by itself or as its toxic transformation product, accumulates in aquatic organisms by a human health bioaccumulation factor of more than 1000 after considering metabolism and other physiochemical properties that might enhance or inhibit bioaccumulation. The human health bioaccumulation factor shall be derived according to R 323.1057(5). Chemicals with half-lives of less than eight weeks in the water column, sediment, and biota are not BCCs. The minimum bioaccumulation concentration factor (BAF) information needed to define an organic chemical as a BCC is either a field-measured BAF or a BAF derived using the biota-sediment accumulation factor (BSAF) methodology. The minimum BAF information needed to define an inorganic chemical as a BCC, including an organometal, is either a field-measured BAF or a laboratory-measured bioconcentration factor (BCF). The BCCs to which these rules apply are identified in Table 5 of R 323.1057 of the Water Quality Standards.

Biosolids are the solid, semisolid, or liquid residues generated during the treatment of sanitary sewage or domestic sewage in a treatment works. This includes, but is not limited to, scum or solids removed in primary, secondary, or advanced wastewater treatment processes, and a derivative of the removed scum or solids.

Bulk biosolids means biosolids that are not sold or given away in a bag or other container for application to a lawn or home garden.

Chronic toxic unit (TU_C) means 100/MATC or $100/IC_{25}$, where the maximum acceptable toxicant concentration (MATC) and IC_{25} are expressed as a percent effluent in the test medium.

Class B biosolids refers to material that has met the Class B pathogen reduction requirements or equivalent treatment by a Process to Significantly Reduce Pathogens (PSRP), in accordance with the Part 24 Rules. Processes include aerobic digestion, composting, anaerobic digestion, lime stabilization, and air drying.

Daily concentration is the sum of the concentrations of the individual samples of a parameter divided by the number of samples taken during any calendar day. If the parameter concentration in any sample is less than the quantification limit, regard that value as zero when calculating the daily concentration. The daily concentration will be used to determine compliance with any maximum and minimum daily concentration limitations (except for pH and dissolved oxygen). When required by the permit, report the maximum calculated daily concentration for the month in the “MAXIMUM” column under “QUALITY OR CONCENTRATION” on the Discharge Monitoring Reports (DMRs).

For pH, report the maximum value of any individual sample taken during the month in the “MAXIMUM” column under “QUALITY OR CONCENTRATION” on the DMRs and the minimum value of any individual sample taken during the month in the “MINIMUM” column under “QUALITY OR CONCENTRATION” on the DMRs. For dissolved oxygen, report the minimum concentration of any individual sample in the “MINIMUM” column under “QUALITY OR CONCENTRATION” on the DMRs.

Daily loading is the total discharge by weight of a parameter discharged during any calendar day. This value is calculated by multiplying the daily concentration by the total daily flow and the appropriate conversion factor. The daily loading will be used to determine compliance with any maximum daily loading limitations. When required by the permit, report the maximum calculated daily loading for the month in the “MAXIMUM” column under “QUANTITY OR LOADING” on the DMRs.

Department means the Michigan Department of Environmental Quality.

Detection level means the lowest concentration or amount of the target analyte that can be determined to be different from zero by a single measurement at a stated level of probability.

PART II

Section A. Definitions

Discharge point is any location on the MS4 owned or operated by the permittee that discharges directly to a surface water of the state, or any location on the MS4 owned or operated by the permittee that discharges to any other separate storm sewer system before discharging to a surface water of the state.

EC_{50} means a statistically or graphically estimated concentration that is expected to cause one or more specified effects in 50 percent of a group of organisms under specified conditions.

Effluent limitation means any restriction on quantities, rates, and concentrations of chemical, physical, biological, and other constituents discharged from point sources.

Fecal coliform bacteria monthly is the geometric mean of the samples collected in a calendar month (or 30 consecutive days). The calculated monthly value will be used to determine compliance with the maximum monthly fecal coliform bacteria limitations. When required by the permit, report the calculated monthly value in the "AVERAGE" column under "QUALITY OR CONCENTRATION" on the DMRs.

Fecal coliform bacteria 7-day is the geometric mean of the samples collected in any 7-day period. The calculated 7-day value will be used to determine compliance with the maximum 7-day fecal coliform bacteria limitations. When required by the permit, report the maximum calculated 7-day concentration for the month in the "MAXIMUM" column under "QUALITY OR CONCENTRATION" on the DMRs.

Flow proportioned sample is a composite sample with the sample volume proportional to the effluent flow.

Grab sample is a single sample taken at neither a set time nor flow.

IC_{25} means the toxicant concentration that would cause a 25 percent reduction in a nonquantal biological measurement for the test population.

Illicit discharge means any discharge to, or seepage into, a separate storm sewer that is not composed entirely of storm water or uncontaminated groundwater, or discharges identified in Part I.A.4.b.3.a. Illicit discharges include non-storm water discharges through pipes or other physical connections; the dumping of motor vehicle fluids, household hazardous wastes, domestic animal wastes, or leaf litter; the collection and intentional dumping of grass clippings or leaf litter; or unauthorized discharges of sewage, industrial waste, restaurant wastes, or any other non-storm water waste directly into a separate storm sewer.

Illicit connection means a physical connection to the MS4 that 1) primarily conveys illicit discharges into the MS4, or 2) is not authorized or permitted by the local authority (where a local authority requires such authorization or permit).

Interference is a discharge which, alone or in conjunction with a discharge or discharges from other sources, both 1) inhibits or disrupts the POTW, its treatment processes or operations, or its sludge processes, use, or disposal; and 2) therefore, is a cause of a violation of any requirement of the POTW's NPDES permit (including an increase in the magnitude or duration of a violation), or of the prevention of sewage sludge use or disposal in compliance with the following statutory provisions and regulations or permits issued thereunder (or more stringent state or local regulations): Section 405 of the Clean Water Act, the Solid Waste Disposal Act (SWDA) (including Title II, more commonly referred to as the Resource Conservation and Recovery Act (RCRA), and including state regulations contained in any state sludge management plan prepared pursuant to Subtitle D of the SWDA), the Clean Air Act, the Toxic Substances Control Act, and the Marine Protection, Research and Sanctuaries Act. [This definition does not apply to sample matrix interference.]

LC_{50} means a statistically or graphically estimated concentration that is expected to be lethal to 50 percent of a group of organisms under specified conditions.

Land application means spraying or spreading biosolids or a biosolids derivative onto the land surface, injecting below the land surface, or incorporating into the soil so that the biosolids or biosolids derivative can either condition the soil or fertilize crops or vegetation grown in the soil.

MGD means million gallons per day.

PART II

Section A. Definitions

Maximum acceptable toxicant concentration (MATC) means the concentration obtained by calculating the geometric mean of the lower and upper chronic limits from a chronic test. A lower chronic limit is the highest tested concentration that did not cause the occurrence of a specific adverse effect. An upper chronic limit is the lowest tested concentration which did cause the occurrence of a specific adverse effect and above which all tested concentrations caused such an occurrence.

Maximum extent practicable: means implementation of best management practices by a public body to comply with an approved storm water management program as required in a national permit for a municipal separate storm sewer system, in a manner that is environmentally beneficial, technically feasible, and within the public body's legal authority.

Monthly concentration is the sum of the daily concentrations determined during a reporting month (or 30 consecutive days) divided by the number of daily concentrations determined. The calculated monthly concentration will be used to determine compliance with any maximum monthly concentration limitations. When required by the permit, report the calculated monthly concentration in the "AVERAGE" column under "QUALITY OR CONCENTRATION" on the DMRs.

For minimum percent removal requirements, the monthly influent concentration and the monthly effluent concentration shall be determined. The calculated monthly percent removal, which is equal to 100 times the quantity [1 minus the quantity (monthly effluent concentration divided by the monthly influent concentration)], shall be reported in the "MINIMUM" column under "QUALITY OR CONCENTRATION" on the DMRs.

Monthly frequency of analysis refers to a calendar month. When required by this permit, an analytical result, reading, value, or observation that must be reported for that period if a discharge occurs during that period.

Monthly loading is the sum of the daily loadings of a parameter divided by the number of daily loadings determined in the reporting month (or 30 consecutive days). The calculated monthly loading will be used to determine compliance with any maximum monthly loading limitations. When required by the permit, report the calculated monthly loading in the "AVERAGE" column under "QUANTITY OR LOADING" on the DMRs.

Municipal separate storm sewer system (**MS4)** means all separate storm sewers that are owned or operated by the United States, a state, city, village, township, county, district, association, or other public body created by or pursuant to state law, having jurisdiction over disposal of sewage, industrial wastes, storm water, or other wastes, including special districts under state law, such as a sewer district, flood control district, or drainage district, or similar entity, or a designated or approved management agency under Section 208 of the federal act that discharges to the waters of the state. This term includes systems similar to separate storm sewer systems in municipalities, such as systems at military bases, large hospital or prison complexes, and highways and other thoroughfares. The term does not include separate storm sewers in very discrete areas, such as individual buildings.

National Pretreatment Standards are the regulations promulgated by or to be promulgated by the United States Environmental Protection Agency (USEPA) pursuant to Section 307(b) and (c) of the Federal Act. The standards establish nationwide limits for specific industrial categories for discharge to a POTW.

No observed adverse effect level (NOAEL) means the highest tested dose or concentration of a substance which results in no observed adverse effect in exposed test organisms where higher doses or concentrations result in an adverse effect.

Noncontact cooling water is water used for cooling which does not come into direct contact with any raw material, intermediate product, by-product, waste product, or finished product.

Nondomestic user is any discharger to a POTW that discharges wastes other than or in addition to water-carried wastes from toilet, kitchen, laundry, bathing, or other facilities used for household purposes.

On-site sewage disposal system (OSDS) means a natural system or mechanical device used to collect, treat, and discharge or reclaim wastewater from one or more dwelling units without the use of community-wide sewers or a centralized treatment system.

POTW is a publicly-owned treatment works.

PART II

Section A. Definitions

Partially-treated sewage is any sewage, sewage and storm water, or sewage and wastewater from domestic or industrial sources that is treated to a level less than that required by the permittee's National Pollutant Discharge Elimination System permit, or that is not treated to national secondary treatment standards for wastewater, including discharges to surface waters from retention treatment facilities.

Point source means a discharge point from an MS4 to the surface waters of the state, or a point where an MS4 discharges into a system operated by another entity.

Pretreatment is reducing the amount of pollutants, eliminating pollutants, or altering the nature of pollutant properties to a less harmful state prior to discharge into a public sewer. The reduction or alteration can be by physical, chemical, or biological processes, process changes, or by other means. Dilution is not considered pretreatment unless expressly authorized by an applicable National Pretreatment Standard for a particular industrial category.

Public means all persons who potentially could affect the authorized storm water discharges, including, but not limited to, residents, visitors to the area, public employees, businesses, industries, and construction contractors and developers.

Quantification level means the measurement of the concentration of a contaminant obtained by using a specified laboratory procedure calculated at a specified concentration above the detection level. It is considered the lowest concentration at which a particular contaminant can be quantitatively measured using a specified laboratory procedure for monitoring of the contaminant.

Quarterly frequency of analysis refers to a three month period, defined as January through March, April through June, July through September, and October through December. When required by this permit, an analytical result, reading, value, or observation that must be reported for that period if a discharge occurs during that period.

Redevelopment means the alteration of developed land that changes the footprint of the site or building, or offers a new opportunity for storm water controls. The term is not intended to include such activities as exterior remodeling, which would not be expected to cause adverse storm water quality impacts.

Regional Administrator is the Region 5 Administrator, USEPA, located at R-19J, 77 West Jackson Boulevard, Chicago, Illinois 60604.

Regulated areas means the permittee’s urbanized areas and other areas identified by the permit applicant to be subject to a watershed planning process.

Separate storm sewer means a conveyance or system of conveyances designed or used for collecting or conveying storm water which is not a combined sewer and which is not part of a publicly-owned treatment works as defined in the Code of Federal Regulations at 40 CFR 122.2.

Separate storm sewer system means a system of drainage, including, but not limited to, roads, catch basins, curbs, gutters, parking lots, ditches, conduits, pumping devices, or man-made channels, which has the following characteristics:

- The system is not a combined sewer where storm water mixes with sanitary wastes.
- The system is not part of a publicly-owned treatment works.

Significant industrial user is a nondomestic user that: 1) is subject to Categorical Pretreatment Standards under 40 CFR 403.6 and 40 CFR Chapter I, Subchapter N; or 2) discharges an average of 25,000 gallons per day or more of process wastewater to a POTW (excluding sanitary, noncontact cooling, and boiler blowdown wastewater); contributes a process wastestream which makes up five (5) percent or more of the average dry weather hydraulic or organic capacity of the POTW treatment plant; or is designated as such by the permittee as defined in 40 CFR 403.12(a) on the basis that the industrial user has a reasonable potential for adversely affecting the POTW's treatment plant operation or violating any pretreatment standard or requirement (in accordance with 40 CFR 403.8(f)(6)).

Storm water includes storm water runoff, snow melt runoff, and surface runoff and drainage.

PART II

Section A. Definitions

Surface waters of the state are defined consistent with the Part 4 Rules (Rules 323.1041 through 323.1117 of the Michigan Administrative Code) to mean all of the following, but not including drainage ways and ponds used solely for wastewater conveyance, treatment, or control:

- The Great Lakes and their connecting waters
- All inland lakes
- Rivers
- Streams
- Impoundments
- Open drains
- Other surface bodies of water within the confines of the state

Tier I value means a value for aquatic life, human health, or wildlife calculated under R 323.1057 of the Water Quality Standards using a tier I toxicity database.

Tier II value means a value for aquatic life, human health, or wildlife calculated under R 323.1057 of the Water Quality Standards using a tier II toxicity database.

Toxicity Reduction Evaluation (TRE) means a site-specific study conducted in a stepwise process designed to identify the causative agents of effluent toxicity, isolate the sources of toxicity, evaluate the effectiveness of toxicity control options, and then confirm the reduction in effluent toxicity.

Treatment means the removal of pollutants through settling, filtration, infiltration, or the equivalent.

Uncontaminated groundwater means groundwater that will not contribute substantially to the violation of a water quality standard or will not be a significant contributor of pollutants upon discharge to the surface waters of the state.

Urbanized area means a place and the adjacent densely-populated territory that together have a minimum population of 50,000 people, as defined by the United States Bureau of the Census and as determined by the latest available decennial census.

Water Quality Standards means the Part 4 Water Quality Standards promulgated pursuant to Part 31, Water Resources protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (Act 451), being Rules 323.1041 through 323.1117 of the Michigan Administrative Code.

Weekly frequency of analysis refers to a calendar week which begins on Sunday and ends on Saturday. When required by this permit, an analytical result, reading, value, or observation must be reported for that period if a discharge occurs during that period.

Yearly frequency of analysis refers to a calendar year beginning on January 1 and ending on December 31. When required by this permit, an analytical result, reading, value, or observation must be reported for that period if a discharge occurs during that period.

24-hour composite sample is a flow-proportioned composite sample consisting of hourly or more frequent portions that are taken over a 24-hour period.

3-portion composite sample is a sample consisting of three equal volume grab samples collected at equal intervals over an 8-hour period.

7-day concentration is the sum of the daily concentrations determined during any 7 consecutive days in a reporting month divided by the number of daily concentrations determined. The calculated 7-day concentration will be used to determine compliance with any maximum 7-day concentration limitations. When required by the permit, report the maximum calculated 7-day concentration for the month in the “MAXIMUM” column under “QUALITY OR CONCENTRATION” on the DMRs.

7-day loading is the sum of the daily loadings of a parameter divided by the number of daily loadings determined during any 7 consecutive days in a reporting month. The calculated 7-day loading will be used to determine compliance with any maximum 7-day loading limitations. When required by the permit, report the maximum calculated 7-day loading for the month in the “MAXIMUM” column under “QUANTITY OR LOADING” on the DMRs.

PART II

Section B. Monitoring Procedures

1. Representative Samples

Samples and measurements taken as required herein shall be representative of the volume and nature of the monitored discharge.

2. Test Procedures

Test procedures for the analysis of pollutants shall conform to regulations promulgated pursuant to Section 304(h) of the Federal Act (40 CFR Part 136 - Guidelines Establishing Test Procedures for the Analysis of Pollutants), unless specified otherwise in this permit. Requests to use test procedures not promulgated under 40 CFR Part 136 for pollutant monitoring required by this permit shall be made in accordance with the Alternate Test Procedures regulations specified in 40 CFR 136.4. These requests shall be submitted to the Chief of the Permits Section, Water Bureau, Michigan Department of Environmental Quality, P.O. Box 30273, Lansing, Michigan 48909-7773. The permittee may use such procedures upon approval.

The permittee shall periodically calibrate and perform maintenance procedures on all analytical instrumentation at intervals to ensure accuracy of measurements. The calibration and maintenance shall be performed as part of the permittee’s laboratory Quality Control/Quality Assurance program.

3. Instrumentation

The permittee shall periodically calibrate and perform maintenance procedures on all monitoring instrumentation at intervals to ensure accuracy of measurements.

4. Recording Results

For each measurement or sample taken pursuant to the requirements of this permit, the permittee shall record the following information: 1) the exact place, date, and time of measurement or sampling; 2) the person(s) who performed the measurement or sample collection; 3) the dates the analyses were performed; 4) the person(s) who performed the analyses; 5) the analytical techniques or methods used; 6) the date of and person responsible for equipment calibration; and 7) the results of all required analyses.

5. Records Retention

All records and information resulting from the monitoring activities required by this permit, including all records of analyses performed, calibration and maintenance of instrumentation, and recordings from continuous monitoring instrumentation shall be retained for a minimum of three (3) years or longer if requested by the Regional Administrator or the Department.

PART II

Section C. Reporting Requirements

1. Start-up Notification

If the permittee will not discharge during the first 60 days following the effective date of the permittee's COC, the permittee shall notify the Department within 14 days following the effective date of the COC, and then 60 days prior to the commencement of the discharge.

2. Submittal Requirements for Self-Monitoring Data

Part 31 of Act 451, as amended, specifically Section 324.3110(3) and Rule 323.2155(2) of Part 21 allows the Department to specify the forms to be utilized for reporting the required self-monitoring data. Unless instructed on the effluent limitations page to conduct "Retained Self Monitoring," the permittee shall submit self-monitoring data via the Michigan DEQ Electronic Environmental Discharge Monitoring Reporting (***e2-DMR***) system.

The permittee shall utilize the information provided on the ***e2-Reporting*** Web site @ **http://secure1.state.mi.us/e2rs/** to access and submit the electronic forms. Both monthly summary and daily data shall be submitted to the Department no later than the **20th day of the month** following each month of the authorized discharge period(s).

3. Retained Self-Monitoring Requirements

If instructed on the effluent limits page (or otherwise authorized by the Department in accordance with the provisions of this permit) to conduct retained self-monitoring, the permittee shall maintain a year-to-date log of retained self-monitoring results and, upon request, provide such log for inspection to the staff of the Department (Department as defined on the COC). Retained self-monitoring results are public information and shall be promptly provided to the public upon written request from the public.

The permittee shall certify, in writing, to the Department, on or before January 10th of each year, that: 1) all retained self-monitoring requirements have been complied with and a year-to-date log has been maintained; and 2) the application on which this permit is based still accurately describes the discharge. With this annual certification, the permittee shall submit a summary of the previous year's monitoring data. The summary shall include maximum values for samples to be reported as daily maximums and/or monthly maximums and minimum values for any daily minimum samples.

Retained self-monitoring may be denied to a permittee by notification in writing from the Department. In such cases, the permittee shall submit self-monitoring data in accordance with Part II.C.2., above. Such a denial may be rescinded by the Department upon written notification to the permittee.

Reissuance or modification of this permit or reissuance or modification of an individual permittee's authorization to discharge shall not affect previous approval or denial for retained self-monitoring unless the Department provides notification in writing to the permittee.

4. Additional Monitoring by Permittee

If the permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit, using approved analytical methods as specified above, the results of such monitoring shall be included in the calculation and reporting of the values required in the Discharge Monitoring Report. Such increased frequency shall also be indicated.

Monitoring required pursuant to Part 41 of the Michigan Act or Rule 35 of the Mobile Home Park Commission Act (Act 96 of the Public Acts of 1987) for assurance of proper facility operation shall be submitted as required by the Department.

PART II

Section C. Reporting Requirements

5. Compliance Dates Notification

Within 14 days of every compliance date specified in this permit, the permittee shall submit a written notification to the Department indicating whether or not the particular requirement was accomplished. If the requirement was not accomplished, the notification shall include an explanation of the failure to accomplish the requirement, actions taken or planned by the permittee to correct the situation, and an estimate of when the requirement will be accomplished. If a written report is required to be submitted by a specified date and the permittee accomplishes this, a separate written notification is not required.

6. Noncompliance Notification

Compliance with all applicable requirements set forth in the Federal Act, Parts 31 and 41 of the Michigan Act, and related regulations and rules is required. All instances of noncompliance shall be reported as follows:

a. 24-hour reporting - Any noncompliance which may endanger health or the environment (including maximum daily concentration discharge limitation exceedances) shall be reported, verbally, within 24 hours from the time the permittee becomes aware of the noncompliance. A written submission shall also be provided within five (5) days.

b. Other reporting - The permittee shall report, in writing, all other instances of noncompliance not described in a. above at the time monitoring reports are submitted; or, in the case of retained self-monitoring, within five (5) days from the time the permittee becomes aware of the noncompliance.

Written reporting shall include: 1) a description of the discharge and cause of noncompliance; and 2) the period of noncompliance, including exact dates and times; or, if not corrected, the anticipated time the noncompliance is expected to continue, and the steps taken to reduce, eliminate and prevent recurrence of the noncomplying discharge.

7. Spill Notification

The permittee shall immediately report any release of any polluting material which occurs to the surface waters or groundwaters of the state, unless the permittee has determined that the release is not in excess of the threshold reporting quantities specified in the Part 5 Rules (Rules 324.2001 through 324.2009 of the Michigan Administrative Code), by calling the Department at the number indicated in the COC, or if the notice is provided after regular working hours call the Department's 24-Hour Pollution Emergency Alerting System telephone number: 1-800-292-4706 (calls from out-of-state dial 1-517-373-7660).

Within ten (10) days of the release, the permittee shall submit to the Department a full written explanation as to the cause of the release, the discovery of the release, response (clean-up and/or recovery) measures taken, and preventative measures taken or a schedule for completion of measures to be taken to prevent reoccurrence of similar releases.

8. Upset Noncompliance Notification

If a process "upset" (defined as an exceptional incident in which there is unintentional and temporary noncompliance with technology based permit effluent limitations because of factors beyond the reasonable control of the permittee) has occurred, the permittee who wishes to establish the affirmative defense of upset, shall notify the Department by telephone within 24 hours of becoming aware of such conditions; and within five (5) days, provide in writing, the following information:

a. That an upset occurred and that the permittee can identify the specific cause(s) of the upset

b. That the permitted wastewater treatment facility was, at the time, being properly operated

c. That the permittee has specified and taken action on all responsible steps to minimize or correct any adverse impact in the environment resulting from noncompliance with this permit.

In any enforcement proceedings, the permittee, seeking to establish the occurrence of an upset, has the burden of proof.

PART II

Section C. Reporting Requirements

9. Bypass Prohibition and Notification

a. Bypass Prohibition - Bypass is prohibited unless:

1) Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage.

2) There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate backup equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass

3) The permittee submitted notices as required under 9.b. or 9.c. below.

b. Notice of Anticipated Bypass - If the permittee knows in advance of the need for a bypass, it shall submit prior notice to the Department, if possible at least ten (10) days before the date of the bypass, and provide information about the anticipated bypass as required by the Department. The Department may approve an anticipated bypass, after considering its adverse effects, if it will meet the three (3) conditions listed in 9.a. above.

c. Notice of Unanticipated Bypass - The permittee shall submit notice to the Department of an unanticipated bypass by calling the Department at the number indicated in the COC (if the notice is provided after regular working hours, use the following number: 1-800-292-4706) as soon as possible, but no later than 24 hours from the time the permittee becomes aware of the circumstances.

d. Written Report of Bypass - A written submission shall be provided within five (5) working days of commencing any bypass to the Department, and at additional times as directed by the Department. The written submission shall contain a description of the bypass and its cause; the period of bypass, including exact dates and times, and if the bypass has not been corrected, the anticipated time it is expected to continue; steps taken or planned to reduce, eliminate, and prevent reoccurrence of the bypass; and other information as required by the Department.

e. Bypass Not Exceeding Limitations - The permittee may allow any bypass to occur which does not cause effluent limitations to be exceeded, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provisions of 9.a., 9.b., 9.c., and 9.d., above. This provision does not relieve the permittee of any notification responsibilities under Part II.C.10. of this permit.

f. Definitions

1) Bypass means the intentional diversion of waste streams from any portion of a treatment facility.

2) Severe property damage means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.

10. Notification of Changes in Discharge

The permittee shall notify the Department, in writing, within 10 days of knowing, or having reason to believe, that any activity or change has occurred or will occur which would result in the discharge of: 1) detectable levels of chemicals on the current Michigan Critical Materials Register, priority pollutants or hazardous substances set forth in 40 CFR 122.21, Appendix D, or the Pollutants of Initial Focus in the Great Lakes Water Quality Initiative specified in 40 CFR 132.6, Table 6, which were not acknowledged in the application or listed in the application at less than detectable levels; 2) detectable levels of any other chemical not listed in the application or listed at less than detection, for which the application specifically requested information; or 3) any chemical at levels greater than five times the average level reported in the complete application (see the COC for the date(s) the complete application was submitted). Any other monitoring results obtained as a requirement of this permit shall be reported in accordance with the compliance schedules.

PART II

Section C. Reporting Requirements

11. Changes in Facility Operations

Any anticipated action or activity, including but not limited to facility expansion, production increases, or process modification, which will result in new or increased loadings of pollutants to the receiving waters must be reported to the Department by a) submission of an increased use request (application) and all information required under Rule 323.1098 (Antidegradation) of the Water Quality Standards or b) by notice if the following conditions are met: 1) the action or activity will not result in a change in the types of wastewater discharged or result in a greater quantity of wastewater than currently authorized by this permit; 2) the action or activity will not result in violations of the effluent limitations specified in this permit; 3) the action or activity is not prohibited by the requirements of Part II.C.12.; and 4) the action or activity will not require notification pursuant to Part II.C.10. Following such notice, the permit may be modified according to applicable laws and rules to specify and limit any pollutant not previously limited.

12. Bioaccumulative Chemicals of Concern (BCC)

Consistent with the requirements of Rules 323.1098 and 323.1215 of the Michigan Administrative Code, the permittee is prohibited from undertaking any action that would result in a lowering of water quality from an increased loading of a BCC unless an increased use request and Antidegradation Demonstration have been submitted and approved by the Department.

13. Transfer of Ownership or Control

In the event of any change in control or ownership of facilities from which the authorized discharge emanates, the permittee shall submit to the Department 30 days prior to the actual transfer of ownership or control a written agreement between the current permittee and the new permittee containing: 1) the legal name and address of the new owner; 2) a specific date for the effective transfer of permit responsibility, coverage and liability; and 3) a certification of the continuity of or any changes in operations, wastewater discharge, or wastewater treatment.

If the new permittee is proposing changes in operations, wastewater discharge, or wastewater treatment, the Department may propose modification of this permit in accordance with applicable laws and rules.

PART II

Section D. Management Responsibilities

1. Duty to Comply

All discharges authorized herein shall be consistent with the terms and conditions of this permit and the permittee's COC. The discharge of any pollutant identified in this permit and/or the permittee's COC more frequently than or at a level in excess of that authorized shall constitute a violation of the permit.

It is the duty of the permittee to comply with all the terms and conditions of this permit and the permittee's COC. Any noncompliance with the Effluent Limitations, Special Conditions, or terms of this permit or the permittee's COC constitutes a violation of the Michigan Act and/or the Federal Act and constitutes grounds for enforcement action; for COC termination, revocation and reissuance, or modification; or denial of an application for permit or COC renewal.

2. Operator Certification

The permittee shall have the storm water treatment and control facilities under direct supervision of an operator certified at the appropriate level for the facility certification by the Department, as required by Sections 3110 and 4104 of the Michigan Act.

3. Facilities Operation

The permittee shall, at all times, properly operate and maintain all treatment or control facilities or systems installed or used by the permittee to achieve compliance with the terms and conditions of this permit. Proper operation and maintenance includes adequate laboratory controls and appropriate quality assurance procedures.

4. Power Failures

In order to maintain compliance with the effluent limitations of this permit and prevent unauthorized discharges, the permittee shall either:

a. Provide an alternative power source sufficient to operate facilities utilized by the permittee to maintain compliance with the effluent limitations and conditions of this permit.

b. Upon the reduction, loss, or failure of one or more of the primary sources of power to facilities utilized by the permittee to maintain compliance with the effluent limitations and conditions of this permit, the permittee shall halt, reduce or otherwise control production and/or all discharge in order to maintain compliance with the effluent limitations and conditions of this permit.

5. Adverse Impact

The permittee shall take all reasonable steps to minimize any adverse impact to the surface waters or groundwaters of the state resulting from noncompliance with any effluent limitation specified in this permit including, but not limited to, such accelerated or additional monitoring as necessary to determine the nature and impact of the discharge in noncompliance.

6. Containment Facilities

The permittee shall provide facilities for containment of any accidental losses of polluting materials in accordance with the requirements of the Part 5 Rules (Rules 324.2001 through 324.2009 of the Michigan Administrative Code). For a Publicly-Owned Treatment Work (POTW), these facilities shall be approved under Part 41 of the Michigan Act.

PART II

Section D. Management Responsibilities

7. Waste Treatment Residues

Residuals (i.e. solids, sludges, biosolids, filter backwash, scrubber water, ash, grit, or other pollutants or wastes) removed from or resulting from treatment or control of wastewaters, including those that are generated during treatment or left over after treatment or control has ceased shall be disposed of in an environmentally compatible manner and according to applicable laws and rules. These laws may include, but are not limited to, the Michigan Act, Part 31 for protection of water resources, Part 55 for air pollution control, Part 111 for hazardous waste management, Part 115 for solid waste management, Part 121 for liquid industrial wastes, Part 301 for protection of inland lakes and streams, and Part 303 for wetlands protection. Such disposal shall not result in any unlawful pollution of the air, surface waters or groundwaters of the state.

8. Right of Entry

The permittee shall allow the Department, any agent appointed by the Department or the Regional Administrator, upon the presentation of credentials:

a. To enter upon the permittee’s premises where an effluent source is located or in which any records are required to be kept under the terms and conditions of this permit.

b. At reasonable times to have access to and copy any records required to be kept under the terms and conditions of this permit; to inspect process facilities, treatment works, monitoring methods, and equipment regulated or required under this permit; and to sample any discharge of pollutants.

9. Availability of Reports

Except for data determined to be confidential under Section 308 of the Federal Act and Rule 2128 (Rule 323.2128 of the Michigan Administrative Code), all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the Department and the Regional Administrator. As required by the Federal Act, effluent data shall not be considered confidential. Knowingly making any false statement on any such report may result in the imposition of criminal penalties as provided for in Section 309 of the Federal Act and Sections 3112, 3115, 4106 and 4110 of the Michigan Act.

PART II

Section E. Activities Not Authorized by This Permit

1. Discharge to the Groundwaters

This permit does not authorize any discharge to the groundwaters. Such discharge may be authorized by a groundwater discharge permit issued pursuant to the Michigan Act.

2. Facility Construction

This permit does not authorize or approve the construction or modification of any physical structures or facilities. Approval for such construction for a POTW must be by permit issued under Part 41 of the Michigan Act. Approval for such construction for a mobile home park, campground, or marina shall be from the Water Bureau, Michigan Department of Environmental Quality. Approval for such construction for a hospital, nursing home or extended care facility shall be from the Division of Health Facilities and Services, Michigan Department of Consumer and Industry Services, upon request.

3. Civil and Criminal Liability

Except as provided in permit conditions on "Bypass" (Part II.C.9. pursuant to 40 CFR 122.41(m)), nothing in this permit shall be construed to relieve the permittee from civil or criminal penalties for noncompliance, whether or not such noncompliance is due to factors beyond the permittee’s control, such as accidents, equipment breakdowns, or labor disputes.

4. Oil and Hazardous Substance Liability

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee may be subject under Section 311 of the Federal Act except as are exempted by federal regulations.

5. State Laws

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable state law or regulation under authority preserved by Section 510 of the Federal Act.

6. Property Rights

The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize the violation of any federal, state, or local laws or regulations, nor does it obviate the necessity of obtaining such permits, including any other Department of Environmental Quality permits, or approvals from other units of government as may be required by law.

APPENDIX

STORM WATER POLLUTION PREVENTION PLANS FOR FLEET MAINTENANCE AND STORAGE YARDS

These requirements apply to areas of fleet maintenance and storage yards in accordance with Part I.A.4.b.6.d.

1. Source Identification

To identify potential sources of significant materials that can pollute storm water and subsequently be discharged from the facility, the Storm Water Pollution Prevention Plan (SWPPP) shall, at a minimum, include the following items:

a. A site map identifying the following:
   1) Buildings and other permanent structures
   2) Storage or disposal areas for significant materials
   3) Secondary containment structures and descriptions of what they contain
   4) Storm water discharge points (numbered for reference)
   5) Location of storm water and non-storm water inlets contributing to each discharge point
   6) Location of NPDES-permitted discharges other than storm water
   7) Outlines of the drainage areas contributing to each discharge point
   8) Structural runoff controls or storm water treatment facilities
   9) Areas of vegetation (with a brief description, such as lawn, old field, marsh, wooded, etc.)
   10) Areas of exposed and/or erodible soils
   11) Impervious surfaces (roofs, asphalt, concrete)
   12) Name and location of receiving water(s)
   13) Areas of known or suspected impacts on surface waters as designated under Part 201 (Environmental Response) of the Michigan Act

b. A list of all significant materials that could pollute storm water. For each material listed, the SWPPP shall include each of the following descriptions:

   1) Ways in which each type of material has been or has reasonable potential to become exposed to storm water (e.g., spillage during handling; leaks from pipes, pumps, and vessels; contact with storage piles, contaminated materials, or soils; waste handling and disposal; deposits from dust or overspray; etc.).

   2) An evaluation and written description of the reasonable potential for contribution of significant materials to run off from at least the following areas or activities:
      a. Loading, unloading, and other material-handling operations
      b. Outdoor storage, including secondary containment structures
      c. Outdoor manufacturing or processing activities
      d. Significant dust or particulate-generating processes
      e. Discharge from vents, stacks, and air emission controls
      f. On-site waste disposal practices
      g. Maintenance and cleaning of vehicles, machines, and equipment
      h. Areas of exposed and/or erodible soils
      i. Sites of Environmental Contamination listed under Part 201 (Environmental Response) of the Michigan Act
      j. Areas of significant material residues
      k. Areas where animals congregate (wild or domestic) and deposit wastes
      l. Other areas where storm water may contact significant materials

   3) Identification of the discharge point(s) through which the material may be discharged if released.

APPENDIX

STORM WATER POLLUTION PREVENTION PLANS FOR FLEET MAINTENANCE AND STORAGE YARDS

Significant materials include any material which could degrade or impair water quality, including, but not limited to: raw materials; fuels; solvents, detergents, and plastic pellets; finished materials such as metallic products; hazardous substances designated under Section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (See 40 CFR 372.65); any chemical the facility is required to report pursuant to Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA); polluting materials (oil and any material, in solid or liquid form, identified as polluting material under the Part 5 Rules [Rules 324.2001 through 324.2009 of the Michigan Administrative Code]); Hazardous Wastes as defined in Part 111 of the Michigan Act; fertilizers; pesticides; and waste products, such as ashes, slag, sludge, and plant and animal wastes that have the potential to be released with storm water discharges

c. A listing of significant spills and significant leaks of polluting materials that occurred at areas that are exposed to precipitation or that otherwise discharge to a point source at the facility. The listing shall include spills that occurred over the three (3) years prior to the effective date of a COC authorizing discharge under this permit. The listing shall include the date, volume and exact location of the release, and the action taken to clean up the material and/or prevent exposure to storm water runoff or contamination of the surface waters of the state. Any release that occurs after the SWPPP has been developed shall be controlled in accordance with the SWPPP and is cause for the SWPPP to be updated as appropriate within 14 calendar days of obtaining knowledge of the spill or loss.

d. A summary of the existing storm water discharge sampling data (if available) describing pollutants in storm water discharges associated with industrial activity at the facility. This summary shall be accompanied by a description of the suspected source(s) of the pollutants detected.

2. Preventive Measures and Source Controls, Non-Structural

To prevent significant materials from contacting storm water at the source, the SWPPP shall, at a minimum, include each of the following nonstructural controls:

a. A program which includes a schedule for routine preventive maintenance. The preventative maintenance program shall consist of routine inspections and maintenance of storm water management and control devices (e.g., cleaning of oil/water separators and catch basins, routine housekeeping activities, and cleaning out catch basins), as well as inspecting and testing plant equipment and systems to uncover conditions that could cause breakdowns or failures resulting in discharges of pollutants to the surface waters. The routine inspection shall include those areas of the facility in which significant materials have the reasonable potential to contaminate runoff. A log of the inspection and corrective actions shall be maintained on file by the permittee, and shall be retained in accordance with the Appendix, Section 5.

b. A schedule for comprehensive site inspection, including a visual inspection of equipment, plant areas, and structural pollution prevention and treatment controls, to be performed at least quarterly. The permittee may request Department approval of an alternate schedule for comprehensive site inspections. A report of the results of the comprehensive site inspection shall be prepared and retained in accordance with the Appendix, Section 5. The report shall identify any incidents of noncompliance with the SWPPP or this permit. If there are no reportable incidents of noncompliance, the report shall contain a certification that the facility is in compliance with this permit.

c. A description of good housekeeping procedures to maintain a clean, orderly facility. Good housekeeping procedures shall include routine inspections of the areas of the facility in which the procedures are implemented. The routine inspections of good housekeeping procedures may be combined with the routine inspections for the preventative maintenance program.

d. A description of material handling procedures and storage requirements for significant materials. The equipment and procedures for cleaning up spills shall be identified in the SWPPP and made available to the appropriate personnel. The procedures shall identify measures to prevent spilled materials or material residues on the outside of containers from being discharged into storm water. The SWPPP may include, by reference, requirements of either a Pollution Incident Prevention Plan (PIPP) prepared in accordance with the Part 5 Rules (Rules 324.2001 through 324.2009 of the Michigan Administrative Code), a Hazardous Waste Contingency Plan prepared in accordance with 40 CFR 264 and 265 Subpart D, as required by Part 111 of the Michigan Act, or a Spill Prevention Control and Countermeasure (SPCC) plan prepared in accordance with 40 CFR 112.

APPENDIX

STORM WATER POLLUTION PREVENTION PLANS FOR FLEET MAINTENANCE AND STORAGE YARDS

e. Identification of areas which, due to topography, activities, or other factors, have a high potential for significant soil erosion. The SWPPP shall also identify measures used to control soil erosion and sedimentation.

f. A description of employee training programs which will be implemented to inform appropriate personnel at all levels of responsibility of the components and goals of the SWPPP. The SWPPP shall identify periodic dates for such training.

g. Identification of significant materials expected to be present in storm water discharges following implementation of nonstructural preventative measures and source controls.

3. Structural Controls for Prevention and Treatment

Where implementation of the measures required by the Appendix, Section 2, does not control storm water discharges to prevent contact with significant materials to the maximum extent practicable, the SWPPP shall provide a description of the location, function, and design criteria of structural controls for prevention and treatment. Structural controls may be necessary:

1) To prevent uncontaminated storm water from contacting or being contacted by significant materials.

2) If preventive measures are not feasible or are inadequate to keep significant materials at the site from contaminating storm water. Structural controls shall be used to treat, divert, isolate, recycle, reuse, or otherwise manage storm water in a manner that reduces the level of significant materials in the storm water to the maximum extent practicable.

4. Keeping Plans Current

a. The permittee shall review the SWPPP annually after it is developed and maintain written summaries of the reviews. Based on the review, the permittee shall amend the SWPPP as needed to ensure continued compliance with the terms and conditions of this permit.

b. The SWPPP developed under the conditions of a previous permit shall be amended as necessary to ensure compliance with this permit.

c. The SWPPP shall be updated or amended whenever changes or spills at the facility increase or have the potential to increase the exposure of significant materials to storm water, or when the SWPPP is determined by the permittee or the Department to be ineffective in achieving the general objectives of controlling pollutants in storm water discharges associated with industrial activity. Updates based on increased activity or spills at the facility shall include a description of how the permittee intends to control any new sources of significant materials or respond to and prevent spills in accordance with the requirements of the Appendix, Sections 1, 2, and 3.

d. The Department may notify the permittee at any time that the SWPPP does not meet minimum requirements. Such notification shall identify why the SWPPP does not meet minimum requirements. The permittee shall make the required changes to the SWPPP within 30 days after such notification from the Department, and shall submit to the Department a written certification that the requested changes have been made.

e. Amendments shall be signed, dated, and retained with the SWPPP.

5. Record Keeping

The permittee shall maintain records of all SWPPP-related inspections and maintenance activities. Records shall also be kept describing incidents such as spills or other discharges that can affect the quality of storm water runoff. All such records shall be retained for three years. The following records are required by this permit:

- Routine maintenance inspections (Appendix, Section 2.a.)
- Good housekeeping inspections (Appendix, Section 2.c.). The routine maintenance inspection and good housekeeping inspection may be combined.
- Comprehensive inspection reports (Appendix, Section 2.b.)
- Written summaries of the annual SWPPP review (Appendix, Section 4.a)

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

JENNIFER M. GRANHOLM
GOVERNOR

STEVEN E. CHESTER
DIRECTOR

March 24, 2006

TO: Ralph Reznick, Nonpoint Source Unit
Water Bureau

FROM: Dave Fongers, Hydrologic Studies Unit
Land and Water Management Division

SUBJECT: 90-Percent Annual Non-Exceedance Storms

Michigan Department of Environmental Quality (MDEQ) Best Management Practice (BMP) guidelines recommend capture and treatment of 0.5 inches of runoff from a single site. The runoff is then released over 24 to 48 hours or is allowed to infiltrate into the ground within 72 hours. However, this is only applicable to a single site. Runoff from multiple or large sites may exhibit elevated pollutant concentrations longer, because the first flush runoff from some portions of the drainage area will take longer to reach the outlet. For multiple sites or watershed wide design, it is better to capture and treat 90 percent of the runoff producing storms (Claytor, 1996, pages 2-22 through 2-23, attached). This "90 percent rule" effectively treats storm runoff that could be reaching the treatment at different times during the storm event. It was designed to provide the greatest amount of treatment that is economically feasible. This criterion is being considered for inclusion in the MDEQ's BMP guidebook.

As requested, the Hydrologic Studies Unit of the Land and Water Management Division has completed an analysis of January 1948 through March 2005, National Oceanic and Atmospheric Administration climatological data, in order to statistically define 90-percent non-exceedance storms statewide. The 90-percent non-exceedance storm is the storm where 90 percent of the runoff-producing storm rainfalls are equal to or less than the specified value. The Center for Watershed Protection recommends using a runoff threshold of 0.10 inches, because impervious areas of the watershed are assumed to generate runoff beginning at approximately 0.10 inches of rainfall.

Data from 13 weather stations were evaluated, as shown in Figure 1. The selected weather stations include at least one station from within each of the ten Michigan climatic divisions, plus three additional stations to improve statewide coverage and comparability. Statistics for this analysis are shown in Table 1.

The limitations of this technique and methods to calculate water quality volumes and peak flows are further discussed by Claytor and Schueler in the attached reference. Although the goal of this memo is simply to statistically define the 90-percent non-exceedance storms statewide, the attached information, or an adaptation of it, will need to be combined with the 90-percent non-exceedance storm information if it is to be meaningful in the BMP manual.

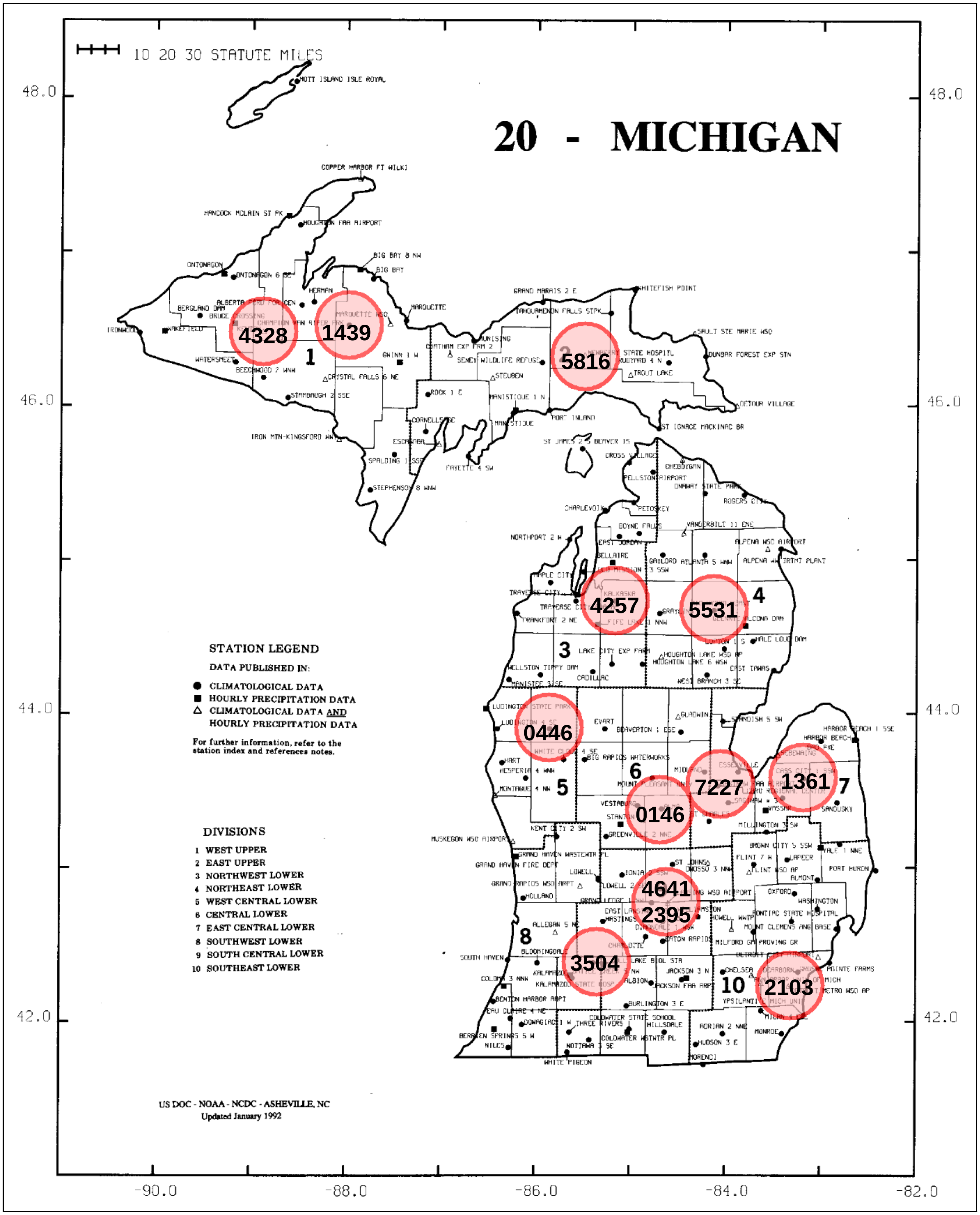

Figure 1: Selected Weather Stations

Table 1: Statistics for storms with more than 0.10" of rainfall at selected weather stations

Weather Station	Kenton	Champion Van Riper	Newberry	Kalkaska	Mio	Baldwin	Alma	Saginaw Airport	Cass City	Gull Lake	Lansing	East Lansing	Detroit Metro
Station Number	4328	1439	5816	4257	5531	0446	0146	7227	1361	3504	4641	2395	2103
Climatic Section	1		2	3	4	5	6	7		8	9		10
90-Percent Non-exceedance Storm	**0.95**	**0.87**	**0.84**	**0.77**	**0.78**	**0.93**	**0.93**	**0.92**	**0.87**	**1.00**	**0.90**	**0.91**	**0.90**
Period of Record	5/48-12/99	12/49-3/05	1/48-12/99	5/48-12/99	5/48-12/99	6/48-12/99	5/48-12/99	1/48-12/99	7/76-3/05	5/48-12/99	5/48-12/99	1/57-12/99	12/58-12/99
Number of Storms	3151	3943	3772	4219	3564	4007	3602	3453	1957	4071	3395	2939	3191
Minimum	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Median	0.30	0.29	0.29	0.26	0.27	0.30	0.30	0.31	0.30	0.32	0.29	0.30	0.30
Mean	0.44	0.41	0.41	0.39	0.38	0.43	0.45	0.44	0.43	0.46	0.42	0.44	0.43
Maximum	5.45	4.41	4.18	3.26	3.13	4.21	9.33	5.51	9.01	3.95	4.95	4.18	4.34

If you have any questions regarding our evaluation, please contact me at 517-373-0210.

Attachment: Claytor, R.A., and T.R. Schueler. 1996. *Design of Stormwater Filtering Systems*. The Center for Watershed Protection, Silver Spring, MD, pages 2-16 through 2-29.

cc: Steve Holden, WB
Ric Sorrell, LWMD

Design of Stormwater Filtering Systems

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PARTICLE SIZE DISTRIBUTION

One additional important aspect of stormwater runoff from different source areas is the relationship of particle size to pollutant load. Work done by Sartor and Boyd (1974) and Pitt (1987) starting in the early 1970's suggests that most of the total particulate load from urban runoff is made up by the coarser fractions, consisting of sand/gravel particle sizes greater than approximately 40 microns. Shaver and Baldwin (1991) reported that while nearly 94% of the urban runoff particulate load is from these coarser grained fractions, more than half of the phosphorus load and significant percentages of other pollutants are associated with fine grained silts and clays.

Particle size distribution is an important consideration for sizing the sedimentation chamber of a filter system. Shaver and Baldwin (1991) and Bell et al. (1995) specify that sand filters should only be used to treat runoff from impervious, or nearly-impervious surfaces. They argue that the larger percentage of particulates from impervious surfaces are in the coarser fractions, and therefore, filtering systems will be less prone to clogging. The logic follows that the sedimentation chamber will capture the coarser grained material, and the filter chamber will capture and treat the relatively small amount of finer grained material. Therefore, filters designed to treat runoff from purely impervious surfaces require less sedimentation area and volume than those designed to treat runoff from more pervious surfaces.

The City of Austin (1988) allows the use of sand filters for a range of land uses and drainage areas. They use a smaller, silt size particle (20 microns) as the target for sizing the sedimentation chamber, probably recognizing that more pervious areas are likely to contribute more fine grained particles In order to quantify and resolve the apparent discrepancy between the above criteria, this manual recommends that for drainage areas less than 75% impervious, the target particle size for designing the sedimentation chamber be set at 20 microns. For drainage areas with imperviousness greater than 75%, the target particle size should be set at 40 microns. See Chapter 5 for discussion and application of these sizing principles.

2.3 *SMALL STORM HYDROLOGY*

Small storms are responsible for most annual urban runoff and likewise are responsible for most pollutant washoff from urban surfaces. Therefore, the small storms are of most concern for water quality resource protection.

Large storms occur infrequently, and although they may contain significant pollutant loads (Chang, G., et al., 1990), their contribution to the annual average pollutant load is really quite small (due to the infrequency of their occurrence). In addition, there are longer periods of recovery available to receiving waters between larger storm events allowing systems to flush themselves and the aquatic environment to recover.

The runoff **volume** is the most important hydrologic variable for water quality protection and design because water quality is a function of the capture and treatment of the mass load of pollutants. The runoff **peak rate** is the most important hydrologic variable for drainage system design and flooding analysis. Water quality facilities are designed to treat a specified quantity or volume of runoff for the full duration of a storm event as opposed to accommodating only an instantaneous peak at the most severe portion of a storm event.

To design effective BMPs and evaluate water quality impacts in urban watersheds, it is necessary to predict the amount of rainfall converted to runoff. The amount of rainfall which is converted to runoff is a function of storm characteristics such as rainfall amount, storm duration, rainfall intensity, and the urban land surface. These surfaces can be broken down into two main categories, pervious and impervious surfaces.

Impervious surfaces are traditionally thought to convert almost all rainfall into runoff, with pervious surfaces contributing much less runoff. In urban areas, particularly for small storms, this is not necessarily the case. Pervious surfaces can be heavily compacted and can have a surprisingly high runoff potential. Impervious surfaces, with minor cracks and expansion joints can have a remarkably high infiltration capability.

Impervious surfaces have five main components which contribute to rainfall losses:

- Interception of rainfall by over-hanging vegetation
- Flash evaporation
- Depression storage
- Sorption by dirt particles
- Infiltration through cracks and seams

The first four processes predominately occur immediately after the start of a rainfall event and dissipate within a relatively short time period and are therefore often referred to as initial abstractions. Infiltration through cracks and seams continues throughout the storm event and depending on the amount of rainfall, can account for significant losses. Many runoff models incorrectly estimate initial abstractions by holding them constant, and few consider infiltration through impervious surfaces for the duration of the storm event (Pitt, 1994).

The amount of runoff generated by pervious surfaces is related to the size of the pervious area, the relationship to impervious surfaces, the permeability of the underlying soils and the condition and type of vegetative cover.

The primary hydrologic methods to estimate storm runoff peak discharges in the Chesapeake Bay Watershed are the Rational Formula and SCS Methods, particularly, TR-55, "Urban Hydrology for Small Watersheds" (USDA, 1986). Several computer models, including SCS, TR-20, "Project Formulation, Hydrology" (USDA, 1982) and the U.S. Army Corps of Engineers', HEC-1 (U.S. Army, COE 1982) also utilize SCS methods to compute discharge rates. These methods are valuable for estimating peak discharge rates for large storms (i.e., >2") and larger drainage areas (> 10 to 25 acres), but can significantly underestimate the runoff from small storm events.

The limiting factors for the Rational Formula are in the computation of the time of concentration (usually set at a minimum of 5 minutes, which is hard to achieve on many small sites), the selection of "C" values for urban developments which do not address soil infiltration capability, and the equal weight placed on drainage area. The rational method is ideally suited for drainage design where peak rates of runoff are required, but does not estimate storm volume and therefore should not be used for water quality design.

Urban Hydrology For Small Watersheds (TR-55), as the title suggests, is recommended for urban watersheds with small drainage basins. This methodology has been used extensively for stormwater management design for quantity control (i.e., 2, 10, and 100 year management). TR-55 relies on a Curve Number (CN) instead of the "C" to reflect the percentage of rainfall converted to runoff. The TR-55 methodology also has the same limitations associated with computing the time of concentration for extremely small drainage areas.

One of the principal short comings of TR-55 is that the methodology assumes a constant CN for a large range of rainfall events. While this assumption does not significantly affect the accuracy of the model for larger storm events (> 2"), smaller rainfall events produce more runoff than are predicted by the SCS procedure (Pitt, 1994). This chapter presents a method for estimating the volume of runoff and peak discharge from small storms. Standard SCS methods should be used by designers for computing volumes and peak discharges for larger storm events (i.e., 2, 10 and 100 year storms).

Dr. Robert Pitt and his colleagues, have conducted several years of research on small storm hydrology, in several diverse geographic regions, over a wide range of land uses with remarkable consistency between simulated and observed results. The results of Pitt's research are described in Table 2.10.

TABLE 2.10: PRINCIPLES OF SMALL STORM HYDROLOGY (ADAPTED FROM PITT, 1994)

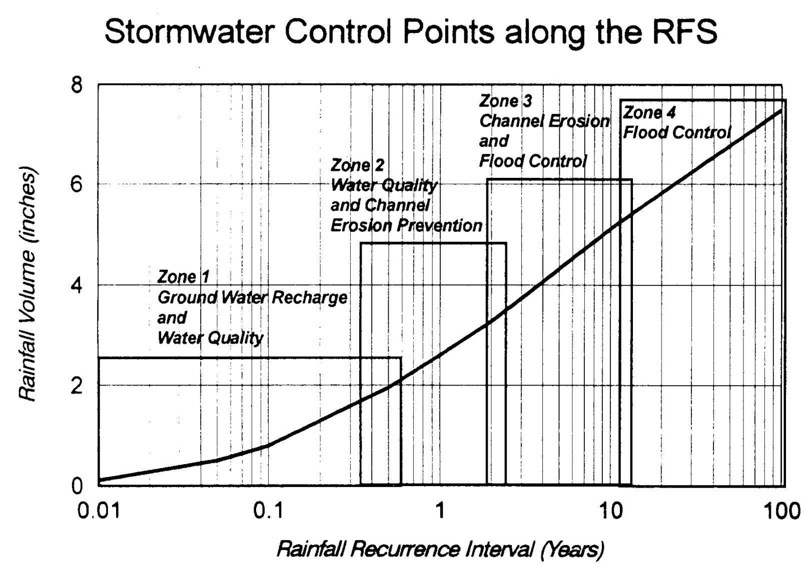
Larger rainfall events correspond reasonably well with SCS CN procedures.
Smaller rainfall events produce more runoff than is predicted by SCS CN procedures.
For strictly pervious surfaces, published CN's are much lower than observed CN's for small storm events. Therefore, less runoff is predicted from pervious areas during small storm events and SCS methodology incorrectly attributes more flow to impervious surfaces. This translates into inaccurate pollutant loading estimates from both pervious and impervious surfaces.
For impervious surfaces, the type of surface (i.e., rooftop, large paved surface, narrow street) has a significant impact on the amount of runoff for small storm events. The infiltration characteristics of these surfaces vary greatly. Remarkably, narrow streets can have a higher infiltration capability than some compacted urban pervious surfaces (such as ballfields).
Disconnecting impervious surfaces can significantly reduce the volume of runoff. The relative amount of reduction is a function of the pervious area flow path, the amount of impervious area draining to pervious areas, and the infiltration capacity of the pervious surfaces. Substantial reductions in runoff are observed for a wide range of land uses when impervious surfaces are disconnected and drained through permeable soils (SCS, Hydrologic Soil Groups (A and B). Reductions are only slight for relatively low density land uses when impervious surfaces are disconnected and drained through relatively impermeable soils (HSG's - C and D). Not surprisingly, disconnecting paved surfaces and rooftops for commercial areas does not result in significant reductions in runoff.

2.4 RAINFALL FREQUENCY SPECTRUM (RFS)

The effectiveness of any stormwater water quality treatment practice is a function of how much stormwater runoff is treated by the system and how much bypasses the practice. Since storms vary dramatically in magnitude, stormwater best management practices must be sized to capture a reasonable percentage of all runoff but bypass excessively large events. The rainfall frequency spectrum or RFS, which is defined as the distribution of all rainfall events, is a useful tool for establishing water quality treatment volume sizing criteria. This distribution is the cumulative volume from all storm events ranging from the smallest most frequent events in any given year to the largest most extreme events over a long duration, say, the 100 year frequency event.

The RFS consists of classes of frequencies often broken down by return interval, such as the two year storm return interval. Four principle classes are typically targeted for control by stormwater management practices. The two smallest, most frequent, classes are often referred to as water quality storms, where the control objectives are groundwater recharge, pollutant load reduction, and to some extent, control of channel erosion producing events. The two larger classes are typically referred to as quantity storms, where the control objectives are channel erosion control, overbank control, and flood control. Figure 2.5 illustrates a theoretical representation of these four classes.

FIGURE 2.5: FOUR CLASSES OF RAINFALL DISTRIBUTION



The distribution and magnitude of the RFS varies from region to region and to some extent, from year to year. Therefore, in order to establish a reasonable water quality treatment design volume for stormwater filtering practices it is necessary to define the RFS for the region of application. Within the Chesapeake Bay Watershed the average precipitation characteristics vary somewhat. This manual presents a sizing criteria based on an in-depth analysis conducted for the Washington, DC metropolitan area, compared with three other locations within the Bay and makes recommendations for establishing the RFS for other locations within the Bay Watershed.

Schueler (1987 and 1992), conducted a detailed evaluation of 50 years of hourly rainfall data in the Washington D.C. area. The recorded precipitation data from Washington National Airport consisted of all storm events separated by at least 3 hours from the next event. The base data collected at National Airport included minor storm events which normally do not produce measurable runoff. These minor events make up approximately 10% of all annual rainfall, are usually less than 0.1 inches, and are therefore excluded from the RFS analysis.

Table 2.11 outlines the RFS for the Washington D.C. metropolitan area and illustrates that the vast majority of all annual runoff is produced from the small frequent storm events.

TABLE 2.11: RAINFALL FREQUENCY SPECTRUM WASHINGTON, DC AREA[a]
SOURCE: DESIGN OF STORWATER WETLAND SYSTEMS (SCHUELER, 1992)

Percent of All Storm Events [b]	*Return Interval*	*Rainfall*[c] *Volume*
30	7 days	0.25
50	14 days	0.40
70	Monthly	0.75
85	Bi-monthly	1.05
90	Quarterly	1.25
95	Semi-annually	1.65
98	Annually	2.40
99	Two-year	2.90

a. 50 year analysis of hourly rainfall record at Washington National Airport, excluding all storms less than 0.10 inches that were separated by three consecutive hours from the next storm. These small storms seldom produce measurable stormwater runoff, yet are numerically the most common rainfall event.

b. Equal to or less than given rainfall volume

c. Watershed inches

2.5 THE 90% RULE-CUMULATIVE RAINFALL VOLUME FOR WATER QUALITY TREATMENT

A careful examination of Table 2.11 suggests that a BMP which is sized to capture and treat the three month storm frequency storm (or 1.25" rainfall) will effectively treat 90% of the annual average rainfall. While this is true, such a practice will also capture and at least partially treat the first 1.25" of larger rainfall events. Therefore treating the 1.25" rainfall will result in a capture efficiency of greater than 90%.

Given the economic considerations of capturing and storing a reasonably large water quality volume, and the realization that stormwater filters tend to lose efficiency as pollutant load input concentrations decrease (Bell, et. al, 1995), a smaller storm event was investigated to evaluate the effectiveness of an alternative treatment criteria. Many jurisdictions require storage of the first one-half inch of runoff from impervious surfaces. While this volume appears to have gained widespread acceptance, there has been little research on the cumulative pollutant load bypassing facilities sized on this principle. One notable exception, is a study conducted in Texas by Chang and his colleagues (1990), where the annual total solids load captured using the half-inch rule showed significant drop-off when imperviousness approached 70%.

To balance the desire to capture and treat as much cumulative rainfall as possible while avoiding an overly burdensome sizing criteria, additional rainfall data was evaluated throughout Chesapeake Bay watershed. In addition to Washington, DC, Three other locations were selected to evaluate longer term rainfall characteristics.

Daily precipitation data was analyzed for an 11 year period (January 1980 through December 1990) at four locations within the Chesapeake Bay Watershed. Norfolk VA, Washington, DC, Frederick MD, and Harrisburg, PA were selected as representative of the bay-wide watershed where new development activity is occurring. In addition locations are separated by 100 to 150 miles and represent a distribution from coastal to inland, and south to north.

The one-inch rainfall was evaluated to assess whether this value could be used to effectively capture 90% of the annual runoff. The average capture percentage using the 1.0" rainfall ranges from approximately 85% to 91% for the four locations. The analysis included the first one-inch of larger rainfall events which will be captured, but probably not completely treated. It is recognized that during these large events treatment conditions may be less than ideal. But it is safe to say that approximately 90% of the annual average rainfall events will be captured and treated using a **one-inch rainfall criteria**.

The results presented in Table 2.12 provide justification for using the 1.0" rainfall event for sizing stormwater filtering practices throughout the Chesapeake Bay Watershed. It must be emphasized that regional rainfall characteristics will differ from specific location to location. Additional rainfall frequency analysis is required for more complete reliance on this value. If a particular jurisdiction has the resources and long term data, a complete RFS should be conducted and the 90% rule applied to establish a local water quality precipitation value. In addition a longer data-set (say 50 years) will make some of the extreme rainfall events or drought periods less statistically significant and may have a minor effect on the capture value derived herein.

TABLE 2.12: COMPARISON OF PRECIPITATION DATA FOR FOUR LOCATIONS WITHIN THE CHESAPEAKE BAY WATERSHED 1980 - 1991 (DAILY ANALYSIS)

	Norfolk, VA	***Washington, DC***	***Harrisburg, PA***	***Frederick, MD***
Annual average precipitation	43.4 inches	37.9 inches	39.6 inches	37.0 inches
Annual average snowfall	7.7 inches	17.2 inches	31.3 inches	Not Obtained
Annual average # of precipitation days *	76 days	67 days	71 days	68 days
Annual average # of precipitation days more than 1.0"	10.5 days	9.5 days	9.5 days	7.7 Days
Annual average # of precipitation days less than 0.1"	39.0 days	45.4 days	55.1 days	Not Obtained
Percent of annual average rainfall ≤ 1.0" *	85.3%	91.4%	86.8%	89.9%
Percent of annual precipitation days ≤ 1.0" *	86.2%	85.9%	86.7%	88.6%
* adjusted to exclude rainfall events ≤ 0.1 (assumed to produce no runoff)				

2.6 STORMWATER FILTERING SYSTEMS - SIZING CONSIDERATIONS

In general, stormwater filtering systems should be sized based on the **volume** of runoff to be filtered. All practices identified in this manual utilize the volume based sizing criteria, except for the grass channel practice, where a peak rate is utilized. It is necessary, however, to utilize a peak rate of discharge for sizing off-line flow diversion structures.

As presented earlier in this chapter, the target rainfall event for estimating the Water Quality Volume (WQV) for sizing all filtering devices is based on the **90% Rule** for capturing annual runoff volume. For the Mid-Atlantic region and much of the Chesapeake Bay Watershed, a rainfall value of **1.0 inches** is suggested.

Some jurisdictions may elect to use other sizing guidelines, such as the ½ inch rule (measured in watershed inches). This criteria may be acceptable for lower imperviousness but will have decreased pollutant capture efficiencies for a higher imperviousness and a lower capture percentage of the annual runoff volume. The individual practice sizing principles contained in this manual are applicable for alternative treatment volumes so a reliance on the 90% Rule is not mandatory. In addition, several filtering practices are ideally suited for retrofit applications where full storage is often constrained. Designers and regulators should recognize that the 90% Rule is targeted mainly at new construction and is based on maximizing pollutant load capture. Practices sized for smaller treatment volumes are certainly acceptable in many situations.

2.7 ESTIMATING WATER QUALITY VOLUME (WQV)

Two methods can be utilized to estimate the Water Quality Volume (WQV). Both rely on computing a volumetric runoff coefficient (R_v) and multiplying this by the rainfall volume to obtain a runoff volume in watershed inches.

The first method, or what we call the **Short Cut Method,** utilizes equation 2.1 to estimate the volumetric runoff coefficient R_v, (Schueler, 1987). It is recommended that the Short Cut Method be utilized where the site consists of predominately one type of land surface or for quick calculations to obtain a reasonably accurate estimate of treatment volume.

$$R_v = 0.05 + 0.009(I) \qquad \textbf{Equation 2.1}$$

where I = site percent impervious

Therefore, the required treatment volume for a site will be equal to:

$WQV = P * R_v$ **Equation 2.2**

P = rainfall, in inches
and WQV = Water Quality Volume, in watershed inches

EXAMPLE CALCULATION

Assume a 3.0 acre shopping center which is 87% impervious, for a 1.0 inch rainfall event.

$R_v = 0.05 + 0.009(87\%)$
$R_v = 0.83$

for P = 1.0 inches
WQV = (1.0")(.83) = .83 watershed inches
WQV = .83"(1/12 "/ft)(3.0 ac)(43,560 ft^2/ac) = 9,039 ft^3

The second method, or **Small Storm Hydrology Method** utilizes the work done by Pitt and others, to compute a volumetric runoff coefficient (R_v) based on the specific characteristics of the pervious and impervious surfaces of the drainage catchment. This method presents a relatively simple relationship between rainfall amount, land surface, and runoff volume. The R_vs used to compute the volume of runoff are identified in Table 2.13. The small storm hydrology model involves the following:

- For a given rainfall depth, the runoff coefficients for land surfaces present on the subject site are selected.
- A weighted runoff coefficient for the entire site is computed.
- If a portion of the site has disconnected impervious surfaces, reduction factors are applied to R_v. The reduction factors (from Table 2.14) are multiplied by the computed R_v for connected impervious areas to obtain the corrected value.
- For the given rainfall, the runoff volume (in watershed inches) is computed. WQV is equal to the rainfall times the R_v (same as equation 2.2 above).

TABLE 2.13: VOLUMETRIC COEFFICIENTS FOR URBAN RUNOFF (DIRECTLY CONNECTED IMPERVIOUS AREAS, ADAPTED FROM PITT, 1994)

Rainfall (inches)	Flat roofs and large unpaved parking lots	Pitched roofs and large impervious areas (large parking lots)	Small impervious areas and narrow streets	Sandy soils HSG-A	Silty soils HSG-B	Clayey soils HSG-C & D
0.75	.82	.97	.66	.02	.11	.20
1.00	.84	.97	.70	.02	.11	.21
1.25	.86	.98	.74	.03	.13	.22
1.50	.88	.99	.77	.05	.15	.24

TABLE 2.14: REDUCTION FACTORS TO VOLUMETRIC RUNOFF COEFFICIENTS FOR DISCONNECTED IMPERVIOUS SURFACES (ADAPTED FROM PITT, 1994)

Rainfall (inches)	Strip commercial and shopping center	Medium to high density residential with paved alleys	Medium to high density residential without alleys	Low density residential
0.75	.99	.27	.21	.20
1.00	.99	.38	.22	.21
1.25	.99	.48	.22	.22
1.50	.99	.59	.24	.24

In order to use the reduction factors for disconnected impervious surfaces, as general guidance, the impervious area above the pervious surface area should be less than one-half of the pervious surface and the flowpath through the pervious area should be at least twice the impervious surface flowpath.

The Small Storm Hydrology method has the advantage of evaluating the precise elements of a particular site and should be utilized for most design applications to estimate accurate runoff volumes. The method requires somewhat more effort to identify the specific land surface area ratios and additional effort is needed to assess the disconnections of impervious areas. The method rewards site designs which utilize disconnections of impervious surfaces by lowering the computed R_v and the required WQV.

EXAMPLE CALCULATION

Assume a 3.0 acre small shopping center having a 1.0 acre flat roof, 1.6 acres of parking and a 0.4 acre open space (sandy soil), for a 1.0 inch rainfall event and no disconnection of impervious surfaces. The weighted volumetric runoff coefficient is:

flat roof:	1.0 acre x .84 = 0.84
parking:	1.6 acres x .97 = 1.55
open space:	0.4 acre x .02 = 0.01
total:	3.0 acres = 2.40

weighted volumetric runoff coefficient R_v = 2.40/3.0 = .80

for P = 1.0 inches
Water Quality Volume (WQV) = (1.0")(.80) = .80 watershed inches
= (.80") (1 ft/12") (3.0 ac) (43,560 ft^2/ac)
= 8,712 ft^3

2.8 ESTIMATING PEAK DISCHARGE FOR THE WATER QUALITY STORM (Q_P)

The peak rate of discharge is needed for the sizing of off-line diversion structures and to design grass channels. As discussed earlier in this chapter, conventional SCS methods underestimate the volume and rate of runoff for rainfall events less than 2". This discrepancy in estimating runoff and discharge rates can lead to situations where a significant amount of runoff by-passes the filtering treatment practice due to an inadequately sized diversion structure or leads to the design of undersized grass channels.

The following procedure can be used to estimate peak discharges for small storm events. It relies on the volume of runoff computed using the Small Storm Hydrology Method and utilizes SCS, TR-55 Graphical Peak Discharge Method.

- Using the water quality volume (WQV), computed using the methods previously presented, a corresponding Curve Number (CN) is computed utilizing equation 2.3.

$$CN = 1000/[10 + 5P + 10Q - 10(Q^2 + 1.25\,QP)^{1/2}]$$ **Equation 2.3**

where P = rainfall, in inches (use 1.0" for the Water Quality Storm)
and Q = runoff volume, in inches (equal to WQV)

Note: Equation 2.3 above, is derived from the SCS Runoff Curve Number method described in detail in NEH-4, Hydrology (SCS 1985) and SCS TR-55 Chapter 2: Estimating Runoff. The CN can also be obtained graphically (also from TR-55).

- Once a CN is computed, the time of concentration (t_c) is computed (based on the methods identified in TR-55, Chapter 3: "Time of concentration and travel time"). The t_c for small sites is often small based on relatively short flow paths; however, a minimum value of 0.1 hours should be used.

- Using the computed CN, t_c and drainage area (A), in acres; the peak discharge (Q_p) for the Water Quality Storm is computed (based on the procedures identified in TR-55, Chapter 4: "Graphical Peak Discharge Method"). For the Chesapeake Bay Watershed use Rainfall distribution type II.

  - Read initial abstraction (I_a), compute I_a/P
  - Read the unit peak discharge (q_u) from Exhibit 4-II for appropriate t_c
  - Using the water quality volume (WQV), compute the peak discharge (Q_p)

$$Q_p = q_u * A * WQV$$ **Equation 2.4**

where Q_p = the peak discharge, in cfs
q_u = the unit peak discharge, in cfs/mi²/inch
A = drainage area, in square miles
and WQV = Water Quality Volume, in watershed inches

EXAMPLE CALCULATION

Using the previous example:

where WQV = .80"
$CN = 1000/[10+5*1.0"+10*.80"-10((0.80")^2+1.25*.80"*1.0")^{1/2}]$
CN = 98

assume t_c = 10 minutes = .17 hours
I_a = 0.041 for CN = 98, I_a/P = 0.041/1.25" = .03
read q_u = 950 csm/in (TR-55 Exhibit 4-II)
A = 3.0 acres/640ac/mi² = .0047mi²
Q_p = 950 csm/in * .0047mi² * .80" =3.6 cfs

For computing runoff volume and peak rate for storms larger than the Water Quality Storm (i.e., 2, 10 and 100 year storms), use the published CN's from TR-55 and follow the prescribed procedure in TR-55.

In some cases the Rational Formula may be used to compute peak discharges associated with the Water Quality Storm. The designer must have available reliable intensity, duration, frequency (IDF) tables or curves for the storm and region of interest. This information may not be available for many locations and therefore the TR-55 method described above is recommended.

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RAINFALL FREQUENCY ATLAS OF THE MIDWEST

by Floyd A. Huff and James R. Angel

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Bulletin 71

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RAINFALL FREQUENCY ATLAS OF THE MIDWEST

by Floyd A. Huff and James R. Angel

Title: Rainfall Frequency Atlas of the Midwest.

Abstract: This report presents the results and methodology of an intense study of rainfall frequency relationships throughout the Midwest (Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). Using primarily 275 long-term daily reporting stations from the National Weather Service (NWS) cooperative network supplemented by 134 daily reporting stations with shatter records, rainfall amounts have been determined for recurrence intervals from 2 months to 100 years and for durations of 5 minutes to 10 days. The results are presented as maps and as climate division averages in tabular form. Several special raingage networks were used to develop relationships between amounts for 24 hours and less. This report also examines the time distributions of heavy rainfall over time, and other storm characteristics such as storm orientation and movement. The assumption of spatially independent observations between stations is also discussed.

Reference: Huff, Floyd A., and James R. Angel. Rainfall Frequency Atlas of the Midwest. Illinois State Water Survey, Champaign, Bulletin 71, 1992.

Indexing Terms: Climatology, heavy rainfall, hydroclimatology, hydrometeorology, Midwest, extreme value distributions, climate change.

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INTRODUCTION

Storms in the Midwest

The type of rainstorm that most frequently produces flash floods in the Midwest is very localized and produces a large amount of rainfall. According to Changnon and Vogel (198l), these storms usually last from 3 to 12 hours, significantly affect fewer than 400 square miles, and have 1- to 4-hour rainfall totals in excess of 3 inches. Changnon and Vogel's study indicates that approximately 40 of these storms occur in an average year in Illinois, or about one storm for very 1,500 square miles of territory. These storms cause serious local flooding problems on farmland (crop damage) and in urban areas, and interfere with small-reservoir operations.

A larger version of the storm described above is the most damaging flood-producing storm experienced in the Midwest and occurs on the average of about once in two years within the region (Huff, 1986). These "blockbuster" storms generally last from 12 to 24 hours, produce extremely heavy rainfall over a 2,000- to 5,000-square-mile area, and typically create 10- to 12-inch amounts of rain at the storm center. Rainfall amounts in excess of the 100-year recurrence-interval value of point rainfall commonly encompass areas of several hundred square miles about the storm's center.

A substantial portion of the maximum point rainfalls recorded in the precipitation data used in the present study occurred in storms of this type. Although they are rather rare occurrences, these storms may occur in clusters. For example, two of the three blockbuster storms that occurred in Illinois in 1957 took place within two weeks of each other. On the other hand, there have been times when no blockbuster storm was observed for several consecutive years.

Other flood-producing storms, affecting relatively large areas ranging from the size of a county to 20,000 or more square miles, result from a series of moderately intense showers and thunderstorms that occur intermittently for periods of 1 to 10 days. Many of these individual storms would produce little or no damage by themselves, but collectively they can cause urban drainage systems to overflow, and creeks and rivers to swell beyond capacity. This can result in both localized and widespread flooding.

The frequency distributions of heavy rainfall resulting from the storm systems described above are of importance to engineers and others involved in designing and operating structures, such as storm sewers and retention ponds, that can be affected by these events. To meet this need, our nine-state study has concentrated on determining rainfall frequency relations over a wide range of storm periods or partial storm periods (5 minutes to 10 days) and recurrence intervals (2 months to 100 years). The large-scale analysis program required was considered necessary to meet the diverse needs for rainfall frequency information, both now and in the foreseeable future.

Rationale for the Study

Some specific needs led to the undertaking of this study. First, frequency relations for the Midwest had not been updated since Hershfield's U.S. Weather Bureau Technical Paper 40 (TP40) in 1961. Second, further stimulation for the study resulted from recent findings (Huff and Changnon, 1987) that an apparent climatic trend operated on the frequency distributions of heavy rainstorms in Illinois from 1901-1980, which was confirmed by Huff and Angel (1990) for portions of the Midwest. Third, there was a need for more detailed spatial description of the variations in rainfall amounts for any given duration and recurrence interval than was provided in the TP40 study.

One of the problems with TP40 is that its 100-year, 24-hour values have been exceeded too frequently in certain regions of the Midwest. Table 1 summarizes the number of times that these values were exceeded for selected, long-term stations in each state. Assuming a binomial distribution, the probability of exceeding a 100-year event in a given year can be calculated for a particular station. For example, in Illinois the probability of exceeding a 100-year event is 0.583 with an average record length of 87 years. With 61 stations, one would expect a 100-year event to have been exceeded approximately 36 times during this period (column d in table 1) rather than the 69 times that were observed (column c in table 1). The results in Michigan are even more striking, with over three times the expected number of storms exceeding the 100-year value. But in Missouri the TP40 values were not exceeded nearly as often as expected, which suggests that these values are too high. For the entire Midwest, 246 storms exceeded the 100-year value against an expected number of 171 storms (a ratio of 1.43).

The present study has used a much larger, longer sample of precipitation data than was available for previous U.S. studies by Yarnell (1935), Hershfield (1961), and Miller et al. (1973), and an Illinois study by Huff and Neill (1959a). The present study has employed a comprehensive data sample from 409 stations in nine states across the Midwest (Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). Records from 275 of these stations date back to the early 1900s. Thus we were able to provide greater spatial detail than was possible in the previous studies. Furthermore, the longer time sample should provide more accurate estimates of the various frequency distributions, particularly for relatively long recurrence intervals (25 years or more).

All the results in this report are expressed in the English system of units. It is anticipated that hydrologists and others who use the information will continue to use the English system in the foreseeable future. The following conversion table can be used in converting English units to metric units.

Table 1. Number of Times the 24-Hour, 100-Year Value from Technical Paper 40 Is Exceeded by State

	(a) Number of stations	*(b)* Average length of record	*(c)* Number of times exceeded	*(d)* Number of times expected	*Ratio (c)/(d)*
Illinois	61	87	69	36	1.92
Indiana	41	64	17	20	0.85
Iowa	43	80	20	24	0.83
Kentucky	25	67	11	12	0.92
Michigan*	46	60	71	21	3.38
Minnesota	25	67	14	12	1.17
Missouri	44	62	4	20	0.20
Ohio	41	60	27	19	1.42
Wisconsin	13	78	13	7	1.86
Midwest			246	171	1.43

*From Sorrell and Hamilton, 1990

Conversion Table

Multiply	*By*	*To obtain*
Inch (in.)	25.4	Millimeter (mm)
Mile (mi)	1.6	Kilometer (km)
Square mile (mi^2)	2.6	Square kilometer (km^2)

Organization of the Report

This report is divided into two main parts: Analyses, and Distribution Maps and Tables. Readers interested solely in obtaining rainfall amounts for particular durations and recurrence intervals should see chapter 3 and part 2. Chapter 10 provides a complete overview. Those interested in how the values were obtained should see the Introduction and chapters 1 and 2, which describe why the study was undertaken, the data sets used, and the statistical analyses that were applied.

Chapters 4, 5, and 7 provide auxiliary information about heavy storms in the Midwest, which may be useful for design and planning purposes. These chapters describe rainfall distribution within a storm, spatial characteristics of storms, and changes in the rainfall distribution through the seasons.

Chapter 6 addresses the issue of climate change and extreme rainfall, and documents significant changes with time over parts of the Midwest. Chapters 6 and 8 address two of the basic statistical assumptions of heavy rainfall events: a stationary time series and spatially independent rain events. Chapter 9 discusses the dispersion of point values around the climate section mean values found in the tables in part 2.

Basic Considerations

The basic philosophy applied in the nine-state study was that a combination of appropriate statistical techniques, guided by available meteorological and climatological knowledge of atmospheric processes, provides the best approach to the problem. In so doing, it is important to remember that the natural laws operating in the atmosphere are not controlled by any particular statistical distribution. Within the limits of the data sampled (for example, 25, 50, or 100 years), however, the application of appropriate statistical analysis provides a means of optimizing the information contained in that data.

The specific type(s) of statistical distribution that will provide the optimal rainfall frequency relations for a given location will vary depending on such factors as climate, land features (topography, large water bodies, etc.), and season of the year (if a seasonal analysis is being performed). Thus climatology would suggest it is doubtful whether the same statistical distribution that provides a good fit for Chicago data would also achieve the same degree of reliability if applied to data for Miami, Phoenix, or Seattle, where the precipitation climates have substantially different characteristics than at Chicago. For example, see Changnon's definition of the nation's rainfall climate zones based on analysis of hourly rainfall amounts and their distributions (Changnon and Changnon, 1989).

It is also important to remember that *any specific statistical distribution serves only as a means of optimizing information contained in the data sample.* One must be very cautious in extrapolating the derived frequency relations beyond the limits of the data. Thus if rainfall frequency relations have been derived from an 80-year data sample, it is reasonable to assume that the relations should be satisfactory for estimating the expected 100-year event, but certainly not the 500-year event. This is too far beyond the limits of the data. In fact, there is no assurance that the natural laws affecting the rainfall will continue to closely follow any particular statistical distribution for the next 500 years. If significant climate changes are occurring, as indicated by numerous investigators, then rainfall processes cannot be assumed to remain stationary in the future.

Before describing the specific procedures used in our nine-state study, it is necessary to mention another basic problem always encountered in rainfall frequency studies. There are two sources of potential variability contained in the data sample for a given location: natural and human-induced variability. The natural variability factor can cause significant differences to appear in the frequency distributions of two stations located within an area of apparent precipitation climate homogeneity. This variability can be caused by one or several storms of abnormal intensity occurring at one station and not the other, even over a long period. This is not an uncommon occurrence in regions such as the Midwest where thunderstorms are the primary producers of heavy rainstorms.

Unfortunately, this natural variability is very difficult, if not impossible, to separate from human-induced variability, which also often affects the data sample at a particular location. This variability is influenced by such factors as improper raingage exposure, the worst source of measurement error; recording errors; and mistakes in processing rainfall data. Vogel (1988) provides some good examples of problems created by improper raingage exposure, data processing inadequacies, and inadequate gage maintenance.

If isohyetal maps of rainfall frequency relations are to be the end product of a study, some scientific judgment must be used in assessing such data differences between stations. These variability errors cannot be completely eliminated by statistical treatment of the data. If areal mean frequency relations are derived for areas of similar precipitation climate, however, this problem can be reduced substantially.

Another important issue is the decision not to use hourly precipitation data to directly calculate rainfall frequency values. The hourly data were not used for three reasons: the period of record is typically shorter than for the daily reporting stations (35 years or less in most cases); there are fewer hourly stations in the region by a factor of 2; and, most importantly, the quality of the data is much poorer than that of the daily data. Sorrell and Hamilton (1990) came to the same conclusion about the drawbacks of the hourly data in their rainfall frequency analysis of Michigan. Developing an analysis based directly on the hourly data with the same accuracy and detail as the daily data would have been impossible. Therefore, the hourly data were only used to develop relationships between the daily data and durations less than daily (see chapter 1 for more discussion on the technique used).

Pilot Study

Initially, a very detailed study of Illinois rainfall frequency relations was made (Huff and Angel, 1989). In this study, the authors explored the use of those statistical distributions considered to have potential for application in Illinois based on (1) the observed characteristics of the data sample and (2) consideration of the precipitation climate and influences generated by certain topographical features and two large, urban areas (Chicago and St. Louis). An 83-year sample of data (1901-1983) for 61 cooperative stations and 34 recording gage stations in and near Illinois was available at the start of the pilot study.

It was assumed that the analytical techniques derived in the Illinois study were applicable to the other eight states in the Midwest, since there are no major changes in the general precipitation climate within this region. That is, there are no changes to a tropical, desert, or maritime climate within the region—the general climate type is humid continental. The above method of deriving analytical techniques from a detailed investigation of one climatically representative state (or area) in the region of interest is considered by the authors to be appropriate, time-saving, and cost-effective.

Information Accumulated for Each State

For each precipitation station in the pilot study, the frequency distribution of rainfall amounts was determined for storm durations of 5 minutes to 10 days and for recurrence intervals ranging from 2 months to 100 years to adequately meet the needs of users. Mean rainfall frequency relations were then calculated for each climatic section in the nine states. The climatic trend at each station was measured through use of the ratio of rainfall amounts in a 40 year-period (1947-1986) to those for the previous 40-year period (1907-1946) for selected recurrence intervals and rain durations.

From the point (station) data, frequency relations were developed in the form of isohyetal maps for selected rain periods and recurrence intervals (those most commonly used by hydrological engineers and others). Regional maps were derived for rain periods of 1, 2, 3, 6, 12, 24, 48, 72, 120, and 240 hours, and for recurrence intervals of 2, 5, 10, 25, 50, and 100 years. Methods have been provided for computing rainfall for the lesser used storm periods of 5 to 30 minutes, and for recurrence intervals of 2 to 12 months.

As indicated above, areal mean relations were also determined for each climatic section in each state. Section locations are shown in figure 1. Results, presented in tabular form, include the entire range of rain periods and recurrence intervals used in the point rainfall computations. Assuming approximate homogeneity of heavy rainfall climate within a section, the average relations are considered more reliable than point values. The mean section relationship helps minimize the effects of the natural variability and human-induced sampling errors, which sometimes distort the true distribution pattern of heavy rainfall at specific sampling points (stations).

Acknowledgments

This report is the culmination of rainfall frequency research originally begun in 1984 under the direction of Stanley A. Changnon. Jr., then Chief of the Illinois State Water Survey. Although the investigation was initially restricted to Illinois, it was expanded in 1988 to include the nine-state Midwest region of the Midwestern Climate Center

(MCC) with Stanley Changnon and Peter J. Lamb as the co-principal investigators. The work was continued and completed under the general direction of Kenneth Kunkel, present MCC Director.

Special appreciation goes to Stan Changnon for his foresight, guidance, and encouragement in establishing and accomplishing the program objectives. He and Ken Kunkel reviewed the report and made useful comments and suggestions. Special thanks go to Richard Katz, National Center for Atmospheric Research; Tibor Farago, Hungarian Meteorological Service; and J.R.M. Hosking, IBM Research Division, for providing software for some of the extreme rainfall analyses. Fred Nurnberger, Michigan State Climatologist, provided valuable long-term precipitation data for his state as well as comments on the manuscript. We also thank the following state climatologists for their review and comments on this project: Wayne Wendland, Illinois; Ken Scheeringa, Indiana; Harry Hillaker, Iowa; Glen Conner, Kentucky; Jim Zandlo, Minnesota; Wayne Decker, Missouri; Jeff Rogers, Ohio; and Pam Naber-Knox, Wisconsin.

John Brother and Linda Hascall supervised the extensive drafting work required for the report. Jean Dennison typed and assembled the report, which Eva Kingston edited and formatted.

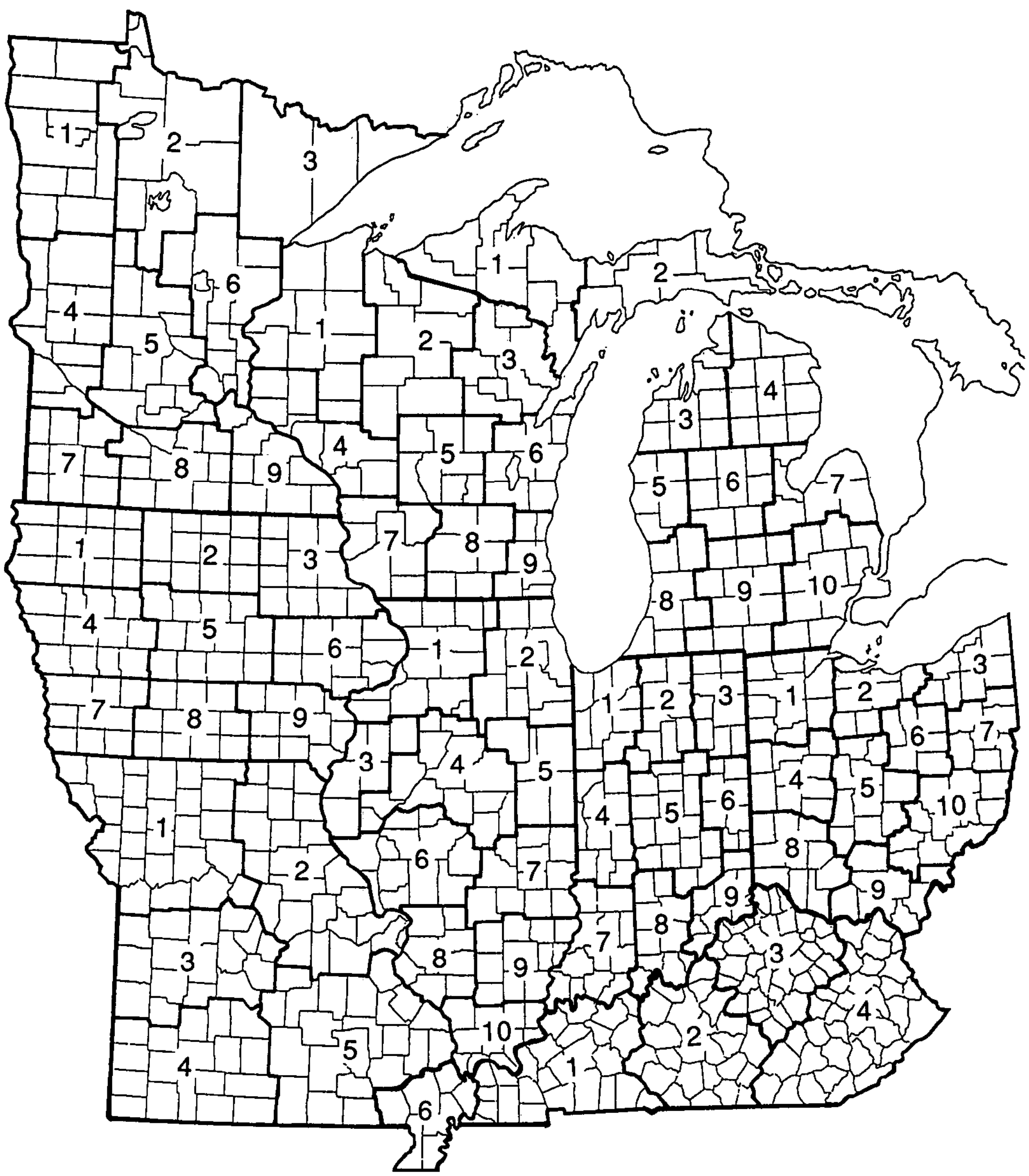

Figure 1. Climatic sections for the Midwest

PART 1. ANALYSES

1. DATA AND ANALYTICAL APPROACH

This study relied primarily on data from 275 daily reporting stations of the National Weather Service (NWS) cooperative network, which had records exceeding 50 years. These data were provided in digital form by the National Climatic Data Center and, in some cases, keypunched by the Midwestern Climate Center from written records. The coverage ranged from good in Illinois, Indiana, Iowa, Michigan, and Missouri to sparse in Minnesota, Wisconsin, Ohio, and Kentucky. These data were supplemented by daily data from 134 cooperative stations with shorter records (1948 to present), by first-order station data, and recording raingage data where available (1948 to present) (figure 2).

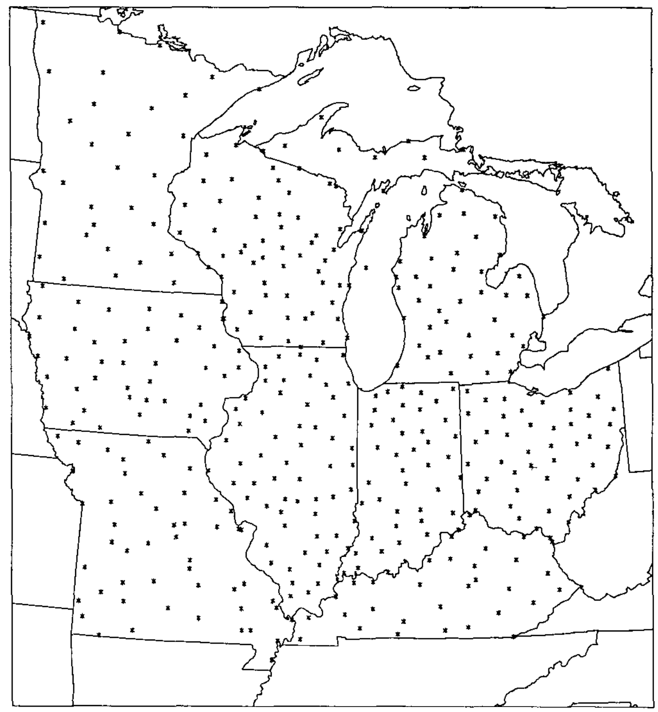

Figure 2. Stations used to derive the rainfall frequencies

Because the cooperative network provides only daily amounts of rainfall, an empirical factor of 1.13 was used to convert calendar-day rainfall to maximum 24-hour rainfall. This empirical factor was developed by NWS analysts (U.S. Weather Bureau, 1953) and confirmed by Hershfield (1961) and Huff and Neill (1959a). This factor was investigated further in the nine-state study by using all recording raingage data for the period 1948-1987 in Indiana and Illinois. Analysis verified the earlier findings that 1.13 represented the average ratio of maximum 24-hour to calendar-day rainfall in heavy rainstorms. Conversion factors of 1.05 and 1.02, respectively, were obtained for converting 2-day rainfall to maximum 48-hour rainfall and 3-day rainfall to maximum 72-hour rainfall in heavy storm events. The ratios decreased to 1.01 for 5-day and 10-day storms. These are average factors that may vary considerably between storms, but should result in only small errors when applied to a large sample of storms, such as used in this study. Table 2 shows the various conversion factors.

Recurrence-interval amounts for rain periods of less than 24 hours were obtained from average ratios of x-hour/24-hour rainfall. These ratios were determined primarily from recording raingage data for 1948-1983 at 34 Illinois stations and 21 stations in adjoining states (Huff and Angel, 1989). Results of a similar study, based on the Chicago urban network data for 1948-1974 (Huff and Vogel, 1976) and ratios developed by Hershfield (1961) were also considered when determining the empirical factors. All the information sources provided ratios that were in close agreement. Results are shown in table 3.

Frequency relations are usually developed for recurrence intervals of one year or longer. To meet some user needs, however, it was necessary to develop frequency relations for time periods shorter than 12 months. The data analysis showed that 2-month to 9-month frequency values are strongly related to the 2-year values. The x-month/24-month ratios were found to be spatially consistent for all recurrence intervals. These ratios are shown in table 4 for storm periods of 24 hours to 10 days. The 24-hour values are also applicable to storm periods of less than 24-hour duration.

For each station, the data were used to determine the annual maxima time series from the highest precipitation amount recorded in each year for a given storm duration. Station (point rainfall) frequency curves were then calculated for the various storm rainfall durations of interest. For this report, however, the annual maxima values were converted to partial duration values by using the transformation factors shown in table 5 (Huff and Neill, 1959a). The partial duration series includes all of the high values recorded during a sampling period without regard to their annual sequence. Thus all of the 50 highest values occurring in a 50-year period will be included in the partial duration series, but not necessarily in the annual maxima series. Although the annual maxima series is more adaptable to statistical testing, our experience indicates that the partial duration values are preferred by most users of heavy rainfall frequency relations, especially engineers involved in the design and operation of water control structures. The rainfall values are interchangeable through use of table 5.

Table 2. Ratio of Maximum Period to Calendar-Day Precipitation

Storm period (days)	*Ratio*
1	1.13
2	1.05
3	1.02
5	1.01
10	1.01

Table 3. Average Ratio of X-Hour/24-Hour Rainfall

Rain period (hours)	*Ratio (x-hour/24-hour)*
18	0.94
12	0.87
6	0.75
3	0.64
2	0.58
1	0.47
0.50 (30 min.)	0.37
0.25 (15 min.)	0.27
0.17 (10 min.)	0.21
0.08 (5 min.)	0.12

Table 4. Relationship Between 2-Year and Shorter Interval Frequency Values for Various Rainstorm Periods

	Mean ratio (x-month to 24-month rainfall) for given rainstorm period					
Storm period (hours)	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*12-month*
24	0.46	0.53	0.58	0.67	0.76	0.83
48	0.44	0.51	0.57	0.66	0.76	0.83
72	0.43	0.51	0.57	0.66	0.76	0.83
120	0.42	0.50	0.57	0.66	0.76	0.83
240	0.41	0.49	0.57	0.66	0.76	0.83

Table 5. Ratio of Partial Duration to Annual Maximum Frequencies

	Ratio for given recurrence interval		
Precipitation period (hours)	*2-year*	*5-year*	*10-year*
24	1.13	1.05	1.01
48	1.09	1.02	1.01
120	1.08	1.01	1.00
240	1.08	1.01	1.00

2. STATISTICAL METHODS

Background

In previous Illinois studies (Huff and Neill, 1959a; Huff and Angel, 1989), various statistical distributions were tested for their applicability in fitting extreme rainfall data in the Midwest. These distributions included log normal, Gumbel (1941). Frechet (Gumbel, 1956), Chow (1954), Jenkinson (1955), and log-Pearson (Reich, 1972). Log-log and semi-log fitting procedures were also investigated. Recently, as part of our nine-state study, an investigation was also made of the application of L-moments and maximum likelihood fitting methods to the generalized extreme value theory (Wallis, 1989; Hosking, 1990). Results were compared with those generated by the Huff-Angel method described below.

No single statistical distribution was found in the earlier Illinois studies (Huff and Neill, 1959b; Huff and Angel, 1989) that would consistently provide a satisfactory fit over the wide range of rain periods and recurrence intervals required to meet user needs. These studies generally showed that the Frechet, log-Pearson, and log-log methods provided the best fit for recurrence intervals exceeding 2 years. These methods, however, produced unsatisfactory estimates of rainfall values for recurrence intervals of 2 months to 2 years. For these shorter intervals, log-normal and semi-log fittings of the data often closely approximated the values indicated by plotting the ranked observational data.

These findings support those of Sevruk and Geiger (1980) who made an extensive appraisal of distribution types for extremes of precipitation for the World Meteorological Organization (WMO). But Sevruk and Geiger's worldwide appraisal did not reach a conclusion concerning the superiority of any particular distribution. They point out that "some distributions, however, may be superior to others under given seasonal and/or geographical conditions." This agrees with earlier Illinois findings, which indicated that the Frechet distribution was most applicable to annual, spring, summer, and fall data, but the log-normal distribution provided the best fit for winter data (Huff and Neill, 1959b).

Analytical Method Employed in the Nine-State Study

For our nine-state study, a log-log graphical analysis, hereafter referred to as the Huff-Angel method, was used for final derivation of the frequency relations. This method resulted in smooth curves, such as those illustrated in the Illinois example in figure 3. This figure shows the frequency distribution of 24-hour maximum rainfall amounts for recurrence intervals varying from 2 months to 100 years. A major change is reflected in the distribution characteristics for the two sectional curves near the 2-year recurrence interval.

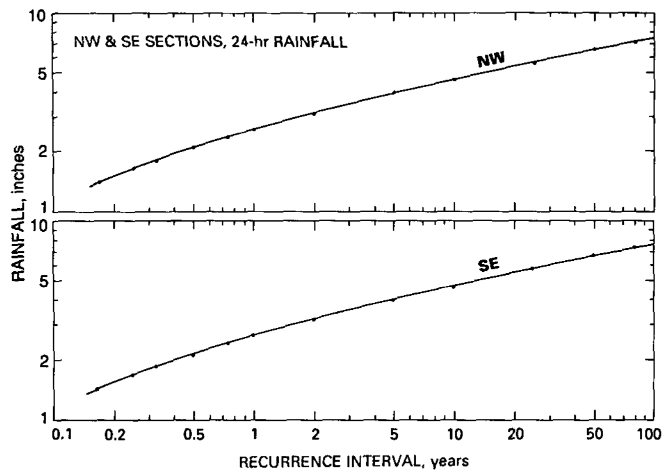

Figure 3. Typical sectional curves in Illinois for various recurrence intervals

Similar curves were obtained for the various sections and individual stations (sampling points) used in our nine-state study. The curve shape varied somewhat among stations, however. For example, at some stations, the change in curvature began closer to the 5-year than the 2-year recurrence interval. Changes in curve characteristics also occurred sometimes with increasing length of rain periods, but a smooth shape was preserved. For most stations, however, a linear fit was provided for return periods of 2 years or more. This method is more subjective than using specific statistical methods, such as L-moments or maximum likelihood, to fit a specific statistical distribution (such as log-normal, Gumbel, etc.). However, it does allow the analyst to incorporate meteorological-climatological knowledge and other pertinent findings from the various analysis procedures employed in the study. For example, human-made sampling errors were sometimes obvious in our nine-state study from comparison of station rainfall values within areas of approximately homogeneous precipitation climate. The integration of all available information is especially helpful in evaluating the rarer events (outliers) appearing in some station records.

The Huff-Angel method places acutoff on extrapolation at or near the 100-year frequency, since the data are not fitted to a specific mathematical distribution. For reasons cited earlier, however, extrapolation of any frequency relation much beyond the limits of the data sample (80+ years at most long-term stations) is not recommended. Furthermore, climatic and physiographic variations can cause the "best-fit" statistical distribution to vary within a single state as shown by Huff and Neill (1959a).

Comparison of Huff-Angel, L-moments, and Maximum Likelihood Methods' Fitting Procedures for Selected States

To evaluate the maximum likelihood and L-moments methods, the generalized extreme value (GEV) distribution was used because of (1) its versatility (the Gumbel and Frechet distributions, for example, are really special cases of the GEV) and (2) the need for a uniform distribution for comparison purposes. A literature search also indicated that the GEV distribution would be the most appropriate statistical distribution for computing point rainfall frequency relations.

Maximum Likelihood Method

The maximum likelihood method is a standard statistical procedure used in fitting a variety of hydrological data (e.g., Kite, 1977; Farago and Katz, 1990). For the stations used in this study, the sample size was always greater than 36 (64 on average). This method should thus yield relatively unbiased estimates of the parameters.

L-moments Method

Recently, another method for fitting distributions appeared in the literature, the L-moments method (Hosking, 1990). This method, analogous to the method of moments (L-mean, L-skewness, etc.), uses linear combinations of order statistics to develop estimates of the distribution. Theoretically, the advantages of this approach over the traditional method of moments are the smaller impact of outliers and the more accurate inferences derived from smaller samples. This method is being used by NWS in updating rainfall frequency relationships in the western United States (Vogel, personal communication, 1991).

In practice, the L-moments method is more involved than either the Huff-Angel or maximum likelihood methods, since it uses regional values to estimate some of the parameters. Thus care must be taken in grouping the stations into appropriate regions by plotting the L-skewness versus L-kurtosis to look for groupings, calculating a discordancy measure by station to indicate potential problems, and examining heterogeneity through Monte Carlo simulations. All this can easily be done using available software (Hosking. 1991). Once the stations are properly grouped, the precipitation amounts for various return periods can be calculated with the appropriate distribution, based on a goodness-of-fit measure.

L-moments Regions

The L-moments technique is relatively new and thus requires a more detailed discussion regarding its application. Because this method uses a regional approach to estimate the frequency distributionsat individual sites, its potential advantages are that it minimizes the sampling errors at individual sites and maximizes the number of available observations. Two crucial factors in this approach include the ability to identify homogeneous regions and the assumption that the individual sites are independent of each other. Hosking and Wallis (1991) describe the four steps to developing a regional frequency analysis.

1. Screening the data. The data are controlled to provide a valid analysis. Hosking and Wallis (1991) employ a discordancy measure based on the sample L-moments and the sample covariance matrix to identify stations that did not fit into the group due to data errors or to identify stations that belong in some other group.

2. Identifying homogeneous regions. Stations are grouped according to their statistical and geographical characteristics. The suggested method compares the L-covariance from the observed data with simulated data from a homogeneous region (using Monte Carlo techniques). The differences are divided by the standard deviation of the simulations to become the measure of heterogeneity (H). If H is less than 1, then the region is fairly homogeneous. Values greater than 2 are considered fairly heterogeneous.

3. Selecting the frequency distribution. Hosking and Wallis (1991) proposed a goodness-of-fit test to identify appropriate distributions from a family of distributions. The test statistics (Z) are the difference between the observed and fitted regional L-kurtosis divided by the standard deviation of the observed L-kurtosis. Values sufficiently close to zero indicate a "'good" fit.

4. Calculating the regional frequency distribution. The homogeneous regions are used to calculate the frequency distributions for the stations in each region.

The application of this methodology to the stations in Indiana and Minnesota proved somewhat difficult and required a number of subjective decisions. Initially, the stations were grouped by NWS climate division since these divisions are widely accepted as areas of reasonably homogeneous climate. Interestingly, several sites yielded high discordancy and heterogeneous indices indicating that they belonged in other regions. After several iterations, seven regions in Indiana (figure 4) and four regions in Minnesota (figure 5) were selected. As the maps show, the final regions are not always geographically coherent. Probably the worst case is the three stations in group 1 in Minnesota (figure 5): on Lake Superior, along the Minnesota-Wisconsin border, and in the southwest comer of the state. As Hosking and Wallis (1991) rightly point out, however, the physical evidence should take precedence over the statistical evidence. Therefore these three stations should be incorporated into the other groups. Since the L-moments method was not used for this report, however, a more sophisticated treatment of the regionalization was not developed.

The task of regional frequency analysis is further complicated by extreme rainfall events that may not be spatially independent (see Chapter 8). Spatial correlations between stations will cause problems with the test statistics, especially the heterogeneity and goodness-of-fit test. Hosking and Wallis (1991) therefore recommend that these statistics only be used as guidelines and not for hypothesis testing.

In general, assuming readily identifiable homogeneous precipitation regions with highly independent stations, one

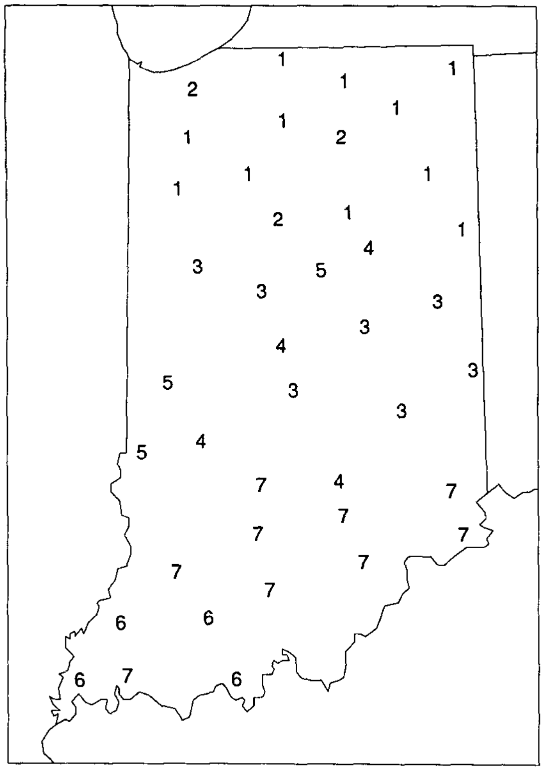

Figure 4. L-moments groups for Indiana

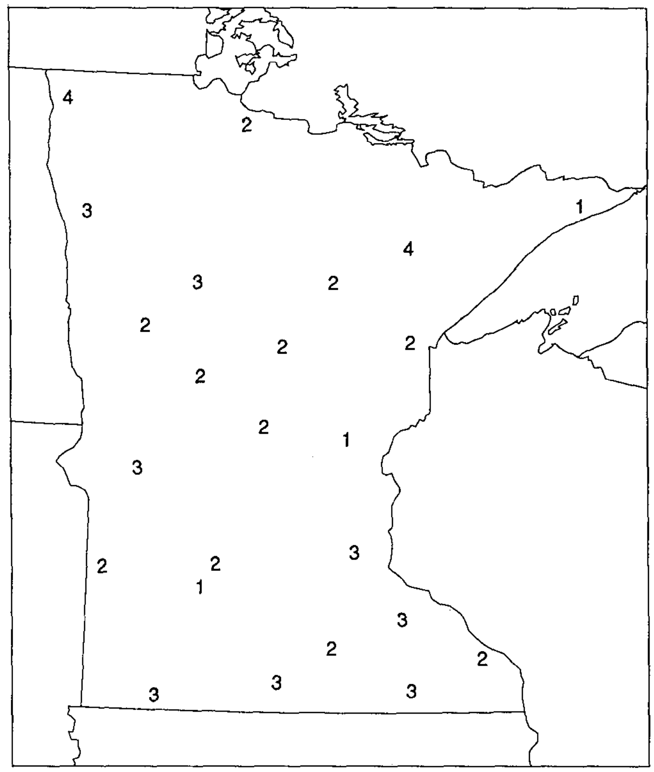

Figure 5. L-moments groups for Minnesota

can take full advantage of regional analysis to overcome sampling errors and short records. In the application here, however, the appropriateness of aregional analysis is not as clear-cut since identifying homogeneous regions is difficult and some spatial correlation exists among extreme rainfall events.

The standard method of moments technique was not used in the comparisons due to its relatively poor performance compared with the other techniques (based on preliminary data). This method has been generally applied to the Gumbel distribution.

Results

For comparison of the three methods, Indiana and Minnesota were selected for their relatively diverse climatic features in the Midwest region. The Huff-Angel values had been previously calculated and were not influenced by the results of the other two methods. The Huff-Angel and maximum likelihood methods were applied to individual stations. On the other hand, the L-moments method was applied to homogeneous groups of stations. The results are presented by state.

Indiana. Tables 6 and 7 summarize the differences found for 41 stations in Indiana from comparison of 24-hour, 100-year rainfall estimates. In general, the Huff-Angel method yielded slightly higher rainfall amounts than either the L-moments or maximum likelihood methods. The root mean square errors (RMSE) are about the same for all three methods. Analysis of the correlation between the L-moments and Huff-Angel methods shows good agreement throughout the 25-year recurrence interval (table 6 and figure 6). This relationship deteriorates somewhat at the longer intervals, as expected, because the methods extrapolate beyond the data, thus increasing the uncertainty in the values. No strong evidence of a bias is present until the 100-year amounts, which are being estimated with less than 100 years of data (35 to 85-year records), are reached, and any differences in the methods become more noticeable at the rarer recurrence intervals. Figure 7 shows examples of good (Albion, IN) and poor agreement (Bloomington, IN).

The 100-year values from the Huff-Angel and the L-moments methods were used in a worst-case comparison. Differences will usually be largest at this return period. The Huff-Angel method resulted in larger 100-year values at 21 stations (51 percent), compared with 19 stations (46 percent) with the L-moments method. One station (2 percent) had equal values with the two methods. The mean of the 100-year values was 6.4 inches for the L-moments method and 6.6 inches with the Huff-Angel method. The median difference (0.2 inch) is equivalent to a 3 percent difference. The median difference (0.3 inches) is equivalent to a 5 percent difference. These relatively small differences are insignificant from a meteorological standpoint. Differences much greater than those obtained from the two fitting methods could result from natural variability, human-induced variability, and extrapolation of the curves beyond the data to determine the 100-year values. For example, for the 100-year values, the spatial variance between the 41 stations was 1.04 inches while the variance of the differences between the Huff-Angel and L-moments methods was 0.54 inch.

Although the data do not strictly satisfy all the assumptions, a simple Analysis of Variance (ANOVA) model shows that there are no significant differences in the state-wide mean

Table 6. Comparison of Three Methods for Estimating 24-hour Maximum Amounts at Selected Return Periods for Indiana

	Huff-Angel vs. Maximum likelihood		*Huff-Angel vs. L-moments*		*Maximum likelihood vs. L-moments*	
Return period	*Mean difference (inches)*	*Corre-lation*	*Mean difference (inches)*	*Corre-lation*	*Mean difference (inches)*	*Corre-lation*
2	-0.03	0.98	-0.03	0.91	0.00	0.97
5	0.05	0.94	0.02	0.90	-0.03	0.98
10	0.07	0.96	0.03	0.92	-0.04	0.96
25	0.07	0.90	0.03	0.88	-0.04	0.89
50	0.06	0.81	0.04	0.79	-0.03	0.84
100	0.07	0.72	0.07	0.70	0.01	0.79

for the three methods. An examination of the data shows that some degree of skewness is present (figure 8). The estimates from the maximum likelihood method are least conservative (have a longer tail), and the L-moments estimates are most conservative with many more values lying in the middle of the distribution. The estimates by the Huff-Angel method rank between the other two methods.

To summarize, there are no meteorological or statistical differences in the methods used. By design, however, the L-moments method gives slightly more conservative values than the other two methods. Since wearedealing with samples from an unknown population, it is difficult to ascertain if more conservative values are better or not. The more conservative estimates may provide a relatively poor fit to the observational data in some cases. For example, in figure 7, the Huff-Angel curve appears to fit the observational data better than the L-moments curve.

The results of the L-moments study for Indiana were mapped, analyzed, and compared with the results of the Huff-Angel method for the 100-year, 24-hour values (figure 9). Although the patterns for both methods are generally similar, some of the spatial detail is lost in the L-moments pattern (figure 9b), especially in southern Indiana. Both maps show a ridge of relatively heavy rainfall extending south-southwest from north-central Indiana to its southwestern border. The L-moments map (figure 9b) indicates an increase in the rainfall gradient northward along theridge—that is, the highest values (8 inches) are indicated in north-central Indians—but the rainfall gradient increases from north to south on the Huff-Angel map (figure 9a). Interstate analyses showed that the ridge continues south-southwest from southwestern Indiana to a maximum in southeastern Illinois and western Kentucky: this agrees with the general climatic gradient of rainfall in these midwestern states. The L-moments high in north-central Indiana (figure 9b) was apparently produced by data from two short-term stations at Logansport and Warsaw. As shown on the Huff-Angel map (figure 9a), the north-central high is squeezed between lows to the west, east, and north, and is the northern extremity of the rainfall high.

In southern Indiana, the Huff-Angel pattern also indicates a low extending northeast from the southern border. This low appears to be an extension of relatively low 100-year rainfall amounts over eastern Indiana, western Ohio, and eastern Kentucky (as shown by interstate analyses). Thus there is relatively strong climatological support for this pattern anomaly. The Indiana low has been essentially eliminated by the L-moments fitting process.

A third region of some disagreement exists in extreme northwestern Indiana. Here, the Huff-Angel map indicates a more intense rainfall center (9 inches) than the L-moments pattern (8 inches). This high has strong climatological support with respect to location and intensity from Valparaiso and LaPorte in Indiana and from stations to the west and northwest in northeastern Illinois (Kankakee, Joliet, and Aurora). The L-moments process recognizes the pattem, but appears to reduce the magnitude more than is supported by the observational data responsible for establishment of the pattern anomaly.

The foregoing examples are presented to emphasize the necessity for integrating meteorological-climatological information and knowledge into rainfall frequency analyses, rather than placing complete dependency on a favored statistical distribution. The strictly statistical approach eliminates the subjectivity factor, but, in so doing, it ignores important scientific information pertinent to the problem. For the Huff-Angel and L-moments methods, the maps of the 100-year recurrence values showed the largest differences. All of the shorter recurrence-interval patterns, however, were in close agreement for the two methods.

Minnesota. In Minnesota, 25 long-term stations were used. Table 8 shows that the Huff-Angel method is in closer

Table 7. Performance of Huff-Angel and L-moments Methods at the 24-Hour, 100-Year Recurrence Interval by 41 Stations in Indiana

Site	*(a) Huff-Angel*	*(b) L-moments*	*Difference*	*Ratio (a):(b)*
Albion	5.3	5.0	0.3	1.1
Anderson	5.6	5.2	0.4	1.1
Angola	6.0	5.4	0.6	1.1
Berne	4.8	5.3	-0.5	0.9
Bloomington	7.9	6.4	1.5	1.2
Bowling Green	7.5	7.2	0.3	1.0
Collegeville	5.6	6.0	-0.4	0.9
Columbus	8.6	7.1	1.5	1.2
Evansville	5.8	6.4	-0.6	0.9
Farmland	5.4	5.5	-0.1	1.0
Ft. Wayne	5.5	4.9	0.6	1.1
Frankfort	5.9	6.0	-0.1	1.0
Goshen College	6.8	5.4	1.4	1.3
Indianapolis	5.4	5.8	-0.4	0.9
Jasper	6.7	7.5	-0.8	0.9
Kokomo	7.9	6.3	1.6	1.3
Logansport	7.1	8.4	-1.3	0.8
Marion	6.0	6.5	-0.5	0.9
Markland Dam	6.2	6.3	-0.1	1.0
Moors Hill	5.7	6.3	-0.6	0.9
Mt. Vernon	6.8	7.9	-1.1	0.9
Oolitic	5.4	6.4	-1.0	0.8
Paoli	6.0	6.3	-0.3	1.0
Plymouth	5.6	5.8	-0.2	1.0
Princeton	9.7	7.9	1.8	1.2
Richmond	6.6	5.5	1.1	1.2
Rockville	7.6	6.9	0.7	1.1
Rushville	5.5	5.7	-0.2	1.0
Scottsburg	7.0	6.4	0.6	1.1
Seymour	6.6	6.1	0.5	1.1

Table 7. Concluded

Site	*(a)* *Huff-Angel*	*(b)* *L-moments*	*Difference*	*Ratio (a):(b)*
South Bend	5.3	5.4	-0.1	1.0
Tell City	7.0	7.8	-0.8	0.9
Terre Haute	6.7	6.3	0.4	1.1
Valparaiso	9.0	7.9	1.1	1.1
Wabash	6.1	5.8	0.3	1.1
Warsaw	7.6	8.2	-0.6	0.9
Washington	7.7	6.4	1.3	1.2
West Lafayette	5.7	5.7	0.0	1.0
Wheatfield	6.2	5.9	0.3	1.1
Whitestown	8.8	7.1	1.7	1.2
Winamac	6.7	6.2	0.5	1.1
Mean	**6.6**	**6.4**	**0.2***	**1.0**
Median	**6.2**	**6.3**	**0.3**	**1.0**
Range	**4.8 to 9.7**	**4.9 to 8.4**	**-1.3 to 1.9**	**0.8 to 1.3**
L-moments < Huff-Angel		**21 (51%)**		
L-moments = Huff-Angel		**1 (2%)**		
L-moments > Huff-Angel		**19 (46%)**		

*This value does not match the one in table 6 because the amounts are to one decimal place in this table.

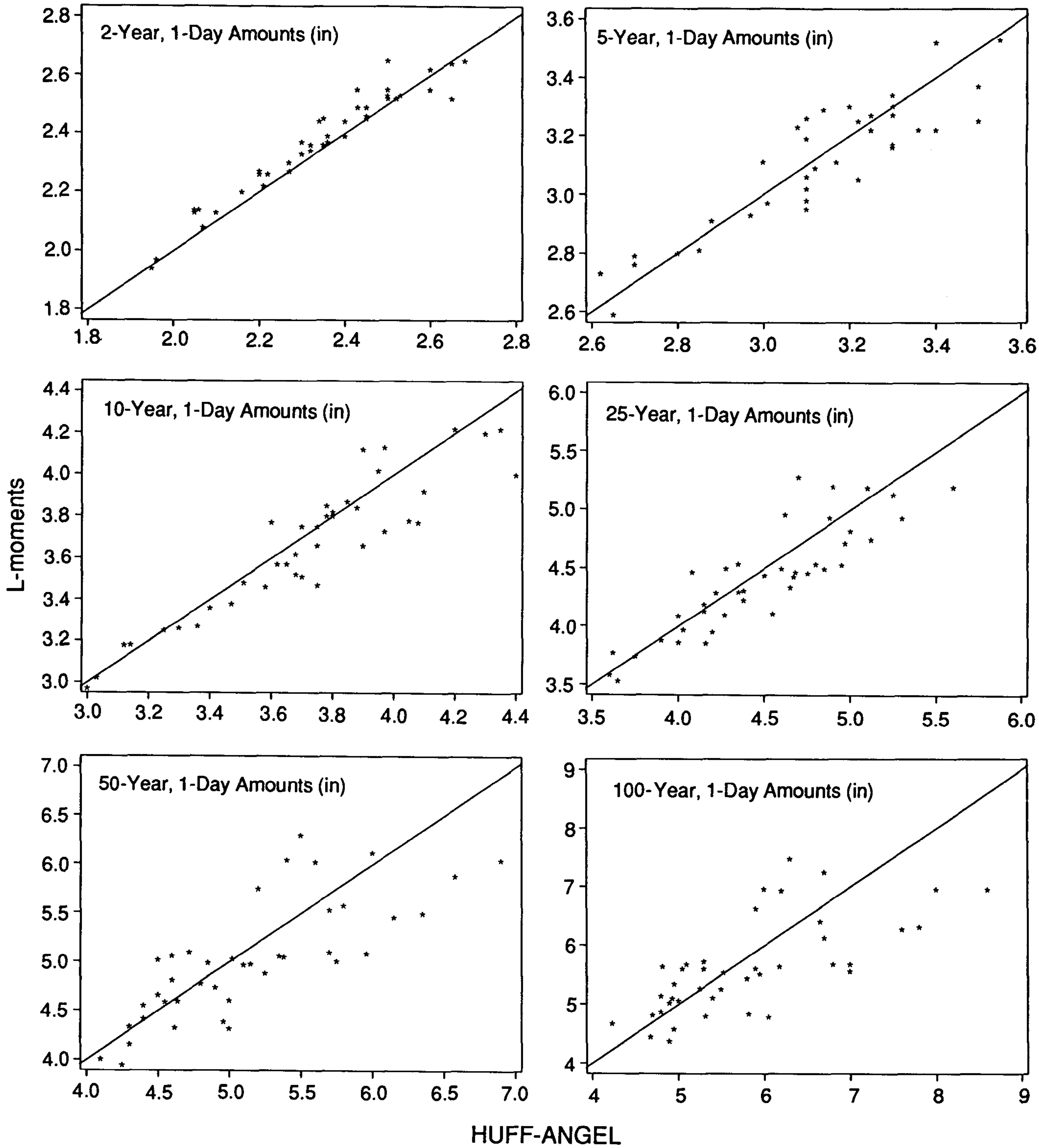

Figure 6. Correlation between L-moments and Huff-Angel methods
for 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals, and 24-hour rainfall amounts

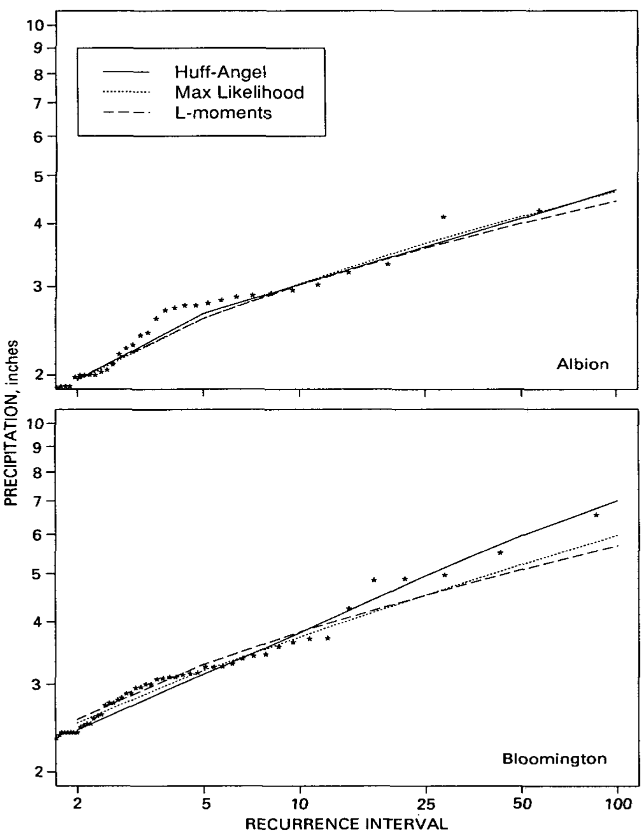

Figure 7. Curve-fitting comparisons for 1-day amounts

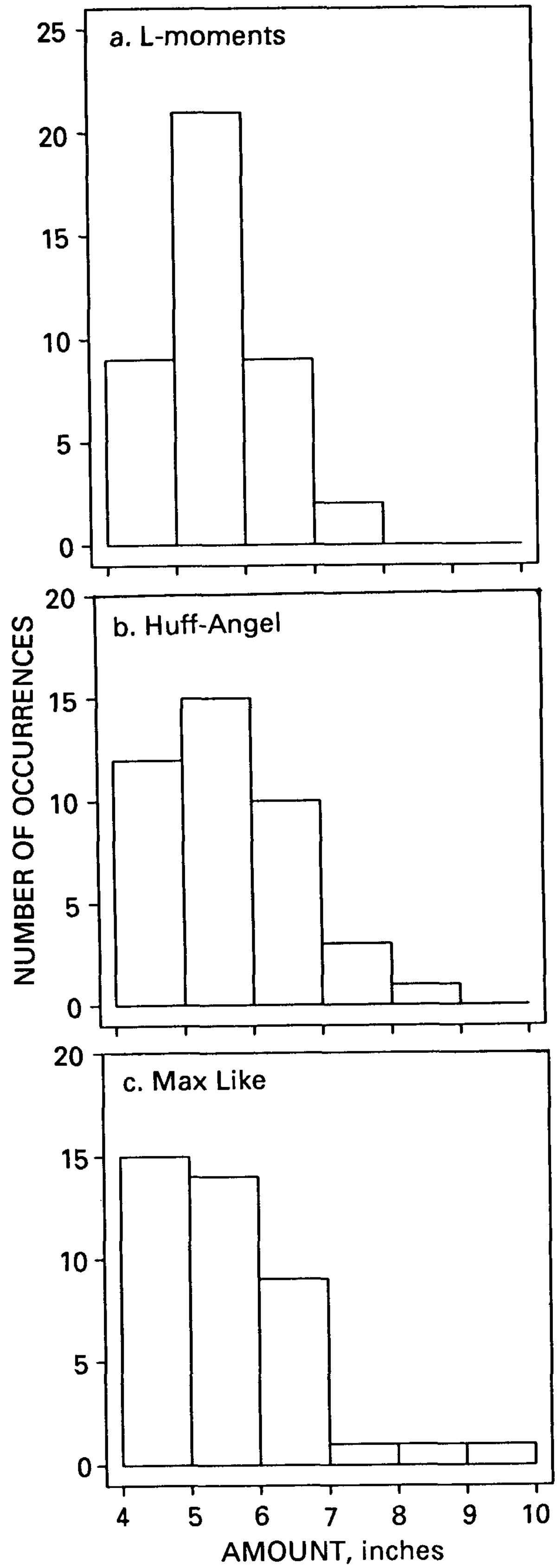

Figure 8. Histogram comparisons for 1-day rainfall amounts in Indiana

agreement with the L-moments method than with the maximum likelihood method. The correlations also remain higher for the 50- and 100-year recurrence intervals than those for Indiana, indicating a better agreement at the longer intervals.

The mean 24-hour, 100-year values for the Huff-Angel, L-moments, and maximum likelihood methods are 5.81, 5.80, and 5.70 inches, respectively. Using a simple Analysis of Variance (ANOVA) model, there are no significant differences in the three methods. The histograms of the 100-year values (figure 10) indicate that the Huff-Angel method more closely approximates a normal distribution than either of the other two methods. Overall, there is less skewness than in the Indiana data. The Huff-Angel method yielded larger values in 10 cases (40 percent), and smaller values in 12 cases (48 percent), compared to the L-moments method. The two methods agreed in 3 cases (12 percent), as shown in table 9.

The differences between the methods are generally neither statistically significant nor (more importantly) meteorologically significant. As in Indiana, there are no systematic biases between the methods except at the longest return period (100 years).

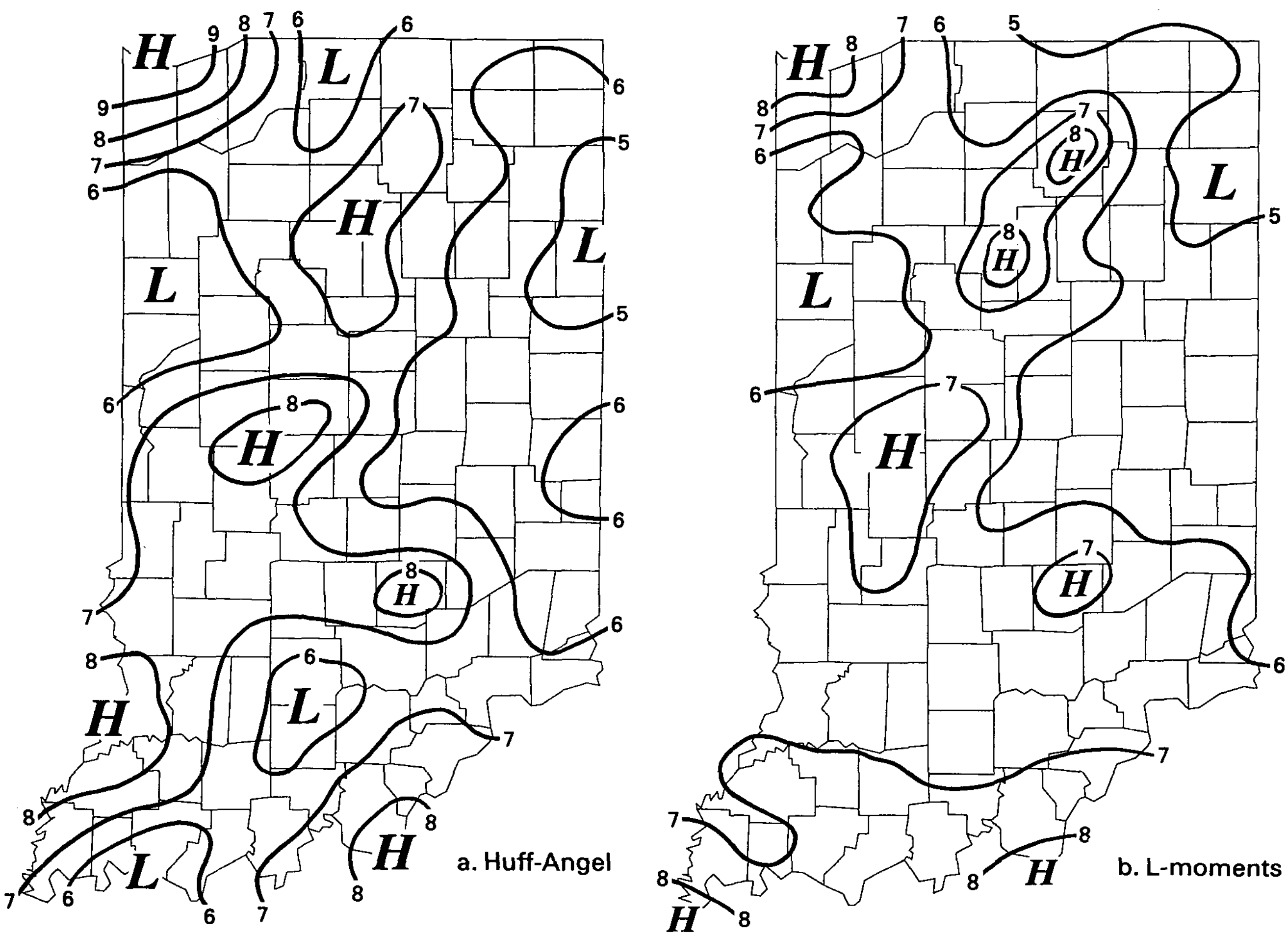

Figure 9. Comparison of Huff-Angel and L-moments methods for 100-year, 24-hour rainfall in Indiana

Table 8. Comparison of Three Methods for Estimating 24-Hour Maximum Amounts at Selected Return Periods for Minnesota

	Huff-Angel vs. Maximum likelihood		*Huff-Angel vs. L-moments*		*Maximum likelihood vs. L-moments*	
Return period	*Mean difference (inches)*	*Corre-lation*	*Mean difference (inches)*	*Corre-lation*	*Mean difference (in.)*	*Corre-lation*
2	0.00	0.94	0.01	0.94	0.01	0.99
5	0.05	0.97	0.05	0.95	0.00	0.98
10	0.11	0.97	0.09	0.92	-0.02	0.96
25	0.14	0.93	0.09	0.89	-0.05	0.93
50	0.15	0.89	0.07	0.85	-0.08	0.90
100	0.11	0.83	0.01	0.80	-0.10	0.87

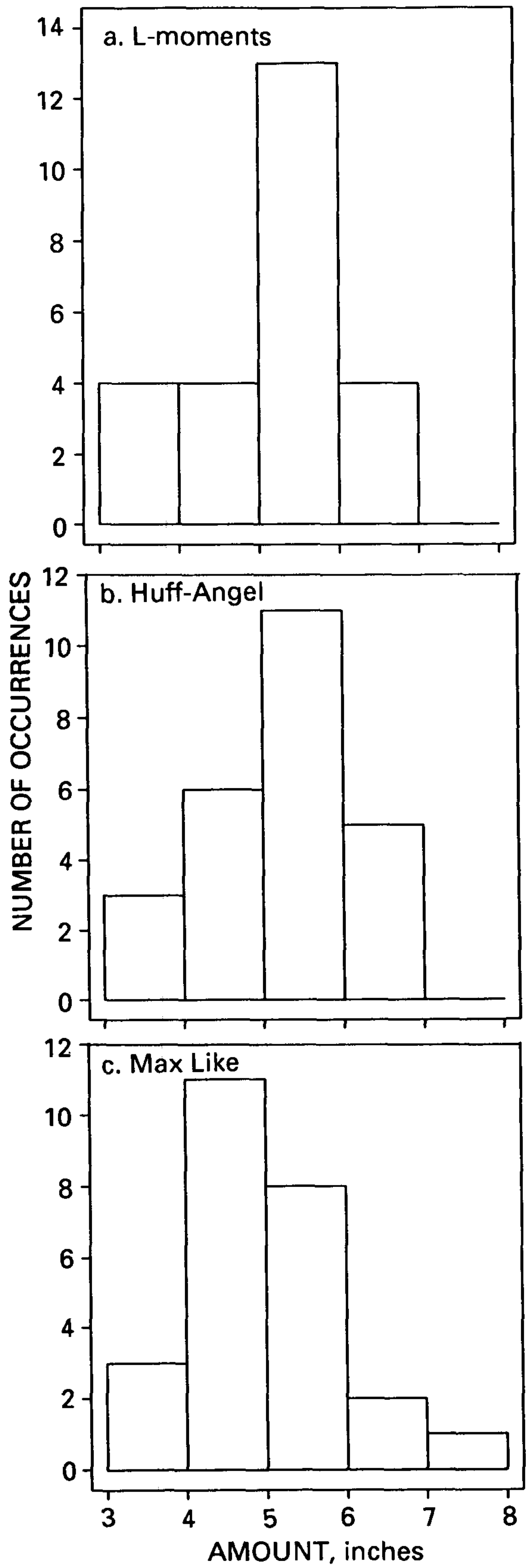

Figure 10. Histogram comparisons for 1-day rainfall in Minnesota

Table 9. Performance of Huff-Angel and L-moments Methods at the 24-Hour, 100-year Recurrence Interval for 25 Stations in Minnesota

Site	*(a) Huff-Angel*	*(b) L-moments*	*Difference*	*Ratio (a):(b)*
Baudette	5.9	4.8	1.1	1.2
Bird Island	5.4	5.4	0.0	1.0
Canby	4.2	5.5	-1.3	0.8
Cloquet	4.7	5.7	-1.0	0.8
Crookston	6.8	6.0	0.8	1.1
Detroit Lake	5.7	4.9	0.8	1.2
Grand Marais	4.2	3.7	0.5	1.1
Grand Meadow	7.0	7.1	-0.1	1.0
Grand Rapids	5.8	5.4	0.4	1.1
Hallock	6.4	5.8	0.6	1.1
Itasca	6.7	6.0	0.7	1.1
Little Falls	5.7	5.7	0.0	1.0
Minneapolis-St. Paul	7.1	6.5	0.6	1.1
Mora	3.9	4.4	-0.5	0.9
Morris	6.5	6.4	0.1	1.0
Pine River Dam	5.0	5.4	-0.4	0.9
Redwood Falls	4.0	4.0	0.0	1.0
Virginia	5.9	6.1	-0.2	1.0
Wadena	5.8	5.9	-0.1	1.0
Waseca	6.4	6.0	0.4	1.1
Willmar	6.2	7.2	-1.0	0.9
Winnebago	7.0	7.1	-0.1	1.0
Winona	5.3	6.0	-0.7	0.9
Worthington	7.0	7.1	-0.1	1.0
Zumbrota	6.7	7.1	-0.4	0.9
Mean	**5.8**	**5.8**	**0.0**	**1.0**
Median	**5.9**	**5.9**	**0.0**	**1.0**
Range	**3.9 to 7.1**	**3.7 to 7.2**	**-1.3 to 1.1**	**0.8 to 1.2**
L-moments < Huff-Angel		**10 (40%)**		
L-moments = Huff-Angel		**3 (12%)**		
L-moments > Huff-Angel		**12 (48%)**		

3. FREQUENCY DISTRIBUTIONS OF HEAVY RAINFALL EVENTS

In our nine-state study, we have used two methods of data analysis and presentation of results: isohytal maps and areal averages. Both methods have advantages and disadvantages, but together they provide adequate information for the varied needs of users. Descriptions of the two methods and the results obtained are presented in this section.

A major problem encountered was how to develop the frequency relations to provide maximum accuracy and reliability for the user. As indicated previously, a major source of sampling error results from poor raingage exposure, inadequate gage maintenance, plus human-induced errors during data entry and data reduction. Nonrepresentative spatial variability may be introduced by rarely experienced severe rainstorms (outlier events), which do not properly reflect the average frequency distribution expected within the 100-year time frame covered by this study. While the time distribution analysis may eliminate outliers with respect to that station, it is much harder to remove systematic biases such as poor exposure or improperly maintained equipment. In both the isohyetal maps and the areal averages, every effort was made to minimize these types of errors.

Point Rainfall Frequency Distributions

Most frequency relations in the past have used isohyetal maps to present the frequency distributions (Yarnell, 1935; Hershfield, 1961). Although this approach can be susceptible to considerable subjectivity and sampling errors, it is useful and familiar to most users. It also facilitates accounting for smaller-scale features in water-control design processes. Examples of small-scale features are increased rainfall found downwind of large urban areas (Huff and Changnon, 1973) and changes associated with small-scale geographical features such as the hills of southern Illinois (Huff et al., 1975). *In the nine-state project, only observations supported by two or more stations have been incorporated into the analyses.*

For each state, isohyetal patterns of point rainfall were developed for the recurrence intervals and rainfall periods indicated earlier (2-year to 100-year; 1-hour to 240-hours). Several variables were used in establishing these patterns: 1) the frequency relations derived for each precipitation station from the recorded data at that station; 2) climatological-meteorological knowledge of the regional precipitation characteristics; and 3) known effects of physiographic features, inadvertent weather modification factors, or both within various regions of the state.

Initially, maps were plotted for each selected recurrence interval and rainfall duration from the individual station frequency distributions. Based strictly on the station data, isohyetal patterns were then lightly sketched to reveal areas where pattern distortions occur. These distortions are most often due to natural and/or human-induced variability (discussed earlier). At this point, consideration of variables (2) and (3) above becomes important in adjusting the isohyetal patterns to overcome unrealistic precipitation differences that may occur within areas of approximately homogeneous precipitation climate. But care must be taken not to overlook real spatial variations related to physiographic and inadvertent weather factors.

For example, in our Illinois pilot study, the isohyetal patterns downwind of the St. Louis metropolitan area showed an expected increase in the occurrence of heavy rainstorms. This was a *real* variation as opposed to a *variability distortion* (Changnon et al., 1977). An increase in the frequency distribution of heavy storm events in western Illinois was determined to be real and related to a well-recognized thunderstorm breeding area in the Missouri Ozarks located to the southwest (upwind of the high identified in the isohyetal analyses). Similarly, climatic variations produced substantial changes in the heavy rainstorm distribution characteristics from north to south in the state. There were also several areas, however, in which no real cause could be found for substantial differences in precipitation within relatively short distances. These differences were considered sampling vagaries *(unreal variation)* and the isohyetal pattern was adjusted to agree with the distributions indicated by other stations in the surrounding region. *In summary, we believe that careful attention to variables (1), (2), and (3) will produce logical, reliable isohyetal patterns that closely approximate the true distribution characteristics of heavy rainstorms within each state and for the nine-state region.* This analytical philosophy was followed throughout the study.

The adjusted isohyetal patterns resulting from the foregoing analytical procedures are shown in the maps in part 2 of this report for selected recurrence intervals ranging from 2 years to 100 years and rainfall periods varying from 1 hour to 10 days. To determine frequency values for rainfall periods of less than 1 hour, recurrence intervals of less than 2 years, or both, tables 3 and 4 in chapter 1 provide information for computing amounts for rain periods as small as 5 minutes and recurrence intervals as short as 2 months. Note that isohyets extending over the Great Lakes are for maintaining continuity and may not reflect actual conditions over the lakes.

The isohyetal gradient sometimes varies appreciably between consecutive maps in part 2. This was necessary to maintain proper display of the spatial pattern characteristics (highs, lows, troughs, ridges, etc.) indicated by the data. It was considered pertinent to show all features of the isohyetal patterns that persisted throughout all or most of the storm durations and recurrence intervals provided in the map series. These features reflect the combined effects of precipitation climate and other factors such as topography (hills, valleys, and large water bodies) and urban influences.

Areal Mean Frequency Distributions

Another approach to the spatial distribution problem is a method used by Huff and Neill (1959) in an earlier Illinois study to alleviate the consequences of spatial variability. The state was divided into regions of approximately homogeneous climate with respect to heavy rainstorm events. Average relations were then developed for each division. In our Midwest study, however, consideration of available climate information on the distribution of heavy rainfall and climatological-meteorological knowledge of storm system characteristics indicated that the well-established NWS climatic divisions could be used to divide the states. The only exception was Illinois, where a slight change was made in the established divisions to more accurately reflect a combined effect from the Ozarks and the Mississippi River valley in the western part of the state. While NWS climate division averages are recommended by the authors for most purposes, hydrologists often prefer to use isohyetal maps (when working with basins that cover two or more climate divisions for example).

The foregoing technique does not eliminate the potential sampling errors in the data samples, but it does moderate their effect in regions of similar precipitation climate, and should produce better estimates of the true distribution of heavy rainstorms across the nine-state region. Unless the divisions are properly selected, however, the averaging technique may mask real small-scale effects, such as those induced in the vicinity of the Great Lakes or the Missouri Ozarks. This problem would become more acute in regions incorporating major changes in topography, such as the Rocky Mountain and Appalachian regions.

Frequency relations for sectional mean rainfall for each state are shown in the sectional mean frequency distribution tables in part 2. Rainfall values are provided for recurrence intervals ranging from 5 minutes to 10 days, and for recurrence intervals varying from 2 months to 100 years in each section.

Use of the tables is indicated by the following example for Indiana (table 2 in part 2). Assume a user wishes to determine the 24-hour rainfall amount expected to occur, on the average, of once in 25 years at a given location in the Northwest Climate Section. Move down the duration column to 24 hours, which corresponds to 5.22 inches in the 25-year column. This is the *average* 25-year amount for the section. *In a specific 25-year period, however, this value may vary somewhat between individual points due to random spatial variability within the relatively homogeneous precipitation climate of the section.*

4. TIME DISTRIBUTIONS OF RAINFALL IN HEAVY STORMS

Modern runoff models used in the design of urban and small-basin water-control structures, necessitate defining the time distribution characteristics within heavy rainstorms. Such information is also pertinent to the use of the frequency distributions presented in this report. Huff (1990) used data from long-term operation of three recording raingage networks in Illinois to develop time distribution relationships. Although based upon Illinois data, these relationships should be applicable to our nine-state region and other locations of similar precipitation. The Illinois study was undertaken because earlier time distribution models, developed by the Soil Conservation Service (1972) and others, were not considered satisfactory for use in the Midwest's heavy rainstorms.

Method and Results of Analysis

The time distributions were expressed as cumulative percentages of storm rainfall and storm duration to enable valid comparisons between storms and to simplify analyses and presentation of data. Relations were developed for point rainfall and for areas of 10 to 400 square miles. Areal groupings showed only small changes in the time distributions with increasing sampling area. Therefore, average relations were determined for point rainfall and for areas of 10 to 50 and 50 to 400 square miles. Rainfall distributions were grouped according to whether the heaviest rainfall occurred in the first, second, third, or fourth quarter of a storm. For each quartile grouping, a family of curves was then derived to provide a quantitative measure of the interstorm variability expected to occur within that group. The interstorm variability was then expressed in probability terms for user application.

Tables 10-12 have been abstracted from the Huff report (1990). Table 10 shows the median time distribution of heavy storm rainfall at a point, table 11 for areas of 10 to 50 square miles, and table 12 for areas of 50 to 400 square miles. These tables show cumulative percent of rainfall expressed as a function of the cumulative percent of total storm time (storm duration) for first-, second-, third-, and fourth-quartile storms.

The median distributions are most commonly used by hydrologists and others. The reader is referred to Huff (1990) for additional information on time distributions for probability levels ranging from 10 to 90 percent. For example, table 13, assembled from the families of curves provided in the referenced report, shows time distributions at the 10, 50, and 90 percent probability levels in first-quartile storms for areas of 50 to 400 square miles. The 10 and 90 percent distributions are useful for estimating runoff relations in the more extreme types of time distributions.

Application of Results

For mean rainfall on *small basins* (≤ 400 square miles), the first- and second-quartile storms were found to be most prevalent (33 percent each), followedby third-quartile storms (23 percent), and fourth-quartile storms (11 percent). For *point rainfall,* first-quartile storms were most prevalent (37 percent), followed by second-quartile storms (27 percent), third-quartile storms (21 percent), and fourth-quartile storms (15 percent).

Storms with durations of 6 hours or less, 6.1 to 12 hours, 12.1 to 24 hours, and greater than 24 hours tended to be associated with first-, second-, third-, and fourth-quartile distributions, respectively.

For most structural design applications, use of the quartile type occurring most often is recommended for the design duration under consideration. For example, use the first-quartile curves for design durations of 6 hours and less, and use the second-quartile distributions for designs involving storm durations of 6.1 to 12 hours.

Using Results in Structural Design Problems: Case Studies

Case One

First, assume that a design based on a 5-inch rainstorm of 6-hour duration is being determined for a given point, based on a median or average time distribution. In this case, a first-quartile median curve would be appropriate. Then, from table 10, one can determine that 33 percent of the rainfall total (1.67 inches) would occur in the first 10 percent (36 minutes) of the storm. Similarly, 60 percent (3.00 inches) would be expected to occur in the first 25 percent (90 minutes) of the storm, and 82 percent (4.10 inches) in the first 50 percent (3 hours) of the rain period.

Case Two

Now, assume that the same design problem involves a 5-inch, 6-hour storm on a basin encompassing 100 square miles. Then, refer to table 12. In this case, the median values indicate that the areal average would be 17 percent of the rain (0.85 inch) in the first 10 percent (36 minutes) of a *first-quartile storm.* During the first 25 percent of the storm (90 minutes), 63 percent of the rain (3.15 inches) would fall, and during the first 50 percent (3 hours), 86 percent (4.30 inches) would fall.

Case Three

If a *second-quartile* instead of a *first-quartile storm* were used as the design basis for the 100-square-mile area, only 4 percent (0.20 inch) would occur in the first 10 percent of the storm. This would increase to 21 percent (1.05 inches) in the first 25 percent (90 minutes) of the storm period.

Then a rapid increase to 73 percent of the total rainfall (3.65 inches) would occur by the halfway point of the storm event.

Table 10. Median Time Distributions of Heavy Storm Rainfall at a Point

	Cumulative storm rainfall (percent) for given storm type			
Cumulative storm time (percent)	*First-quartile*	*Second-quartile*	*Third-quartile*	*Fourth-quartile*
5	16	3	3	2
10	33	8	6	5
15	43	12	9	8
20	52	16	12	10
25	60	22	15	13
30	66	29	19	16
35	71	39	23	19
40	75	51	27	22
45	79	62	32	25
50	82	70	38	28
55	84	76	45	32
60	86	81	57	35
65	88	85	70	39
70	90	88	79	45
75	92	91	85	51
80	94	93	89	59
85	96	95	92	72
90	97	97	95	84
95	98	98	97	92

Table 11. Median Time Distributions of Heavy Storm Rainfall on Areas of 10 to 50 Square Miles

	Cumulative storm rainfall (percent) for given storm type			
Cumulative storm time (percent)	*First-quartile*	*Second-quartile*	*Third-quartile*	*Fourth-quartile*
5	12	3	2	2
10	25	6	5	4
15	38	10	8	7
20	51	14	12	9
25	62	21	14	11
30	69	30	17	13
35	74	40	20	15
40	78	52	23	18
45	81	63	27	21
50	84	72	33	24
55	86	78	42	27
60	88	83	55	30
65	90	87	69	34
70	92	90	79	40
75	94	92	86	47
80	95	94	91	57
85	96	96	94	74
90	97	97	96	88
95	98	98	98	95

Table 12. Median Time Distributions of Heavy Storm Rainfall on Areas of 50 to 400 Square Miles

	Cumulative storm rainfall (percent) for given storm type			
Cumulative storm time (percent)	*First-quartile*	*Second-quartile*	*Third-quartile*	*Fourth-quartile*
5	8	2	2	2
10	17	4	4	3
15	34	8	7	5
20	50	12	10	7
25	63	21	12	9
30	71	31	14	10
35	76	42	16	12
40	80	53	19	14
45	83	64	22	16
50	86	73	29	19
55	88	80	39	21
60	90	86	54	25
65	92	89	68	29
70	93	92	79	35
75	95	94	87	43
80	96	96	92	54
85	97	97	95	75
90	98	98	97	92
95	99	99	99	97

Table 13. Time Distributions of Areal Mean Rainfall on 50 to 400 Square Miles in First-Quartile Storms at Probability Levels of 10, 50, and 90 Percent

	Cumulative storm rainfall for given storm probability		
Cumulative storm time (percent)	*10 percent*	*50 percent*	*90 percent*
5	24	8	2
10	50	17	4
15	71	34	13
20	84	50	28
25	89	63	39
30	92	71	46
35	94	76	49
40	95	80	52
45	96	83	55
50	97	86	57
55	98	88	60
60	98	90	63
65	98	92	67
70	99	93	72
75	99	95	76
80	99	96	82
85	99	97	89
90	99	98	94
95	99	99	97

5. SEASONAL DISTRIBUTIONS OF HEAVY RAINFALL

Background

In the design of some hydrological systems or structures, it is pertinent to know the seasonal characteristics of heavy rainstorms as well as the frequency distributions of maximum storm rainfall amounts for various storm durations. For example, when the soil is near saturation, a spring storm of intensity equivalent to a 5-year recurrence interval may have different consequences than had the same storm occurred in a drier summer month. Winter storms, while generally producing less precipitation than summer storms, can be devastating if they occur over frozen ground. With or without snow cover, these winter storms can cause rapid flooding. Heavy rainfall storms in the early spring and late fall may lead to higher rates of erosion due to tillage practices and a lack of vegetative cover.

Unfortunately, a lack of resources prohibited an extensive analysis of seasonal rainfall frequencies, comparable to the annual analysis. This report, however, presents three studies by the authors to provide some insight regarding the behavior of heavy rainstorms across the seasons in the Midwest.

Analysis and Results

The studies used the traditional four seasons: winter (December-February), spring (March-May), summer (June-August), and fall (September-November).

Seasonal Precipitation

Prior to a discussion of heavy rainstorms, it is helpful to understand the seasonal change in temperature and precipitation in the Midwest. In general, summer in the Midwest is not only the warmest season, but also the wettest one. Mean July precipitation ranges from 5.2 inches in Kentucky to 2.4 inches in Michigan. By contrast, mean January precipitation ranges from 4.0 inches in Kentucky to 0.6 inches in Minnesota. The largest differences in precipitation occur in winter, with the northern states (Minnesota, Wisconsin, and Michigan) receiving 50 to 80 percent less precipitation than in summer. Table 14 shows the annual precipitation and percent contribution by season. In general, Kentucky is the wettest state in the region with a nearly uniform distribution of precipitation throughout the four seasons. Minnesota is the driest state with 42 percent of its precipitation falling in summer and only 9 percent in winter. For all nine states combined, summer provides the largest contribution, followed by spring, fall, and winter with 32,27,25, and 16 percent, respectively.

In the Midwest, the temperatures for all four seasons and the annual mean temperature decrease northward (table 15). In general, Kentucky is the warmest state while Minnesota is the coldest state. In winter, Kentucky is the warmest state with much of its precipitation falling as rain rather than snow.

Seasonal Distribution of Heavy Rainstorms

The number of heavy storms in the Midwest changes from season to season as well as from state to state. Table 16 shows the seasonal contribution of the top-ranked, 1-day storms for 275 stations in the region. Three-fourths of such storms occur in the summer. The summertime maximum is most pronounced in Minnesota, Iowa, Illinois, Indiana, and Wisconsin. This is probably due to the shorter convective season in the northern latitudes. In Michigan, Missouri, and Ohio, the fall also contributes a significant number of storms. It is not known what physical process causes this effect in these three geographically diverse states. Missouri is also noteworthy in that 13 percent of its heavy storms occur in winter. Overall, the largest number of storms occur in June, July, August, and September.

Similar results were found for the top-ranked 2-, 3-, 5-, and 10-day totals. In each case, the largest percentage of storms occurred in the summer. A significant number of the storms in Kentucky, however, occurred in winter for these longer durations. Similar results were also obtained for all the annual maximum storms at each station. Summer continued to be the season of most frequent occurrences although the percentages were closer to 50 percent of the total (compared to 75 percent for the top-ranked storms). The contributions in spring and fall were from 20 to 25 percent of the total.

While summer is the dominant season for the Midwest for 1-day storms, an analysis of the top-ranked storms occurring in the warm season (April - September) compared with the cold season (October - March) indicates that the southernmost part of the region is more likely to experience its heaviest storms in the cold season at longer durations. This feature becomes most predominant in the 10-day storms. The top-ranked 10-day storms (figure 11) occur mostly in the cold season for the southern half of Missouri and for a large, coherent region along the Ohio River valley. These events are probably associated with the synoptic-scale cyclones that pass through those regions during those months. This pattern is not found for the 1-day storms, but becomes increasingly evident for the 2-, 3-, and 5-day storms. Because this pattern only occurs in the southern portions of Missouri, Indiana, and Ohio, it is not discernible in the state values in table 16.

In general, more of the heavier storms occurred in summer than in any other season, while the least number occurred in winter for shorter durations. In states with a shorter convective season (e.g., Minnesota), the peak in summer was more prominent than in regions where substantial convective activity may occur throughout the year (e.g., Kentucky).

Rainfall Frequencies by Season

The seasonal distribution of storms suggests that the magnitude of the seasonal rainfall frequency curves may change as one moves northward. For example, in the southern region where the number of storms is more evenly distributed

Table 14. Seasonal Rainfall Distribution (inches) for 1961-1990 by State

State	*Annual rainfall*	*Winter (percent)*	*Spring (percent)*	*Summer (percent)*	*Fall (percent)*
Illinois	38.69	16.7	29.1	29.8	24.3
Indiana	40.59	18.8	28.9	29.1	23.1
Iowa	33.08	9.2	28.2	38.1	24.6
Kentucky	48.15	23.6	28.6	25.9	22.0
Michigan	32.17	17.4	24.0	30.0	28.6
Minnesota	26.63	8.7	25.1	41.8	24.5
Missouri	41.15	15.8	29.4	28.5	26.2
Ohio	38.14	19.1	28.1	29.8	23.0
Wisconsin	31.68	11.1	25.4	36.6	26.9
Midwest	36.70	15.6	27.4	32.2	24.8

Table 15. Seasonal Temperature Distribution (°F) for 1961-1990 by State

State	*Annual*	*Winter*	*Spring*	*Summer*	*Fall*
Illinois	51.6	27.2	51.5	73.3	54.2
Indiana	51.4	28.3	51.0	72.2	53.9
Iowa	47.6	20.7	48.0	71.7	50.2
Kentucky	55.3	34.7	55.1	74.1	57.0
Michigan	44.2	20.7	42.3	66.0	47.6
Minnesota	40.8	11.0	41.3	66.9	43.9
Missouri	54.3	31.3	54.4	75.2	56.2
Ohio	50.3	28.3	49.6	70.6	53.0
Wisconsin	42.9	16.0	42.7	66.8	46.1
Midwest	48.7	24.2	48.4	70.8	51.4

Table 16. Seasonal Contribution of Top-Ranked 1-Day Storms

State	Winter (percent)	Spring (percent)	Summer (percent)	Fall (percent)	Most frequent month
Illinois	3.3	20.0	65.0	11.7	July
Indiana	2.4	17.1	63.4	17.1	July
Iowa	0.0	2.3	72.1	25.6	August
Kentucky	4.0	20.0	52.0	24.0	June
Michigan	2.3	14.0	39.5	44.2	September
Minnesota	0.0	7.7	80.8	11.5	August
Missouri	13.0	10.9	41.3	34.8	September
Ohio	4.9	14.6	48.8	31.7	July, September
Wisconsin	0.0	5.0	76.7	18.3	August
Midwest	3.4	12.2	60.3	24.2	July, August

across the seasons, one would expect similar seasonal rainfall frequency curves. In the northern region where there is a noticeable summer maximum in heavy storms, one would expect the summer rainfall frequency curves to be much higher than those for the other seasons. To examine this further, a transect was drawn from southeast Kentucky to northwest Minnesota, and 12 stations were chosen at approximately equal intervals (figure 12). Seasonal time series were developed for the period 1949-1990 (42 years) for all four seasons. The 1-day rainfall frequency amounts were calculated for 2-, 5, 10-, 25-, and 50-year recurrence intervals using the maximum likelihood method and the Generalized Extreme Value (GEV) distribution (Farago and Katz, 1990).

For each station, the four rainfall frequency curves are plotted for comparison (figure 13). The stations are arranged from north to south. It is readily apparent that the wintertime frequency curves are much lower than the other frequency curves in the northern states. At the same time, the summertime curves are nearly equal to the annual curves in the north. At the southern stations, the seasonal curves are closer together, and the summertime curves are not as close to the annual curves.

To generalize these findings, the ratio of the values of the seasonal curves to the annual curves was calculated for all recurrence intervals. Because the ratio did not change significantly from one recurrence interval to the next, an average for all recurrence intervals was calculated for each season at each station. These ratios are expressed as percentages in figure 14. Keeping in mind that a lower station number represents higher latitudes, the percentage of the winter values to annual values is very low in Minnesota, and increases dramatically to the south. A similar effect is noticeable, although not as pronounced, in the relationship for spring. On the other hand, the percentages of summer and fall values show little change with latitude. The summer percentages are all within 20 percent of the annual values.

In practice, the seasonal distribution of heavy rainfall may become important with respect to antecedent soil moisture conditions. For example, the USDA Soil Conservation Service (1968) discusses three categories of antecedent moisture conditions (AMC):

Type I. Soils are dry but not to the wilting point or when plowing or cultivation occurs (typical at times in spring, summer, and fall).

Type II. Average conditions precede previous annual maximum floods (the average case).

Type III. Heavy rainfall or light rainfall and low temperatures have occurred during the last five days prior to the given storm, and the soil is nearly saturated (particularly in late fall to early spring, especially in the southern third of the Midwest region).

Assuming a soil with a moderate infiltration rate (hydrological soil group B), the curve number for a row crop (straight row) can range from 61 to 90 (see table 17). This

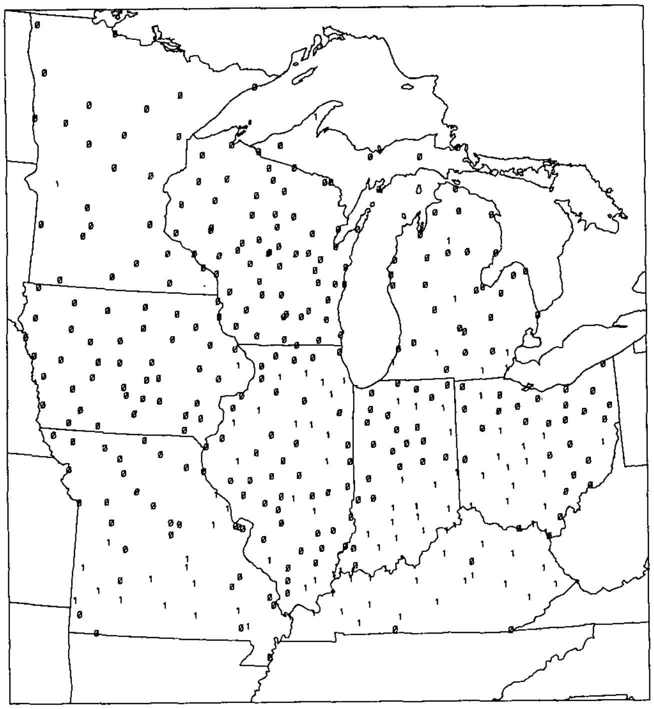

Figure 11. Top-ranked 10-day storms by season (1 = cold, 0 = warm)

Figure 12. Stations used in comparing seasonal variations in frequency curves

Table 17. Curve Number (CN) and Runoff(Q) Values from Three Antecedent Moisture Conditions (AMC) for Row Crops

AMC	*CN*	*Q (inches)*
I	61	2.0
II	78	3.8
III	90	5.4

wide range of curve numbers can lead to large differences in runoff. Assuming a 6-inch, 24-hour, 100-year rainfall, the calculated direct runoff can range from 2.0 to 5.4 inches, depending on the antecedent soil conditions (table 17). Therefore, in places with typically heavy winter precipitation (Kentucky), AMC type III can lead to much higher runoff values than by using the annual amounts and AMC type II.

Summary

Differences in the seasonal rainfall frequency values are evident due to differences in the seasonal contribution of heavy rainstorms. In the Midwest, these differences can be quite significant in the northern states where summer precipitation dominates. In the southern states, significant heavy storms occur in all seasons. For example, in southern Missouri, Indiana, and Ohio, the heaviest amounts for the longer duration storms (5-day and 10-day) are most likely to occur in the cold season. The impacts of all heavy rainstorm events will vary from season to season, depending on soil moisture, state of the soil (frozen or nonfrozen), and vegetative cover.

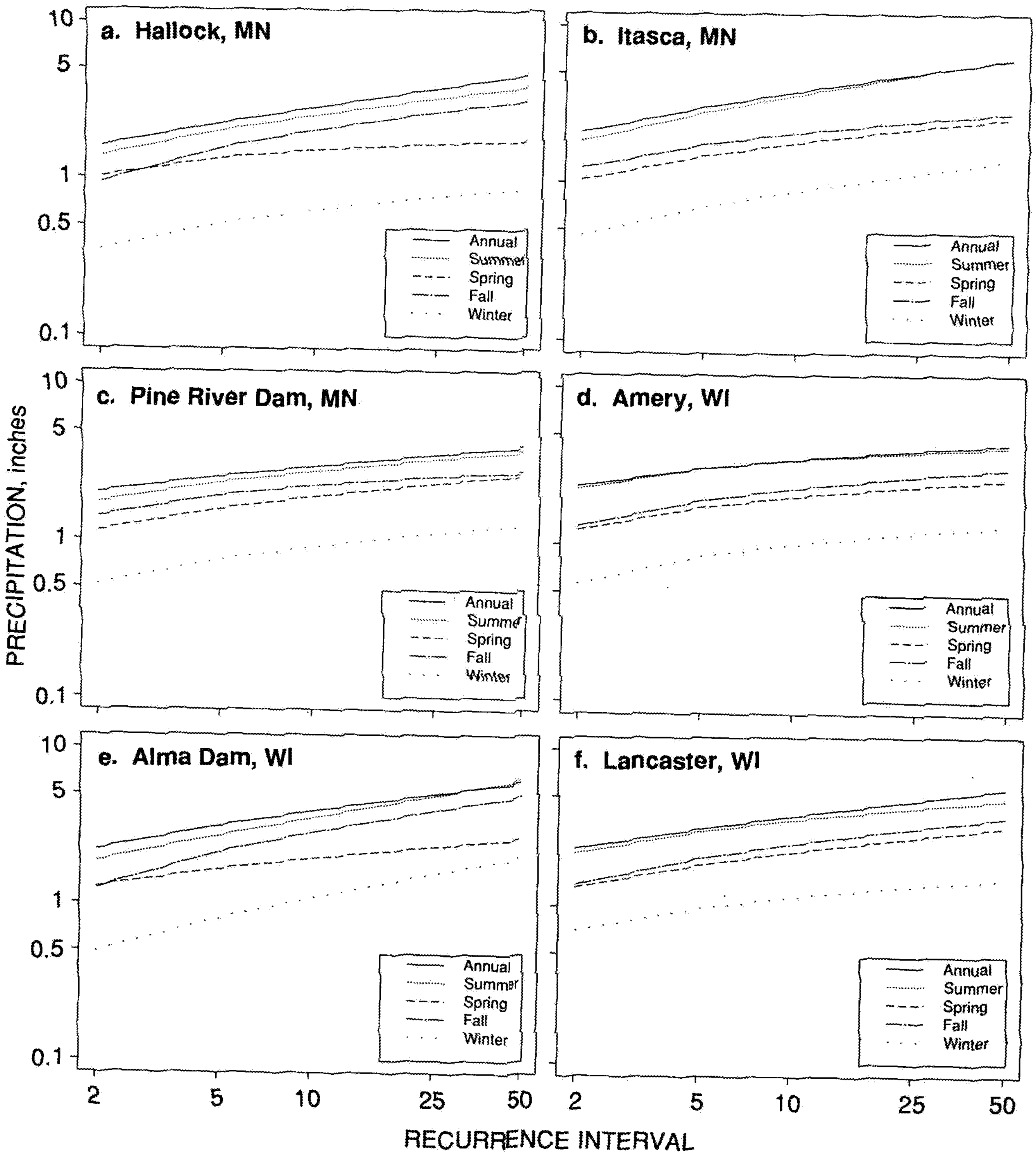

Figure 13. Seasonal rainfall frequency curves

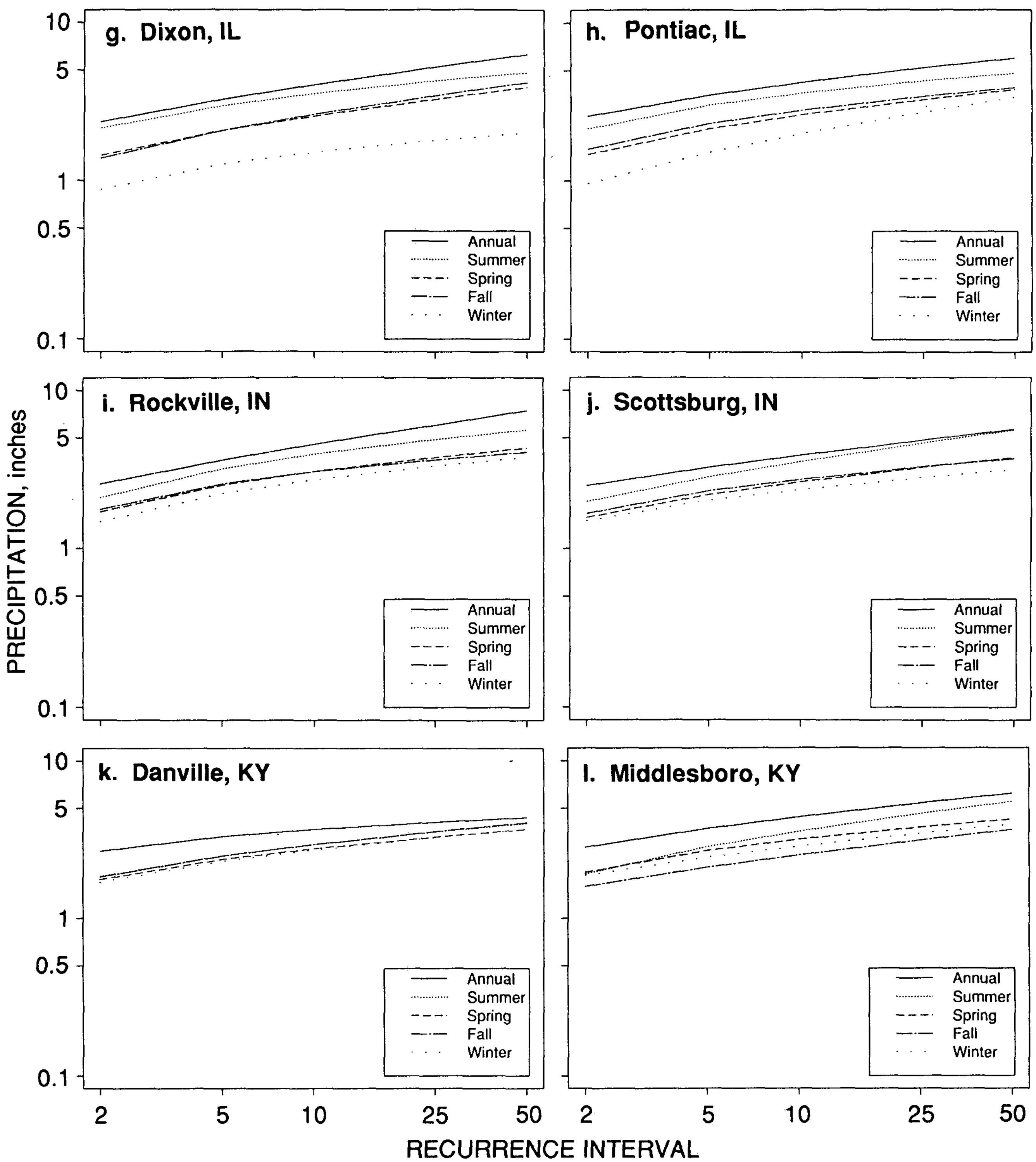

Figure 13. Concluded

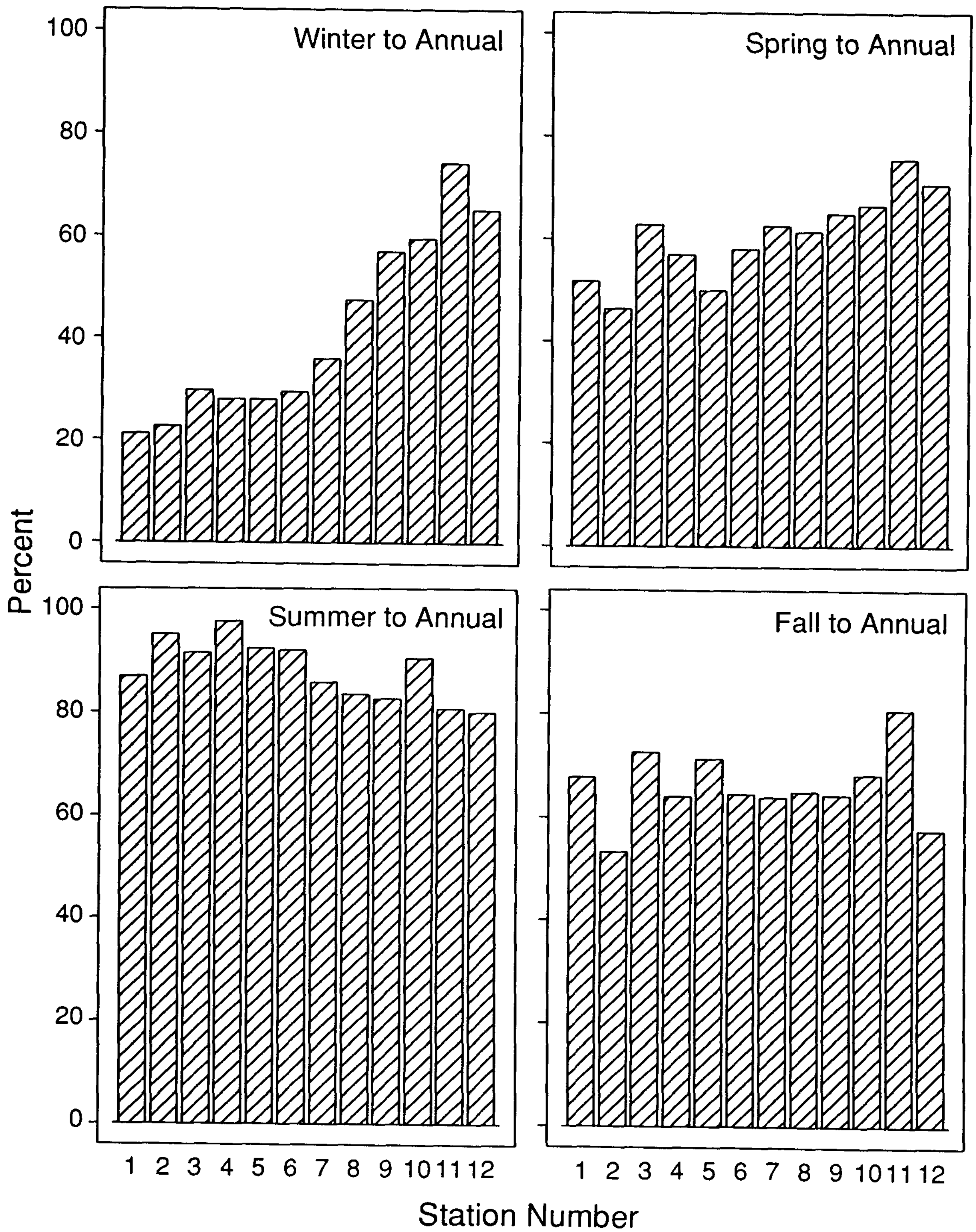

Figure 14. Ratio of seasonal curve to annual curve amounts expressed in percentages

6. FLUCTUATIONS IN FREQUENCY DISTRIBUTIONS OF HEAVY RAINSTORMS IN THE MIDWEST

Background

Heavy rainfall events are important in the design of water-related structures (e.g., storm sewer systems), in agriculture, in weather modification, and in monitoring climate change. Traditionally, hydrometeorologists have fit various statistical distributions to historical precipitation data to derive the recurrence intervals for selected storm durations. The assumption underlying the derivation of these values has been that there are year-to-year variations in the precipitation record, but the time series is stationary without major temporal fluctuations or long-term trends during the typical design life (50 to 100 years for most water-related structures). This assumption allows the use of all available historical data with equal weight. However, a preliminary study of Illinois by Huff and Changnon (1987) using 1901-1980 data for 22 stations investigated the possibility of a climatic trend in the distribution of heavy rainstorms in Illinois. A comparison of l-day and 2-day rainfall amounts for 2-year to 25-year recurrence intervals showed significant changes in the northern two-thirds of the state for two 40-year periods (1901-1940 and 194l-1980). This was supported by an earlier study of Illinois climate fluctuations (Changnon, 1984), which showed sizable shifts in total precipitation and thunderstorms for 1901-1980.

Analytical Approach and Results

Illinois

In Illinois, a 61-station sample was used to investigate the properties of the frequency distribution of maximum 24-hour and 48-hour storms derived from two 40-year periods (1901-1940 and 1941-1980). The frequency distributions were derived from the partial duration series of rainstorms for each station. The frequency values were obtained from log-log curves derived for each station. The l-day and 2-day values obtained were converted to maximum 24-hour and 48-hour amounts using the transformation factors 1.13 and 1.05, respectively, derived by Hershfield (1961) and Huff and Neill (1959).

The change between the two periods was expressed in terms of the ratio of values from the 1941-1980 period to those for the 1901-1940 period. A value > 1 indicates an increase in intensity, and a value < l indicates a decrease in intensity for a given storm duration and recurrence interval.

The results of the expanded study in Illinois supported the findings of Huff and Changnon (1987). For the two 40-year periods, there is a general increase in the northern two-thirds of the state and a slight decrease in the southern one-third. Figure 15 shows the pattern of ratios (1941-1980/1901-1940) calculated for 24-hour, 2-year rainfalls derived from station frequency curves based on data for each 40-year period. The pattern in the figure holds for the 5-year, 10-year, and 25-year recurrence intervals at the 24-hour and 48-hour storm durations (Huff and Angel, 1989). The ratio for the two 40-year periods had similar spatial behavior for the two storm durations. Within the state, 62 percent of the stations had ratios exceeding 1.00, and 36 percent exceeding 1.10 for 24-hour storms with a recurrence interval of 2 years. For a 2-year, 48-hour rainstorm, 68 percent of the stations had ratios exceeding 1.00,40 percent exceeding 1.10. The data were inadequate to derive 50-year and 100-year ratios from the station frequency curves.

The results for the two 40-year periods are supported by other studies in Illinois. In a study of the 1901-1980 period, Changnon (1985) found gradual changes to a wetter regime in Illinois that was most pronounced in the last 15 years (1965-1980). In an earlier study, Changnon (1983) noted increased flooding in recent years. especially in northeastern Illinois. This agrees with the 20 to 40 percent increase in the heavy rainfall distribution for northeastern Illinois found in our study.

Table 18 illustrates the effect of climatic variations between the two 40-year periods on heavy rainstorm frequency distributions (Huff and Angel, 1990). For 24-hour maximum rainfall at average recurrences of 2,5, and 10 years, six stations were selected to reflect different degrees of change during the 80-year sampling period. At Rockford in

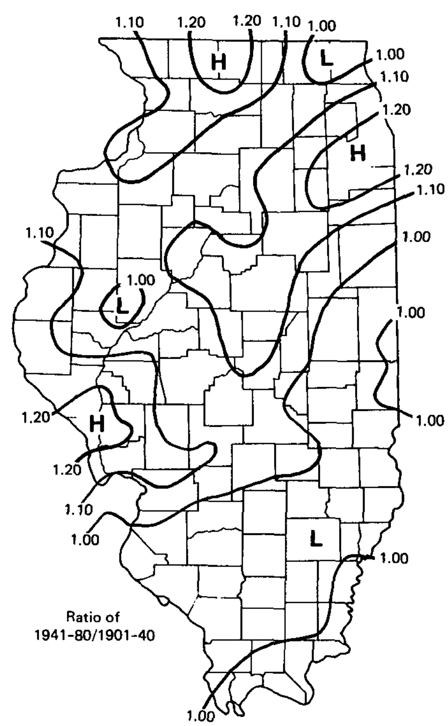

Figure 15. Ratio for two 40-year periods (1941-1980 and 1901-1940) for 2-year, 24-hour storms

Table 18. Examples of Variation in Recurrence Intervals Indicated for Maximum 24-Hour Rainfall Between Frequency Curves Derived from 1901-1940 and 1941-1980 Data in Illinois

Recurrence interval (1941-1980 curves)	*Equivalent Recurrence Interval for Selected Locations (1901-1940 curves)*					
	Rockford (NW)	*Kankakee (E)*	*Quincy (W)*	*Peoria (C)*	*Effingham (ESE)*	*Belleville (SW)*
2	5	5	5	3+	3+	2-
5	15	16	13	9	19	4
10	35	35	27	17	21	8

northern Illinois, the 2-year value on the frequency curve derived from 194l-1980 data corresponds to the 5-year value on the 1901-1940 curve. Similarly, the 5-year amount estimated by the 1941-1980 curve corresponds to the 15-year amount on the 1901-1940 curve, and the 10-year value corresponds to the 35-year value. If a structure with a 70-year lifetime was designed for rainstorms with a 35-year recurrence interval using the 1901-1940 data it would be implicitly expected to be exposed to only two such storms. The 1941-1980 data, however, suggests it might be exposed seven times to a storm of such magnitude over 70 years (on average). The underestimates would be most pronounced in northern and western Illinois (Rockford, Kankakee, and Quincy).

The Midwest

The next step was to extend the analyses to the neighboring states in the Midwest to determine if the pattern continued outside Illinois. For the other eight states (Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin), analyses similar to that employed in Illinois were used for comparisons between two 40-year periods (1907-1946 and 1947-1986). The Illinois values were also adjusted to this time frame. Comparisons were made for selected recurrence intervals for 24-hour storms. Unfortunately, the number of long-term stations with digital records is less in the other states than in Illinois. Whereas 61 stations were available for Illinois, records for only 24 stations were available on tape for Indiana, 35 for Iowa, 12 for Kentucky, 39 for Michigan, 24 for Minnesota, 27 for Missouri, 15 for Ohio, and 13 for Wisconsin. Thus the spatial detail and accuracy is diminished somewhat in these other states (especially Ohio and Wisconsin). Figure 16 shows the stations used in this section.

Figure 17 shows the 40-year ratios for 2-year, 24-hour storms. The shaded areas show regions with ratios > 1.00; that is, an increase in rainfall amounts for a given frequency and duration. There is a large area of increased values throughout the region. Decreased amounts are indicated in Missouri, Wisconsin, and along the Ohio River valley. There is some degree of spatial coherency in the area of increased values. That is, these are not just isolated, random pockets of high values. The areas with ratios > 1.10 (10 percent), a more significant threshold, show a narrow band starting near St. Louis and continuing to the northeast through Illinois, northwest Indiana, and into lower Michigan. Minnesota also has a larger area through the northwestern portion of the state with significantly higher ratios, There are other small pockets of high values in Iowa, Missouri, and Kentucky. These smaller regions may have been caused by smaller-scale effects, such as one exceptionally heavy rainstorm.

The map of 40-year ratios for a 5-year, 24-hour storm shows a pattern similar to the 2-year, 24-hour map for ratios > l.00 (figure 18). This coherence between return periods is consistent with the results found in Illinois. The areas of 5-year, 24-hour storm ratios > l.10 (10 percent) show the same band as before with an extension into northern Ohio as well as an area in northwest Missouri. The values within this band are also more intense. For example, the ratios near Chicago are 25 to 40 percent on the 5-year, 24-hour map, but only 20 percent on the 2-year, 24-hour map. The similar appearance between the 2- and 5-year, 24-hour maps suggests the changes are due to something other than sampling vagaries. The patterns of the 10-year, 24-hour analysis (not shown) were similar to those for the shorter intervals.

To investigate whether the patterns are indeed true and not due to random noise, correlations were calculated between the ratio maps and two random patterns, which were generated by randomly shuffling the station locations for the 2-year, 24-hour data. Thus the data values are the same although their locations are different. Table 19 shows the results of the correlation analysis. Although there is high correlation among the real patterns, no relationship was found for the random patterns.

Table 20 shows the percentage of stations having ratios ≥1.00 and ≥1.10. In general, two-thirds of the stations showed some increase while one-third showed increases > 10 percent between the two 40-year periods.

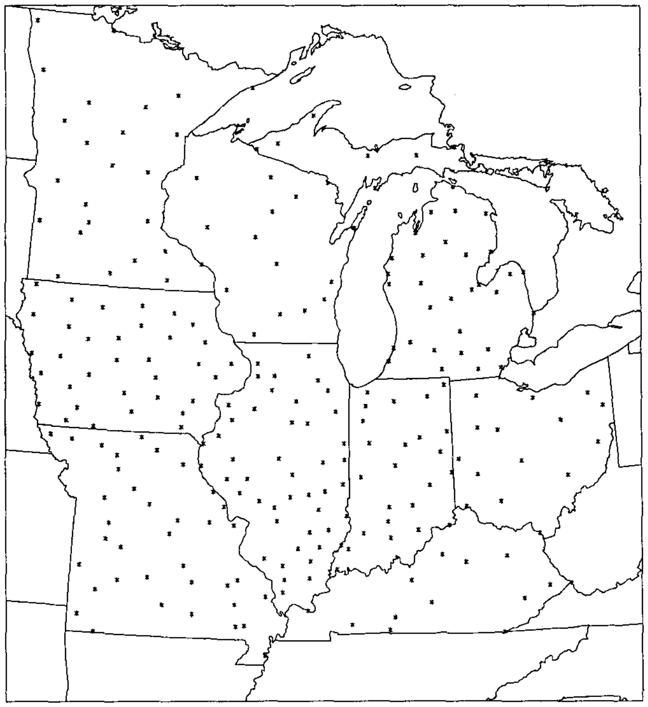

Figure 16. Stations used in temporal change study

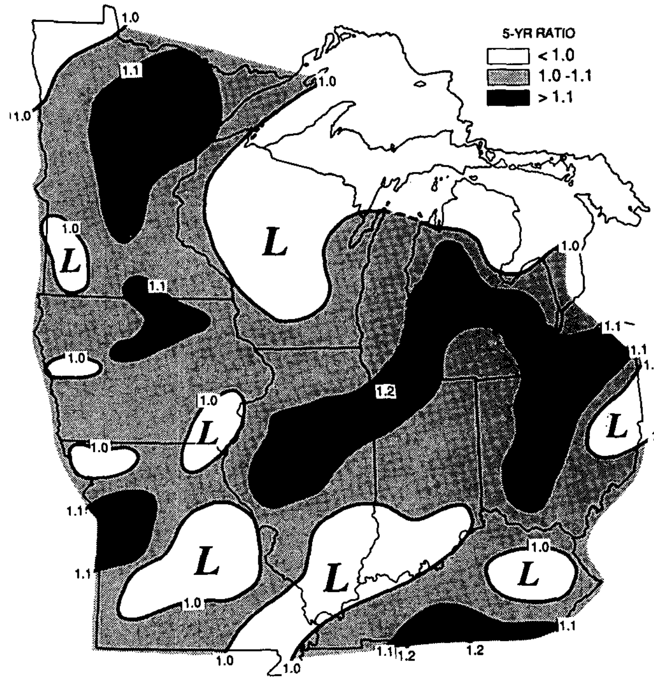

Figure 18. Ratio pattern for 5-year, 24-hour storms

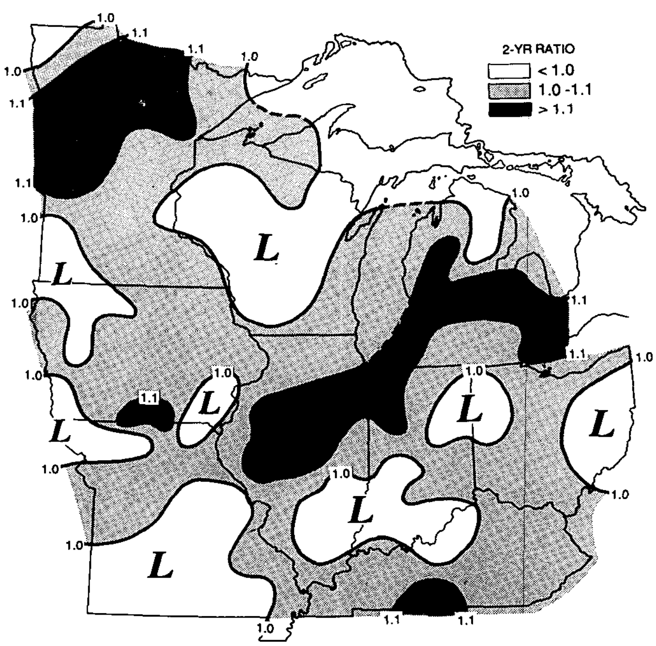

Figure 17. Ratio pattern for 2-year, 24-hour storms

Summary and Conclusions

This study has examined the change over time of the heavy rainfall distribution in the Midwest. A detailed study in Illinois suggests an increase in rainfall amounts for 2-, 5, and 10-year recurrence intervals during recent years. This is supported by other temporal studies of precipitation and related variables in Illinois. Preliminary results for other parts of the Midwest show a southwest to northeast axis of maximum change extending from Missouri to Michigan and northern Ohio. The increases appear to be greater than expected from natural climatic variability and are sufficiently large to have implications for water structure designs and other aspects of applied climatology. Furthermore, the findings suggest that the assumption of a stationary time series for fitting statistical distributions to historical precipitation data may be invalid. The results also suggest the need to update rainfall frequency relations more frequently. An update on the order of every 20 years would be appropriate to capture any substantial changes. It cannot be determined at this time what underlying physical processes may be involved with these changes.

Table 19. Correlation Analysis Between the Three Real Maps and Two Random Maps

	2-Year	*5-Year*	*10-Year*	*Random #1*	*Random #2*
2-Year	1.00	0.76	0.53	-0.03	0.00
5-Year	0.76	1.00	0.90	-0.02	-0.04
10-Year	0.53	0.90	1.00	-0.03	-0.03
Random #1	-0.03	-0.02	-0.03	1.00	0.05
Random #2	0.00	-0.04	-0.03	0.05	1.00

Table 20. Percentage of Stations Showing Increased Precipitation Amounts at Selected Return Periods for 24-Hour Storms Between Two 40-year Periods (1947-1986 and 1907-1946)

	Ratio >1.00	*Ratio >1.10*
2-year	63	24
5-year	63	31
10-year	60	34

7. SPATIAL CHARACTERISTICS OF HEAVY RAINSTORMS IN THE MIDWEST

Data from dense raingage networks operated by the Illinois State Water Survey have supported numerous studies of the spatial distribution characteristics of heavy rainstorms such as those in this report. Key results from several of these studies have been abstracted from published reports and technical papers and included here for the convenience of the user. They provide pertinent information for both hydrological designers and systems operators. Although based on Illinois data, the relationships are considered generally applicable to the Midwest.

Relation Between Point and Areal Mean Rainfall Frequency

Knowledge of the frequency distribution of areal mean rainfall is pertinent to the efficient design of hydraulic structures such as dams, urban storm sewers, highway culverts, and water-supply facilities. In the United States, a relatively large amount of data is available on the frequency distribution of point rainfall, but there is little information on the frequency distribution of areal mean rainfall. Consequently, there has been a need to determine how the mean rainfall frequency distributions for small areas about a point are related to the point frequency distributions.

Hershfield (1961) presented area-depth curves for estimating areal mean rainfall frequencies from point rainfall frequencies. Information was provided for areas ≤400 square miles and for storm durations of 0.5 to 24 hours. The relations were developed from limited raingage network data and apparently considered applicable throughout the United States. Huff (1970) used data from dense raingage networks in Illinois to provide similar relationships more applicable to the Midwest for storm durations of 0.5 to 48 hours. Results are summarized in table 21.

Storm Shape

Runoff characteristics in heavy storms are influenced by the shape and movement of the storms. Two studies have been made to determine the shape characteristics of heavy rainstorms in Illinois. In one study, data from 260 storms on a dense raingage network in central Illinois were used to investigate shapes on areas of 50 to 400 square miles (Huff, 1967). Storms were used in which areal mean rainfall exceeded 0.50 inch. In the other study, historical data for 350 heavy storms having durations up to 72 hours were used in a shape study of large-scale, flood-producing rain events. These were storms in which maximum l-day amounts exceeded 4 inches or in which 2-day and 3-day amounts exceeded 5 inches (StoutandHuff, 1962).Storms encompassed areas that ranged from 200 to 10,000 square miles.

The study of historical storms indicated that the rain intensity centers most frequently had an elliptical shape. The ratio of major to minor axis tended to increase with increasing area enclosed within a given isohyet; that is, the ellipse becomes more elongated. Within limits employed in the study, no significant difference in the shape factor occurred with increasing storm magnitude or with durations ranging from a few hours to 72 hours.

In the network study, elliptical patterns were found also to be the most prevalent type, but the heaviest storms tended to be made up of a series of rainfall bands. Intensity centers within these bands, however, were most frequently elliptical. From these two studies, a mean shape factor was determined that can be used as guidance in hydrologic problems in which storm shape is a significant design factor. The shape curve is shown in figure 19 for areas of 10 to 1,000 square miles. For those interested, the curve can be continued to 10,000 square miles because storms up to this size were included in the historical storm study.

Table 21. Relation Between Areal Mean and Point Rainfall Frequency Distributions

Storm period (hours)	*Ratio of areal to point rainfall for given area (square miles)*					
	10	*25*	*50*	*100*	*200*	*400*
0.5	0.88	0.80	0.74	0.68	0.62	0.56
1.0	0.92	0.87	0.83	0.78	0.74	0.70
2.0	0.95	0.91	0.88	0.84	0.81	0.78
3.0	0.96	0.93	0.90	0.87	0.84	0.81
6.0	0.97	0.94	0.92	0.89	0.87	0.84
12.0	0.98	0.96	0.94	0.92	0.90	0.88
24.0	0.99	0.97	0.95	0.94	0.93	0.91
48.0	0.99	0.98	0.97	0.96	0.95	0.94

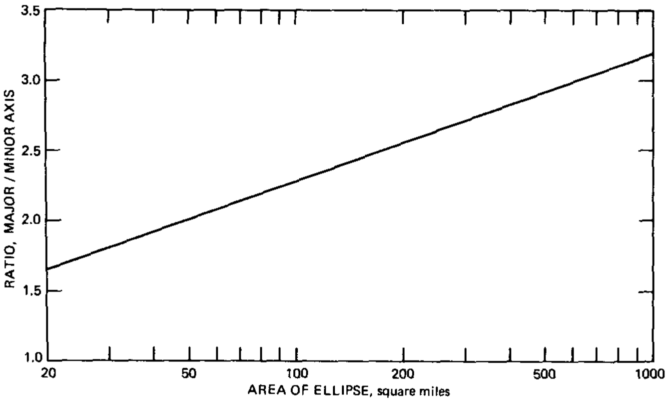

Figure 19. Mean shape factor for heavy storms

Storm Orientation

An important consideration in any region is the orientation of the major axis of heavy rainstorms. For example, if the axes of heavy rainstorms tend to be parallel to a river basin or other area of concern, then the total runoff in this region will be greater, on the average, than in a region perpendicular to most storm axes. The orientation of the storm axis also provides an indication of the movement of the major precipitation-producing entities embedded in any large-scale weather system. Because most individual storm elements have a component of motion from the west, an azimuth angle ranging from 180 to 360° was ascribed to each storm. Thus, if a storm had an orientation of 230°, the orientation was along a line from 230 to 050° (southwest to northeast).

No significant difference was found between the orientation of storms when they were stratified according to mean rainfall and areal extent. Table 22 shows the distribution in 260 heavy storms having mean rainfall exceeding one inch over a contiguous areas ≤10,000 square miles (Huff and Semonin, 1960). This distribution is considered typical for heavy storms in Illinois and the Midwest. Other studies have supported the results shown in table 22 (Huff and Vogel, 1976; Vogel and Huff, 1978).

Table 22. Orientation of Heavy Rainstorms

Azimuth (degrees)	*Storms (percent)*	*Azimuth (degrees)*	*Storms (percent)*
180-215	4	276-295	20
216-235	6	296-315	12
236-255	30	316-335	6
256-275	21	336-360	1

Heavy rainstorms were found to be oriented most frequently from west-southwest to east-northeast through west to east or west-northwest to east-southeast (table 22). The median orientation of the 260 storms used in deriving table 22 was 265° (nearly west to east). In general, it has been found that the orientations of very heavy storms tend to be nearly west to east. Heavy, but less severe storms, are usually oriented west-southwest to east-northeast or west-northwest to east-southeast. Moderately heavy storms, especially those of short duration (1 to 3 hours), are frequently oriented west-southwest to east-northeast or southwest to northeast.

Storm Movement

In the Midwest, heavy rainstorms are usually produced by one or more squall lines or squall areas traversing a basin or other area of interest. Each system (squall line or squall area) consists of a number of individual convective entities, usually thunderstorms, and these entities have a motion that is strongly related to the wind field in which they are embedded. These entities are often referred to as raincells. Network studies of the motion of heavy raincells (Huff, 1975) have provided the frequency distribution of cell movements shown in table 23. The most frequent raincell movements are from west-southwest through west to west-northwest (240-299°), which accounts for 42 percent of the total number analyzed in the Huff study. Of the total, 84 percent exhibited motion with a westerly component.

Table 23. Frequency Distribution of Heavy Raincell Movements

Azimuth (degrees)	*Storms (percent)*	*Azimuth (degrees)*	*Storms (percent)*
180-209	6	O-29	4
210-239	16	30-59	2
240-269	22	60-89	2
270-299	20	90-119	2
300-329	13	120-149	2
330-359	7	150-179	4

8. INDEPENDENCE OF EXTREME RAINFALL EVENTS

One of the problems involved in the development of rainfall frequency distributions is the *independence* (or lack thereof) of the observations. This is pertinent to selecting the method of analysis and grouping of the data in the analytical procedures.

One method of evaluating the magnitude of this problem is to examine the time distribution of the events incorporated into the frequency distributions for storm periods of varying duration. A pilot study was made using Indiana data for 1-, 2-, and 3-day storm periods to calculate 24-hour to 72-hour frequency relations. A total of 41 stations were used in deriving the Indiana relations.

First, the maximum recorded 1-day and 2-day amounts for each station were examined to determine whether both occurred in the same storm system. Among the 41 stations, 22 (54 percent) recorded both their 1-say and 2-day maxima in the same storm systems. Thus, 54 percent of the time the 1-day and 2-day events were not independent of each other, at least from a meteorological standpoint.

Next, the same type of examination was performed on 2-day and 3-day events. Results showed that 78 percent or 32 stations had their maximum amounts on days when both 2-day and 3-day records were established. Further examination showed that in 44 percent or 18 cases, the station maxima for all three storm periods (l-, 2-, and 3-day) occurred in single storm systems.

The conclusion suggested by this pilot study is that storm events that produce the data for deriving heavy rainfall frequency relations cannot be assumed to represent random occurrences with respect to storm periods of less than 72 hours. Unfortunately, these are the storm events of most concern to hydrologists involved in the design and operation of systems for the control of flood waters.

Next, comparisons were made between the top ten ranked storms for l-day and2-day events. Among the 25 long-term stations having records of 58 to 86 years, an average of 60 percent of the storm systems producing the ten largest l-day amounts also resulted in amounts ranked among the ten heaviest rain events for 2-day periods. The top ten storm events for these long-term stations exert a strong control over rainfall amounts derived for recurrence intervals of 10 years or longer. The median was also 60 percent, and the range varied from 40 to 80 percent (4 to 8 cases) among the 25 stations.

A similar analysis was made for the 16 short-term stations having records for 35-40 years. The mean and median were both 70 percent and the range varied from 60 to 90 percent at individual stations. Because of the shorter records, the top ten ranked storms exert a strong control on determining recurrence-interval amounts for intervals of 5 years or longer. The comparisons between the ten heaviest storms for l-day and 2-day rain periods strongly support the results from the analyses of maximum recorded values described previously.

The same comparative analysis was applied to the top ten ranked storms for 2- and 3-day periods. For the long-term stations, the average and median were both 80 percent, and the range was from 60 percent (6) to 100 percent (10). For the short-term stations, the average and median were 76 and 70 percent, respectively, and the range was from 50 to 90 percent. The above comparisons for 2 and 3 days are similar to those for 1 and 2 days, and also support the earlier conclusion relating to the independence of 24- to 72-hour frequency distributions of heavy rainfall.

Examples of Outstanding Storms

A determination was made of the number of occurrences of rainfall amounts that ranked among the ten heaviest in some of the most widespread storms in Indiana and Illinois. For this analysis, 2-day storm periods were selected, because many of the heaviest storms extend from late afternoon into evening and even later. Although these are single storms, they are split between two days at stations of the climate network that report once daily at approximately 1800 Central Standard Time.

One of the most outstanding storms occurred within a 24-hour period on October 5-6, 1910. Table 24 shows the stations at which a rank 1-10 amount occurred, the amount of rainfall, and its rank position among all storms at that station. Thus, 11 stations in Indiana qualified, and the storm ranked first among all storms at 4 stations. Similarly, Illinois had 12 stations with 1-10 ranks, and the storm ranked first among all storms at 5 stations. For the two states combined, there *were* 23 stations with rank 1-10 storms. Of these, nine experienced storms ranked first among 2-day storm periods. Thus 23 percent of all the 102 Indiana-Illinois stations had a rank 1-10 amount, and 9 percent had their heaviest 2-day storm on record.

Table 25 shows information on another outstanding 2-day event. On March 25-26, 1913, 15 Indiana stations recorded rank 1-10 storms. Among these, five stations recorded their heaviest 2-day storm on record. In Illinois, nine stations recorded rank 1-10 storms, but only one was ranked #l. Thus, for both states combined, 24 percent had rank 1-10 events, and 6 percent had their most severe 2-day storm on record. This particular storm was noted by the U.S. Weather Bureau (1913):

"In a period of 4 days, beginning on March 23 and ending on March 27, the average rainfall over the watershed of the WestFork of the WhiteRiver was 7.81 inches, and over the watershed of the East Fork, 8.41 inches. This extraordinary rainfall produced one of the greatest floods in the history of the state."

A third example of outstanding storms with respect to area enveloped and storm intensity is summarized inTable 26. This storm occurred in a 2-day period on August 14-16, 1946. It extended across central Missouri into southwestern and

Table 24. Distribution of Rank 1 to 10 Amounts in October 5-6, 1910, Storm in Indiana and Illinois

Station	*Rainfall (inches)*	*All-storm rank*
INDIANA		
Bloomington	7.68	1
Moore's Hill	8.23	1
Mt. Vernon	7.68	1
Scottsburg	7.86	1
Columbus	8.12	2
Richmond	5.60	2
Rushville	5.64	2
Paoli	6.32	3
Princeton	6.33	4
Washington	5.15	5
Markland Dam	5.55	7
ILLINOIS		
Cairo	9.24	1
Carbondale	8.67	1
Harrisburg	10.71	1
New Brunswick	10.72	1
Anna	9.70	1
DuQuoin	6.80	2
McLeansboro	6.42	3
Palestine	5.40	4
Fairfield	5.64	6
Flora	5.90	6
Mt. Carmel	5.16	9
Olney	5.09	10

Table 25. Distribution of Rank 1 to 10 Amounts in March 25-26, 1913, Storm in Indiana and Illinois

Station	*Amount (inches)*	*All-storm rank*
INDIANA		
Columbus	8.65	1
Rushville	7.84	1
Richmond	9.47	1
Farmland	7.39	1
Washington	7.91	1
Bloomington	7.68	2
Berne	4.90	2
Marion	5.13	3
Princeton	6.37	3
Whitestown	6.07	3
Markland Dam	5.65	4
Paoli	6.25	4
Scottsburg	6.10	5
Moore's Hill	4.88	5
Rockville	4.72	8
ILLINOIS		
Mt. Carmel	7.70	1
Fairfield	8.35	3
DuQuoin	6.12	4
Olney	5.59	4
Mt. Vernon	5.40	6
McLeansboro	5.95	8
Flora	5.68	8
Palestine	5.01	8
Paris	4.79	8

Table 26. Distribution of Rank 1 to 10 Amounts in August 14-16, 1946, Storm in Missouri and Illinois

Station	*Amount (inches)*	*All-storm rank*
MISSOURI		
St. Louis	11.71	1
Warsaw	8.70	1
St. Charles	8.48	1
Ellsberry	6.98	2
Salem	6.62	2
Boliver	6.85	3
Clinton	6.72	3
Lebanon	6.99	3
Rolla	5.25	8
Warrensburg	5.21	10
ILLINOIS		
Belleville	13.41	1
Mt. Vernon	10.43	1
Greenville	7.44	1
White Hall	5.15	8
Pana	5.04	8
New Burnside		9

southern Illinois. As indicated in the table, ten Missouri and six Illinois stations recorded rank 1-10 storms and six of these ranked #1 among 2-day storms on record.

Figure 20 further illustrates the areal extent and intensity of the storm of October 5-6, 1910. At each station, rainfall amounts (inches) and the rank of the storm in the station's history are shown. The northern boundary of the intense rainfall also is indicated by the dashed line. Only one reporting station in Illinois and none in Indiana south of the dashed line failed to report a rank 1-10 amount. It is likely that this storm also extended into Kentucky and southeastern Missouri, but records for these states were not available for 1910. This was undoubtedly one of the most severe rainstorms ever experienced in the nine-state area covered by this report.

Figure 21 shows the extent and intensity of the storm of March 25-26, 1913, and is similar in presentation to figure 20. This storm overlapped the area incorporated in the October 1910 storm. Rank 1-10 amounts were experienced at ten Indiana and seven Illinois stations in both storms. Only one reporting station within the dashed-line outline encompassing most of central and northern Indiana and southeastern Illinois did not record a rank 1-10 storm event. This is another illustration of the effect imposed on point rainfall frequency relations by a few very extreme rainfall events.

Additional Analyses

In view of the widespread nature of the three storms just discussed, further analyses were undertaken to ascertain the importance of such storm events in establishing the characteristics of rainfall frequency curves for 10-year to 100-year recurrence intervals. Data for Ohio, Indiana, Illinois, and Missouri were used to obtain an adequate sample of midwestern conditions. The storm data included 2-day amounts during the 1901-1987 period except for Missouri where records prior to 1912 were not available for all of the data set.

Two data stratifications included individual storms that produced five or more and ten or more qualifying amounts among the rank 1-10 values. The analyses were made separately for each state. Results are briefly summarized in

Figure 20. Areal extent and magnitude of storm of October 5-6, 1910

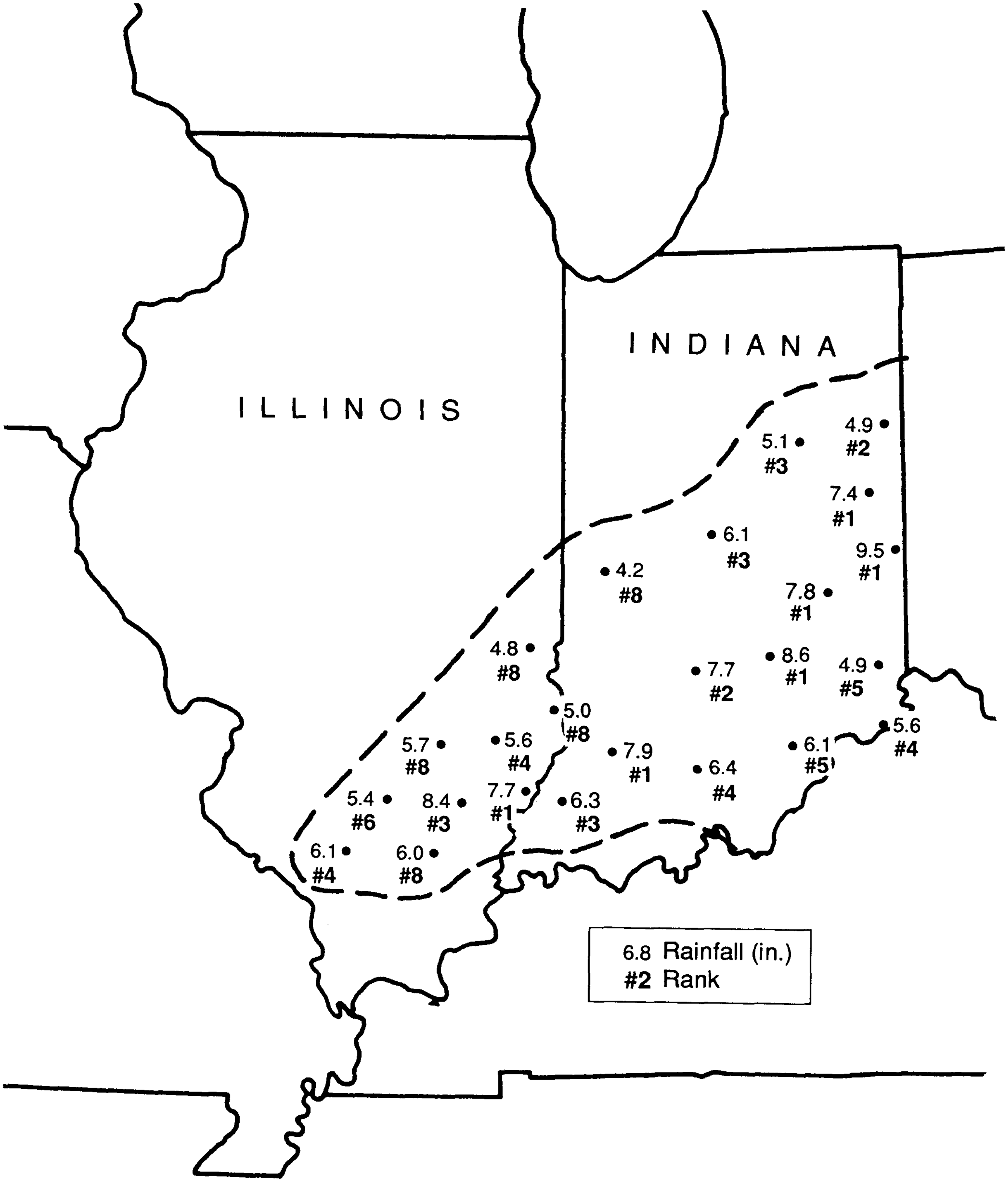

Figure 21. Areal extent and magnitude of storm of March 25-26, 1913

table 27, and provide further evidence of the relatively strong dependency of 10-year to 100-year recurrence interval values on a small portion of the heavy storm events used in establishing the frequency curves of point or areal mean rainfall.

In table 27, the first two columns show the total number of observational stations used in each state and the average precipitation gage density (mi²/gage). Gage density will influence the number of rank l-10 events observed in heavy storm systems. However, except for Missouri, the gage density differences among the four states are relatively small.

Following the first two columns, the number of storms (NS), the number of rank 1-10 qualifiers in these storms (NQ), and the percentage of the total number of rank l-10 values (Q%) are shown for each of the two data stratifications. The total number of qualifiers is the number of stations multiplied by 10.

Table 27 indicates that the percentage of total qualifiers accounted for by storms producing five or more qualifying amounts varied from a high of 34 percent in Indiana to a low of 25 percent in Ohio. The four-state average is 29 percent. The total number of qualifying storms (71) ranged from 24 in Illinois to 12 in Ohio. The summary for those storms having 10 or more qualifying amounts shows that these accounted for 10 to 16 percent of the total qualifiers, and these came from only three to six storm events among the states.

Summary

Results of this limited study indicate that the frequency distributions derived for 24- to 72-hour durations cannot be assumed to be independent. Frequently, qualifying amounts involve storm systems that dictate all three durations, especially among storms that determine the 10-year and longer recurrence-interval values. Examination of the heaviest IL-day storm events in Indiana and Illinois showed that the frequency distributions in the southern parts of these states were strongly influenced by two storms. Each of these storms produced amounts that ranked among the ten heaviest on record at over 20 percent of the 102 reporting stations in the two states. In one storm, 9 percent of all stations received their heaviest IL-day rainfall on record, and in the other, 6 percent of all stations recorded their heaviest amount.

Table 27. 2-Day Storms Producing 5 or More and 10 Or More Rank 1-10 Events

			≥ 5 Qualifiers			*≥ 10 Qualifiers*		
	N	G	NS	NQ	Q(%)	NS	NQ	Q(%)
Ohio	41	1000	12	101	25	3	46	11
Indiana	41	880	18	134	34	5	64	16
Illinois	61	915	24	192	31	6	69	11
Missouri	45	1530	17	120	27	4	46	10

Notes:
N = number of stations
G = gage density (mi²/gage)
NS = number of qualifying storms
NQ = total number of observations in qualifying storms
Q(%) = percent of all qualifiers accounted for by NQ

9. VARIABILITY WITHIN CLIMATIC SECTIONS

Frequency relations for climatic sections and individual points are presented in chapter 3 and part 2. The sectional relations provide estimates of the expected mean rainfall for various recurrence intervals and rain periods in areas of similar precipitation climate with respect to heavy rainfall occurrences. Naturalvariability, however, will produce variations for any given recurrence interval and storm period. This variability may be substantial even when long periods of record are used to develop frequency relations. Thus a measure of this variability is presented here for those who require such information.

The method employed involved comparing the variations in rainfall amounts between the frequency distributions derived for individual stations within a given climatic section and those indicated by the sectional mean distributions. The variability obtained by this methodresults primarily from random sampling variations due to the spatial distribution of heavy rainstorms in a particular climatic section during the sampling period. Variability due to other causes, such as observational and processing errors, has been minimized by using the individual frequency distributions, rather than the raw data observations, to measure the dispersion around the sectional mean frequency distributions.

The effects of "outliers" and "inliers", which are nonrepresentative of the expected rainfall for a given recurrence interval and storm duration, are also minimized but not completely eliminated by the methods used in our nine-state study. "Outliers" and "inliers" are rainfall amounts that are greater than or less than, respectively, any value expected to occur normally within the period of record undergoing analysis. For example, the 200-year storm event must occur in some year, and at some of the observational points this could have occurred during our observation period.

Table 28 shows the coefficient of variation, the standard deviation divided by the mean (expressed as a percentage), for each state for 24-hour to 10-day durations and 2-year to 100-year recurrence intervals. For a normal distribution, 68 percent of the observations are within one standard deviation of the mean, 95 percent are within two standard deviations, and 99 percent are within three standard deviations. The coefficient of variation is a measure of how well the individual station values fit the sectional mean values. For example, if the coefficient of variation is 4 percent, then 68 percent (one standard deviation) of the individual station values are expected be within 4 percent of the mean value. Larger coefficients of variation indicate wider scatter of station values above and below the sectional mean values. In practice, one may construct the 95 percent confidence band (two standard deviations) around the mean value. To do this, multiply the coefficient of variation by 2 to get two standard deviations (95 percent). So the 4 percent mentioned above now becomes 8 percent. One can then state that there is 95 percent confidence that any station value in that section will fall within 8 percent of the mean value.

Initial analyses of the individual climate sections showed that the coefficient of variation could be summarized on a state-by-state basis by averaging all climate section coefficients of variation for each state. This is advantageous since individual climate sections usually contained a small number of stations, which could lead to unreliable estimates of the coefficient of variation.

There are three general features of the coefficient of variation found in table 28. *It tends to increase with the longer recurrence intervals.* This is due to the fact that the uncertainty increases because of sampling inadequacies at the longer recurrence intervals. *It also tends to decrease at longer storm durations.* This is probably because longer duration values are associated with large-scale precipitation events, whereas the 24- and 48-hour values are more closely related to small-scale, convective activity. *Comparing the statesas a whole, one sees that at long recurrence intervals in Michigan, Minnesota, and Wisconsin, the coefficient of variation is generally higher than in the other states.* The authors speculate that this may be related to the relatively short convective season in these states limiting the number of stations exposed to the large rain-producing events in a given time period.

Use of the percentages in table 28 to compute the dispersion of point rainfall values about any sectional mean frequency distribution is illustrated in the following example. To determine the maximum positive and negative departures that will include 9.5 percent of the occurrences for a 50-year, 24-hour storm in northwestern Illinois, refer to the mean frequency distribution for 24-hour storms in northwestern Illinois (table 1 in part 2) or 6.53 inches.

Table 28 shows a coefficient of variation of 5 percent for a 50-year, 24-hour storm in Illinois. Multiply 5 percent by 2 to obtain the value encompassing 95 percent of the future point rainfall frequency distributions for northwestern Illinois. Then multiply this value (10 percent) by 6.53 inches to obtain the rainfall amount to be added or subtracted from the 6.53 inches to obtain the 95-percent confidence band. This calculation shows that 95 percent of the point rainfall estimates of the 50-year, 24-hour storm are expected to fall between 5.88 inches and 7.18 inches. The sectional frequency distributions (tables in part 2) and table 28 can be used to derive tables and curves for any climatic section and any storm duration to obtain a measure of that section's expected natural variability during a particular time period (5 years, 10 years, etc.).

Table 28. Dispersion of Point Rainfall Frequency Distributions about Section Mean Distributions for Various Recurrence Intervals and Rain Durations

	Coefficient of variation (percent)					
Duration	*2-Year*	*5-Year*	*10-Year*	*25-Year*	*50-Year*	*100-Year*
ILLINOIS						
24-Hour	3	4	4	5	5	7
48-Hour	3	4	4	4	5	6
72-Hour	3	4	4	4	5	6
5-Day	4	4	4	4	5	6
10-Day	3	4	4	4	5	6
INDIANA						
24-Hour	5	3	4	5	7	9
48 -Hour	4	4	4	6	7	9
72-Hour	4	3	4	6	7	8
5-Day	4	4	4	5	5	6
10-Day	4	4	5	5	5	6
IOWA						
24-Hour	4	4	5	7	8	9
48-Hour	4	4	5	7	8	9
72-Hour	3	4	5	6	7	8
5-Day	4	3	4	5	5	7
10-Day	3	4	4	4	4	5
KENTUCKY						
24-Hour	6	5	7	7	8	9
48 -Hour	6	5	6	7	8	9
72-Hour	5	5	6	7	7	8
5-Day	6	5	6	7	7	7
10-Day	6	5	6	5	5	5
MICHIGAN						
24-Hour	4	4	5	6	8	10
48-Hour	4	4	5	6	8	9
72-Hour	3	4	5	6	7	9
5-Day	4	5	5	6	7	8
10-Day	4	4	5	6	7	8
MINNESOTA						
24-Hour	4	5	6	9	10	12
48-Hour	4	5	6	8	10	13
72-Hour	4	5	6	8	8	11
5-Day	4	4	5	6	8	9
10-Day	5	4	5	6	6	7
MISSOURI						
24-Hour	4	5	6	7	8	8
48-Hour	4	5	5	6	7	7
72-Hour	4	5	5	6	6	7
5-Day	4	4	5	5	5	5
10-Day	4	4	4	4	5	6

Table 28. Concluded

Duration	*2-Year*	*5-Year*	*10-Year*	*25-Year*	*50-Year*	*100-Year*
OHIO						
24-Hour	4	5	6	6	7	7
48-Hour	4	4	5	5	6	7
72-Hour	4	4	5	6	6	7
5-Day	5	5	5	5	6	7
10-Day	4	5	5	6	7	8
WISCONSIN						
24-Hour	4	4	5	6	8	10
48-Hour	4	4	5	6	8	10
72-Hour	4	4	5	6	8	10
5-Day	4	4	5	6	8	9
10-Day	3	3	3	4	5	7

10. GENERAL SUMMARY AND CONCLUSIONS

The basic philosophy applied in our nine-state study is that a combination of appropriate statistical techniques, guided by available meteorological and climatological knowledge of heavy rainfall events, provides the best approach to developing reliable frequency distributions. It was recognized that the natural laws controlling the atmospheric processes are not governed by any specific statistical distribution. Within the limits of the data sampled, however, the application of appropriate statistical analysis provides a means of optimizing the information contained in that data.

Initially, a very detailed study of Illinois frequency relations was made. Methods and techniques developed in this study were then applied in the other eight midwestem states. Illinois is located near the center of this nine-state area, and there are no major changes in the general precipitation climate within this region.

Data and Analytical Approach

The study relied primarily upon data for 275 daily reporting stations within the NWS cooperative network. All of these stations had records exceeding 50 years. These data were supplemented by 134 cooperative stations with shorter records, by first-order station data, and by recording raingage data where available. Because the cooperative network provides only daily amounts of precipitation, well-established empirical factors were used to convert calendar-day rainfall to maximum 24-, 48-, and 72-hour amounts. Recurrence-interval amounts for rain periods of less than 24 hours were obtained from average ratios of x-hour/24-hour rainfall. These ratios were determined primarily from recording raingage data for 1948-1983 at 34 Illinois stations and 21 stations in adjoining states. Frequency relations for time periods shorter than 12 months were calculated from ratios relating x-month/24-month rainfall for various recurrence intervals.

For each station, the data were used to determine the annual maxima time series. Station frequency curves were then derived from the annual series values. For this report, however, the annual maxima values were converted to partial duration values. The annual maxima series is more adaptable to statistical testing, but the partial duration values are preferred by most users, especially engineers involved in the design and operation of water control structures.

Statistical Methods

As part of our nine-state research, an evaluation was made of various statistical methods and techniques considered to have potential for use in deriving the frequency distributions of heavy rainstorms. Major emphasis was placed on the applicability of (1) the L-moments method, which has received considerable attention in recent years; (2) the maximum likelihood methods; and (3) the Huff-Angel method used in the nine-state study. Except in a small percentage of the cases, the methods provided results that were not significantly different from either a statistical or meteorological standpoint, considering the inherent variability (real and human-induced) in the data samples. In general, the Huff-Angel estimates lie between those of the other two methods. From selected isohyetal maps comparing the L-moments and Huff-Angel distributions, it was concluded that the Huff-Angel spatial patterns conformed somewhat better with available climatological knowledge on the distribution of heavy storm rainfall in the Midwest. The largest differences occurred most frequently with the 100-year estimates, which represent an extension beyond the limits of all the data samples. Unfortunately, there is no reliable method of determining which estimate is “best” at predicting the most severe events.

Frequency Distribution of Heavy Rainfall Events

In our nine-state study, two methods of data analysis and presentation of results were used. For the first method, point rainfall frequencies were developed and presented in the form of isohyetal maps for various recurrence intervals and storm durations. This is the method most commonly used by past investigators. For the second method, areal mean rainfall frequency relations were developed in each state for regions of approximately homogeneous heavy rainfall climate. For both methods, frequency relations were developed for recurrence intervals ranging from 2 months to 100 years, and for rain periods varying from 5 minutes to 10 days. This wide range of frequency values was considered necessary to meet the needs of all potential users.

Point Rainfall Frequency Distributions

Isohyetal maps derived from individual station frequency relations were used to portray the spatial distribution of point rainfall for selected rain periods of 1 hour to 10 days, and recurrence intervals ranging from 2 to 100 years. Other rain durations and recurrence intervals can be calculated by transformation factors provided earlier in this report (tables 3 and 4). The isohyetal presentation is susceptible to considerable subjectivity and to natural and human-induced sampling errors undetected by statistical analyses. The method is useful and familiar to most users, however, and allows for incorporation of small-scale spatial differences resulting from localized influences if the sampling density is adequate.

Area1 Mean Rainfall Frequency Distributions

In the Midwest, consideration of available climate information on the distribution of heavy rainstorms, along with climatological-meteorological knowledge of storm system characteristics, indicated that the well-established NWS climate divisions could be used to divide the states into approximately homogeneous climate regions with respect to the frequency and intensity of extreme rainfall events. For each division, average frequency distributions were then developed using all stations within the division and those in neighboring divisions near its boundaries. The foregoing technique does not eliminate potential sampling errors in the data samples, but it does moderate their effects. Unless the divisions are properly selected, however, the averaging techniques may mask actual small-scale effects. This problem would be more acute in regions incorporating major changes in topography, such as the Appalachian and Rocky Mountain regions.

Time Distributions of Rainfall in Heavy Storms

Modem runoff models for urban and small-basin designs of water-control structures require definition of the time distribution characteristics within heavy rainstorms. Consequently, statistical time distributions developed for various types of storm systems in an Illinois study have been incorporated into this report. Although based on dense raingage network data in Illinois, the relationships should be applicable in the nine-state region and other areas of similar precipitation climate. These time distribution models can be used in conjunction with the frequency distributions presented in this report to accommodate hydrological needs.

Seasonal Distribution of Heavy Rainfall

The seasonal distribution of heavy rainstorms is pertinent in hydrology, agriculture, and other fields. In our nine-state study, available resources prohibited an extensive evaluation of seasonal rainfall frequencies. Three studies were pursued on a limited basis, however, and their results are included in this report to partially meet existing needs for seasonal information. These studies involved (1) the distribution of total precipitation in each of the four seasons (spring, summer, fall, and winter), (2) the seasonal distribution of heavy rainstorms, and (3) general characteristics and differences in seasonal frequency relations throughout the nine-state region. Results indicate that in the northern parts of the region, heavy rainstorms occur most often in the summer, followed by spring and fall, and are practically nonexistent in winter. In the southern parts of Missouri, Indiana, and Ohio, however, the heaviest amounts in long-duration storms (5 to 10 days) are most likely to occur in the cold season from mid-fall to early spring.

Temporal Fluctuations in Frequency Distribution of Heavy Rainstorms

Using the available data sample for 1901-1987, an investigation was made to determine whether climate trends or long-term fluctuations were indicated. For this purpose, the data were divided to provide two 40-year samples. Amounts for 2-, 5, and 10-year recurrence intervals were analyzed. The 87-year sample was not adequate to examine longer periods. Comparisons were then made between the various periods. In general, the results indicated an area of increasing frequency and/or intensity of heavy storms along an axis extending from Missouri north east ward through Illinois to southern Michigan and northern Ohio. The increases appear to be greater than expected from climate variability and sufficiently large to have an impact on water-control structural designs and other aspects of applied climatology.

Other Studies

Limited information has been presented that relates to the various spatial characteristics of heavy rainstorms in the Midwest. These have been abstracted from Illinois studies and include the relationship between point and areal mean rainfall frequency, storm shape, storm orientation, and storm movement.

Another limited study was concerned with the independence of extreme rainfall events. One of the numerous problems involved in the development of rainfall frequency relations is the independence of the observations. Results indicated that the 1-day to 3-day frequency distributions frequently involve storm systems that dictate all three events. This is especially evident in those storms that produce the long recurrence-interval values. For example, examination of the heaviest 2-day storm events in Indiana and Illinois showed that the frequency distributions in the southern parts of these states were strongly influenced by two storms. In the storm of October 5-6, 1910, 23 percent of all the long-period reporting stations in the two states had 2-day amounts that ranked among the ten heaviest on record, and 9 percent recorded their heaviest storm of the 1901-1987 period. In the storm of March 25-26, 1913, 24 percent of the stations in the two states reported amounts that rank among the first ten on record, and 6 percent had their heaviest storm ever observed.

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Part 2. Spatial Distribution Maps and Sectional Mean Frequency Distribution Tables

(The data for the sectional mean frequency tables are available on disk from the Midwestern Climate Center at the Illinois State Water Survey. Please call (217)244-8226 for further information.)

The user should consult the introduction and chapter 3 in part 1 before using the maps and tables in part 2 to understand their strengths and weaknesses.

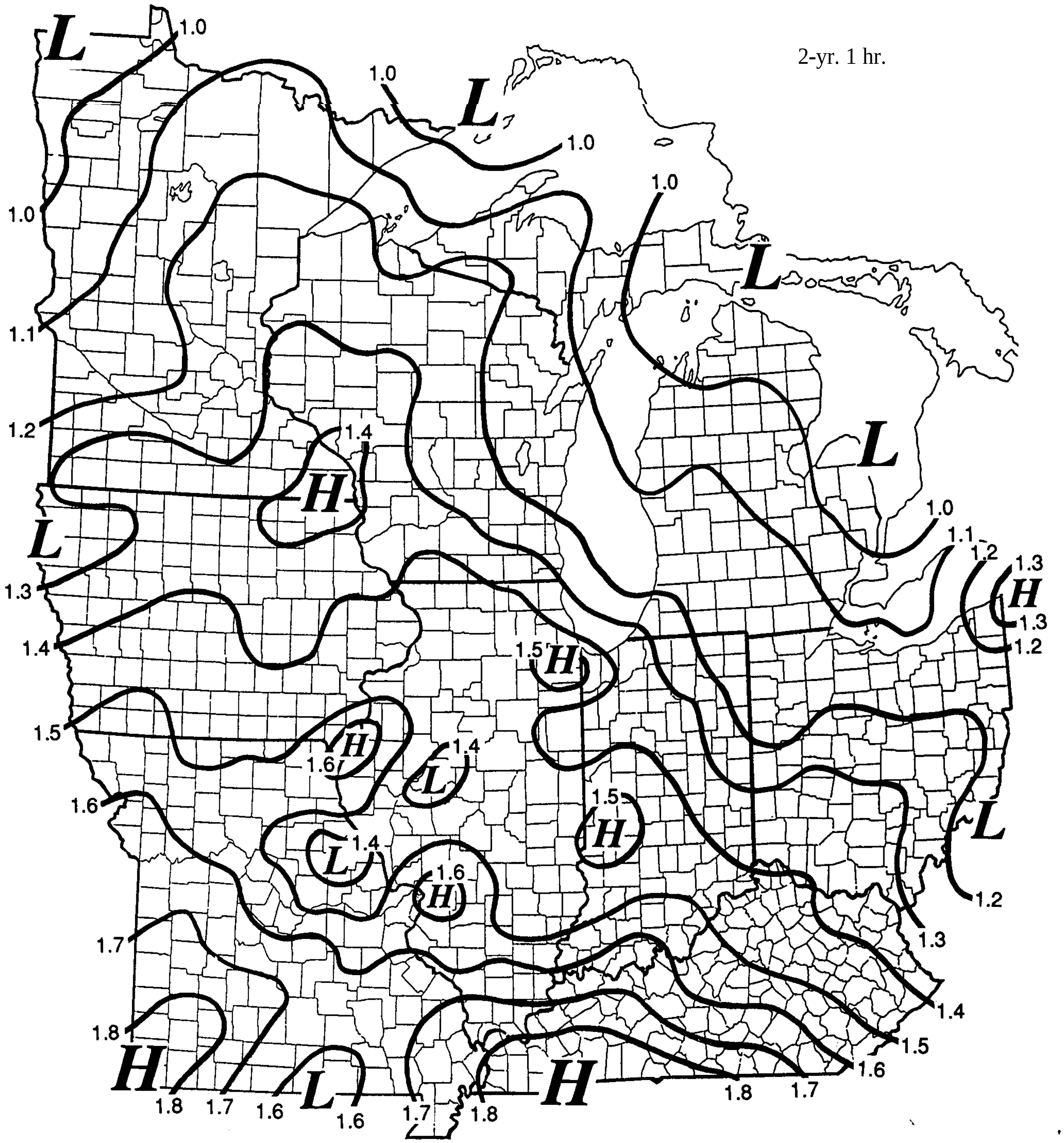
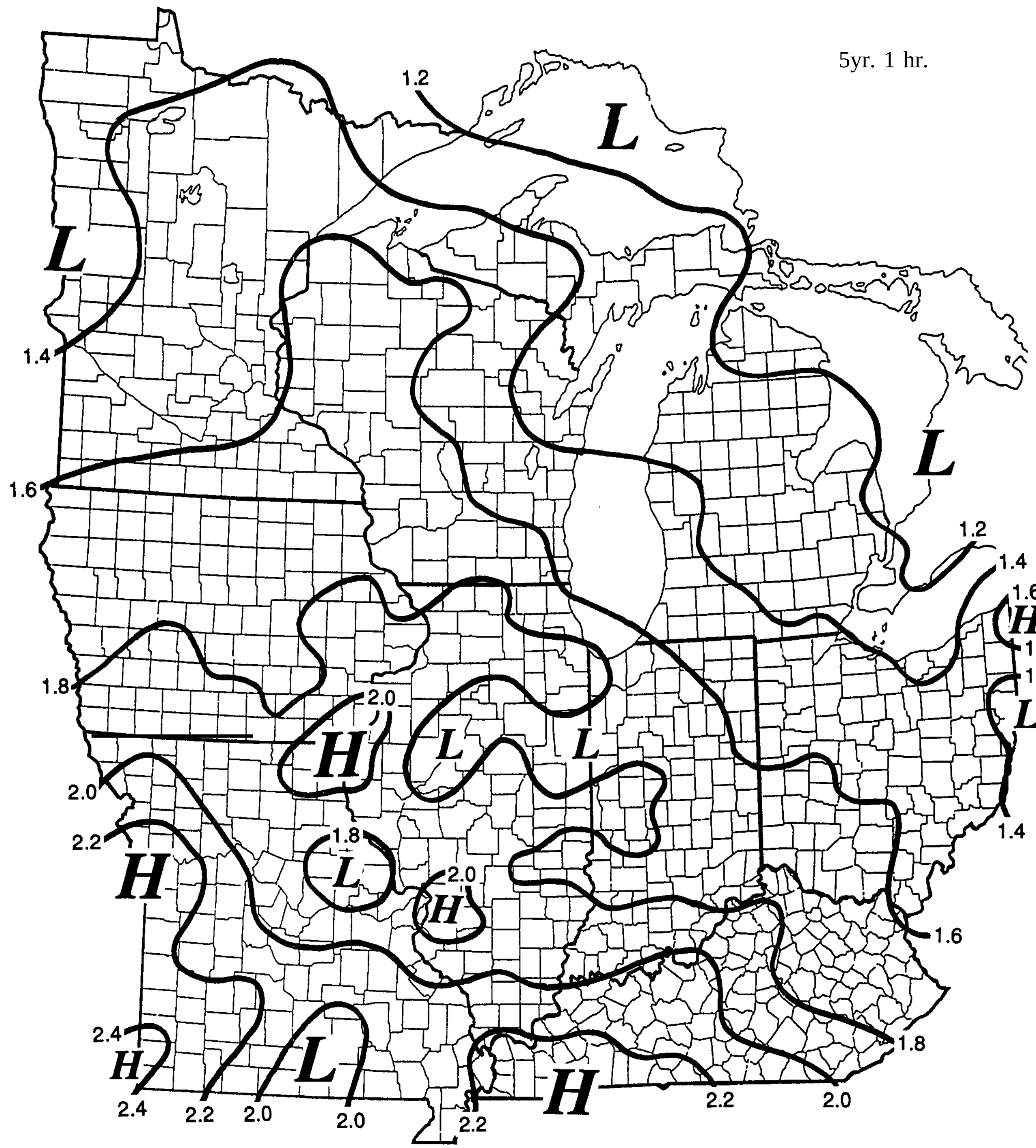


Figure 1. Spatial distribution of 1 -hour rainfall (inches)



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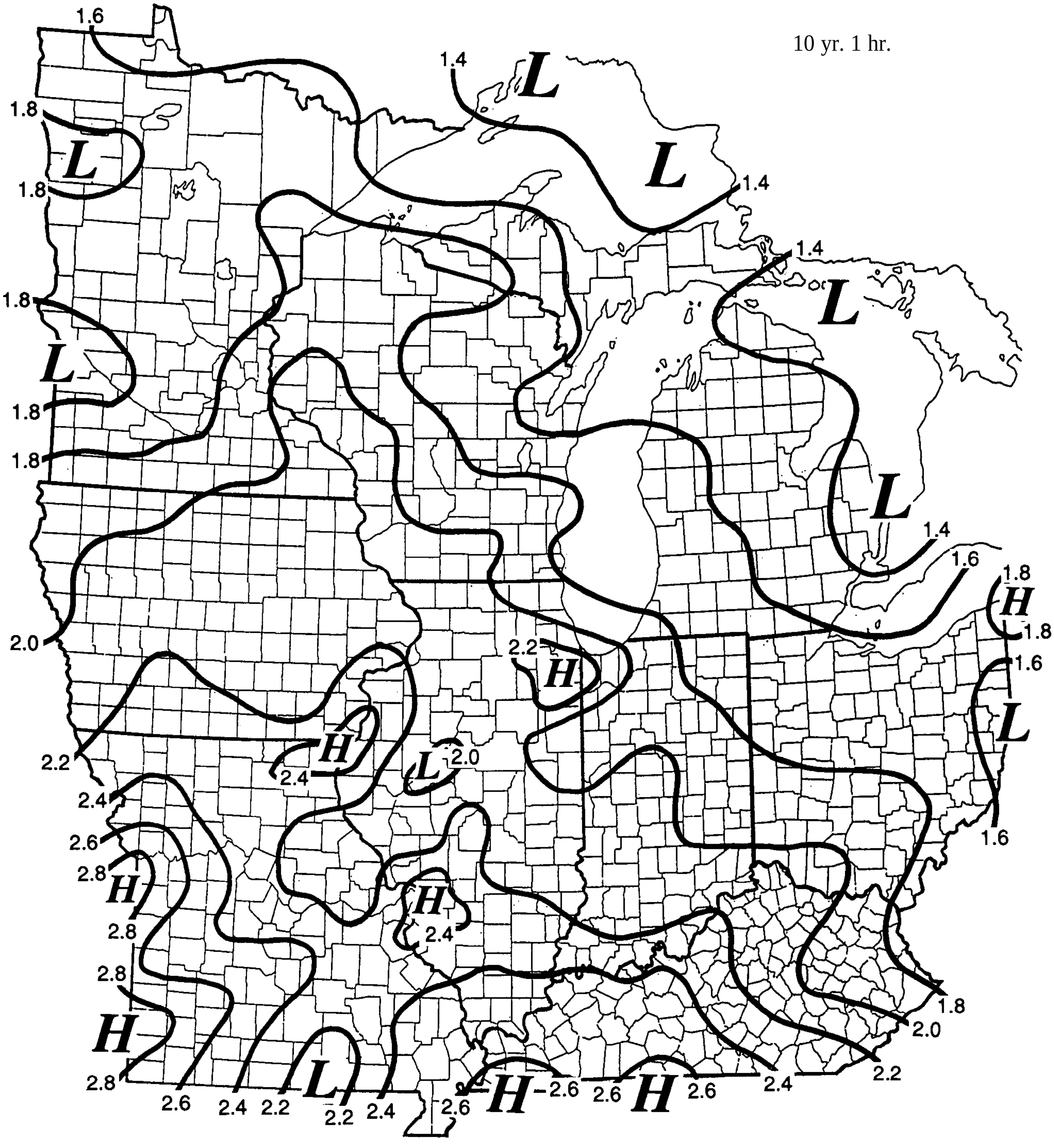

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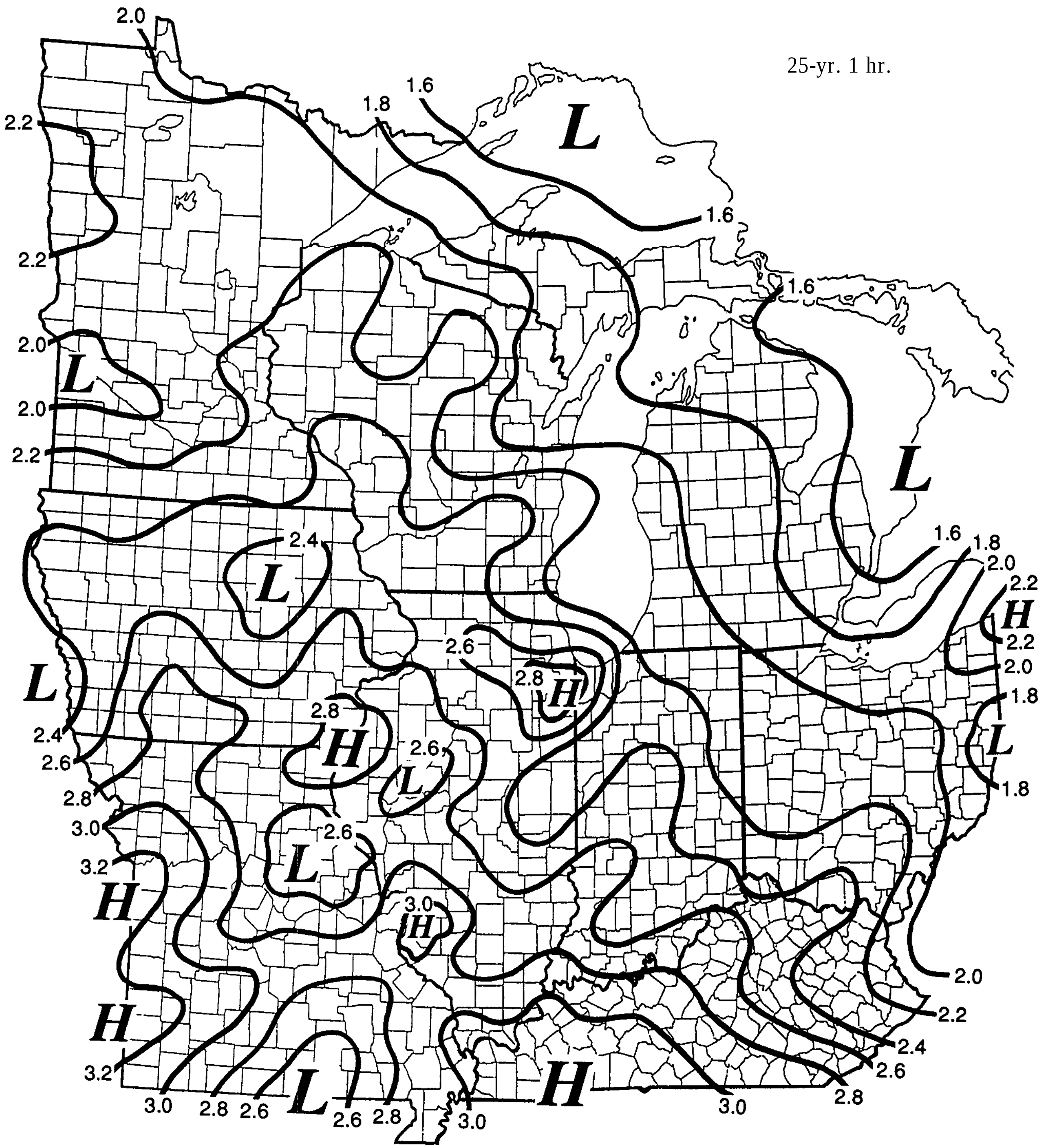

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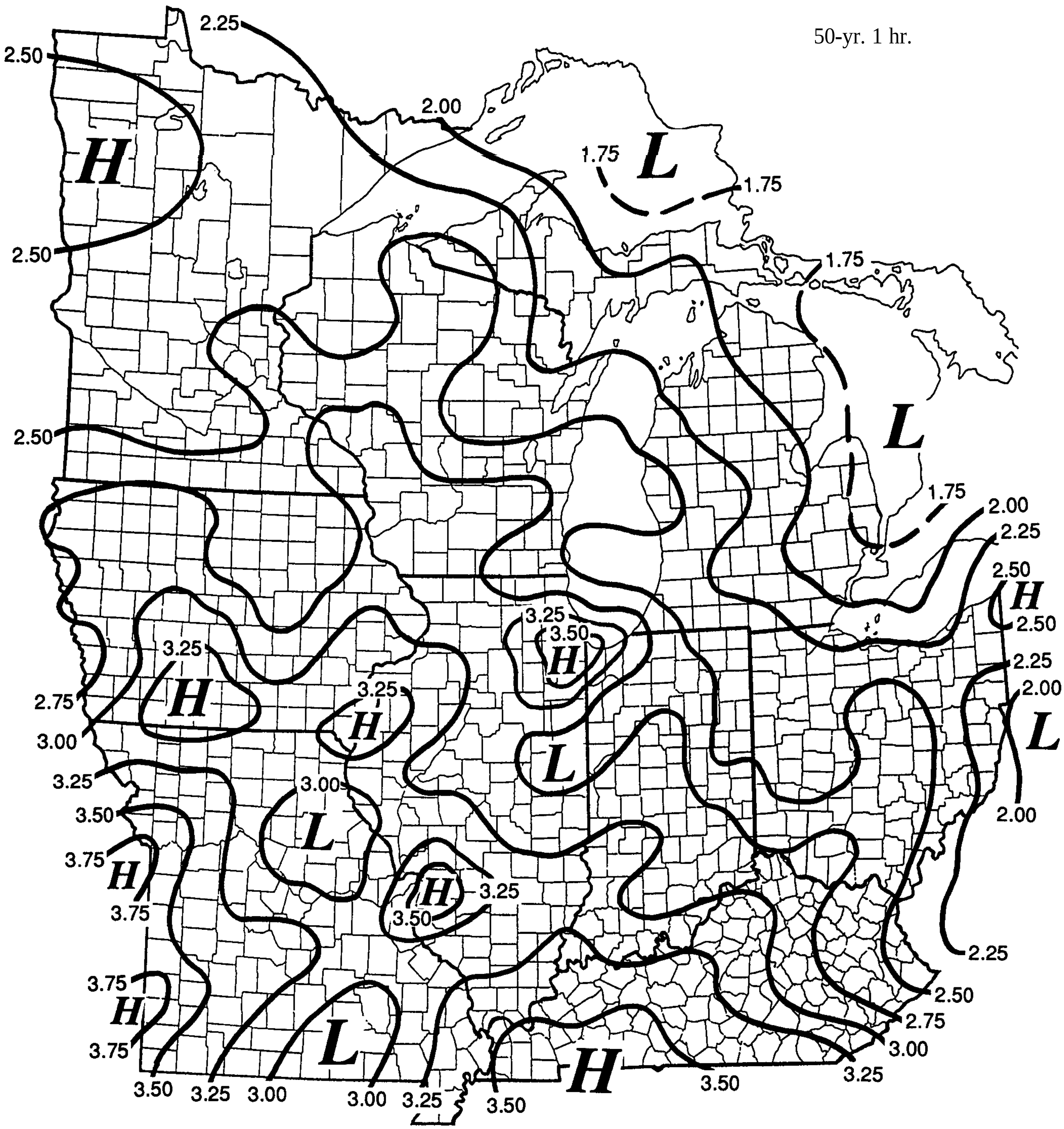
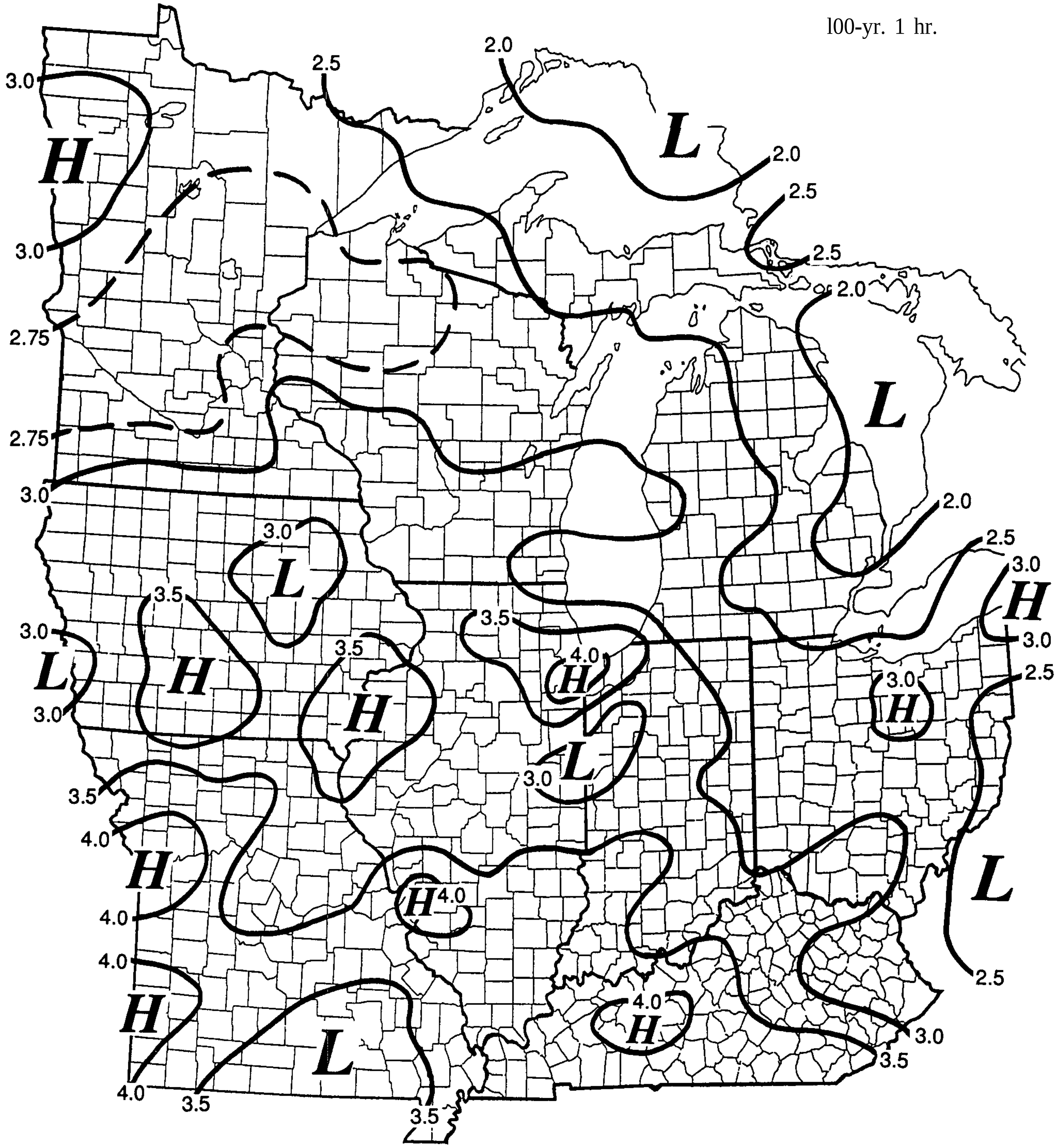


Figure 1. Continued

Correction: the 3.25 and 3.50 inch contours in northeastern Illinois should be 3.00 and 3.25 inches respectively.



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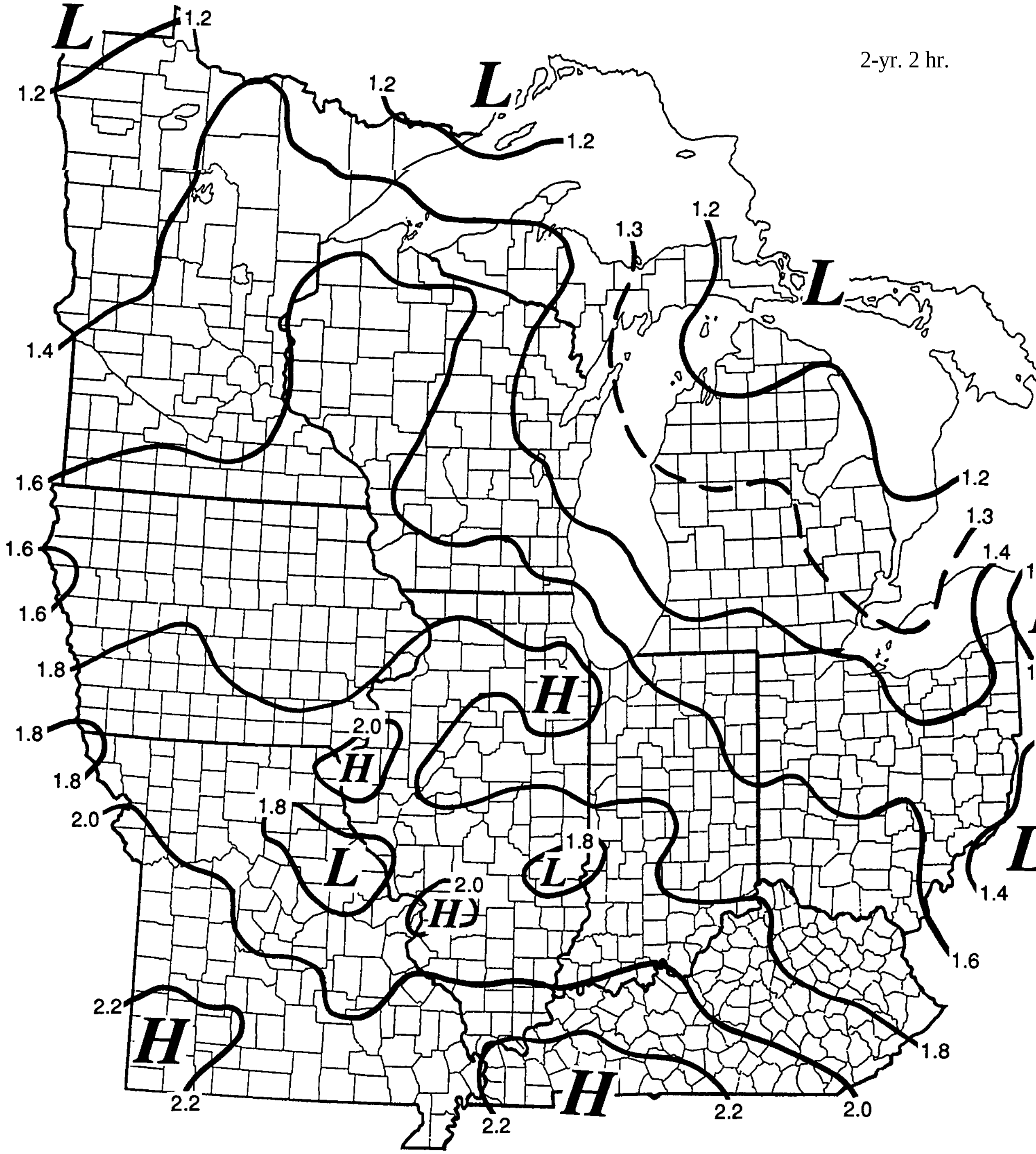
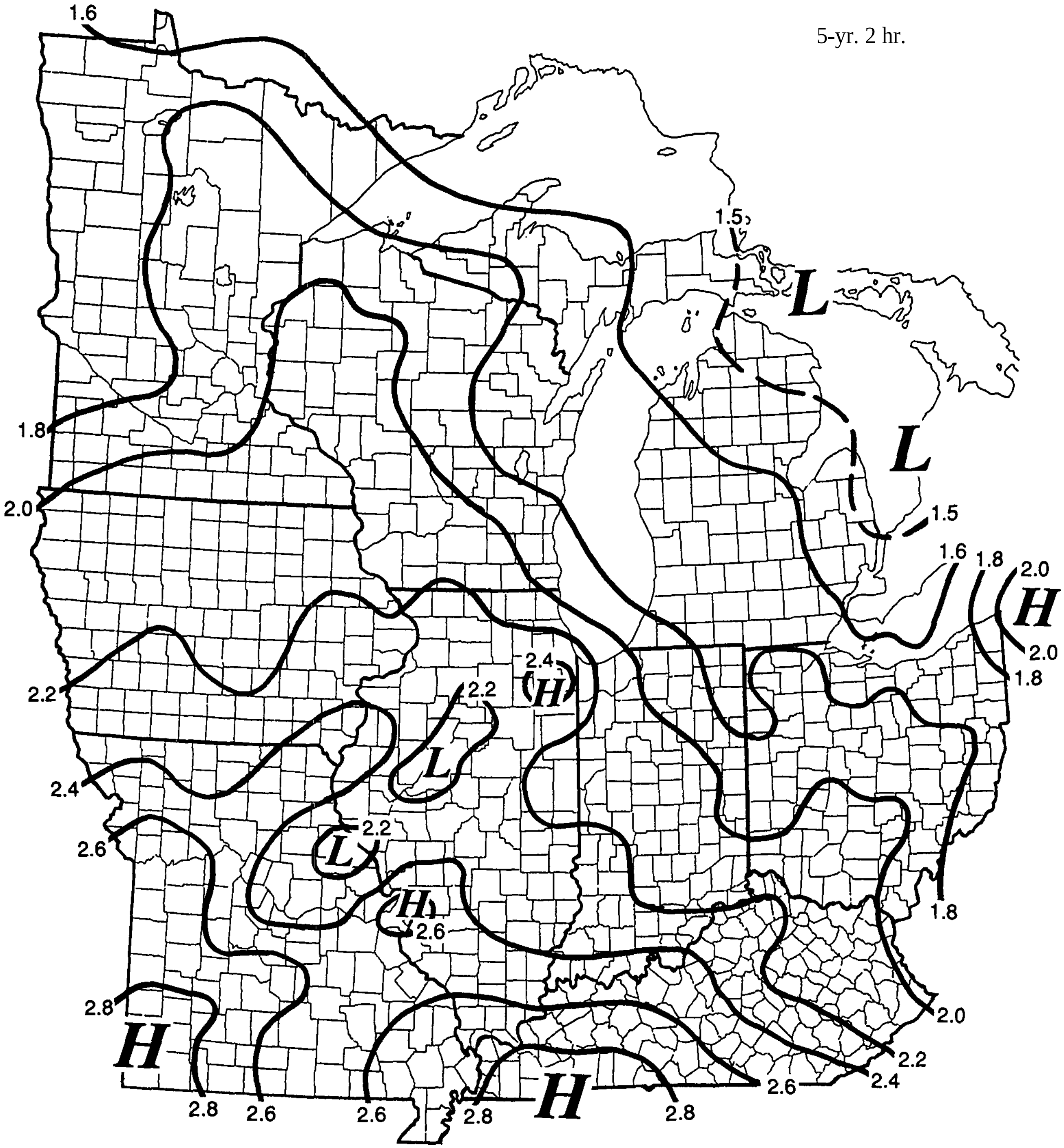


Figure 2. Spatial distribution of 2-hour rainfall (inches)



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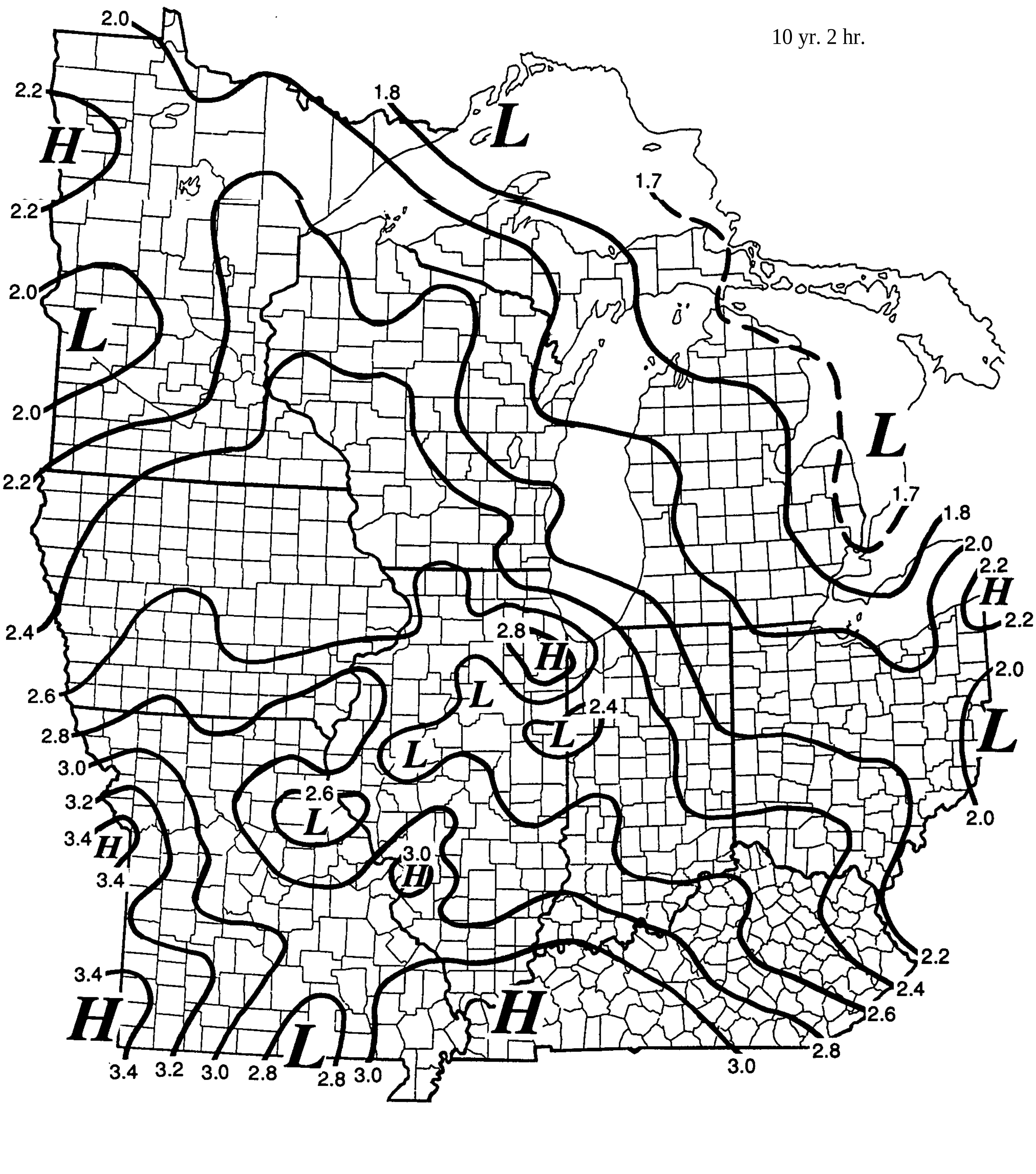

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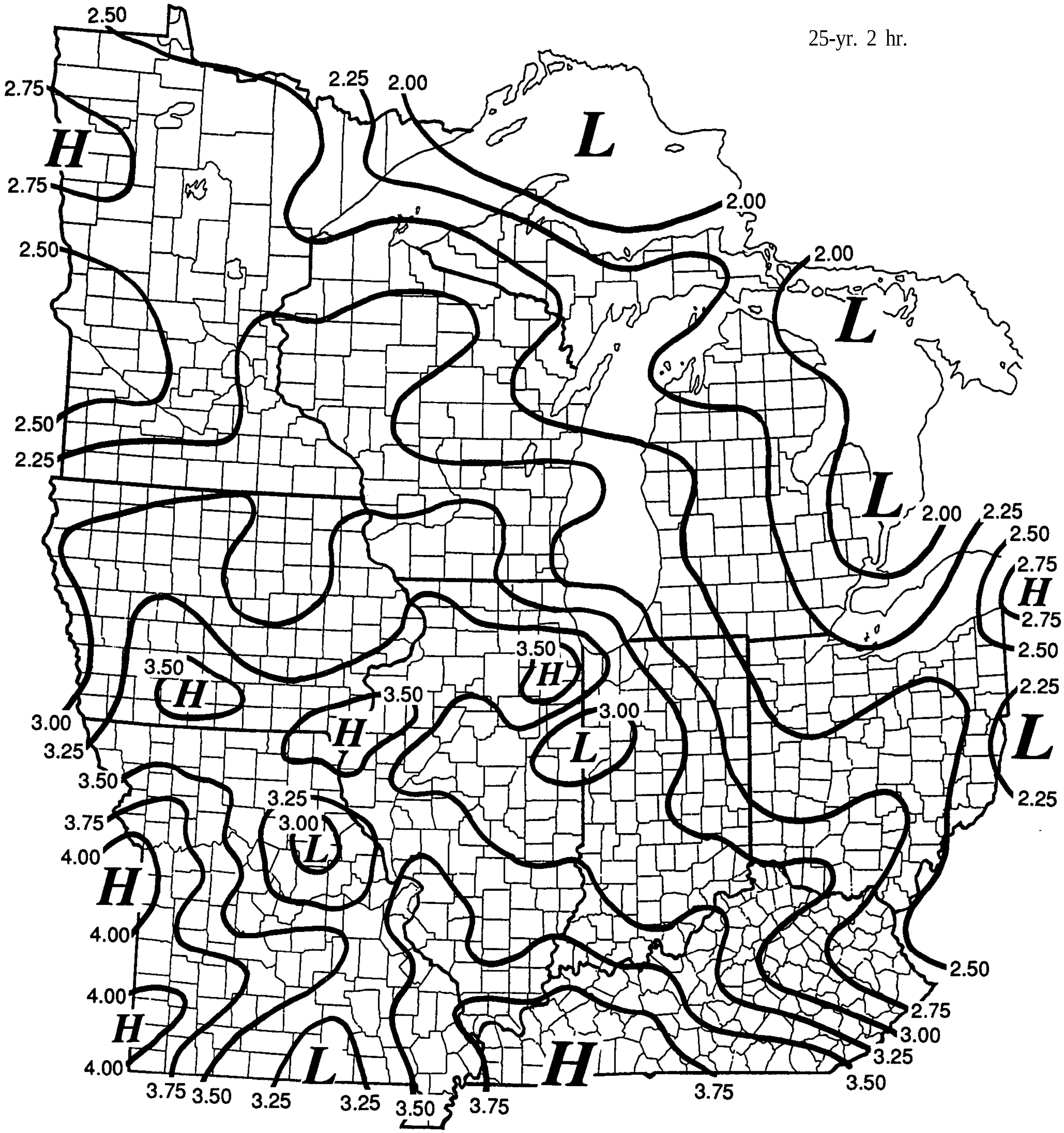

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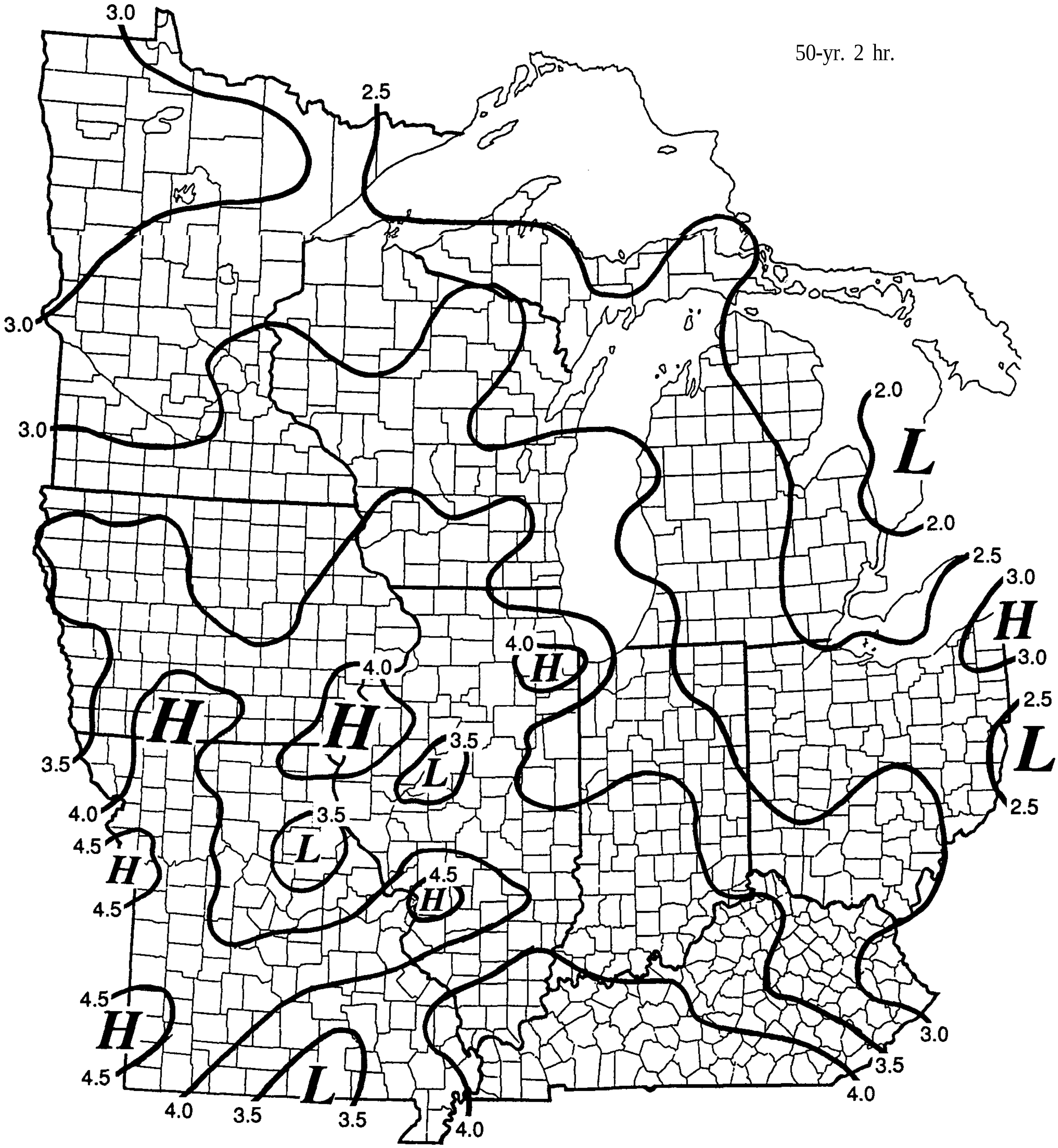

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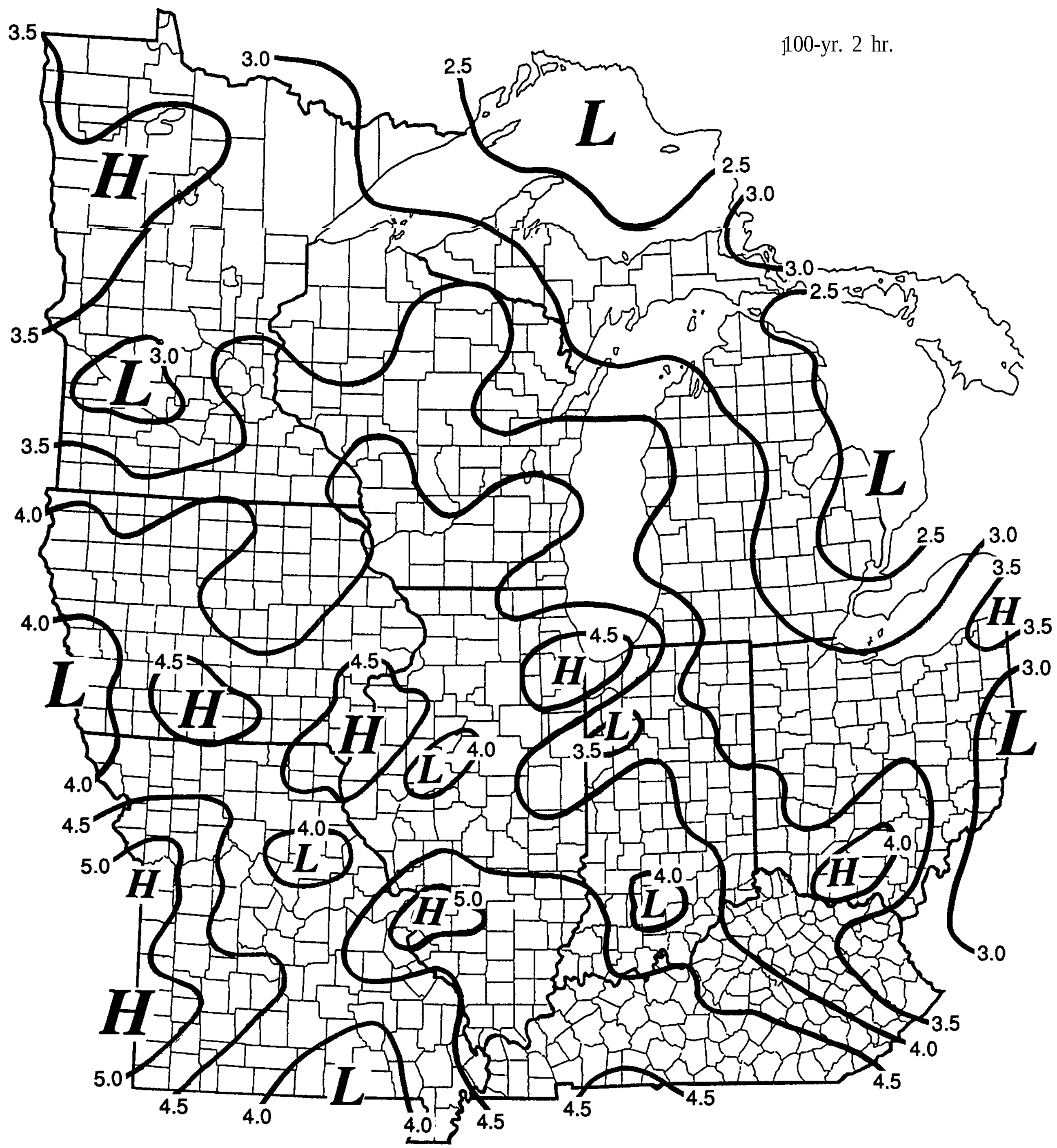

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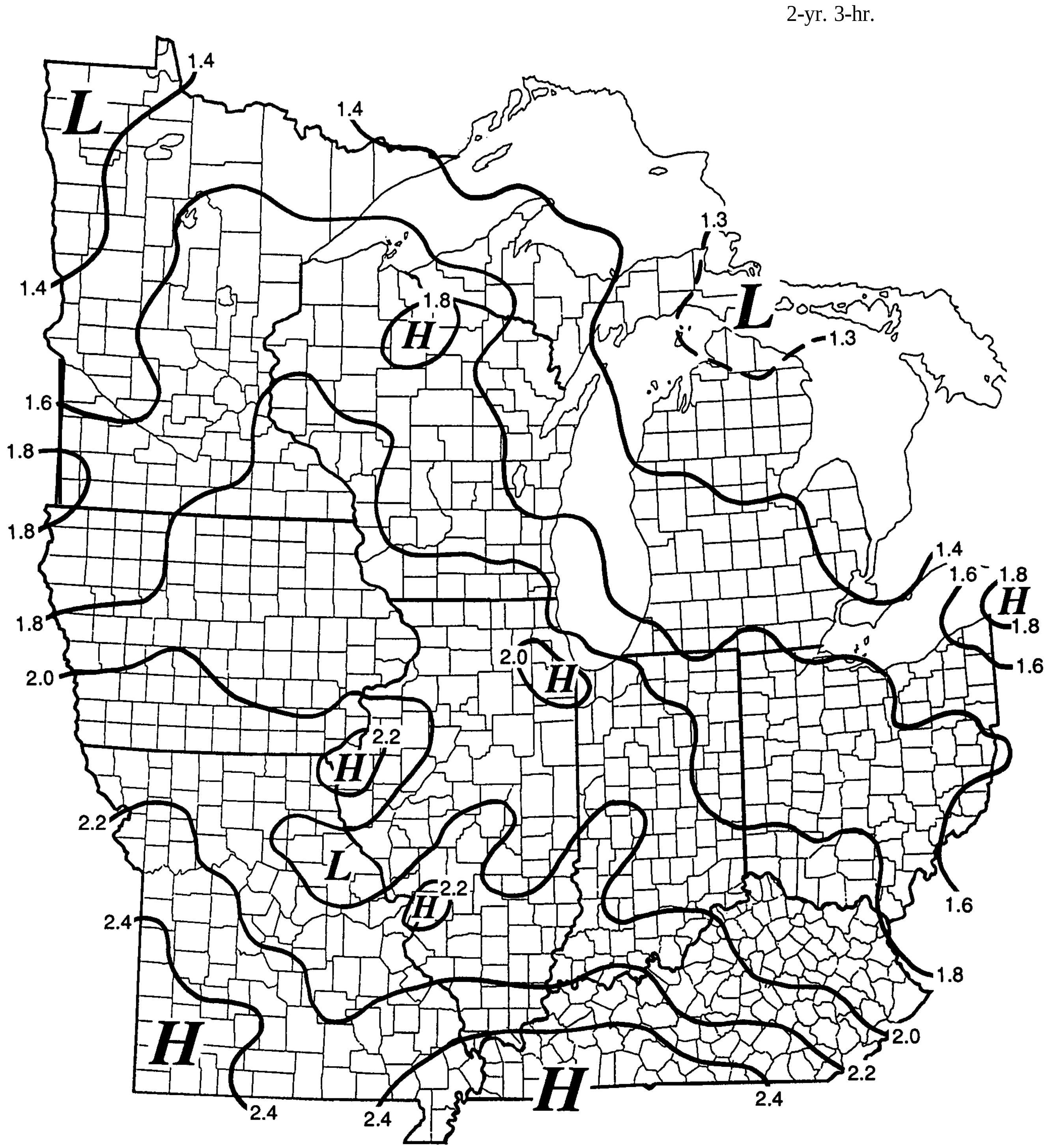
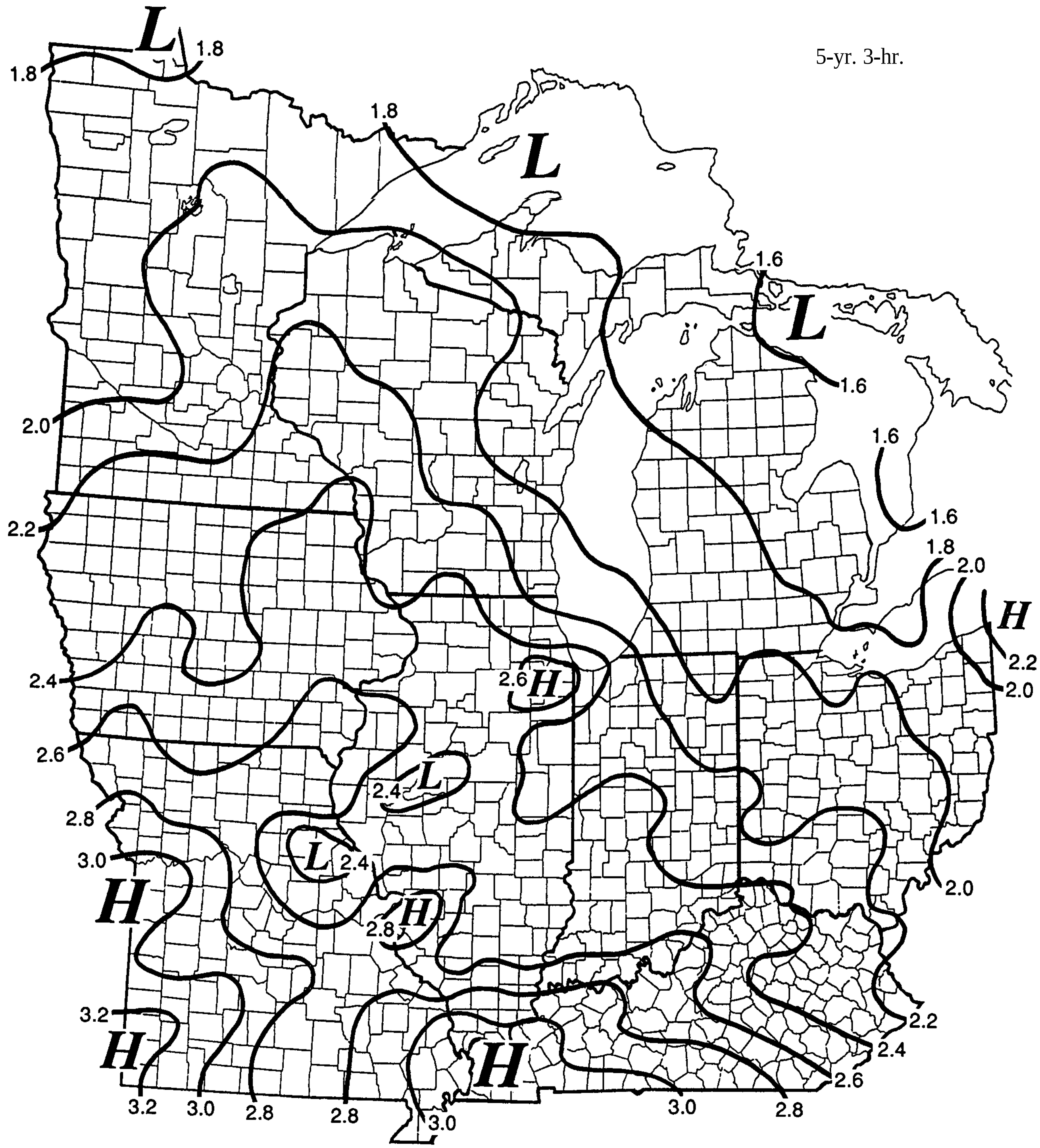


Figure 3. Spatial distribution of 3-hour rainfall (inches)



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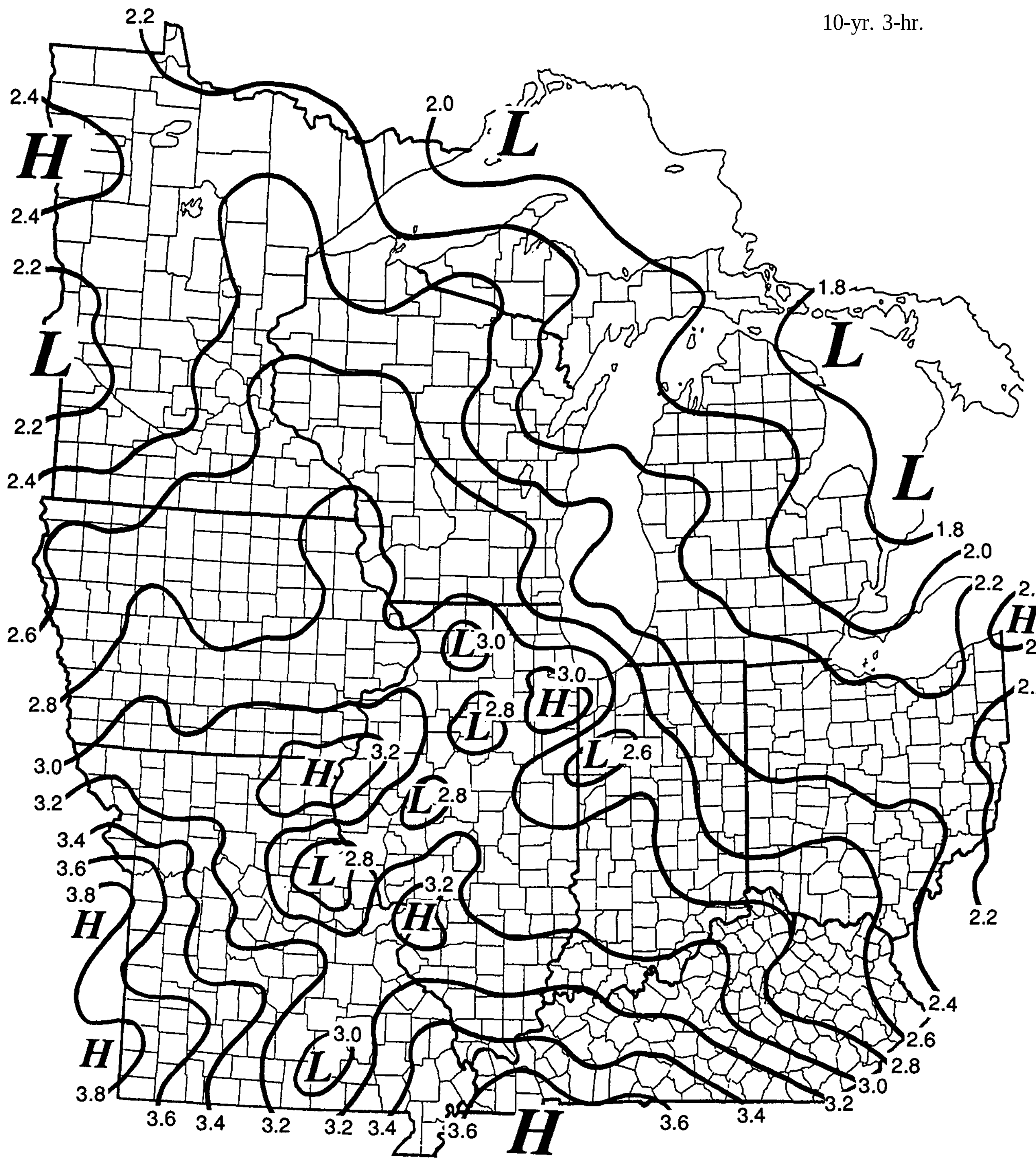

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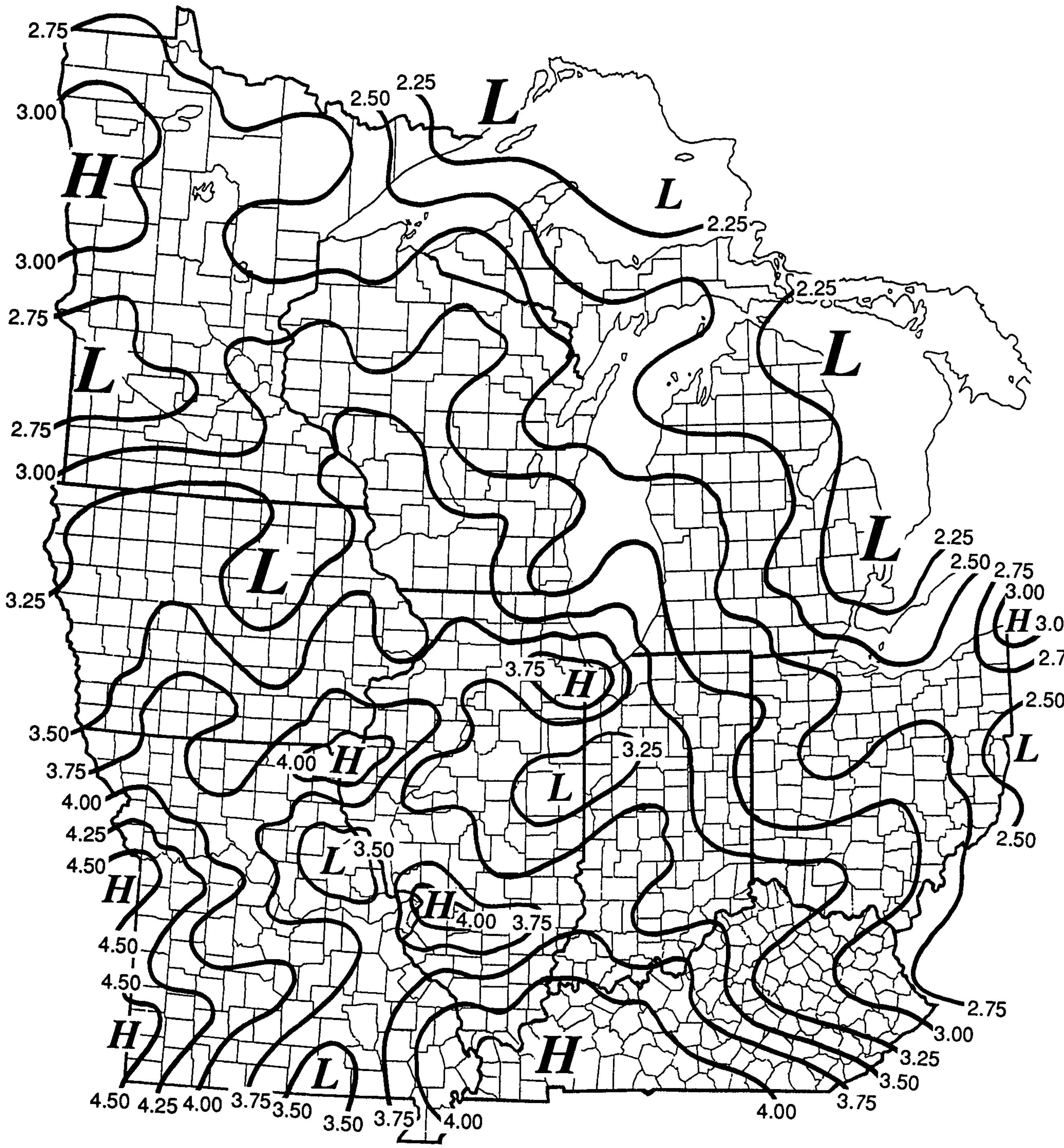
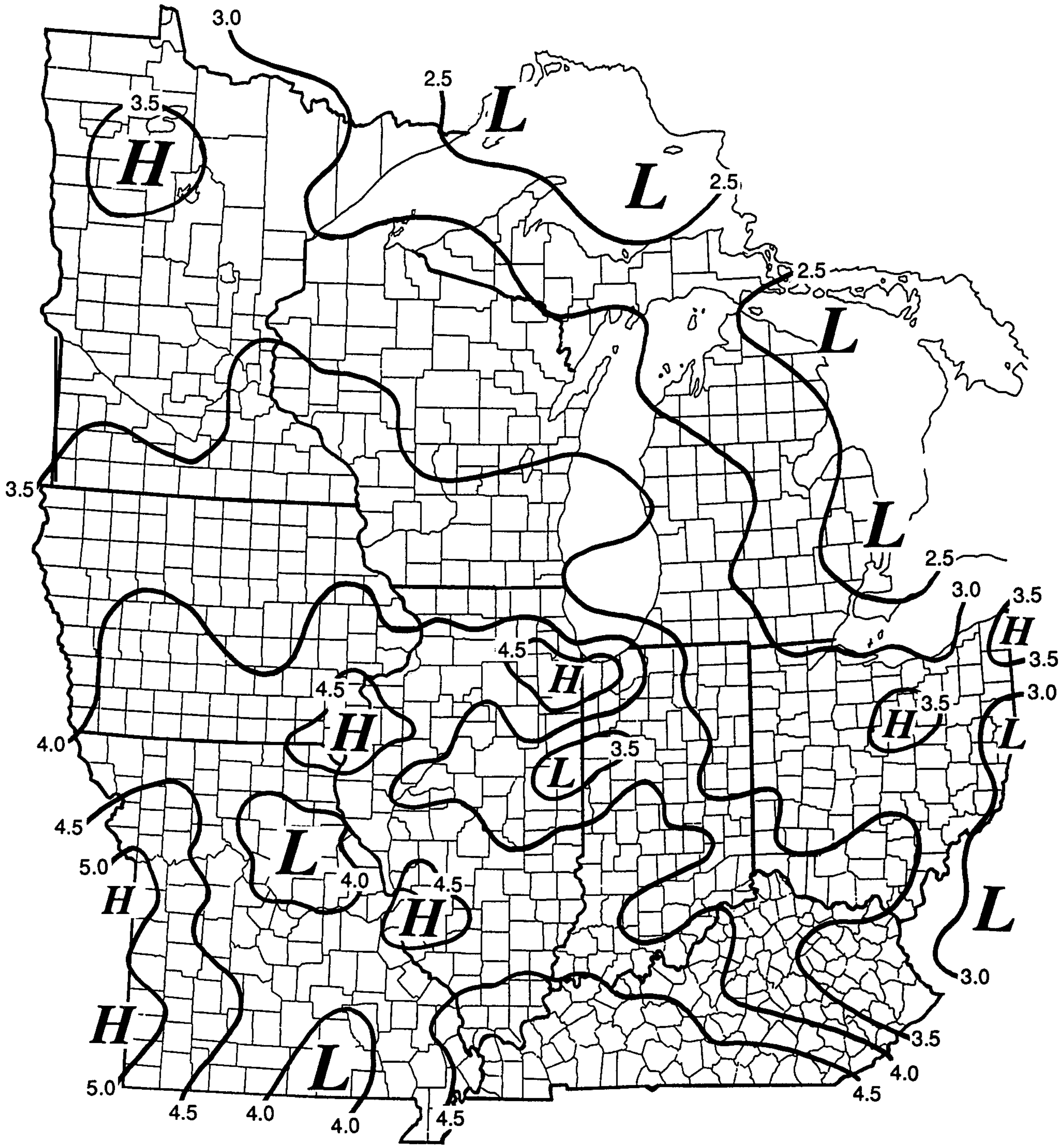


Figure 3. Continued

50-yr. 3-hr.



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100-yr. 3-hr.

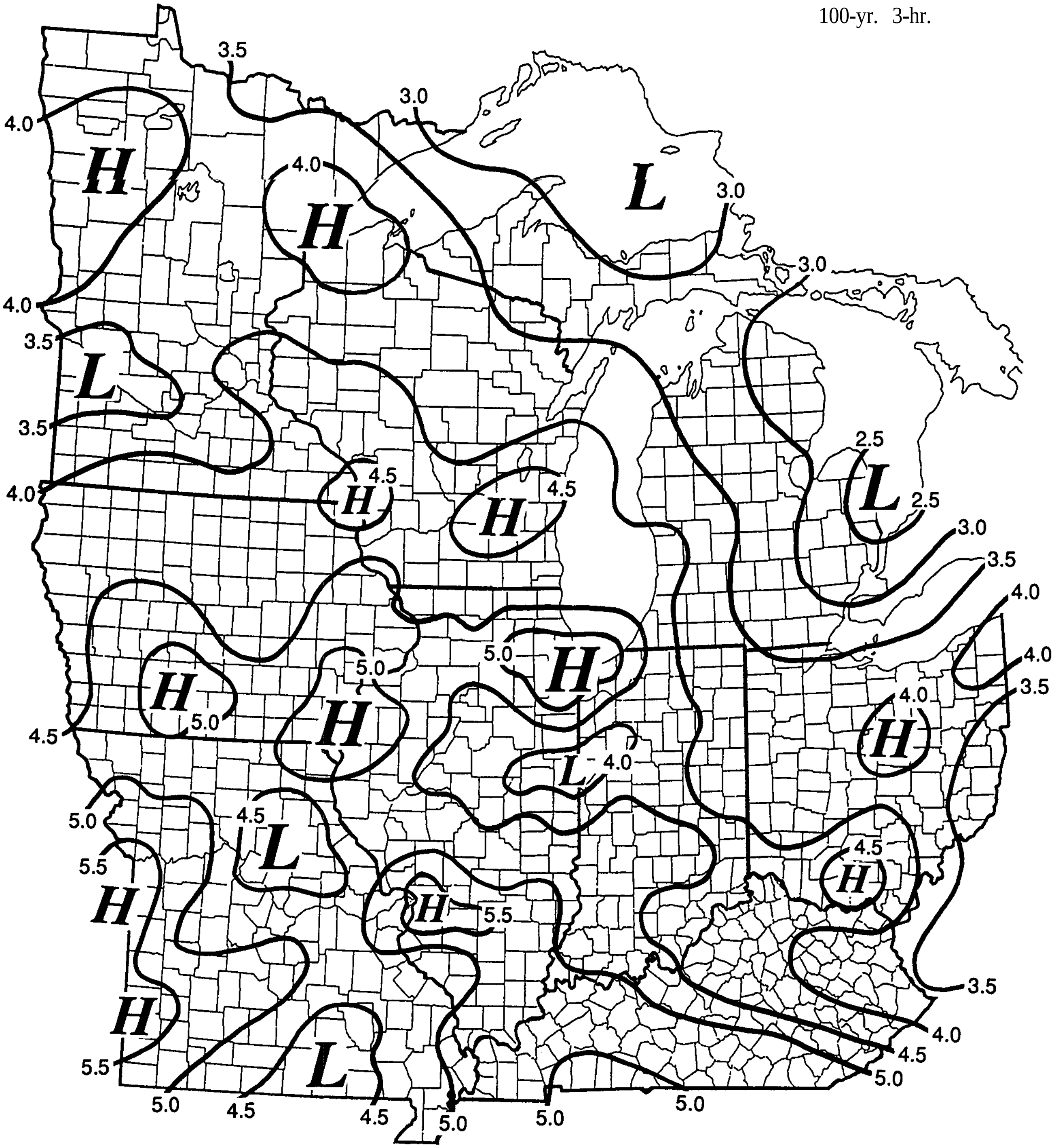


Figure 3. Concluded

2-yr. 6-hr.

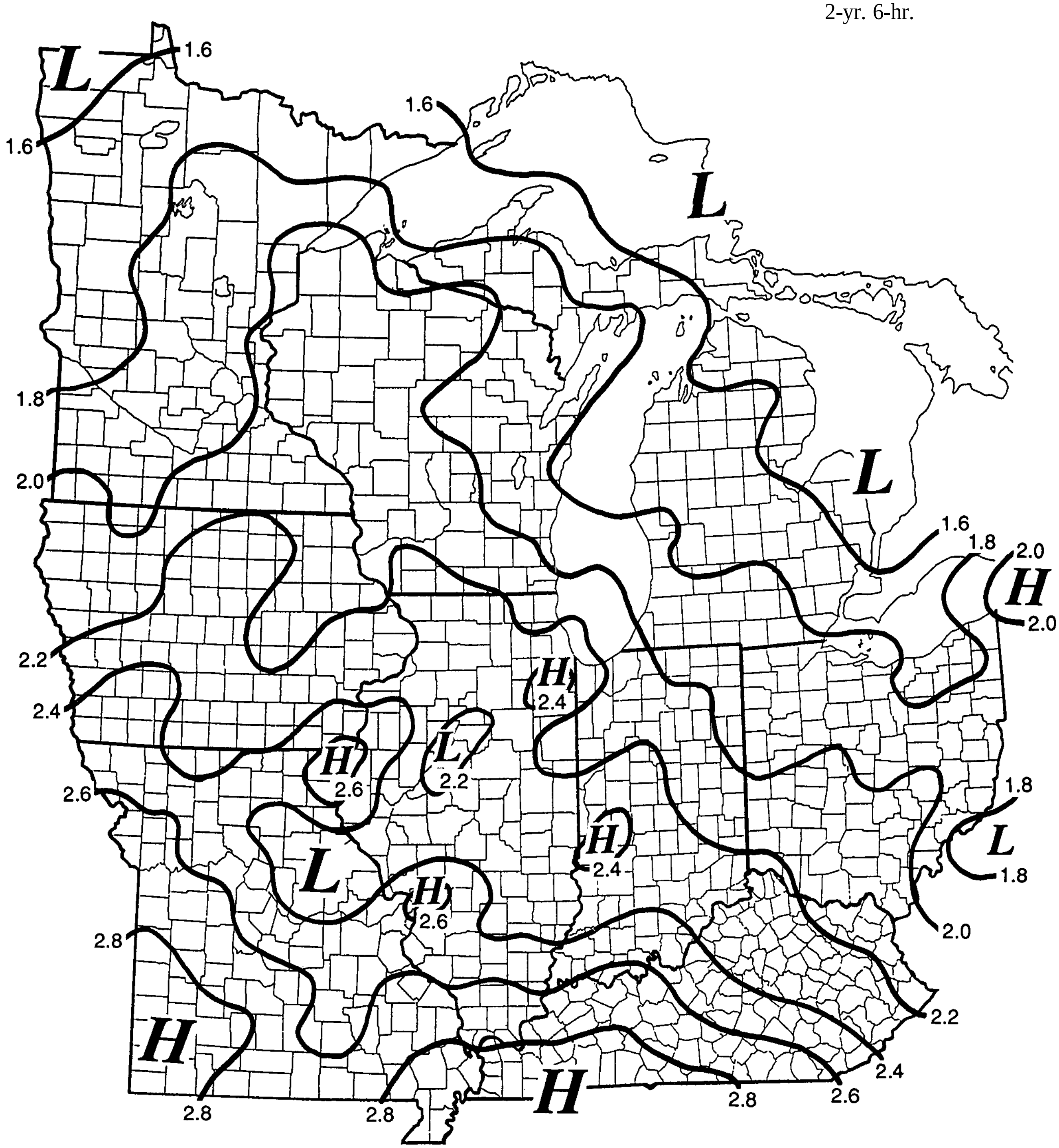
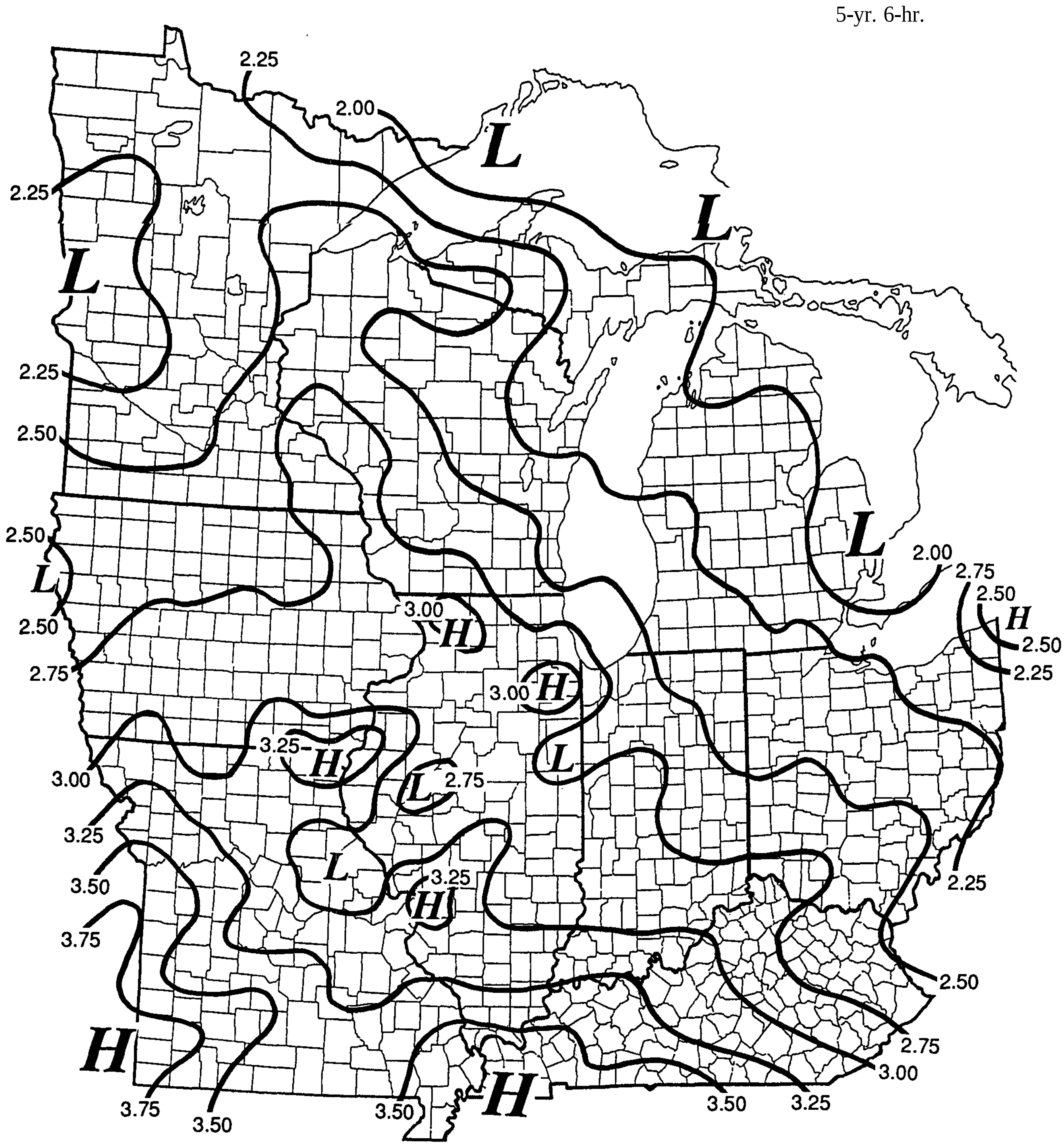


Figure 4. Spatial distribution of 6-hour rainfall (inches)



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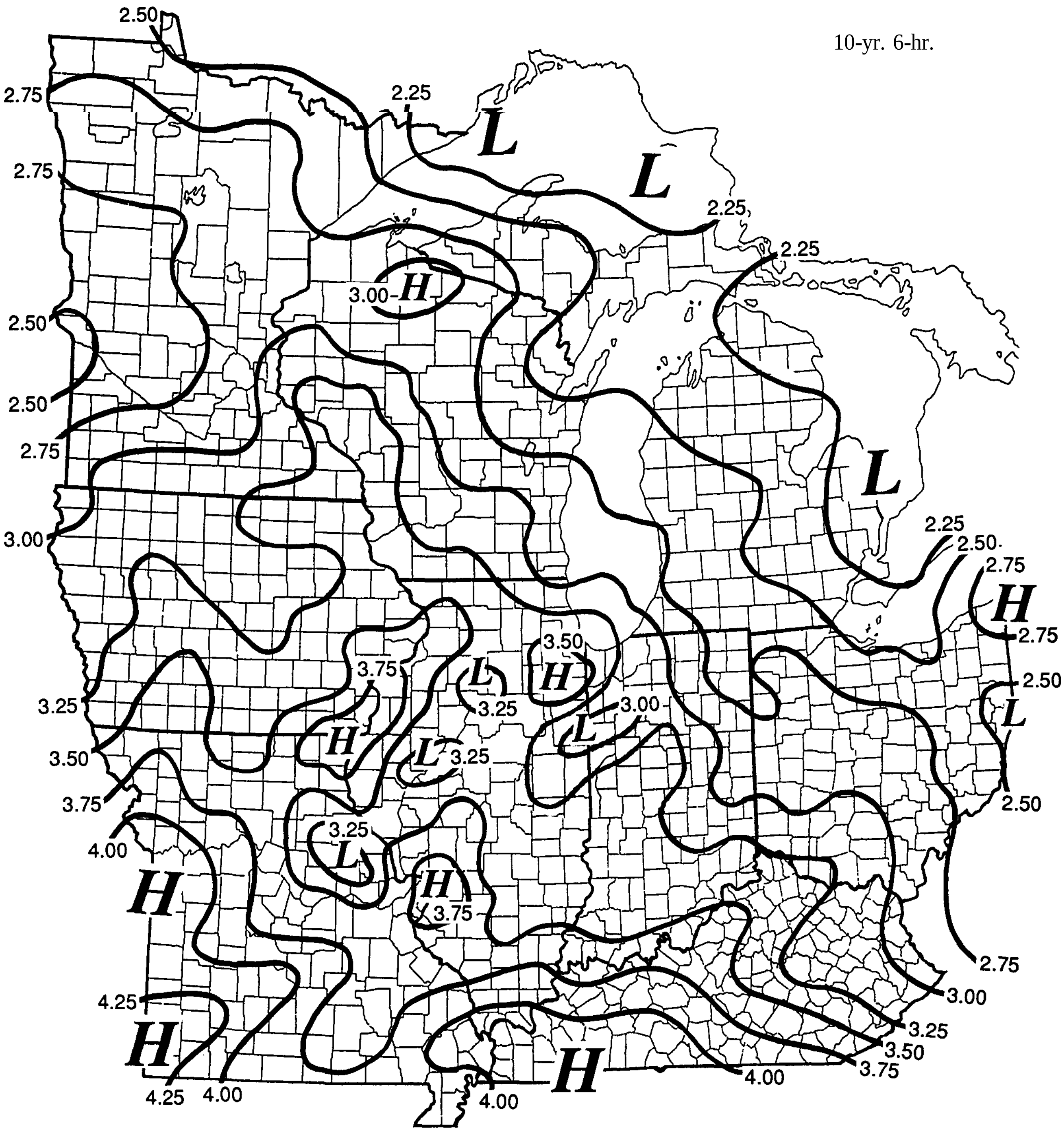
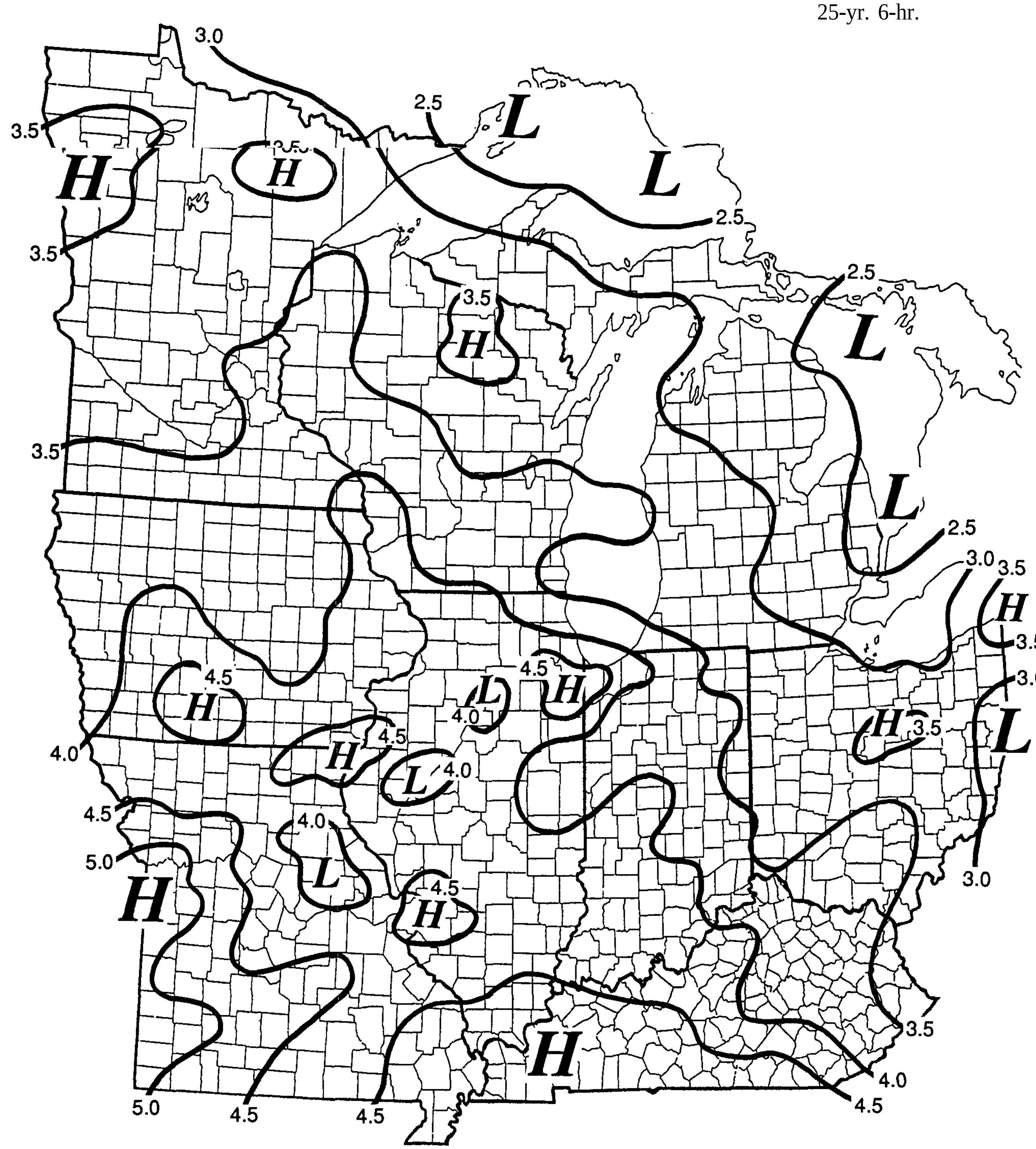


Figure 4. Continued

25-yr. 6-hr.



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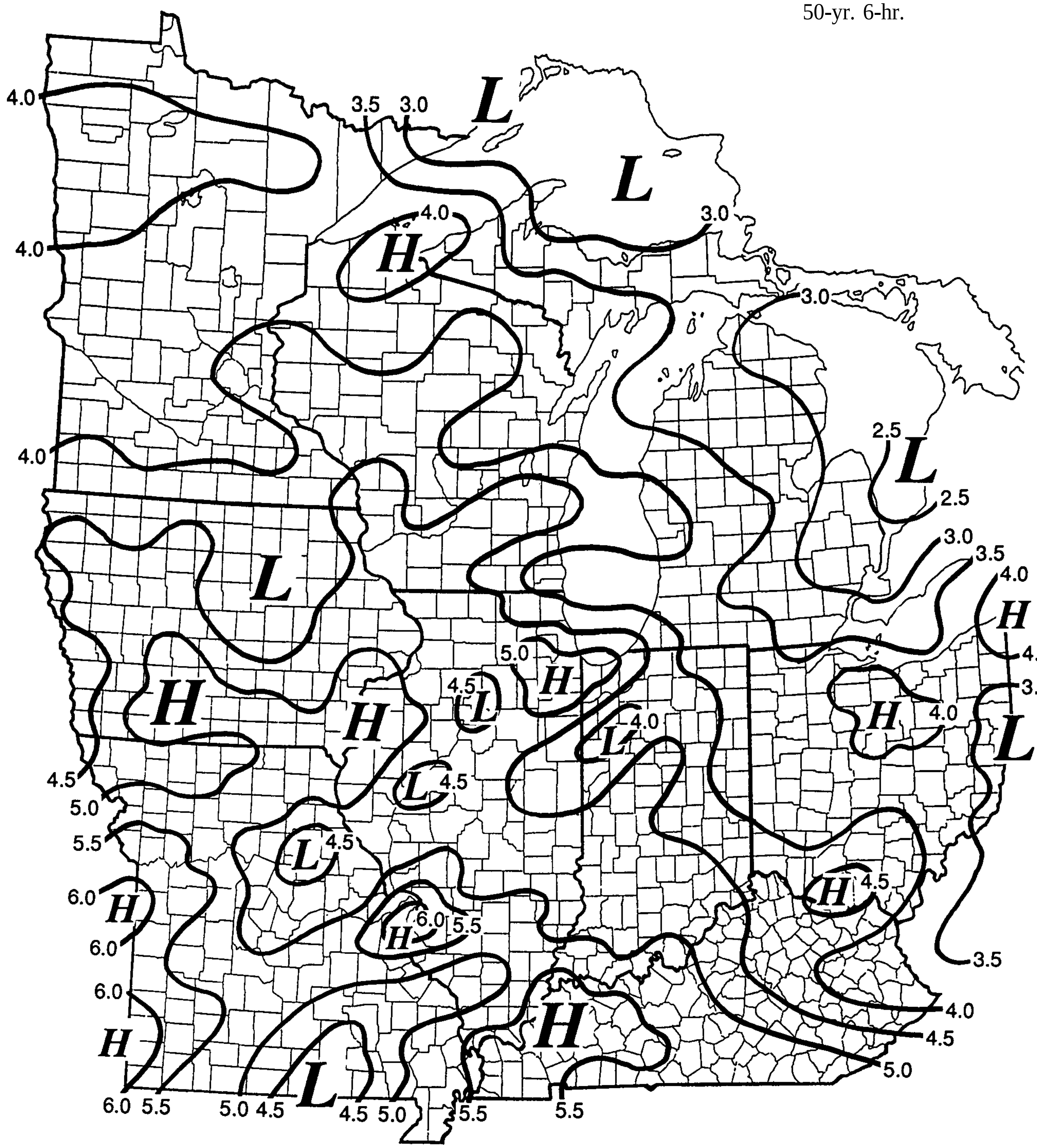
50-yr. 6-hr.



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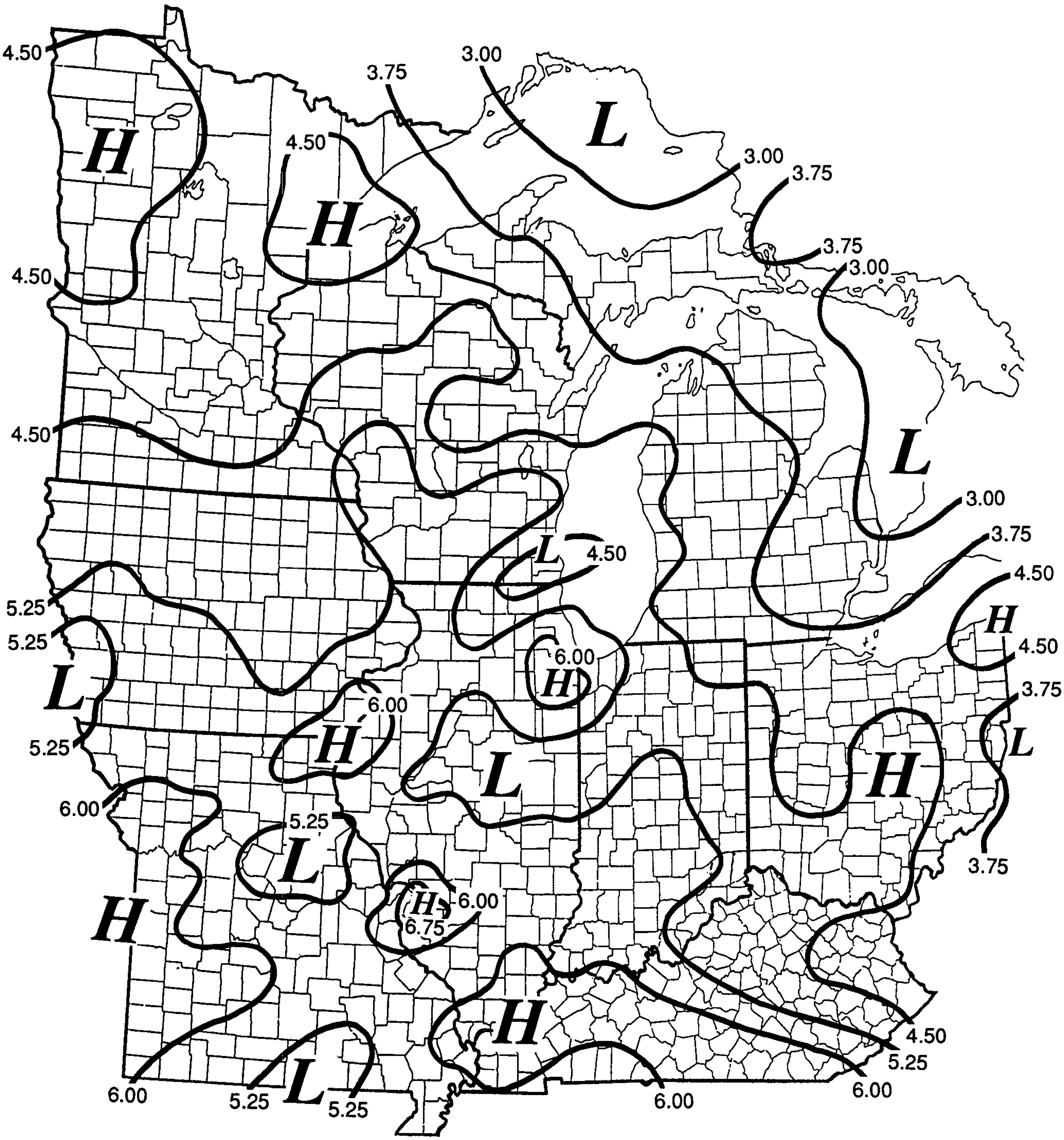


Figure 4. Concluded

2-yr. 12-hr.

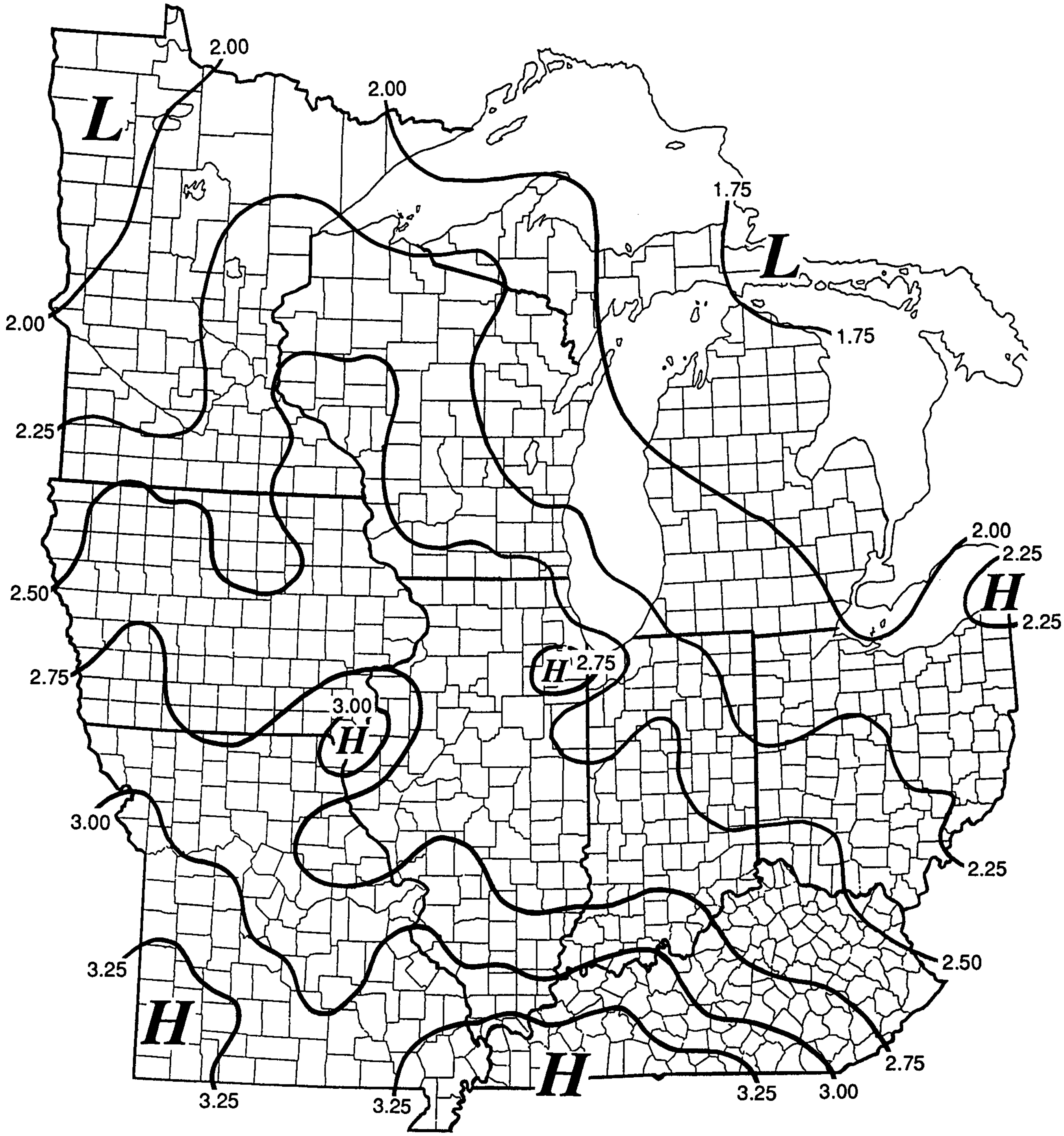
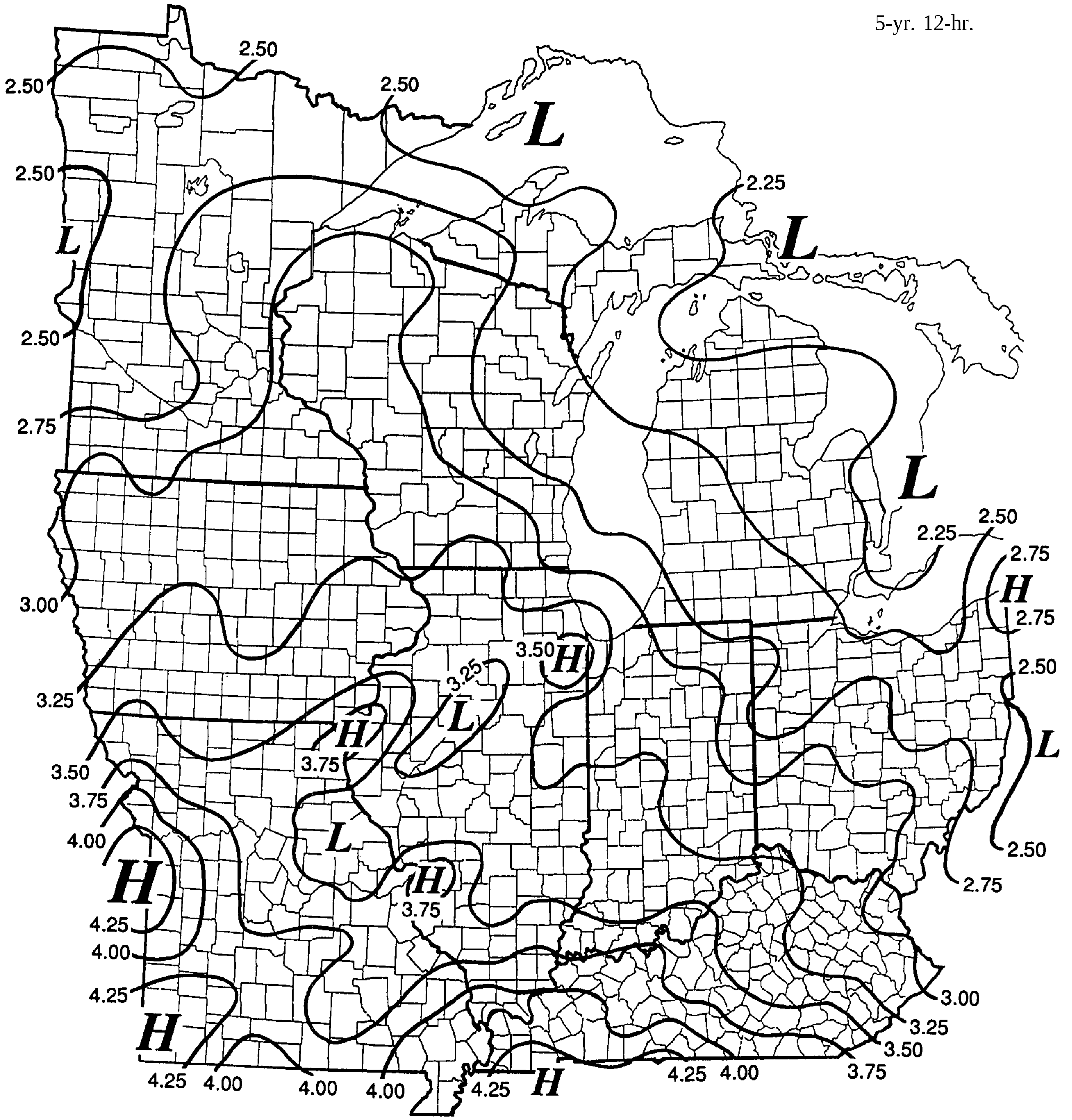


Figure 5. Spatial distribution of 12-hour rainfall (inches)



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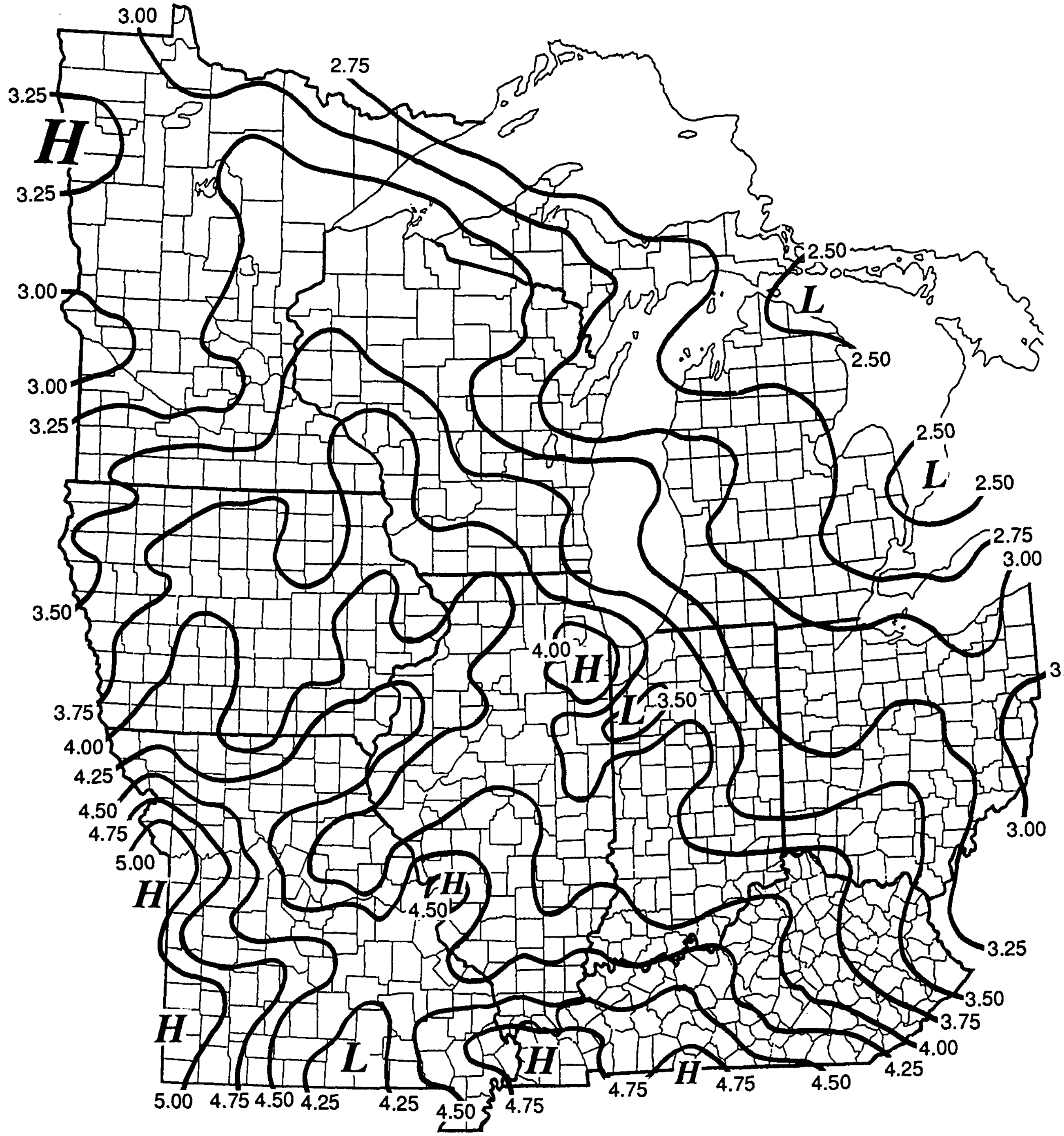

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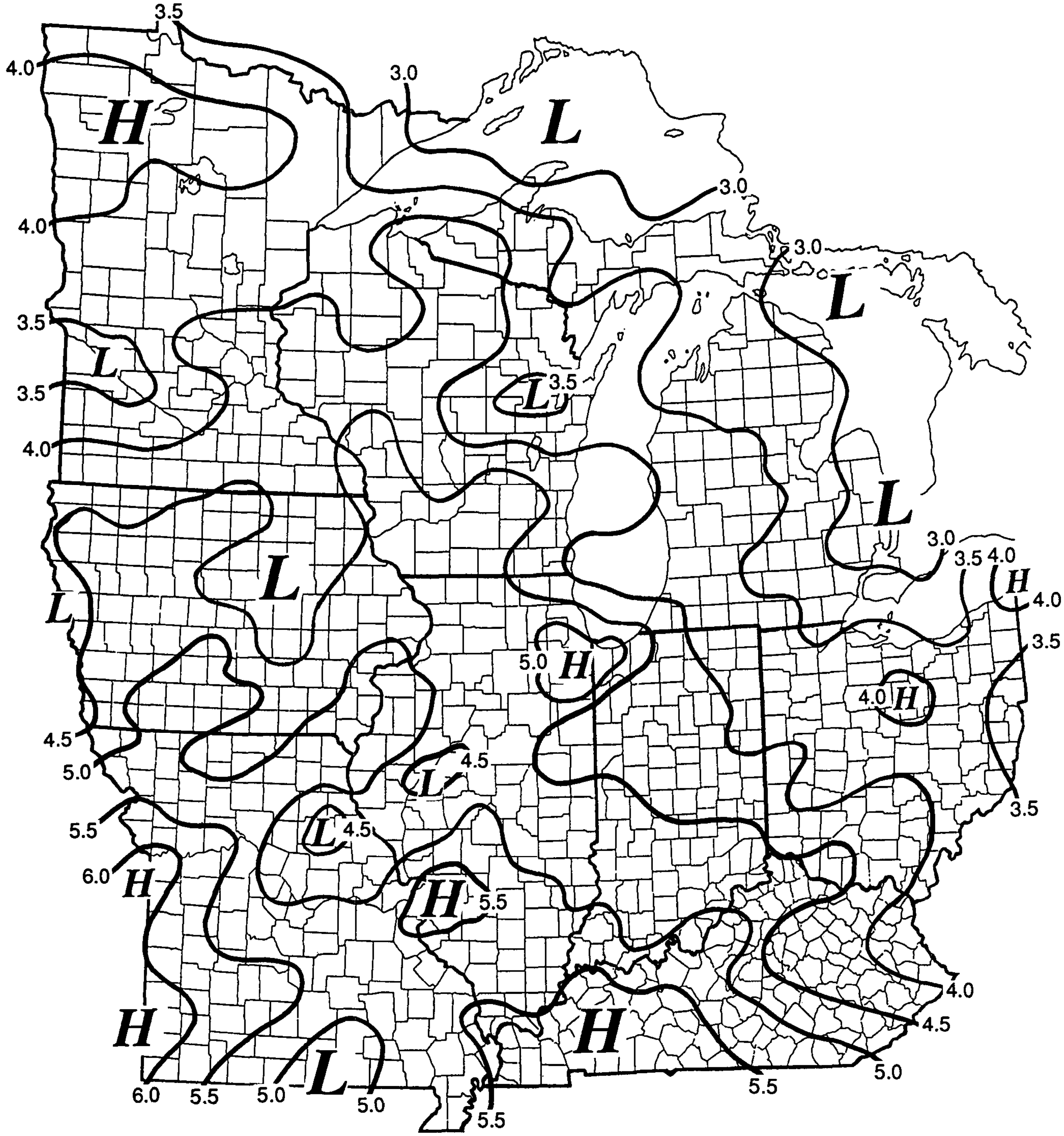

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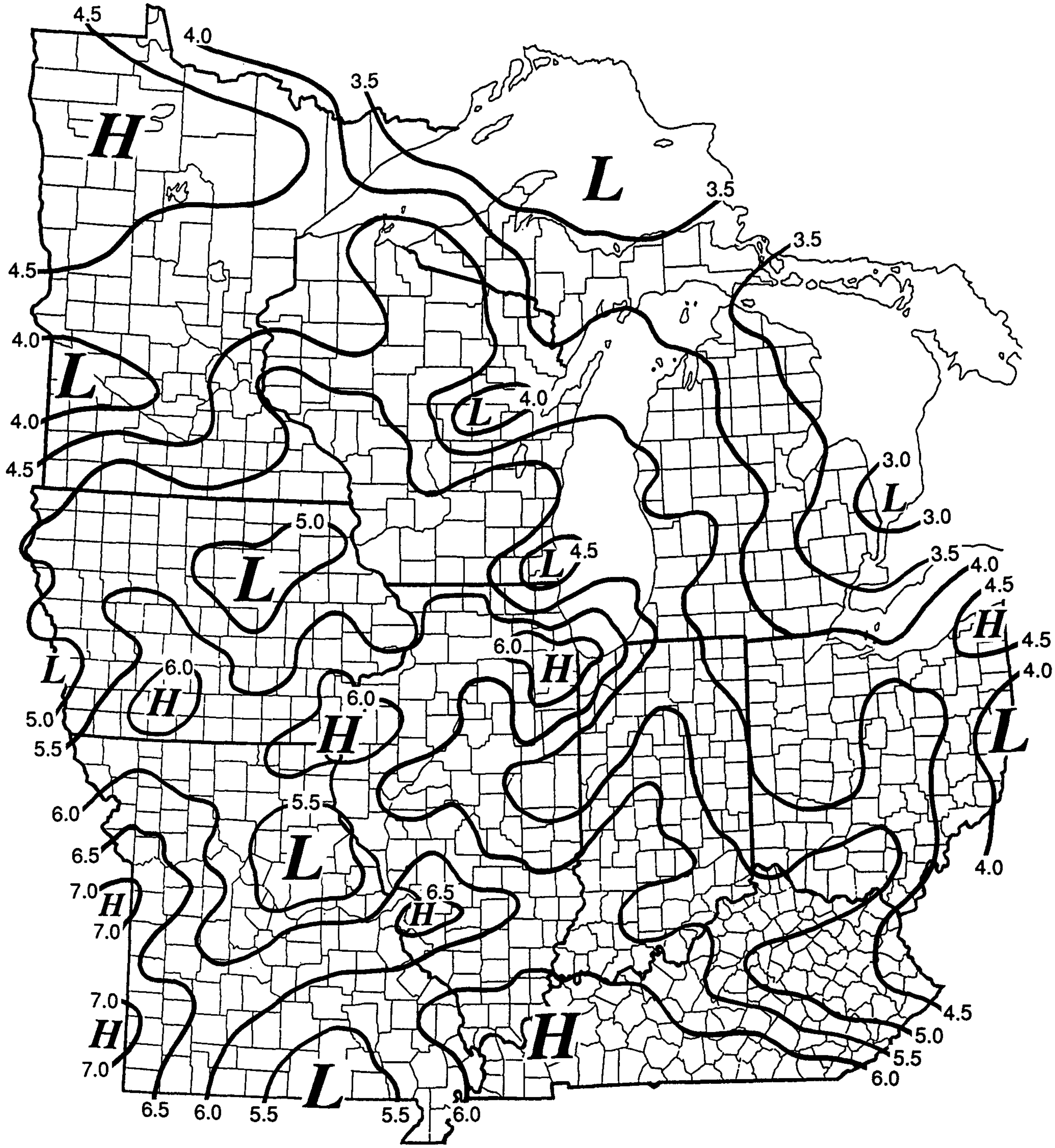
50-yr. 12-hr.



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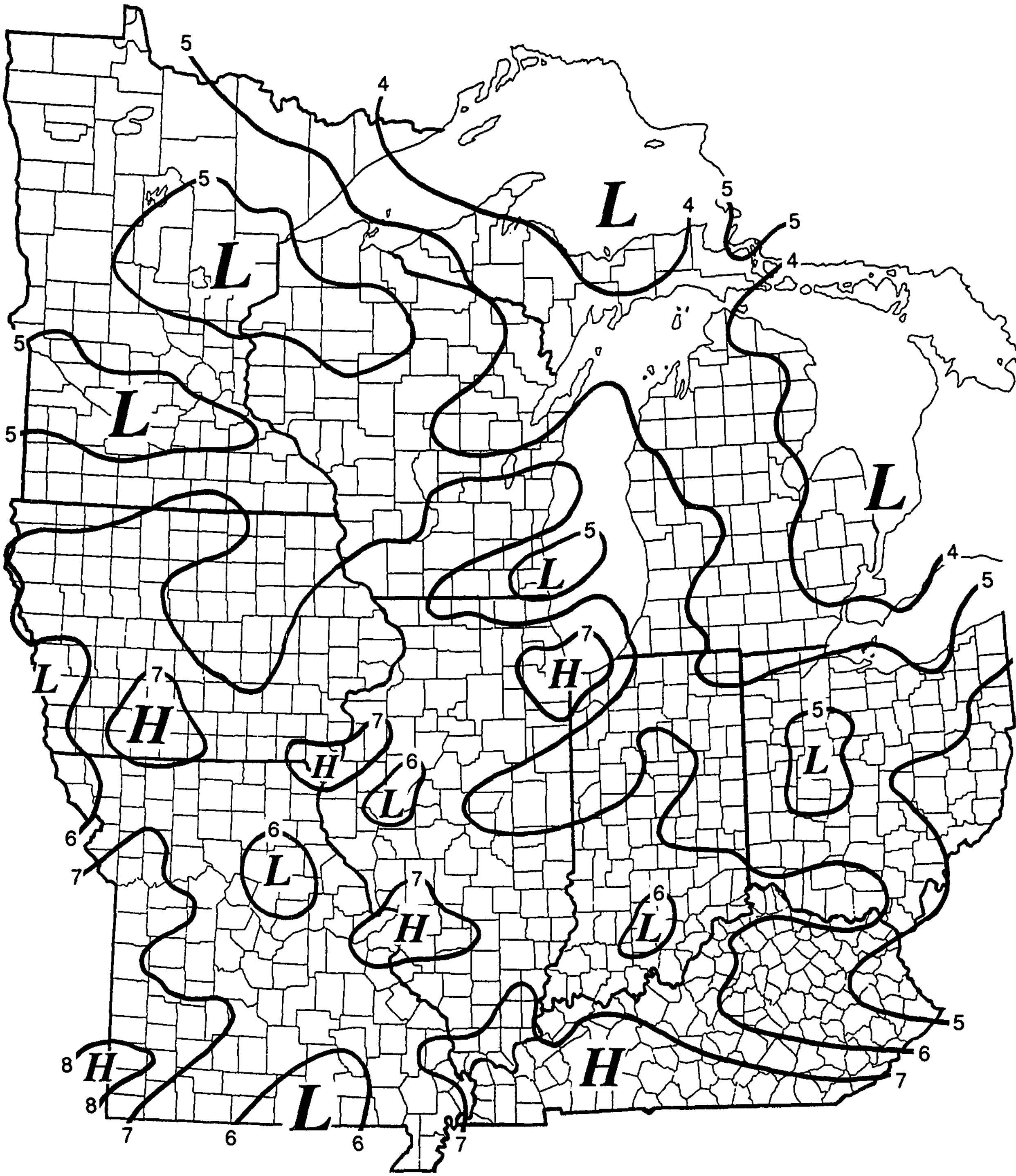

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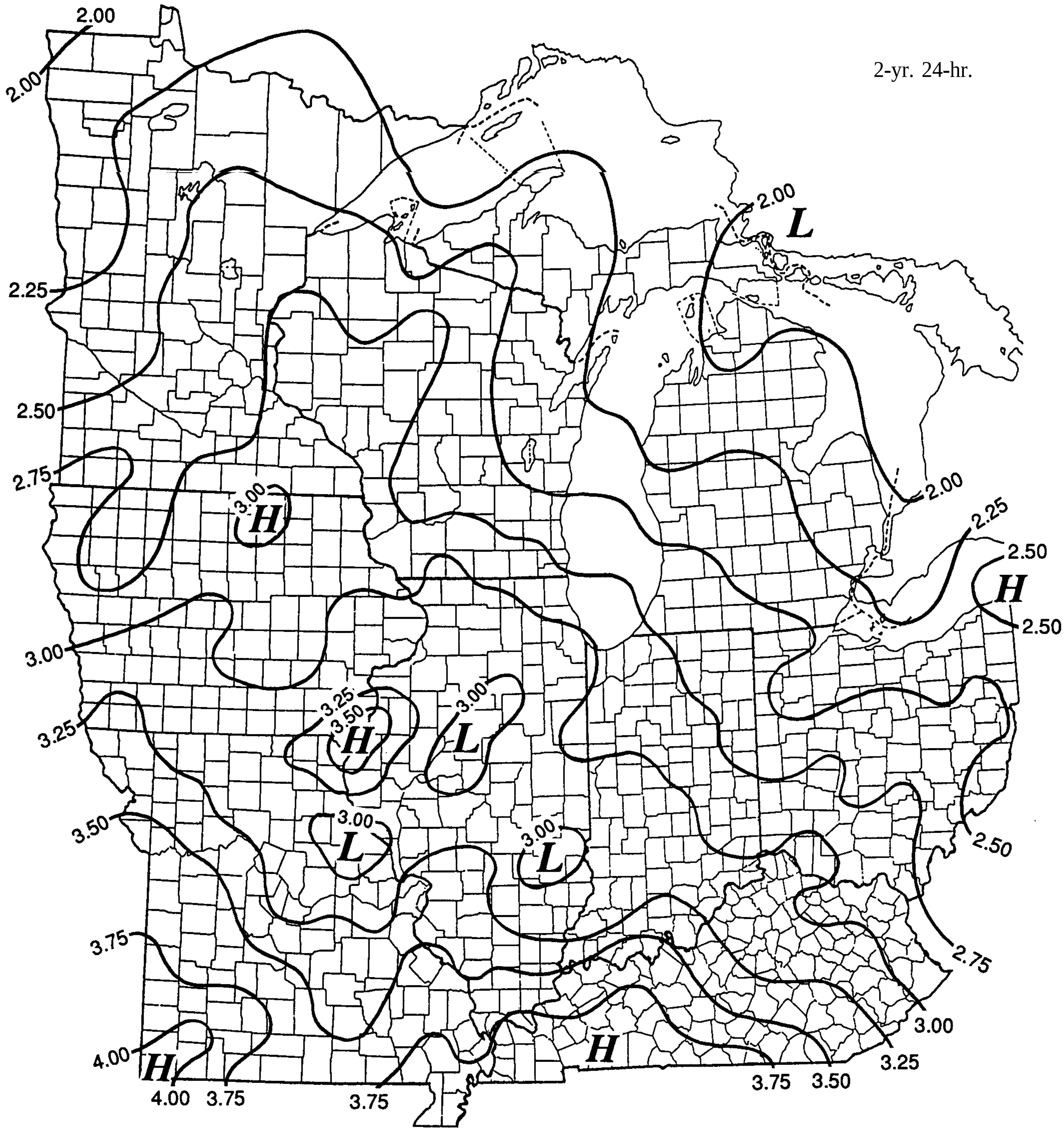
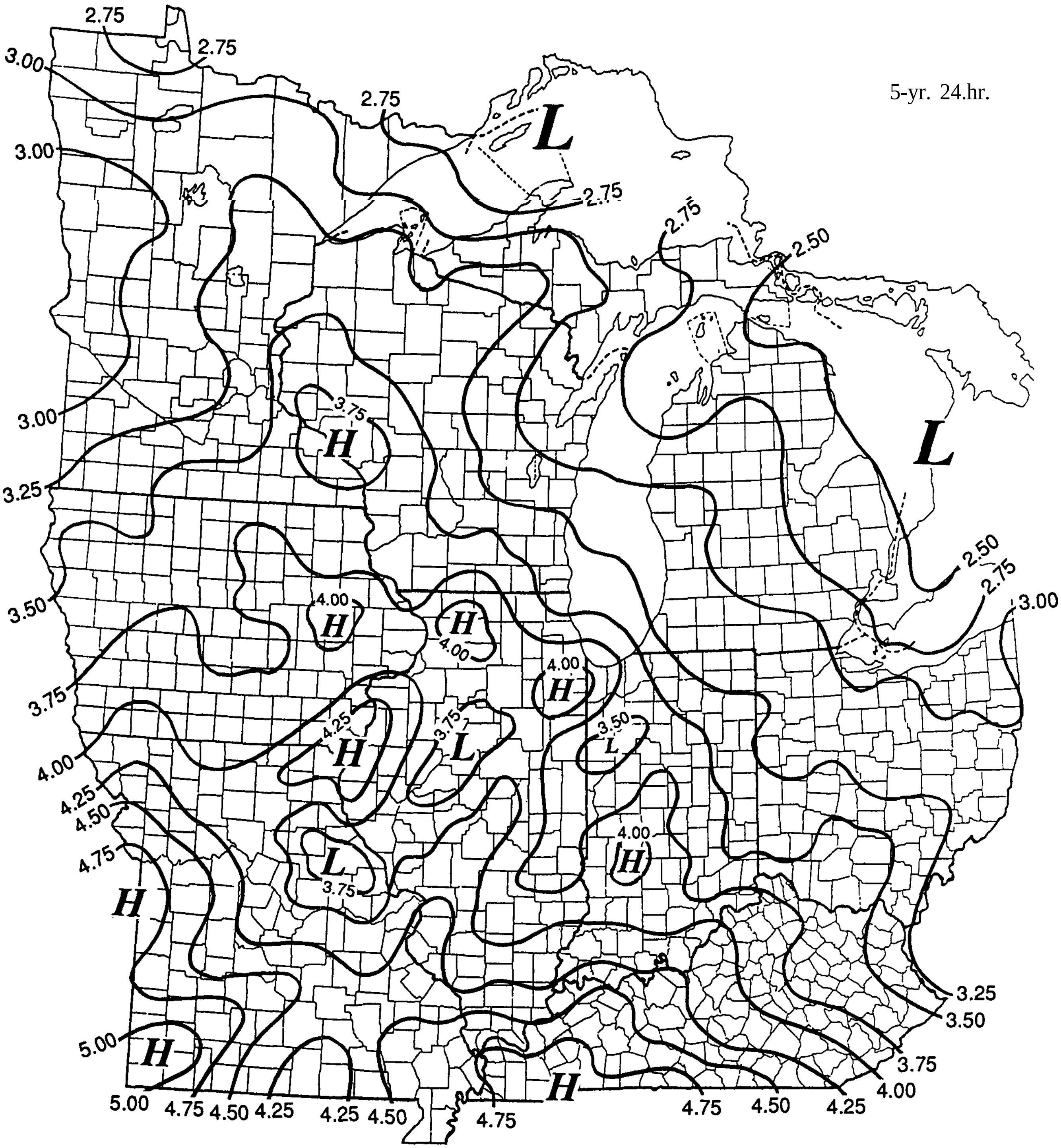


Figure 6. Spatial distribution of 24-hour rainfall (inches)



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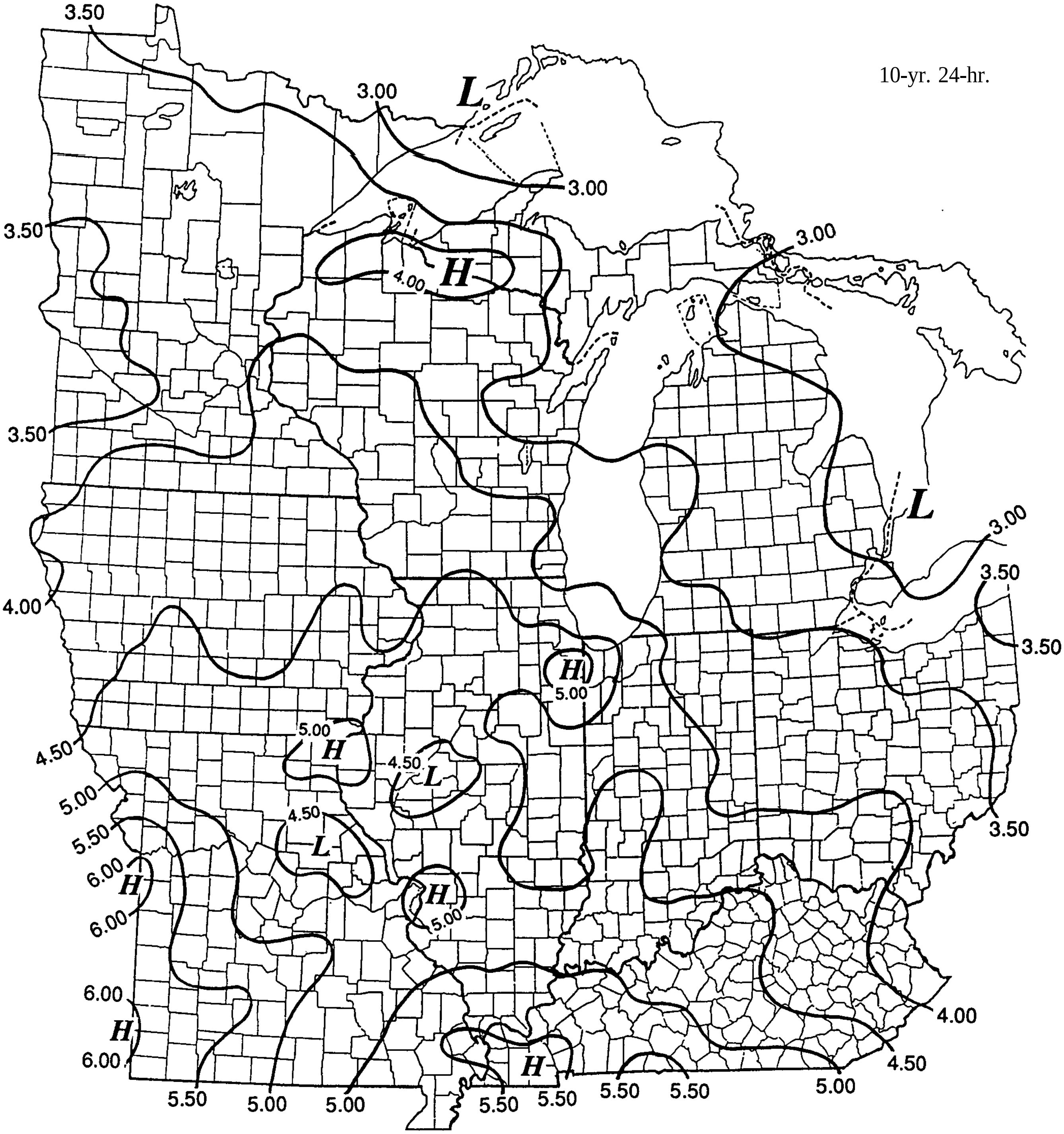

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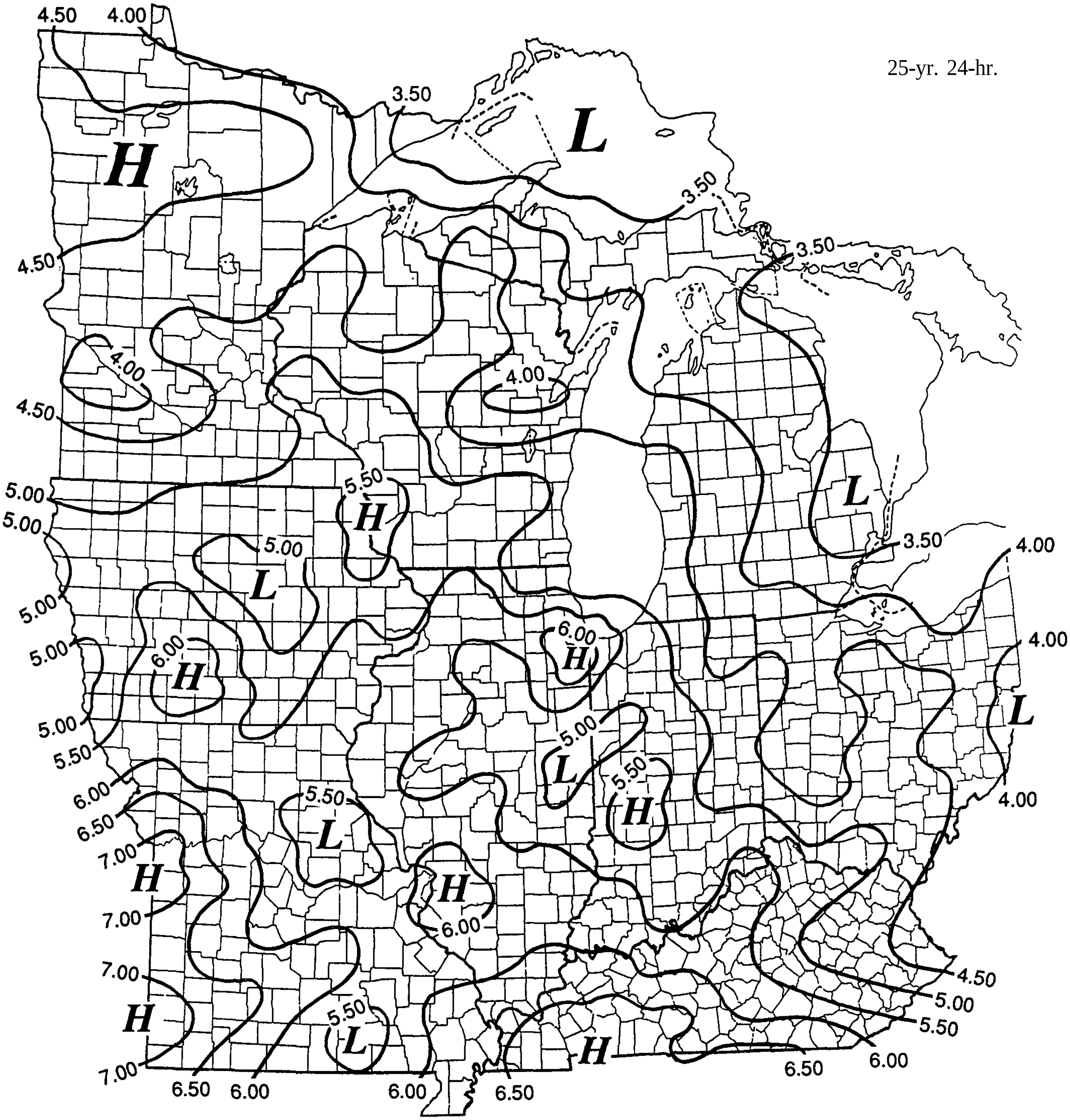

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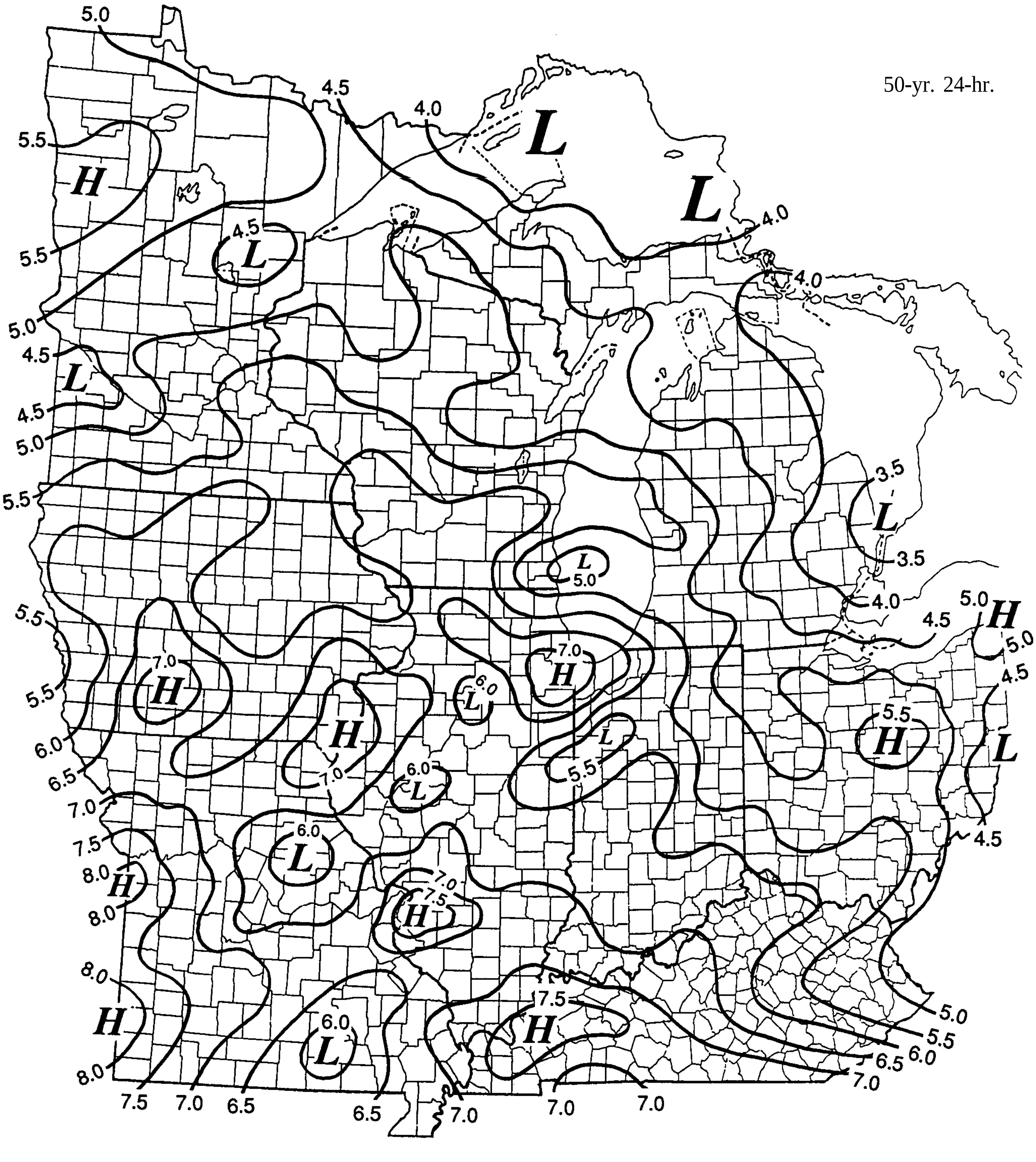

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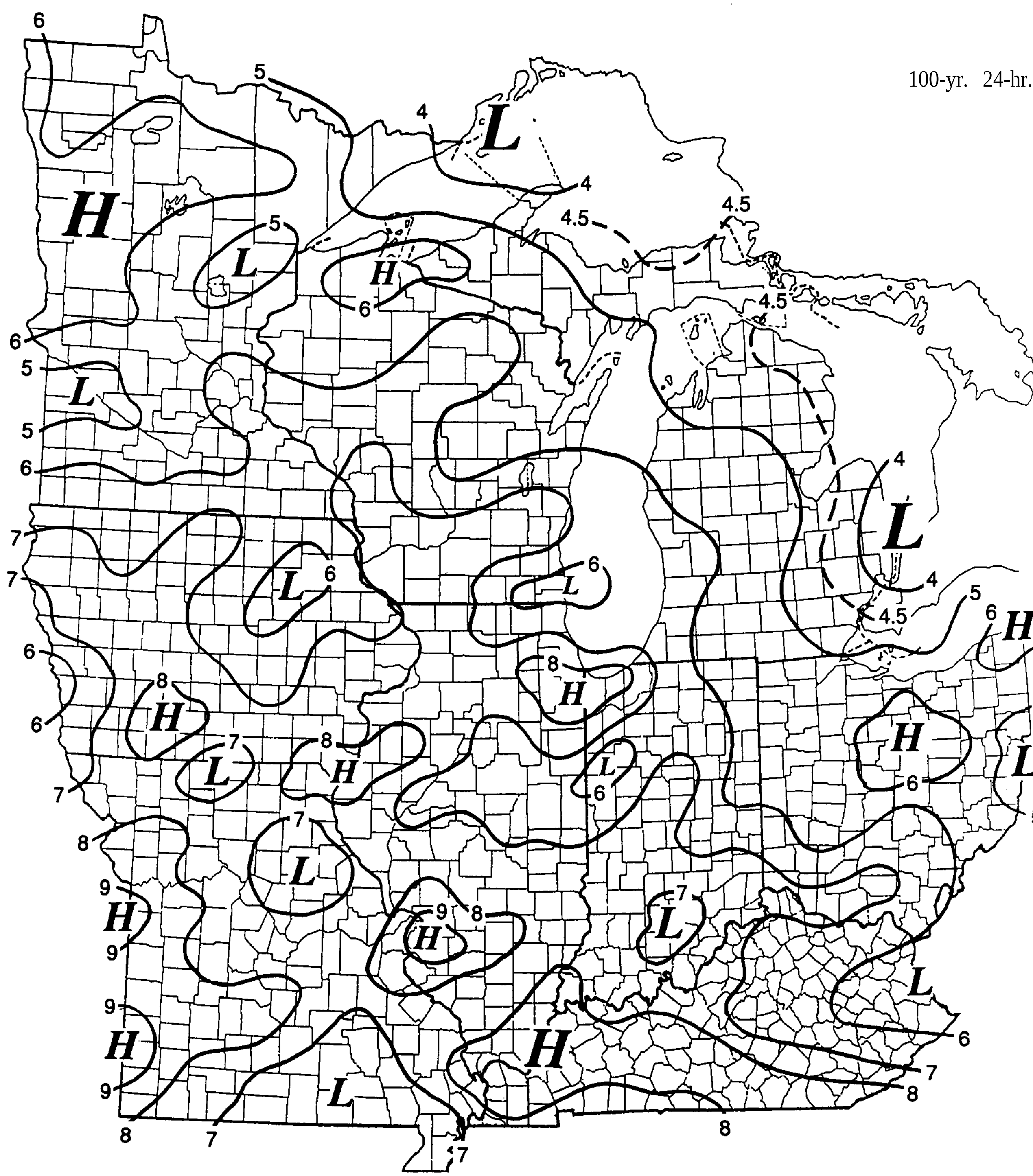

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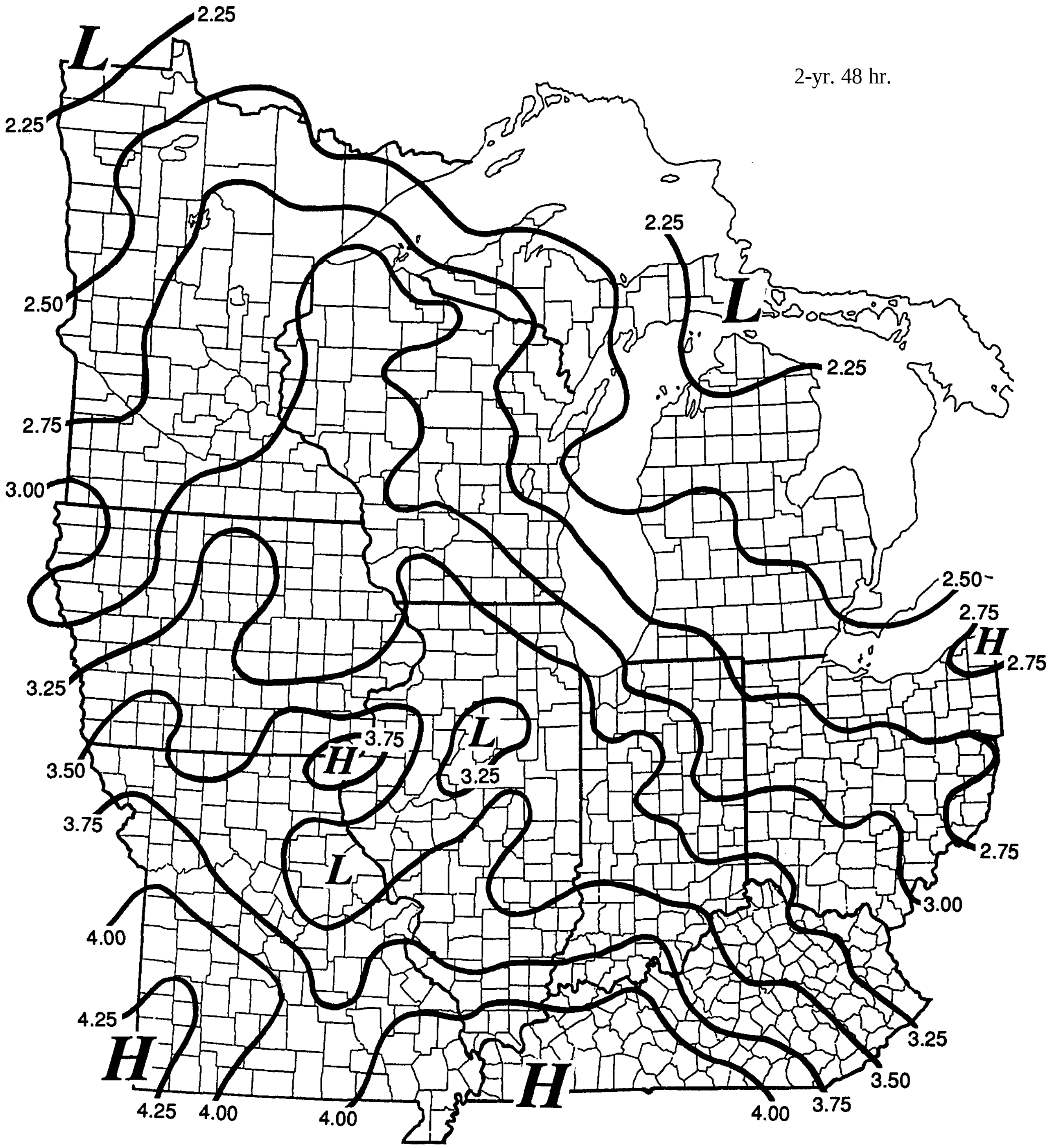
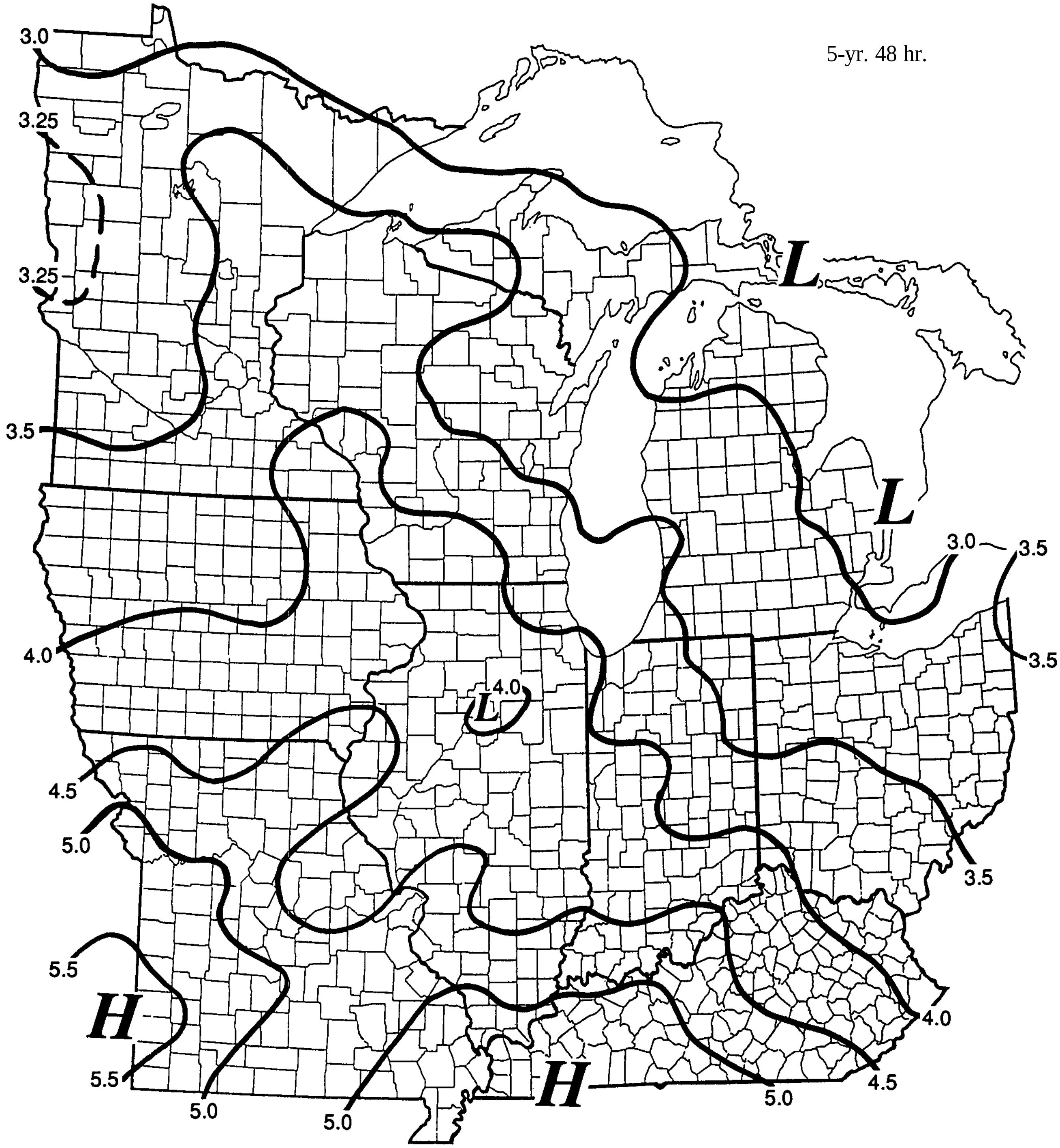


Figure 7. Spatial distribution of 48-hour rainfall (inches)



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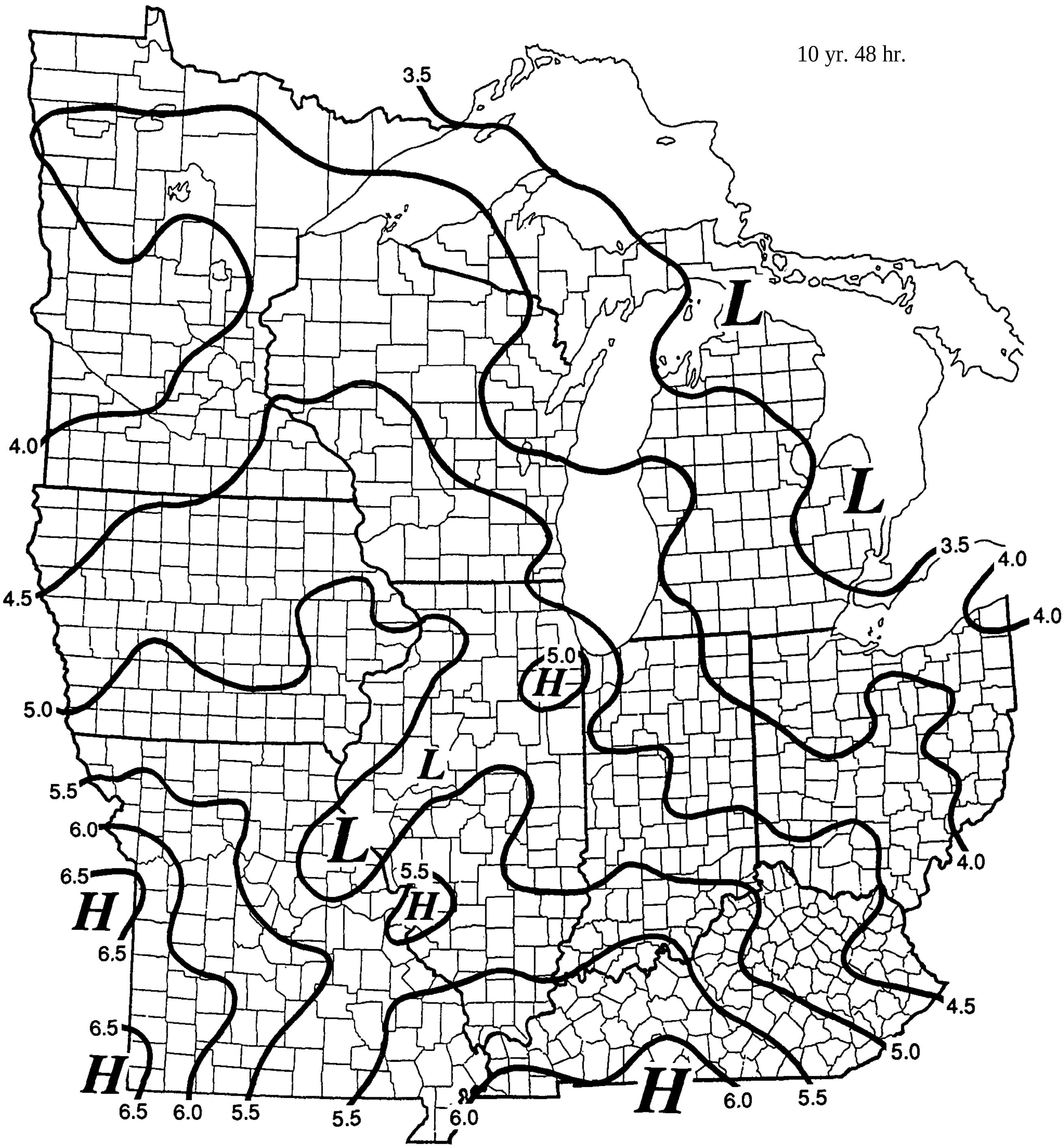

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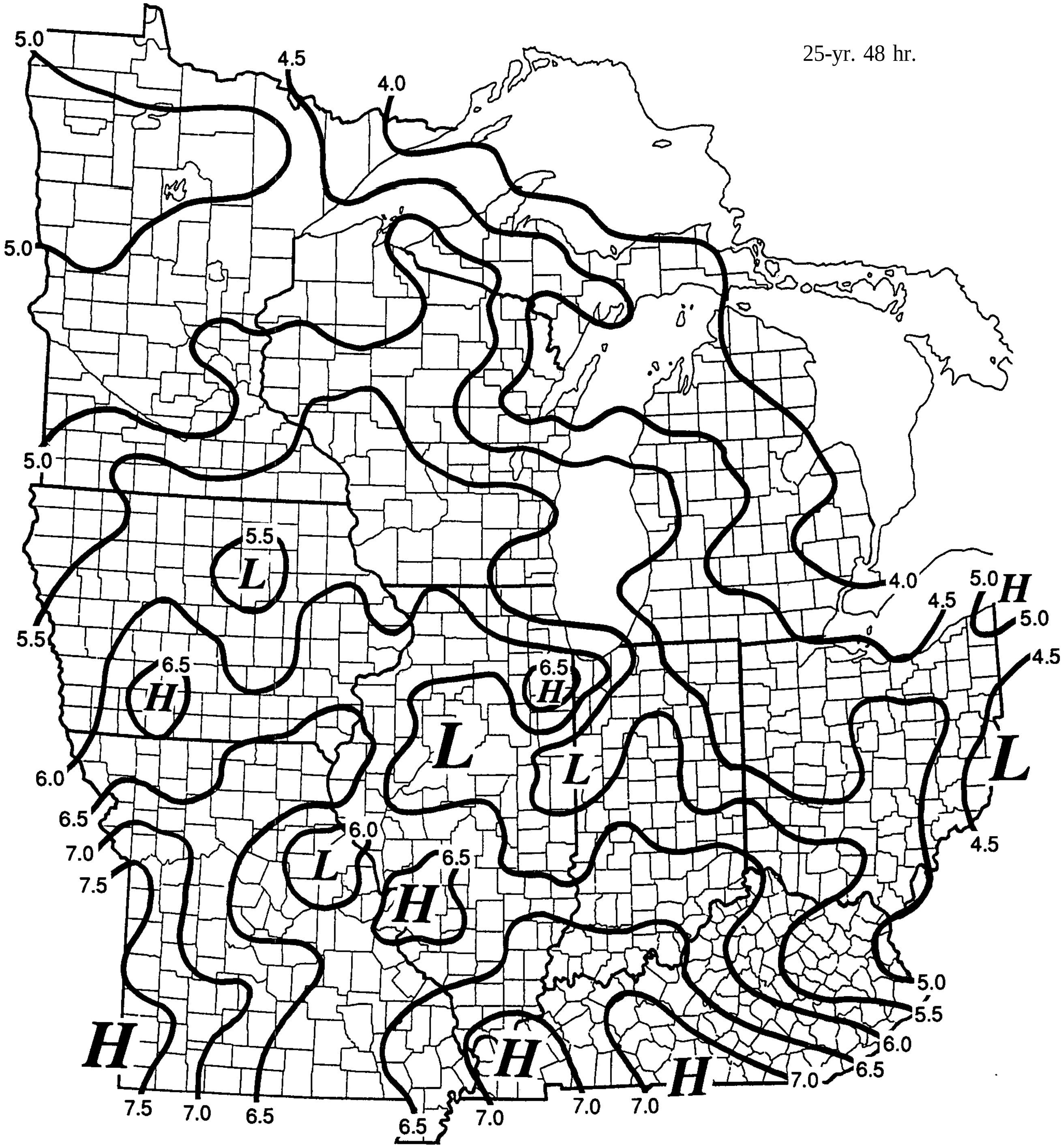

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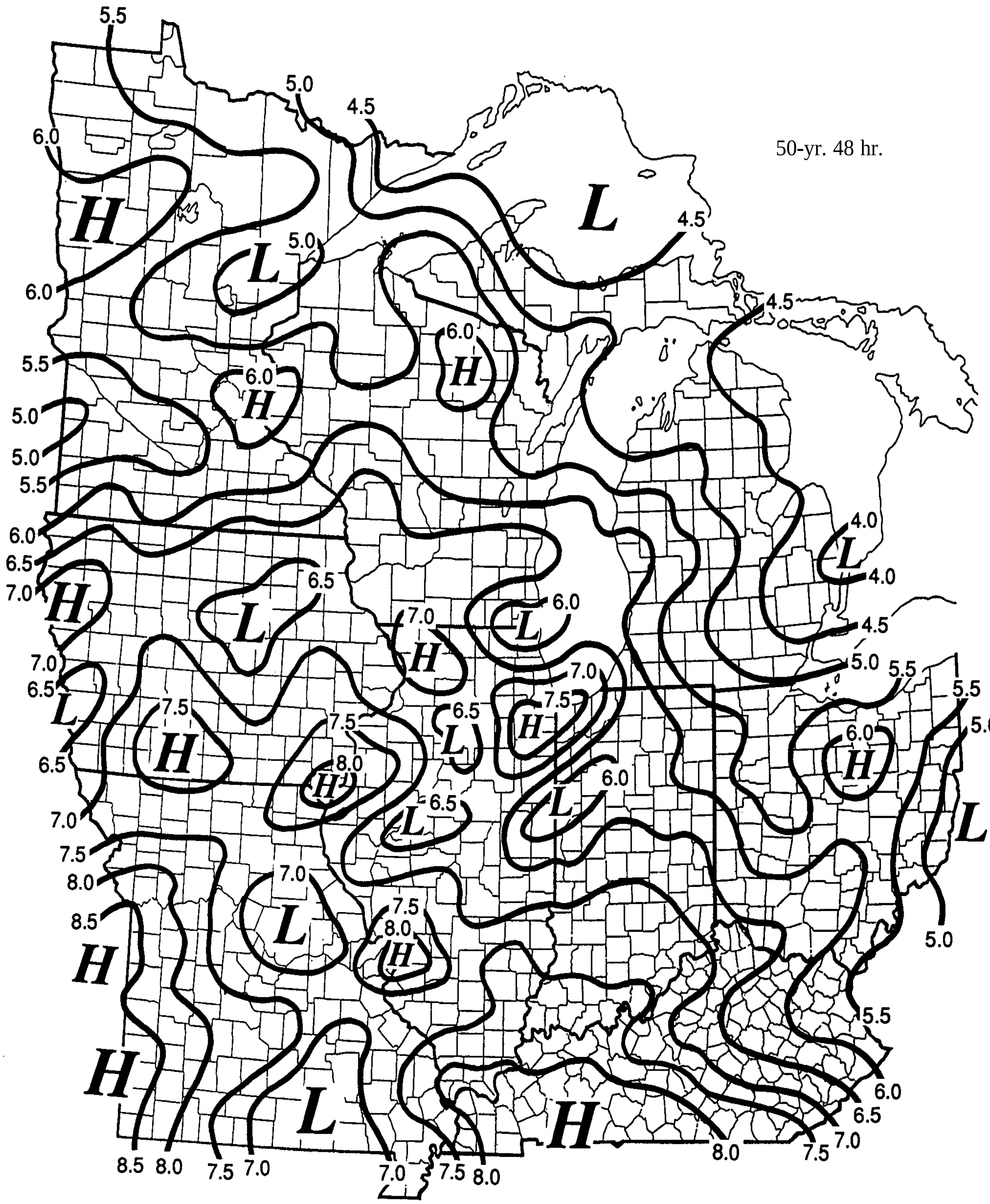

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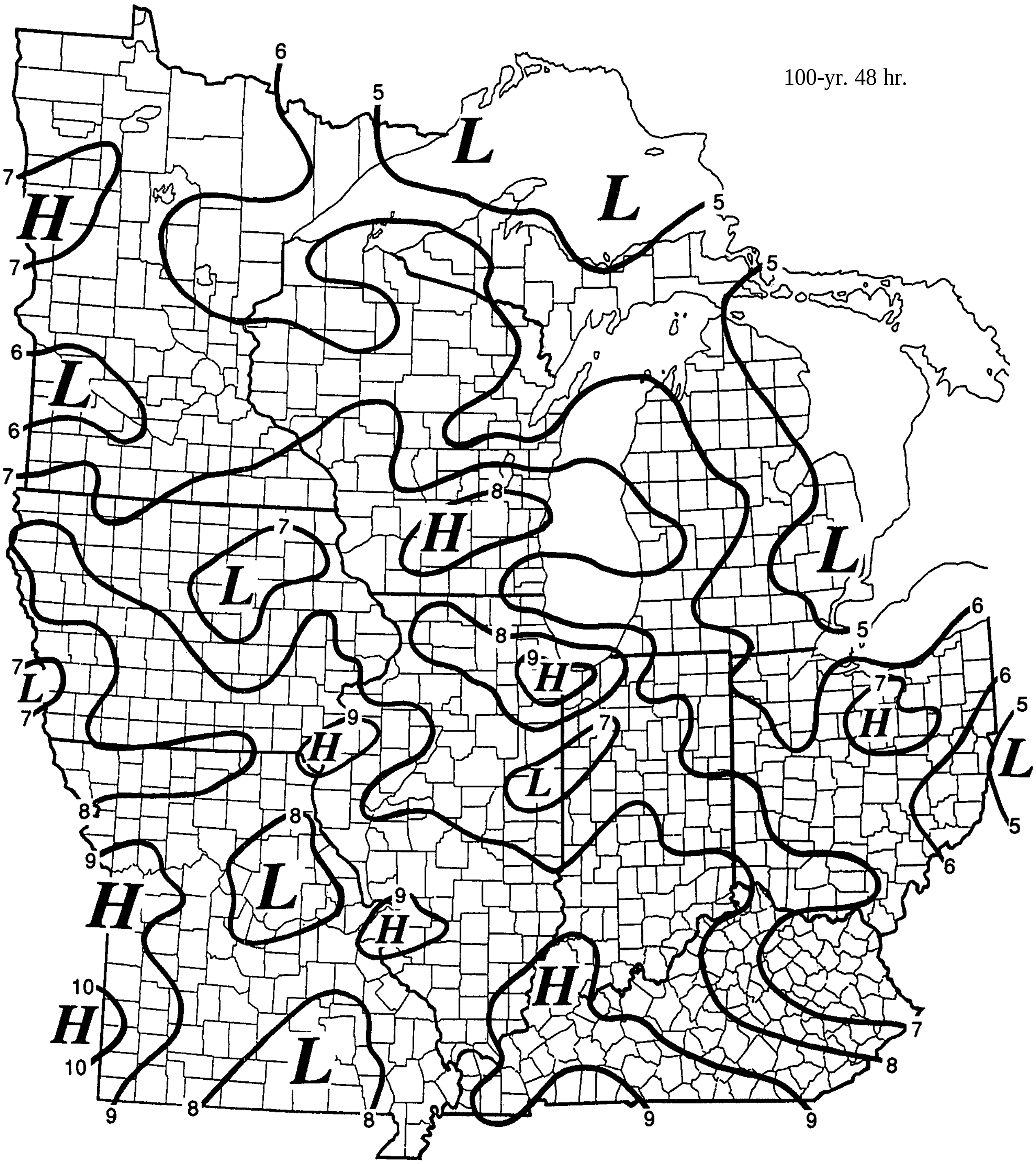

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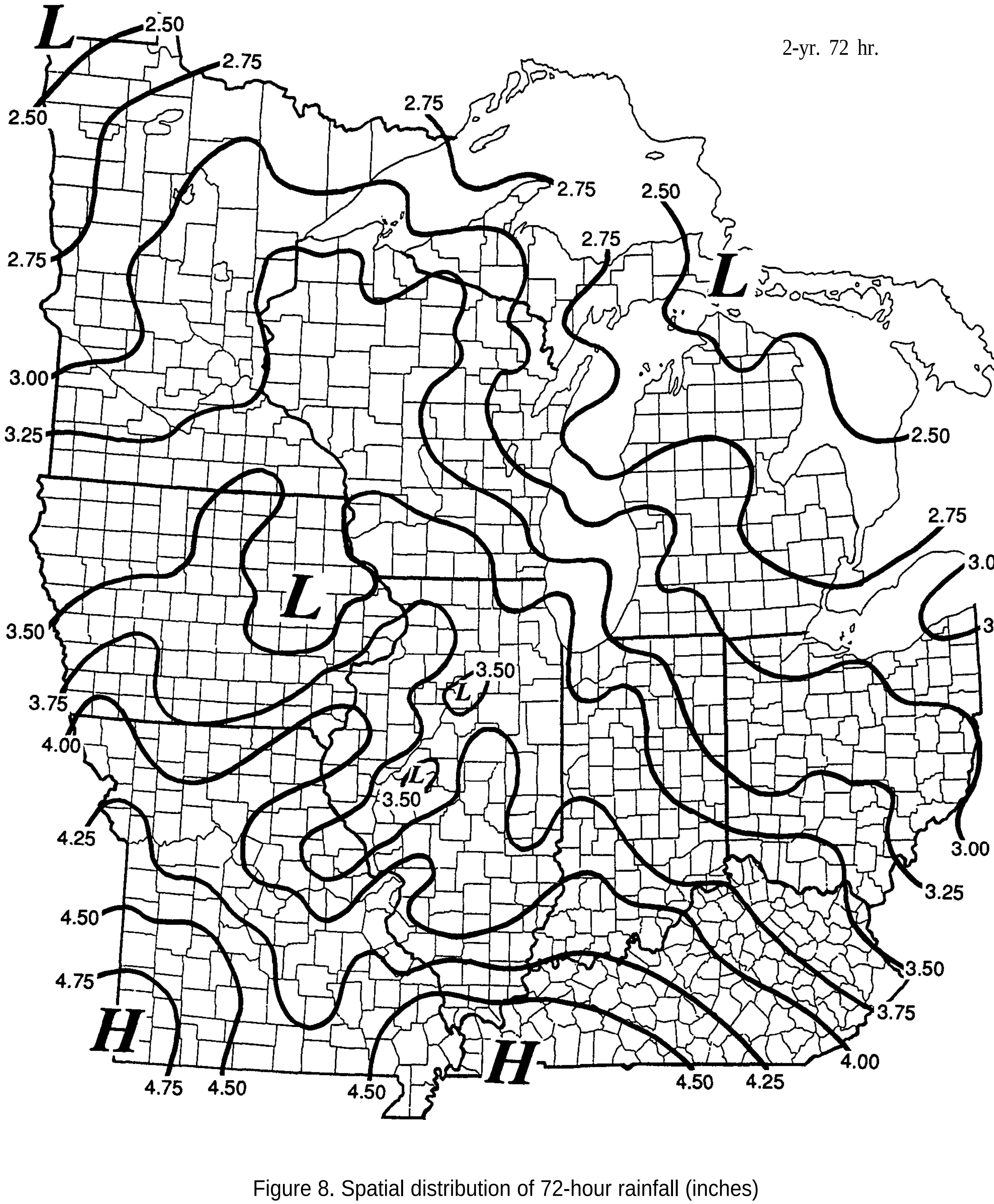
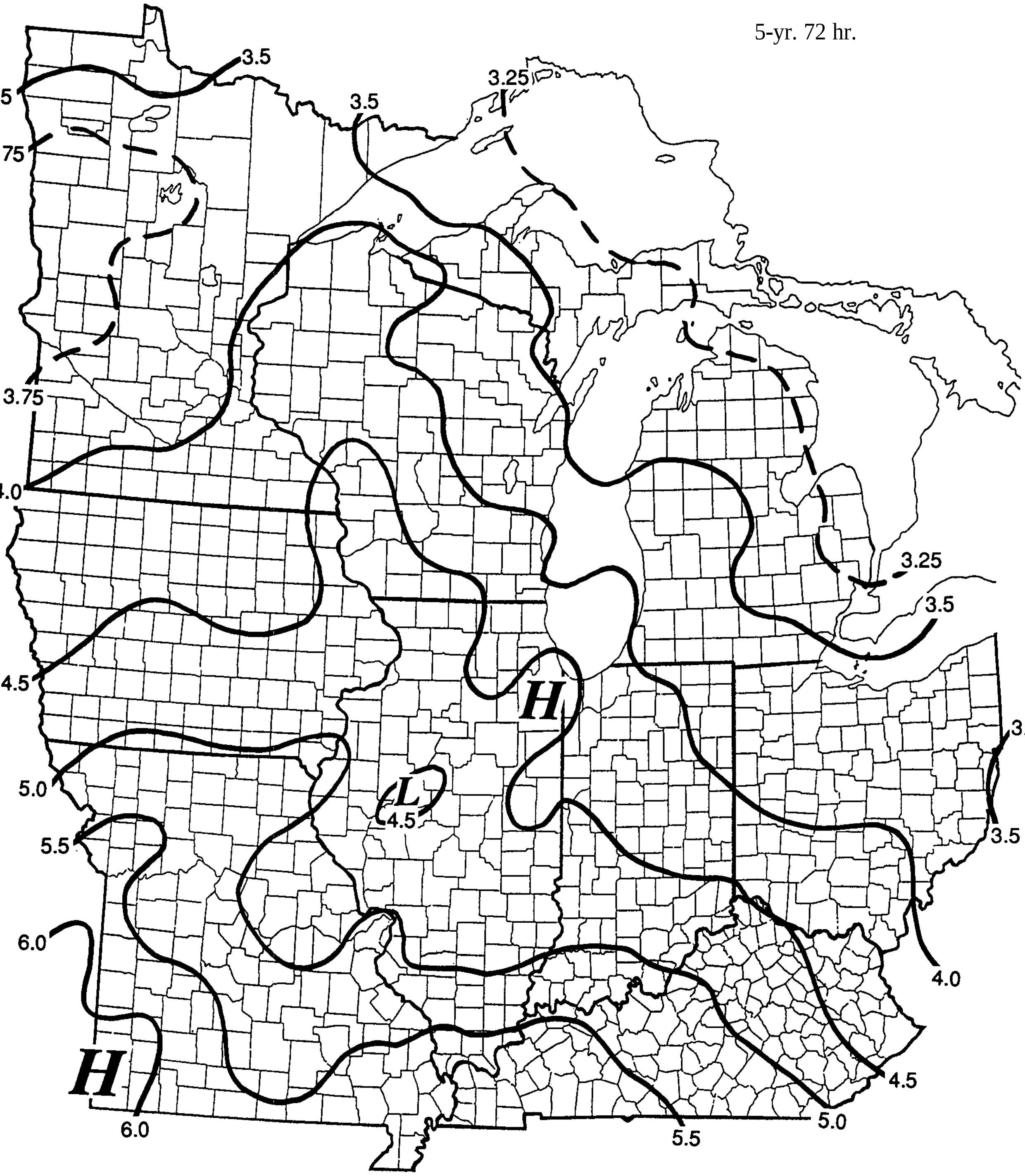


Figure 8. Spatial distribution of 72-hour rainfall (inches)



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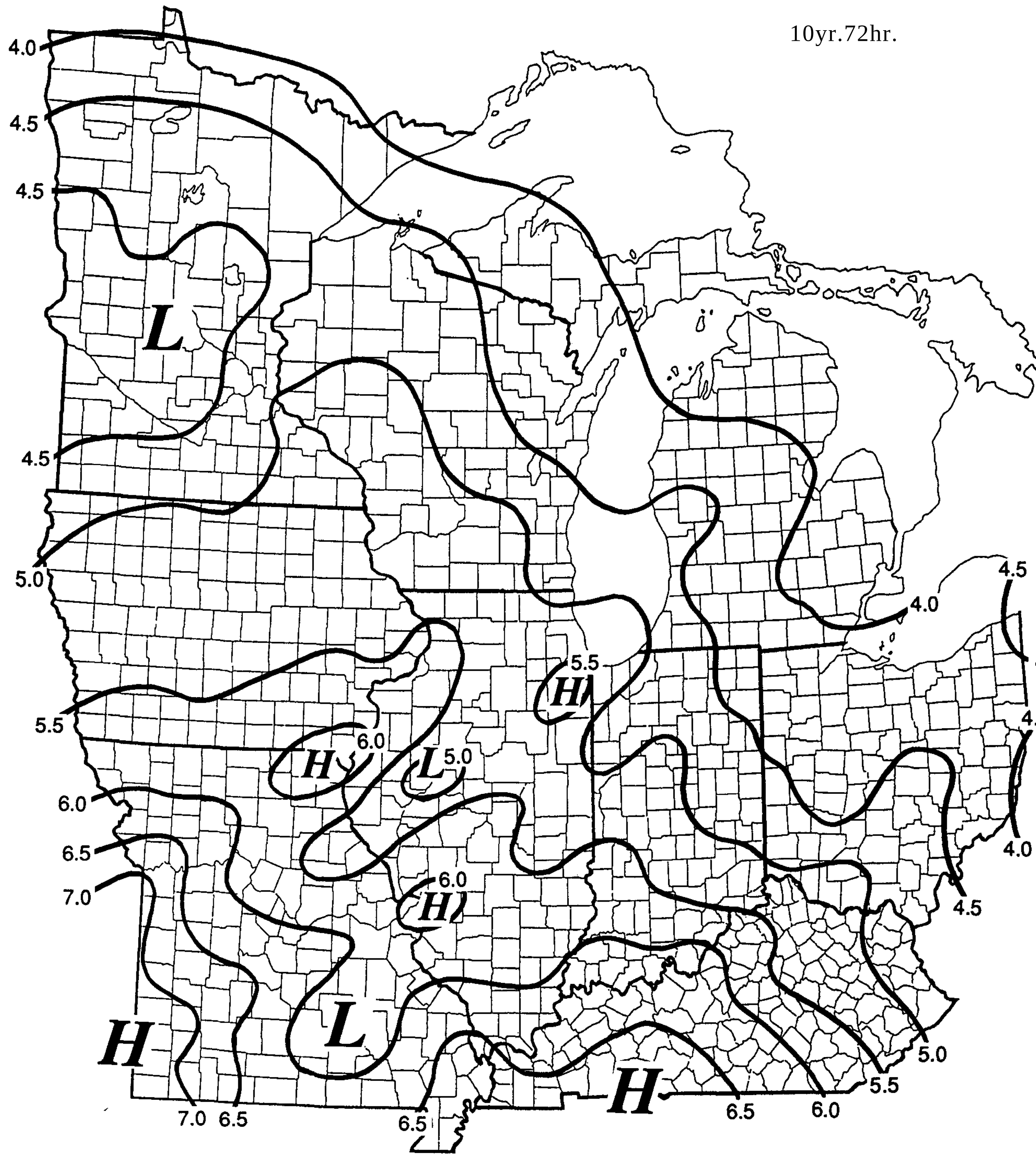

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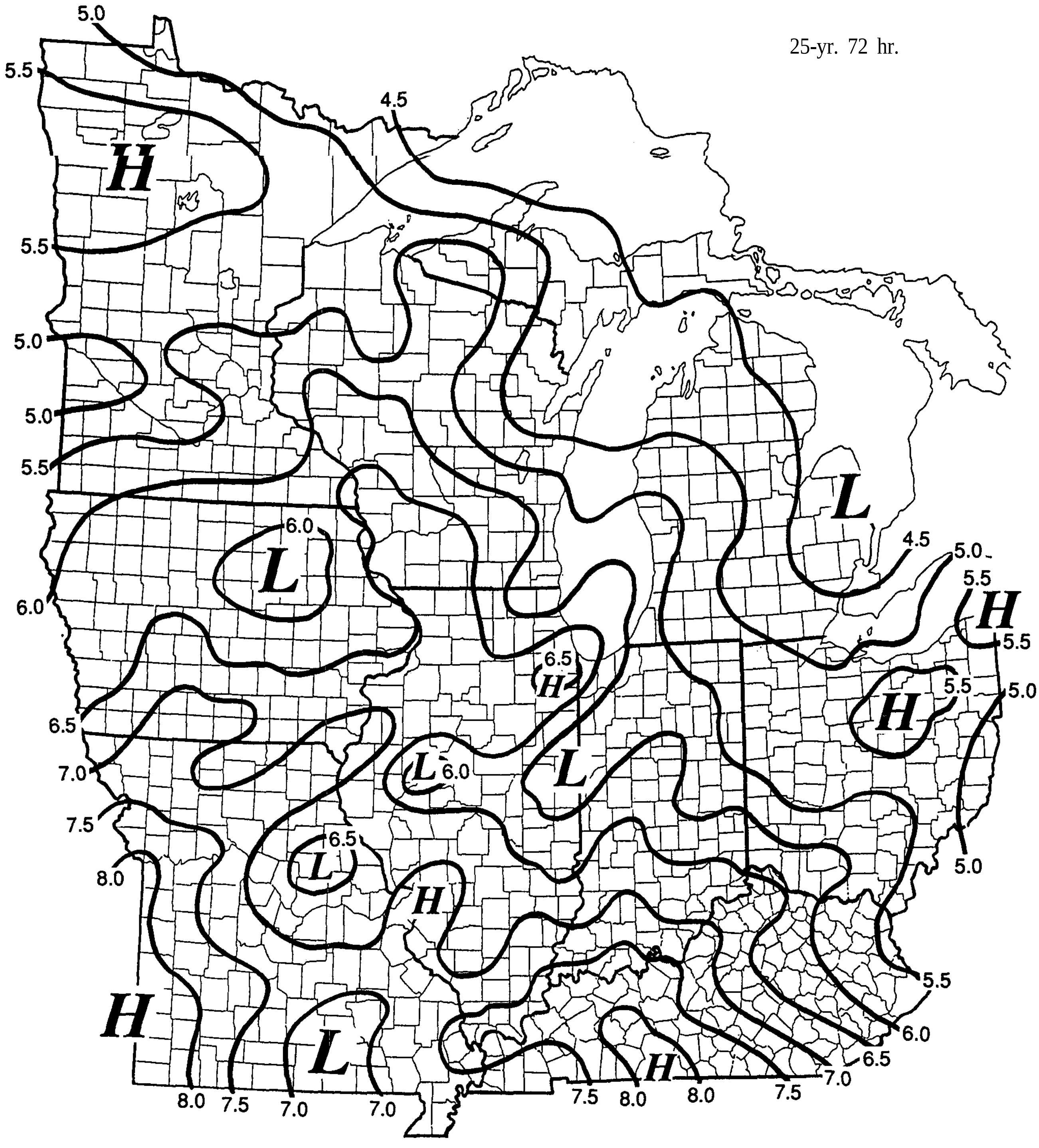

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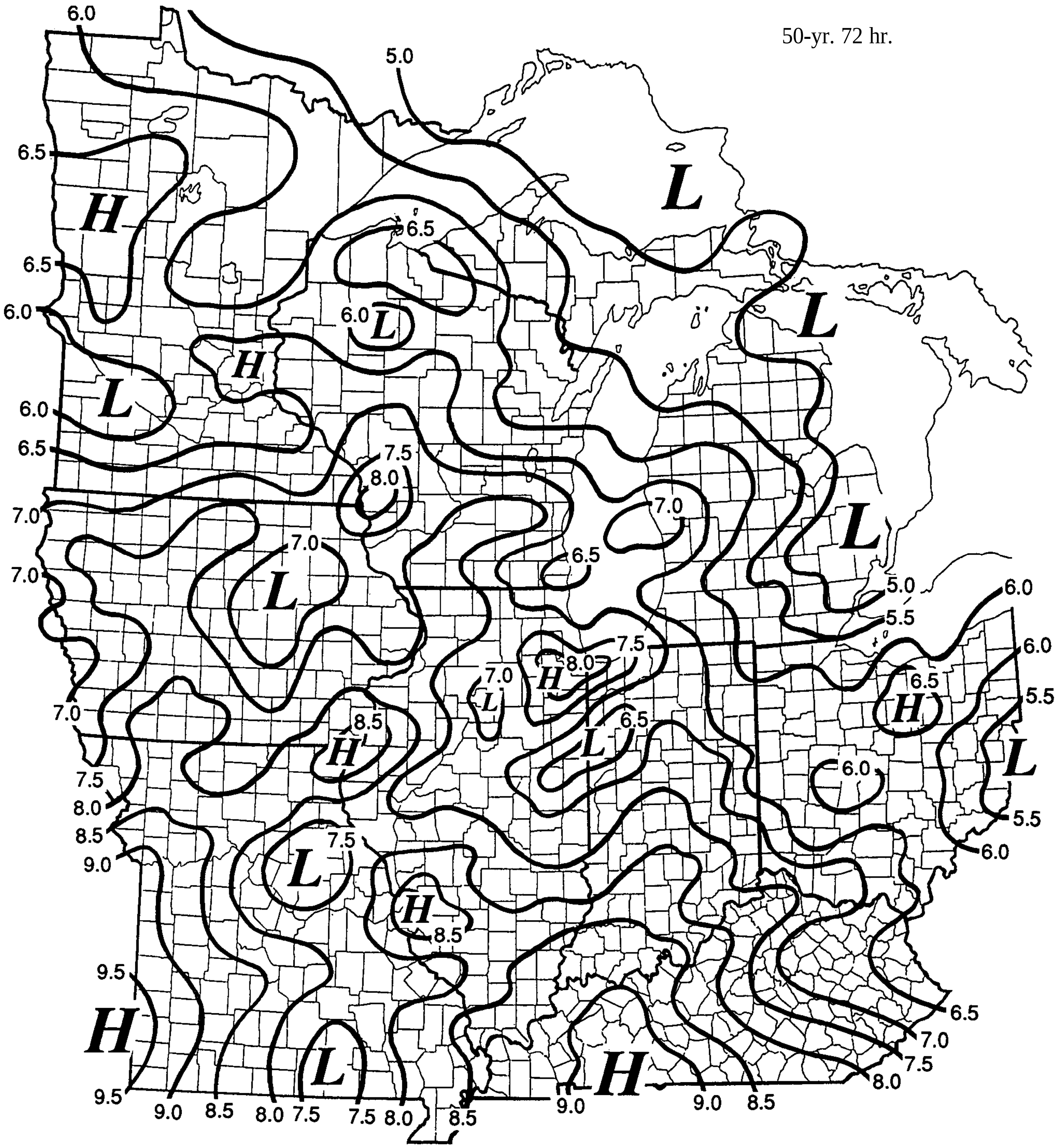
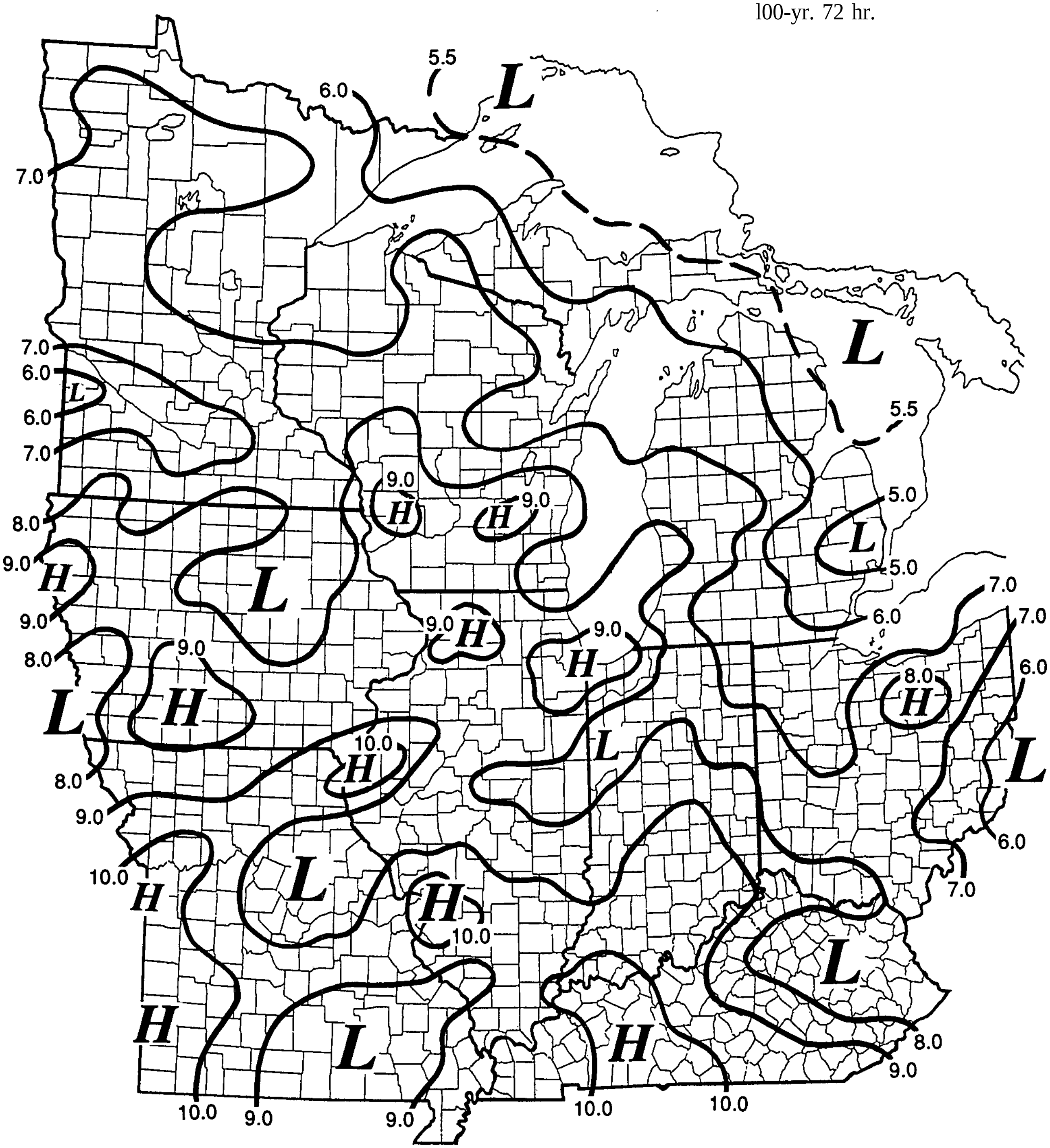


Figure 8. Continued

l00-yr. 72 hr.



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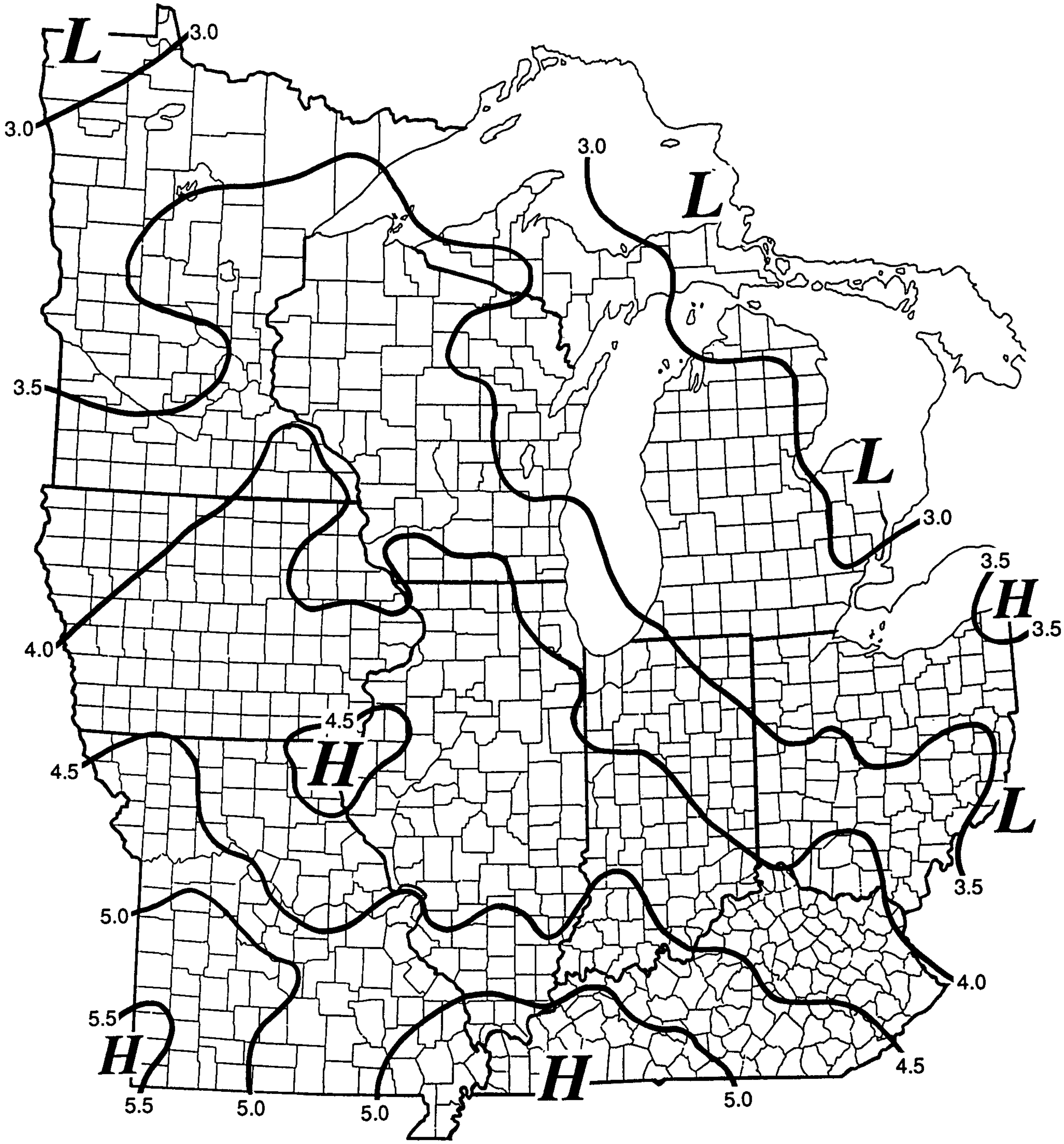

Figure 9. Spatial distribution of 5-day rainfall (inches)

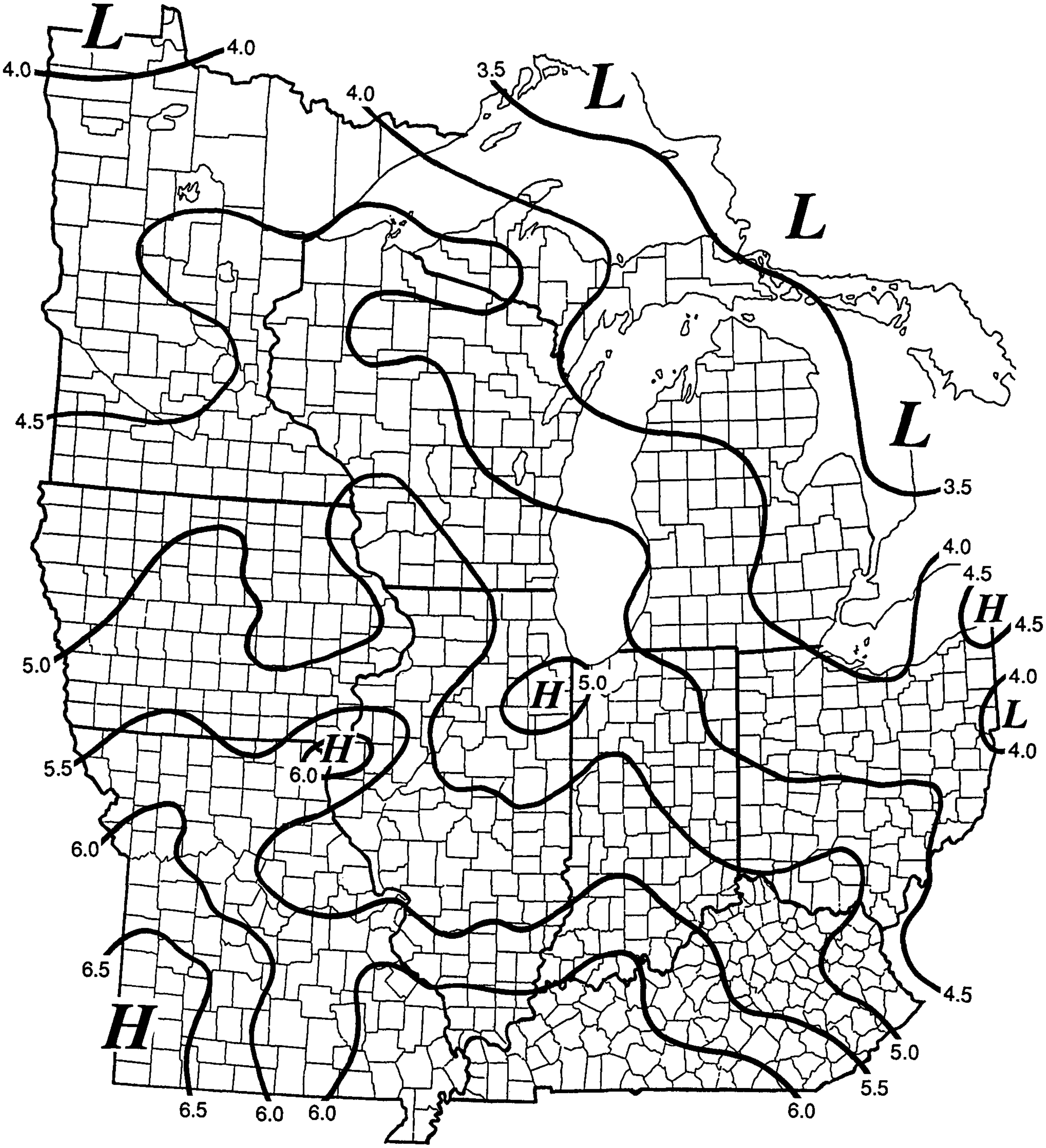

Figure 9. Continued

10-yr. 5 day

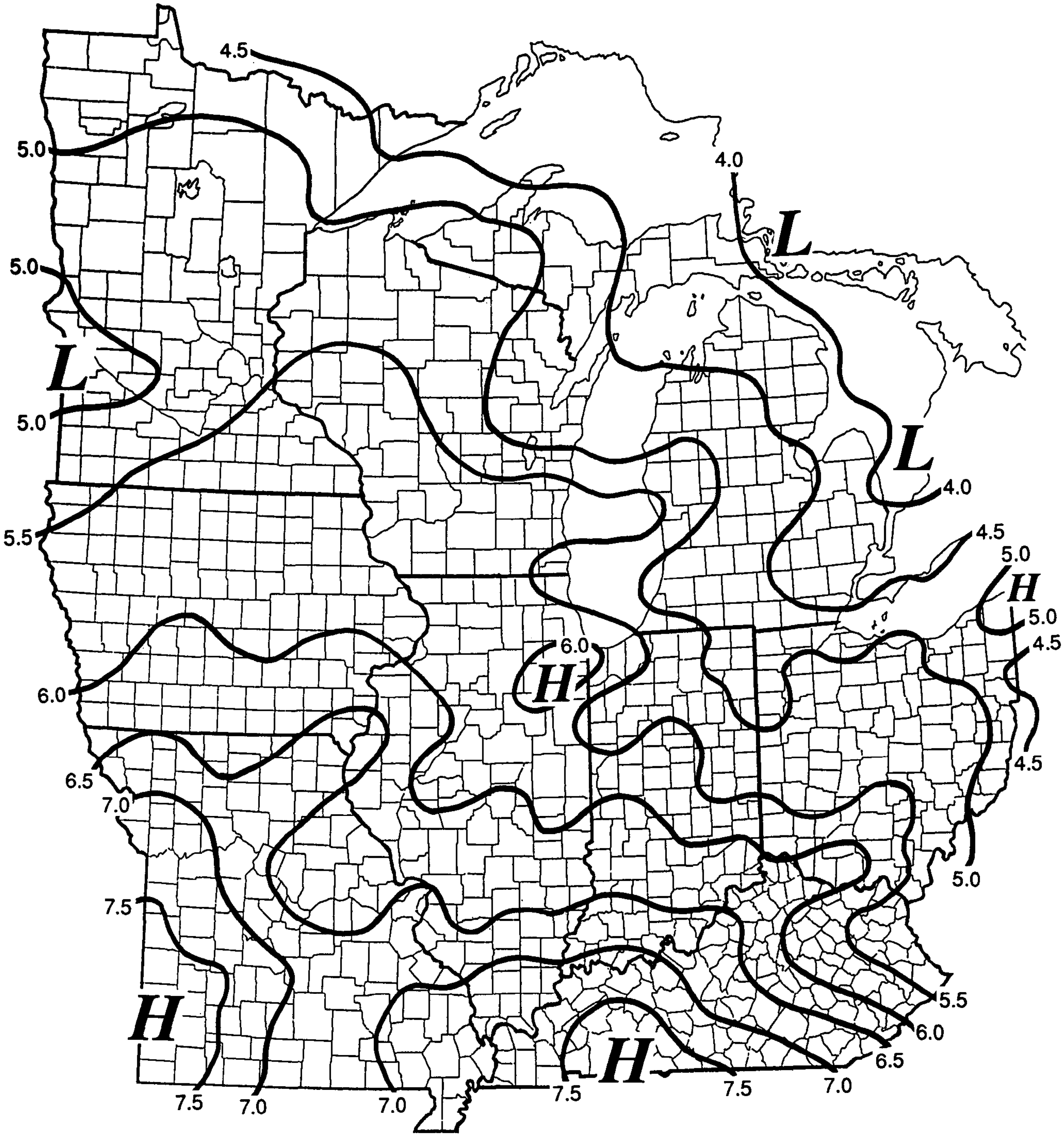

Figure 9. Continued

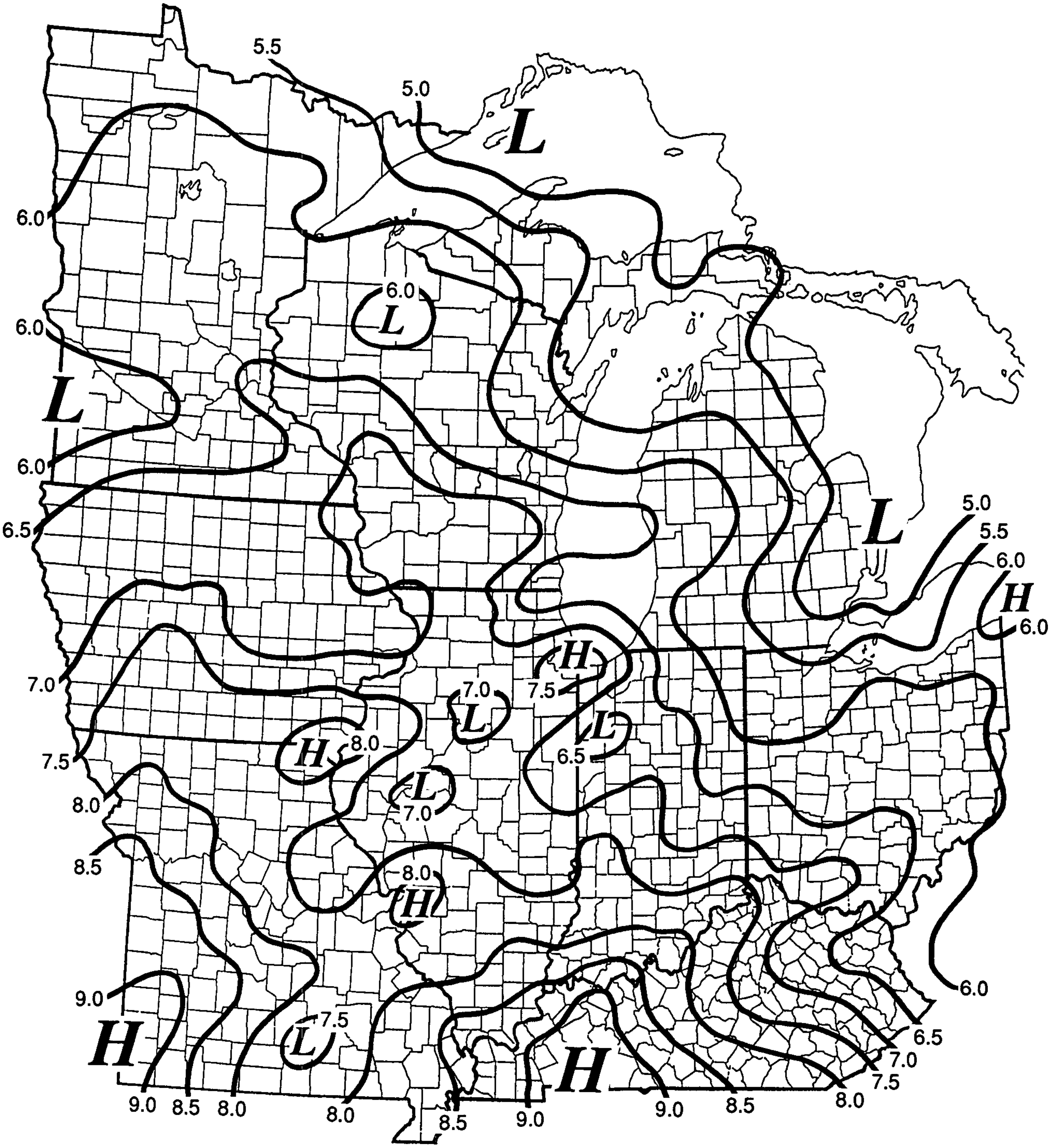

Figure 9. Continued

50-yr. 5 day

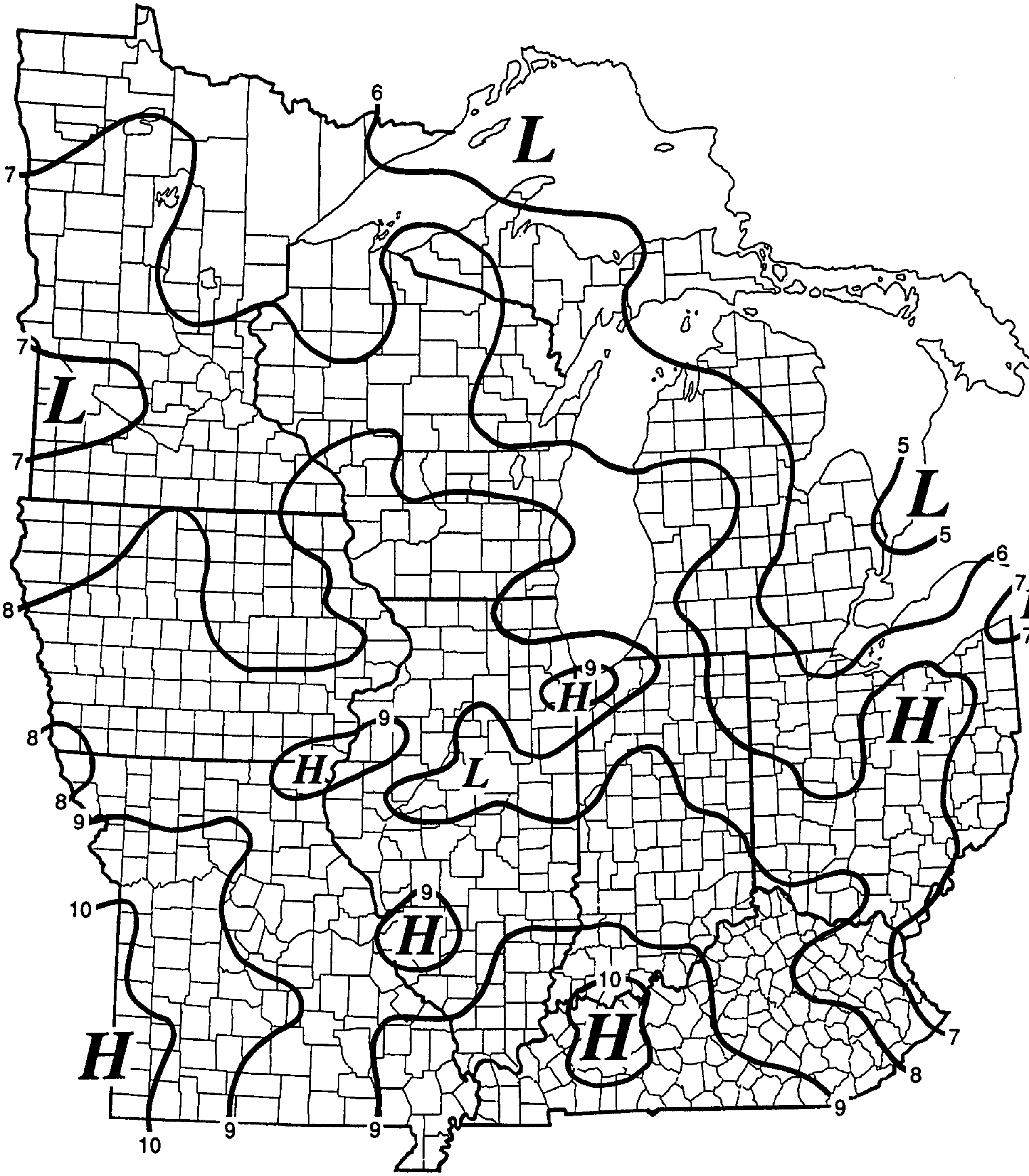

Figure 9. Continued

l00-yr. 5 day

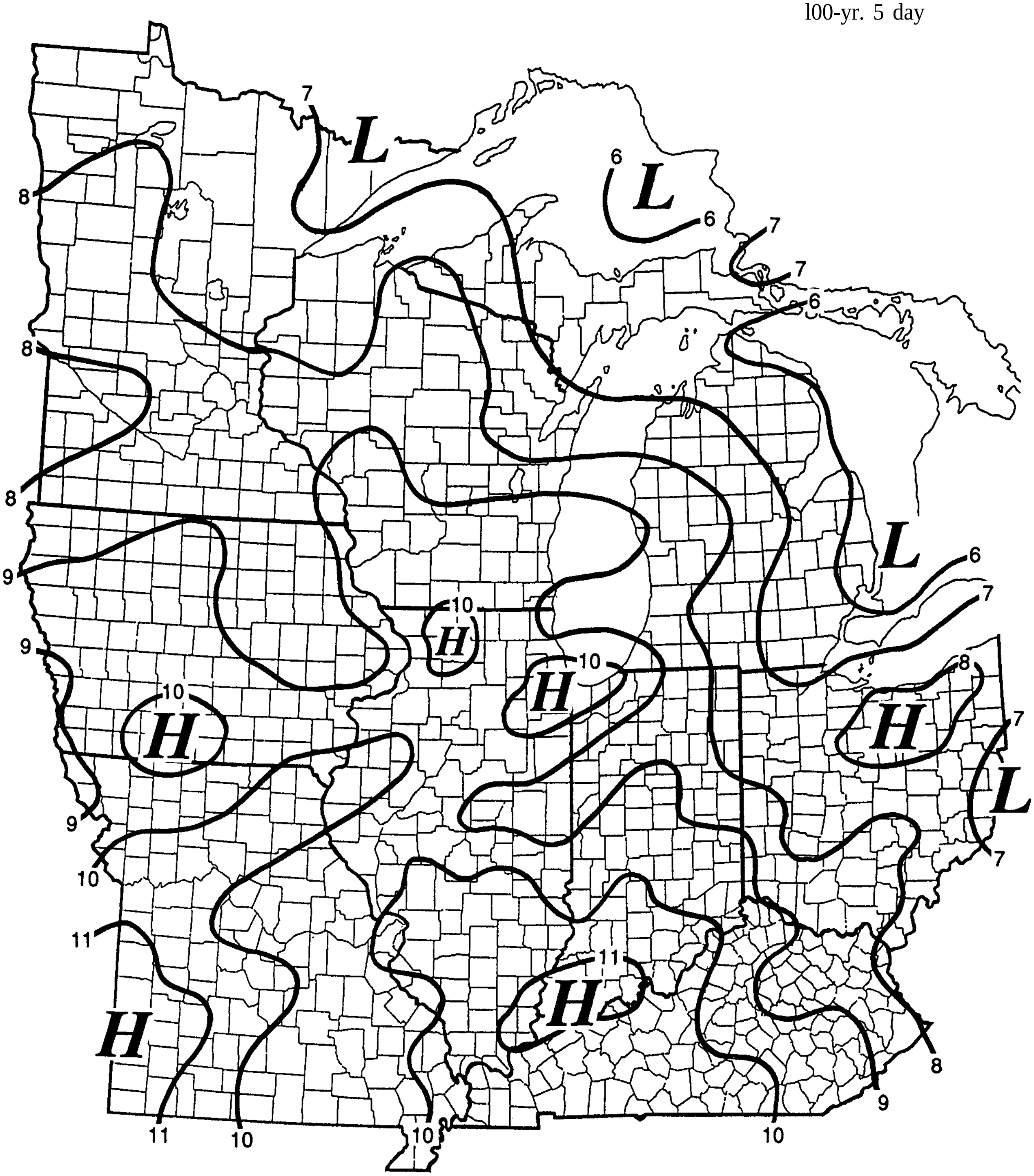

Figure 9. Concluded

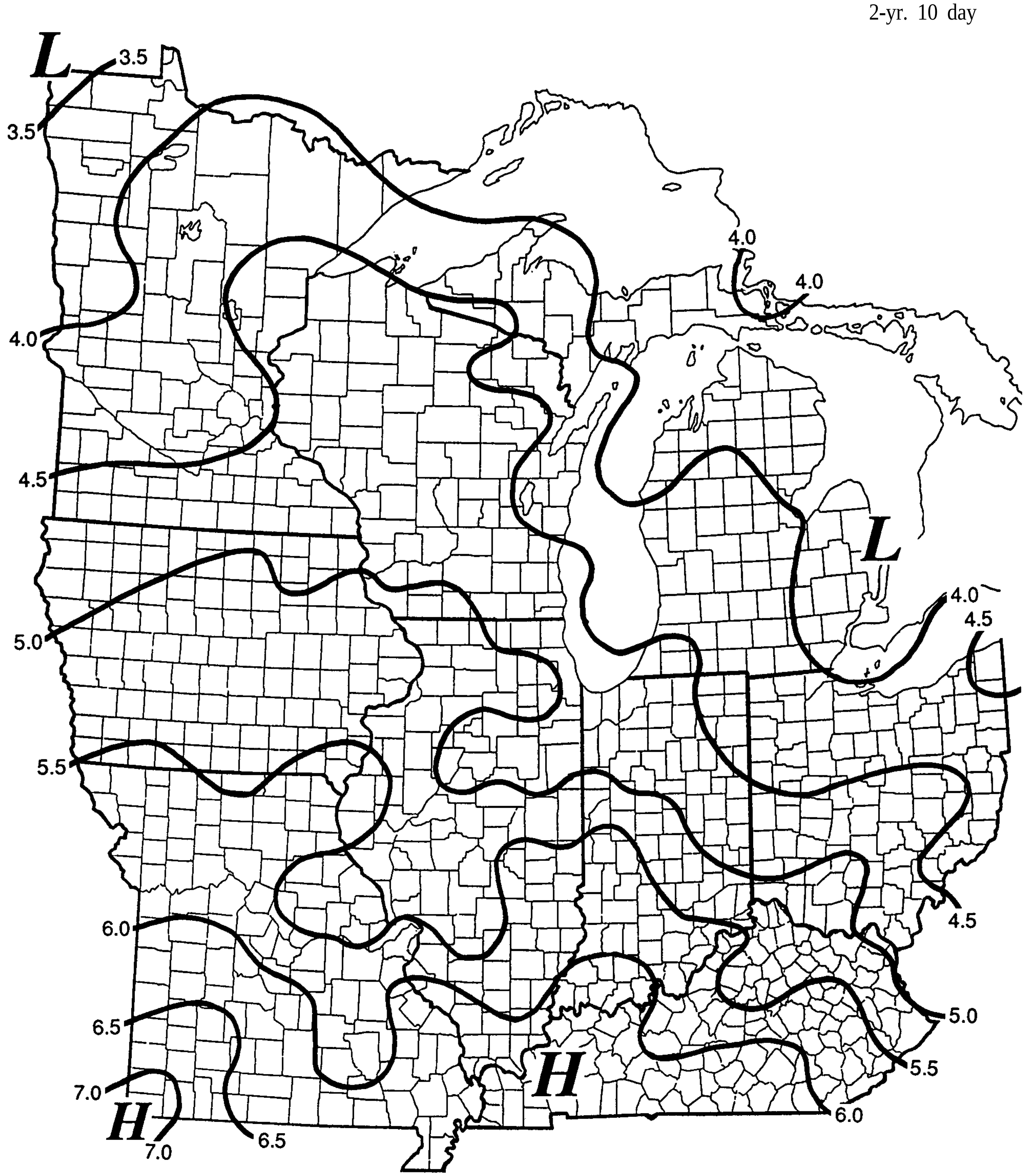

Figure 10. Spatial distribution of 10-day rainfall (inches)

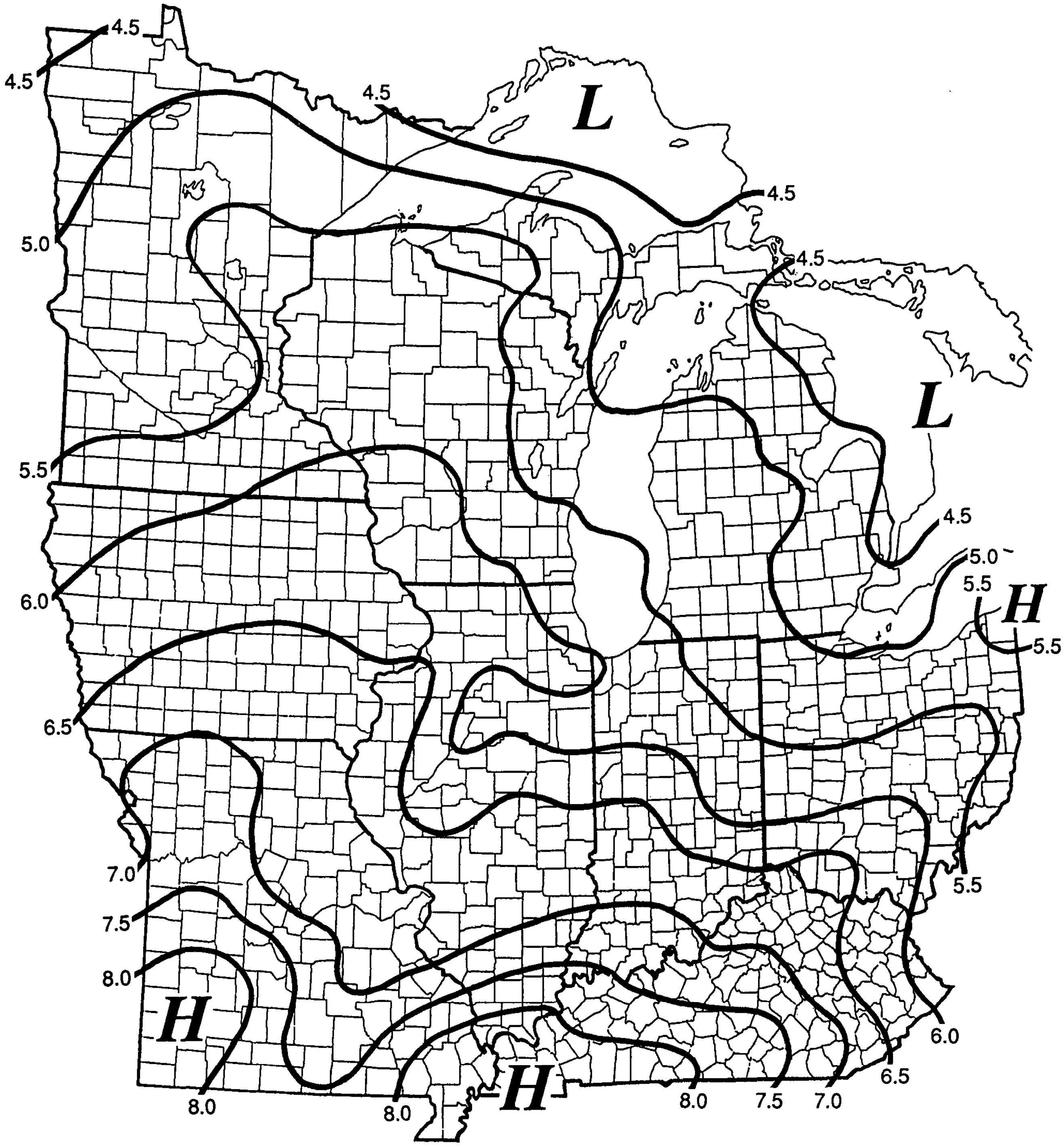

Figure 10. Continued

10-yr. 10 day

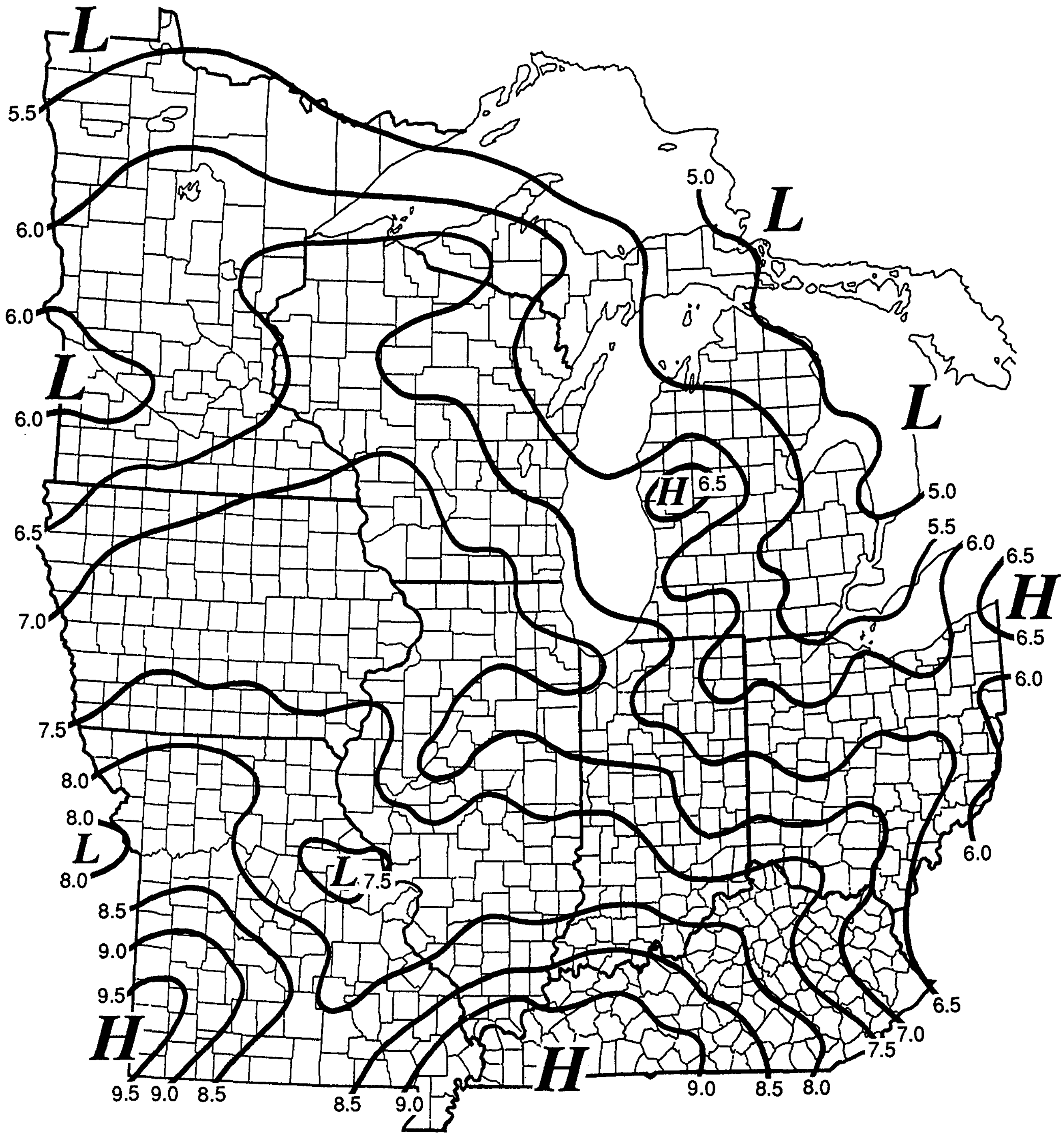

Figure 10. Continued

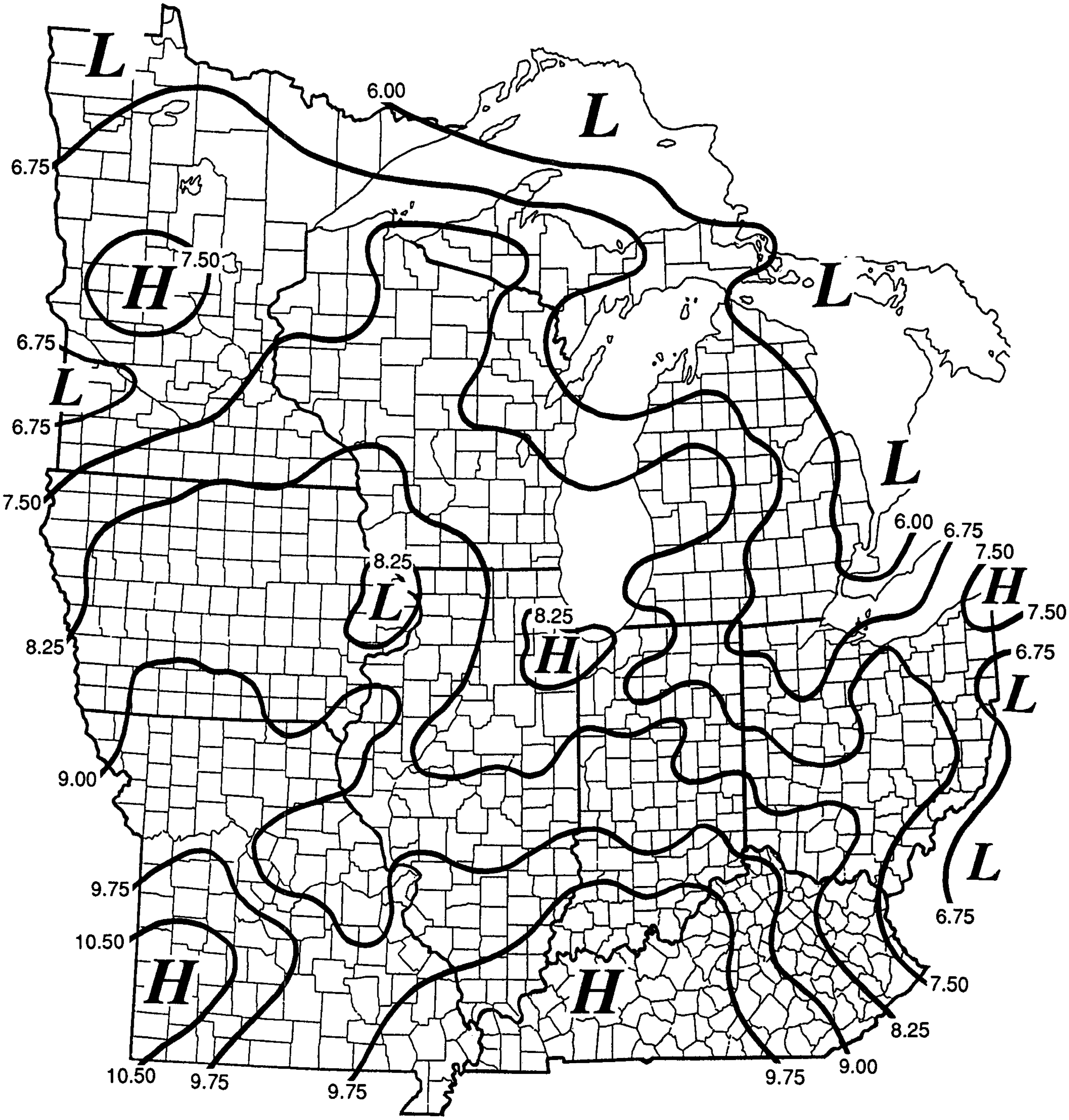

Figure 10. Continued

50-yr. 10 day

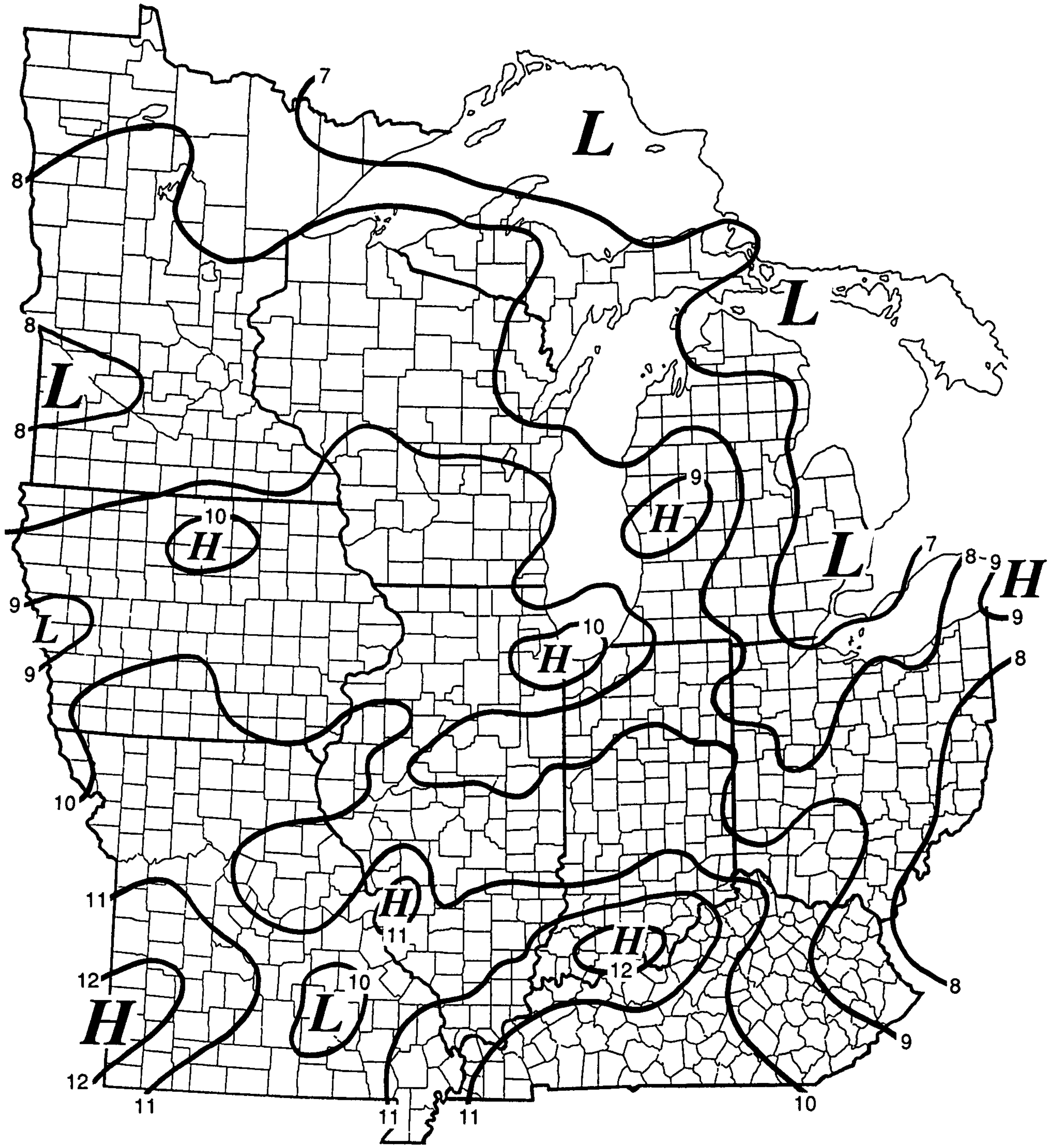

Figure 10. Continued

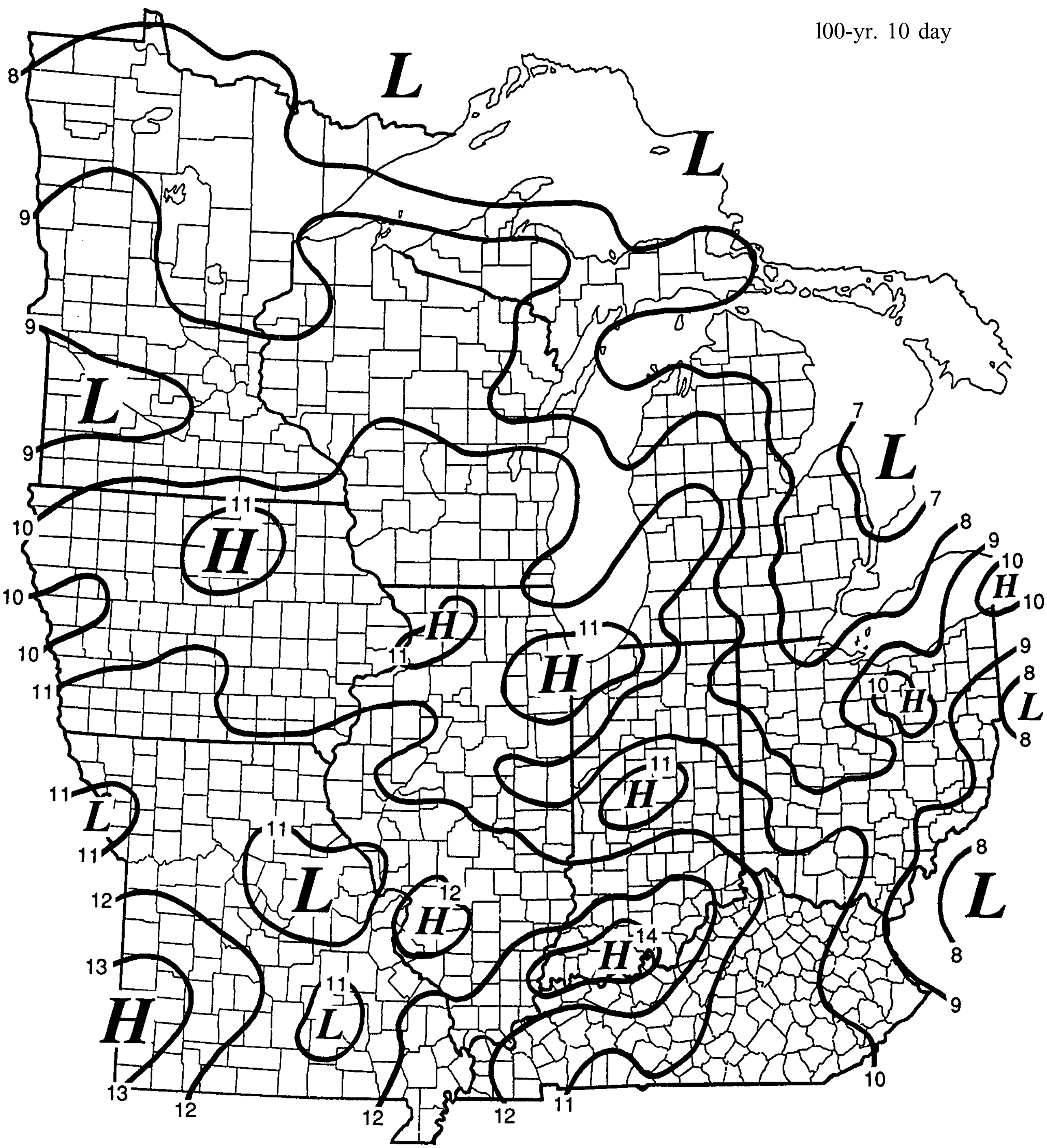

Figure 10. Concluded

Table 1. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Illinois

Sectional code (see figure 1 on page 4)

01 - Northwest	*06 - West Southwest*
02 - Northeast	*07 - East Southeast*
03 - West	*08 - Southwest*
04 - Central	*09 - Southeast*
05 - East	*10 – South*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	2.14	2.60	2.97	3.50	4.02	4.37	5.23	6.30	7.14	8.39	9.64	11.09
01	5-day	1.76	2.12	2.38	2.76	3.17	3.45	4.13	5.10	5.91	7.21	8.36	9.97
01	72-hr	1.58	1.90	2.11	2.45	2.82	3.06	3.73	4.67	5.42	6.59	7.64	8.87
01	48-hr	1.47	1.74	1.93	2.24	2.58	2.80	3.42	4.28	4.96	6.07	7.02	8.07
01	24-hr	1.40	1.64	1.80	2.08	2.36	2.57	3.11	3.95	4.63	5.60	6.53	7.36
01	18-hr	1.30	1.52	1.66	1.92	2.18	2.37	2.86	3.63	4.26	5.15	6.01	6.92
01	12-hr	1.23	1.43	1.57	1.81	2.06	2.24	2.71	3.43	4.03	4.88	5.66	6.51
01	6-hr	1.06	1.24	1.37	1.56	1.77	1.93	2.33	2.96	3.48	4.20	4.90	5.69
01	3-hr	0.91	1.06	1.16	1.33	1.52	1.65	1.99	2.53	2.97	3.59	4.18	4.90
01	2-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.83	2.33	2.74	3.31	3.86	4.47
01	1-hr	0.67	0.78	0.86	0.98	1.11	1.21	1.46	1.86	2.18	2.63	3.07	3.51
01	30-min	0.52	0.61	0.68	0.77	0.87	0.95	1.15	1.46	1.71	2.07	2.42	2.77
01	15-min	0.38	0.45	0.50	0.57	0.64	0.70	0.84	1.07	1.25	1.51	1.76	1.99
01	10-min	0.31	0.36	0.40	0.46	0.52	0.57	0.68	0.87	1.02	1.23	1.44	1.62
01	5-min	0.17	0.20	0.22	0.25	0.29	0.31	0.37	0.47	0.56	0.67	0.78	0.89
02	10-day	2.02	2.48	2.80	3.30	3.79	4.12	4.95	6.04	6.89	8.18	9.38	11.14
02	5-day	1.66	1.98	2.24	2.60	2.99	3.25	3.93	4.91	5.70	6.93	8.04	9.96
02	72-hr	1.53	1.83	2.02	2.34	2.70	2.93	3.55	4.44	5.18	6.32	7.41	8.78
02	48-hr	1.44	1.70	1.90	2.18	2.49	2.70	3.30	4.09	4.81	5.88	6.84	8.16
02	24-hr	1.38	1.61	1.76	2.03	2.31	2.51	3.04	3.80	4.47	5.51	6.46	7.58
02	18-hr	1.26	1.47	1.61	1.86	2.12	2.30	2.79	3.50	4.11	5.06	5.95	6.97
02	12-hr	1.20	1.40	1.53	1.77	2.01	2.18	2.64	3.31	3.89	4.79	5.62	6.59
02	6-hr	1.03	1.21	1.32	1.52	1.74	1.88	2.28	2.85	3.35	4.13	4.85	5.68
02	3-hr	0.88	1.02	1.13	1.30	1.47	1.60	1.94	2.43	2.86	3.53	4.14	4.85
02	2-hr	0.81	0.95	1.05	1.20	1.36	1.48	1.79	2.24	2.64	3.25	3.82	4.47
02	1-hr	0.65	0.76	0.84	0.96	1.09	1.18	1.43	1.79	2.10	2.59	3.04	3.56
02	30-min	0.51	0.60	0.65	0.75	0.86	0.93	1.12	1.41	1.65	2.04	2.39	2.80
02	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.82	1.03	1.21	1.49	1.75	2.05
02	10-min	0.30	0.35	0.39	0.45	0.51	0.55	0.67	0.84	0.98	1.21	1.42	1.67
02	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.36	0.46	0.54	0.66	0.78	0.91
03	10-day	2.27	2.78	3.13	3.68	4.23	4.60	5.60	6.91	7.89	9.24	10.36	11.90
03	5-day	1.92	2.30	2.56	2.97	3.41	3.71	4.57	5.80	6.65	7.90	8.95	10.50
03	72-hr	1.72	2.05	2.28	2.64	3.02	3.30	4.08	5.11	5.87	6.97	7.95	9.48
03	48-hr	1.61	1.88	2.09	2.42	2.76	3.01	3.68	4.56	5.50	6.45	7.56	8.80
03	24-hr	1.53	1.77	1.95	2.24	2.56	2.79	3.45	4.29	4.93	6.07	7.04	8.20
03	18-hr	1.41	1.64	1.80	2.07	2.36	2.57	3.18	3.95	4.53	5.59	6.47	7.55
03	12-hr	1.34	1.56	1.70	1.94	2.22	2.43	2.98	3.73	4.29	5.28	6.13	7.14
03	6-hr	1.15	1.34	1.47	1.67	1.91	2.10	2.58	3.22	3.70	4.55	5.28	6.15
03	3-hr	0.98	1.15	1.26	1.44	1.65	1.79	2.21	2.75	3.15	3.89	4.51	5.25
03	2-hr	0.91	1.06	1.17	1.32	1.50	1.65	2.02	2.53	2.91	3.58	4.15	4.84
03	1-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.60	2.02	2.32	2.86	3.31	3.85
03	30-min	0.57	0.66	0.73	0.83	0.95	1.03	1.27	1.59	1.82	2.25	2.61	3.03
03	15-min	0.41	0.48	0.53	0.61	0.69	0.75	0.91	1.16	1.33	1.64	1.90	2.21
03	10-min	0.34	0.39	0.43	0.49	0.56	0.61	0.74	0.94	1.08	1.33	1.55	1.81
03	5-min	0.18	0.21	0.23	0.26	0.30	0.33	0.40	0.51	0.59	0.73	0.84	0.98

Table 1. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	2.10	2.58	2.92	3.43	3.93	4.29	5.12	6.27	7.10	8.19	9.10	10.18
04	5-day	1.77	2.12	2.37	2.78	3.20	3.48	4.17	5.11	5.84	6.96	7.98	9.21
04	72-hr	1.59	1.91	2.12	2.44	2.80	3.05	3.70	4.55	5.26	6.15	7.25	8.16
04	48-hr	1.48	1.76	1.95	2.25	2.58	2.81	3.38	4.19	4.86	5.78	6.62	7.51
04	24-hr	1.39	1.63	1.80	2.04	2.32	2.52	3.02	3.76	4.45	5.32	6.08	6.92
04	18-hr	1.27	1.51	1.66	1.88	2.12	2.28	2.75	3.46	4.09	4.90	5.59	6.37
04	12-hr	1.19	1.40	1.53	1.77	2.01	2.17	2.62	3.27	3.87	4.63	5.29	6.02
04	6-hr	1.03	1.21	1.34	1.53	1.74	1.89	2.26	2.82	3.33	3.99	4.56	5.19
04	3-hr	0.89	1.03	1.13	1.30	1.47	1.61	1.93	2.41	2.85	3.41	3.89	4.43
04	2-hr	0.82	0.95	1.04	1.19	1.37	1.48	1.78	2.22	2.62	3.14	3.59	4.08
04	1-hr	0.65	0.76	0.83	0.95	1.09	1.18	1.42	1.77	2.09	2.50	2.86	3.25
04	30-min	0.52	0.60	0.66	0.75	0.86	0.93	1.12	1.39	1.64	1.97	2.25	2.56
04	15-min	0.37	0.44	0.49	0.56	0.63	0.68	0.81	1.02	1.20	1.44	1.64	1.87
04	10-min	0.30	0.35	0.39	0.45	0.50	0.55	0.66	0.83	0.98	1.17	1.34	1.52
04	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.36	0.45	0.53	0.64	0.73	0.83
05	10-day	2.13	2.62	2.96	3.48	4.00	4.35	5.15	6.21	6.97	8.04	8.90	9.92
05	5-day	1.75	2.10	2.37	2.75	3.15	3.42	4.12	4.96	5.67	6.76	7.65	8.78
05	72-hr	1.61	1.93	2.16	2.48	2.85	3.10	3.71	4.57	5.20	6.17	6.97	7.83
05	48-hr	1.51	1.77	1.95	2.26	2.57	2.82	3.40	4.16	4.77	5.66	6.40	7.16
05	24-hr	1.36	1.58	1.75	2.00	2.27	2.47	3.01	3.71	4.26	5.04	5.83	6.61
05	18-hr	1.25	1.47	1.62	1.84	2.09	2.27	2.77	3.41	3.92	4.63	5.37	6.08
05	12-hr	1.18	1.38	1.53	1.74	1.98	2.15	2.62	3.23	3.71	4.38	5.08	5.75
05	6-hr	1.00	1.18	1.32	1.49	1.70	1.85	2.26	2.78	3.20	3.78	4.38	4.96
05	3-hr	0.87	1.02	1.12	1.28	1.46	1.58	1.93	2.37	2.73	3.22	3.74	4.23
05	2-hr	0.79	0.93	1.03	1.17	1.34	1.46	1.78	2.19	2.52	2.97	3.44	3.90
05	1-hr	0.64	0.74	0.81	0.93	1.07	1.16	1.41	1.74	2.00	2.39	2.74	3.11
05	30-min	0.50	0.58	0.64	0.74	0.84	0.91	1.11	1.37	1.57	1.87	2.16	2.45
05	15-min	0.37	0.43	0.47	0.54	0.62	0.67	0.81	1.00	1.14	1.37	1.60	1.85
05	10-min	0.30	0.35	0.38	0.43	0.49	0.54	0.66	0.81	0.94	1.12	1.28	1.46
05	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.36	0.44	0.51	0.61	0.70	0.79
06	10-day	2.16	2.65	2.99	3.52	4.05	4.40	5.35	6.62	7.45	8.66	9.79	11.26
06	5-day	1.77	2.13	2.39	2.78	3.19	3.47	4.19	5.32	6.20	7.44	8.53	9.93
06	72-hr	1.63	1.95	2.16	2.50	2.88	3.13	3.81	4.85	5.68	6.84	7.76	8.92
06	48-hr	1.52	1.81	2.00	2.30	2.64	2.87	3.49	4.45	5.21	6.28	7.12	8.19
06	24-hr	1.42	1.66	1.84	2.10	2.38	2.59	3.11	3.93	4.65	5.57	6.46	7.45
06	18-hr	1.31	1.53	1.68	1.93	2.19	2.38	2.86	3.61	4.28	5.12	5.95	6.85
06	12-hr	1.24	1.44	1.57	1.82	2.07	2.25	2.71	3.39	3.97	4.84	5.62	6.48
06	6-hr	1.07	1.24	1.37	1.57	1.78	1.94	2.33	2.95	3.48	4.18	4.85	5.59
06	3-hr	0.91	1.07	1.18	1.34	1.52	1.66	1.99	2.51	2.98	3.56	4.14	4.77
06	2-hr	0.84	0.98	1.08	1.24	1.41	1.53	1.84	2.32	2.74	3.28	3.81	4.39
06	1-hr	0.67	0.79	0.87	0.99	1.12	1.21	1.46	1.85	2.19	2.62	3.04	3.50
06	30-min	0.53	0.61	0.68	0.78	0.88	0.96	1.15	1.46	1.72	2.06	2.39	2.75
06	15-min	0.38	0.45	0.49	0.57	0.64	0.70	0.84	1.06	1.26	1.52	1.75	2.01
06	10-min	0.31	0.36	0.40	0.46	0.52	0.57	0.68	0.87	1.02	1.22	1.42	1.64
06	5-min	0.17	0.20	0.22	0.25	0.29	0.31	0.37	0.47	0.56	0.67	0.78	0.89

Table 1. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	2.30	2.80	3.16	3.70	4.27	4.64	5.58	6.80	7.61	8.66	9.70	10.87
07	5-day	1.85	2.22	2.50	2.90	3.31	3.63	4.34	5.33	6.11	7.28	8.37	9.65
07	72-hr	1.62	1.90	2.15	2.50	2.87	3.12	3.73	4.64	5.32	6.39	7.35	8.54
07	48-hr	1.52	1.78	1.98	2.30	2.64	2.87	3.42	4.26	4.88	5.84	6.75	8.00
07	24-hr	1.40	1.63	1.78	2.07	2.35	2.55	3.03	3.80	4.44	5.37	6.23	7.41
07	18-hr	1.29	1.50	1.64	1.90	2.16	2.35	2.79	3.49	4.08	4.94	5.73	6.81
07	12-hr	1.21	1.42	1.55	1.80	2.04	2.22	2.63	3.30	3.86	4.67	5.42	6.45
07	6-hr	1.06	1.23	1.37	1.55	1.74	1.87	2.27	2.85	3.33	4.03	4.67	5.56
07	3-hr	0.89	1.05	1.15	1.32	1.50	1.63	1.94	2.43	2.84	3.44	3.99	4.74
07	2-hr	0.83	0.97	1.07	1.22	1.38	1.50	1.79	2.24	2.62	3.17	3.67	4.39
07	1-hr	0.66	0.77	0.85	0.97	1.10	1.20	1.42	1.78	2.09	2.52	2.93	3.48
07	30-min	0.52	0.60	0.66	0.76	0.86	0.93	1.12	1.41	1.64	1.99	2.31	2.74
07	15-min	0.38	0.44	0.49	0.56	0.63	0.69	0.82	1.03	1.20	1.45	1.68	2.00
07	10-min	0.31	0.36	0.40	0.45	0.51	0.56	0.66	0.83	0.98	1.18	1.37	1.63
07	5-min	0.17	0.20	0.22	0.25	0.29	0.31	0.36	0.46	0.54	0.64	0.75	0.89
08	10-day	2.22	2.74	3.09	3.63	4.18	4.54	5.54	6.80	7.80	9.20	10.44	11.81
08	5-day	1.85	2.21	2.49	2.90	3.31	3.62	4.40	5.46	6.34	7.68	8.88	10.68
08	72-hr	1.67	1.97	2.20	2.54	2.93	3.22	3.94	4.92	5.74	6.97	8.12	9.55
08	48-hr	1.57	1.85	2.06	2.38	2.75	2.97	3.59	4.52	5.26	6.43	7.36	8.81
08	24-hr	1.49	1.73	1.90	2.20	2.48	2.71	3.28	4.13	4.76	6.02	7.07	8.21
08	18-hr	1.35	1.59	1.74	2.00	2.29	2.49	3.02	3.80	4.38	5.54	6.51	7.55
08	12-hr	1.28	1.50	1.64	1.88	2.15	2.35	2.86	3.60	4.14	5.24	6.15	7.14
08	6-hr	1.12	1.30	1.44	1.64	1.87	2.03	2.45	3.10	3.57	4.52	5.30	6.16
08	3-hr	0.95	1.12	1.22	1.40	1.59	1.73	2.10	2.63	3.08	3.86	4.52	5.25
08	2-hr	0.88	1.02	1.13	1.28	1.47	1.60	1.94	2.44	2.87	3.55	4.20	4.84
08	1-hr	0.70	0.81	0.89	1.02	1.15	1.26	1.54	1.93	2.27	2.84	3.32	3.86
08	30-min	0.55	0.64	0.71	0.81	0.92	1.00	1.22	1.53	1.78	2.25	2.62	3.03
08	15-min	0.40	0.47	0.52	0.59	0.67	0.73	0.89	1.12	1.29	1.63	1.91	2.22
08	10-min	0.33	0.38	0.42	0.49	0.55	0.60	0.72	0.91	1.05	1.32	1.55	1.81
08	5-min	0.18	0.21	0.23	0.26	0.30	0.33	0.40	0.50	0.58	0.72	0.85	0.99
09	10-day	2.30	2.88	3.23	3.80	4.33	4.75	5.74	7.09	8.07	9.54	10.68	11.79
09	5-day	1.90	2.29	2.59	3.00	3.45	3.75	4.48	5.57	6.50	7.91	9.16	10.57
09	72-hr	1.73	2.02	2.25	2.62	3.00	3.27	3.92	4.92	5.75	7.05	8.23	9.40
09	48-hr	1.59	1.87	2.07	2.40	2.76	3.00	3.60	4.52	5.28	6.48	7.58	8.62
09	24-hr	1.44	1.68	1.85	2.12	2.41	2.62	3.16	4.00	4.62	5.79	6.71	7.73
09	18-hr	1.33	1.55	1.71	1.95	2.22	2.41	2.91	3.68	4.25	5.33	6.17	7.11
09	12-hr	1.25	1.46	1.60	1.85	2.10	2.28	2.75	3.48	4.02	5.04	5.84	6.72
09	6-hr	1.08	1.27	1.41	1.60	1.81	1.97	2.37	3.00	3.47	4.34	5.03	5.80
09	3-hr	0.92	1.08	1.21	1.37	1.55	1.68	2.02	2.56	2.96	3.71	4.29	4.95
09	2-hr	0.85	1.00	1.12	1.26	1.43	1.55	1.85	2.36	2.72	3.41	3.96	4.56
09	1-hr	0.68	0.79	0.88	1.00	1.13	1.23	1.49	1.88	2.20	2.72	3.15	3.63
09	30-min	0.53	0.62	0.68	0.78	0.89	0.97	1.17	1.47	1.73	2.14	2.48	2.86
09	15-min	0.39	0.46	0.50	0.58	0.65	0.71	0.85	1.08	1.25	1.56	1.81	2.09
09	10-min	0.32	0.37	0.41	0.47	0.53	0.58	0.70	0.88	1.02	1.27	1.48	1.70
09	5-min	0.18	0.20	0.22	0.26	0.29	0.32	0.38	0.48	0.55	0.69	0.81	0.93

Table 1. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
10	10-day	2.55	3.15	3.58	4.21	4.84	5.26	6.36	7.81	8.90	10.34	11.36	12.50
10	5-day	2.09	2.52	2.83	3.29	3.77	4.10	4.99	6.20	7.21	8.45	9.45	10.82
10	72-hr	1.88	2.25	2.49	2.87	3.30	3.59	4.36	5.48	6.34	7.53	8.54	9.52
10	48-hr	1.75	2.08	2.31	2.65	3.02	3.30	4.00	5.03	5.80	6.93	7.86	8.79
10	24-hr	1.63	1.91	2.10	2.41	2.74	2.97	3.62	4.51	5.21	6.23	7.11	8.27
10	18-hr	1.51	1.77	1.95	2.22	2.52	2.74	3.33	4.15	4.79	5.74	6.54	7.61
10	12-hr	1.42	1.66	1.83	2.10	2.38	2.59	3.15	3.93	4.53	5.42	6.19	7.20
10	6-hr	1.23	1.44	1.58	1.71	2.05	2.23	2.73	3.39	3.91	4.68	5.31	6.21
10	3-hr	1.06	1.23	1.35	1.54	1.75	1.90	2.32	2.89	3.33	3.99	4.55	5.29
10	2-hr	0.97	1.13	1.25	1.43	1.62	1.76	2.14	2.66	3.07	3.68	4.20	4.88
10	1-hr	0.77	0.90	0.99	1.13	1.29	1.40	1.70	2.12	2.45	2.93	3.34	3.89
10	30-min	0.61	0.70	0.77	0.89	1.01	1.10	1.34	1.66	1.93	2.31	2.63	3.06
10	15-min	0.43	0.51	0.56	0.65	0.74	0.80	0.98	1.22	1.41	1.68	1.92	2.23
10	10-min	0.36	0.42	0.46	0.53	0.60	0.65	0.80	0.99	1.14	1.37	1.56	1.82
10	5-min	0.20	0.23	0.25	0.29	0.33	0.36	0.43	0.54	0.62	0.75	0.85	0.99

Table 2. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Indiana

Sectional code (see figure 1 on page 4)

01- Northwes
02 - North Central
03 - Northeast
04 - West Central
05 - Central
06 - East Central
07 - Southwest
08 - South Central
09- Southeast

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	2.07	2.50	2.88	3.38	3.89	4.23	4.84	5.79	6.67	8.03	9.23	10.58
01	5-day	1.68	2.01	2.27	2.63	3.03	3.29	3.84	4.70	5.50	6.81	7.99	9.37
01	72-hr	1.53	1.80	2.04	2.36	2.71	2.95	3.46	4.24	4.97	6.10	7.17	8.38
01	48-hr	1.40	1.64	1.83	2.12	2.44	2.65	3.12	3.87	4.56	5.58	6.52	7.58
01	24-hr	1.33	1.55	1.69	1.96	2.23	2.42	2.89	3.61	4.22	5.22	6.10	7.12
01	18-hr	1.25	1.45	1.59	1.84	2.09	2.27	2.72	3.39	3.97	4.91	5.73	6.69
01	12-hr	1.16	1.35	1.48	1.71	1.94	2.11	2.51	3.14	3.67	4.54	5.31	6.19
01	6-hr	1.00	1.16	1.27	1.47	1.67	1.82	2.17	2.71	3.16	3.91	4.57	5.34
01	3-hr	0.85	0.99	1.08	1.26	1.43	1.55	1.85	2.31	2.70	3.34	3.90	4.56
01	2-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.68	2.09	2.45	3.03	3.54	4.13
01	1-hr	0.63	0.73	0.80	0.92	1.05	1.14	1.36	1.70	1.98	2.45	2.87	3.35
01	30-min	0.50	0.58	0.63	0.73	0.83	0.90	1.07	1.34	1.56	1.93	2.26	2.63
01	15-min	0.36	0.42	0.45	0.53	0.60	0.65	0.78	0.97	1.14	1.41	1.65	1.92
01	10-min	0.28	0.33	0.36	0.41	0.47	0.51	0.61	0.76	0.89	1.10	1.28	1.50
01	5-min	0.16	0.19	0.20	0.23	0.27	0.29	0.35	0.43	0.51	0.63	0.73	0.85
02	10-day	2.04	2.45	2.83	3.33	3.83	4.16	4.75	5.64	6.45	7.69	8.80	10.03
02	5-day	1.68	2.01	2.28	2.64	3.04	3.30	3.80	4.62	5.38	6.57	7.63	8.85
02	72-hr	1.48	1.74	1.97	2.28	2.62	2.85	3.33	4.10	4.79	5.88	6.86	8.00
02	48-hr	1.37	1.60	1.78	2.06	2.37	2.58	3.02	3.73	4.36	5.36	6.25	7.28
02	24-hr	1.30	1.51	1.65	1.91	2.17	2.36	2.78	3.43	4.00	4.90	5.67	6.54
02	18-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.61	3.22	3.76	4.61	5.33	6.15
02	12-hr	1.13	1.31	1.43	1.66	1.89	2.05	2.42	2.98	3.48	4.26	4.93	5.69
02	6-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.09	2.57	3.00	3.68	4.25	4.90
02	3-hr	0.83	0.97	1.06	1.22	1.39	1.51	1.78	2.20	2.56	3.14	3.63	4.19
02	2-hr	0.75	0.88	0.96	1.11	1.26	1.37	1.61	1.99	2.32	2.84	3.29	3.79
02	1-hr	0.61	0.71	0.78	0.90	1.02	1.11	1.31	1.61	1.88	2.30	2.66	3.07
02	30-min	0.48	0.56	0.61	0.70	0.80	0.87	1.03	1.27	1.48	1.81	2.10	2.42
02	15-min	0.35	0.41	0.45	0.52	0.59	0.64	0.75	0.93	1.08	1.32	1.53	1.77
02	10-min	0.28	0.32	0.35	0.41	0.46	0.50	0.58	0.72	0.84	1.03	1.19	1.37
02	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.33	0.41	0.48	0.59	0.68	0.78
03	10-day	1.81	2.18	2.52	2.96	3.40	3.70	4.25	5.12	5.84	6.96	8.01	9.16
03	5-day	1.52	1.82	2.06	2.38	2.74	2.98	3.46	4.18	4.81	5.83	6.76	7.80
03	72-hr	1.35	1.59	1.79	2.08	2.39	2.60	3.01	3.68	4.27	5.21	6.06	7.01
03	48-hr	1.27	1.48	1.65	1.91	2.20	2.39	2.77	3.38	3.92	4.78	5.57	6.45
03	24-hr	1.19	1.38	1.51	1.75	1.99	2.16	2.52	3.04	3.52	4.29	5.02	5.77
03	18-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.37	2.86	3.31	4.03	4.72	5.42
03	12-hr	1.03	1.20	1.32	1.52	1.73	1.68	2.19	2.64	3.06	3.73	4.37	5.02
03	6-hr	0.89	1.04	1.13	1.31	1.49	1.62	1.89	2.28	2.64	3.22	3.76	4.33
03	3-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.61	1.95	2.25	2.75	3.21	3.69
03	2-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.46	1.76	2.04	2.49	2.91	3.35
03	1-hr	0.56	0.65	0.71	0.83	0.94	1.02	1.18	1.43	1.65	2.02	2.36	2.71
03	30-min	0.44	0.51	0.56	0.65	0.74	0.80	0.93	1.12	1.30	1.59	1.86	2.13
03	15-min	0.32	0.37	0.41	0.47	0.53	0.58	0.68	0.82	0.95	1.16	1.36	1.56
03	10-min	0.25	0.29	0.31	0.36	0.41	0.45	0.53	0.64	0.74	0.90	1.05	1.21
03	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.30	0.36	0.42	0.51	0.60	0.69

Table 2. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	2.32	2.80	3.22	3.79	4.36	4.74	5.43	6.47	7.33	8.50	9.48	10.65
04	5-day	1.85	2.21	2.50	2.90	3.34	3.63	4.24	5.15	5.97	7.25	8.31	9.55
04	72-hr	1.64	1.93	2.18	2.53	2.91	3.16	3.76	4.53	5.34	6.43	7.45	8.55
04	48-hr	1.53	1.79	1.99	2.30	2.65	2.88	3.38	4.12	4.75	5.77	6.66	7.65
04	24-hr	1.45	1.68	1.84	2.13	2.42	2.63	3.12	3.83	4.47	5.39	6.17	7.01
04	18-hr	1.36	1.58	1.73	2.00	2.27	2.47	2.93	3.60	4.20	5.07	5.80	6.59
04	12-hr	1.26	1.47	1.60	1.85	2.11	2.29	2.71	3.33	3.89	4.69	5.37	6.10
04	6-hr	1.08	1.26	1.38	1.60	1.81	1.97	2.34	2.87	3.35	4.04	4.63	5.26
04	3-hr	0.92	1.08	1.18	1.36	1.55	1.68	2.00	2.45	2.86	3.45	3.95	4.49
04	2-hr	0.84	0.98	1.07	1.24	1.41	1.53	1.81	2.22	2.59	3.13	3.58	4.07
04	1-hr	0.68	0.79	0.87	1.00	1.14	1.24	1.47	1.80	2.10	2.53	2.90	3.29
04	30-min	0.53	0.62	0.68	0.79	0.89	0.97	1.15	1.42	1.65	1.99	2.28	2.59
04	15-min	0.39	0.45	0.50	0.58	0.65	0.71	0.84	1.03	1.21	1.46	1.67	1.89
04	10-min	0.30	0.35	0.38	0.45	0.51	0.55	0.66	0.80	0.94	1.13	1.30	1.47
04	5-min	0.18	0.20	0.22	0.26	0.29	0.32	0.37	0.46	0.54	0.65	0.74	0.84
05	10-day	2.13	2.56	2.95	3.47	3.99	4.34	5.06	6.07	6.96	8.36	9.57	10.86
05	5-day	1.73	2.07	2.34	2.71	3.12	3.39	3.97	4.86	5.66	6.91	8.07	9.44
05	72-hr	1.52	1.79	2.02	2.34	2.70	2.93	3.45	4.27	5.04	6.15	7.17	8.31
05	48-hr	1.42	1.66	1.85	2.14	2.47	2.68	3.18	3.94	4.63	5.65	6.56	7.55
05	24-hr	1.35	1.57	1.72	1.99	2.26	2.46	2.92	3.64	4.25	5.16	5.95	6.84
05	18-hr	1.27	1.48	1.62	1.87	2.13	2.31	2.74	3.42	3.99	4.85	5.59	6.43
05	12-hr	1.18	1.37	1.50	1.73	1.97	2.14	2.54	3.17	3.70	4.49	5.18	5.95
05	6-hr	1.02	1.18	1.29	1.50	1.70	1.85	2.19	2.73	3.19	3.87	4.46	5.13
05	3-hr	0.86	1.00	1.10	1.27	1.44	1.57	1.87	2.33	2.72	3.30	3.81	4.38
05	2-hr	0.79	0.92	1.00	1.16	1.32	1.43	1.69	2.11	2.46	2.99	3.45	3.97
05	1-hr	0.64	0.74	0.81	0.94	1.07	1.16	1.37	1.71	2.00	2.43	2.80	3.21
05	30-min	0.50	0.58	0.64	0.74	0.84	0.91	1.08	1.35	1.57	1.91	2.20	2.53
05	15-min	0.36	0.42	0.46	0.53	0.61	0.66	0.79	0.98	1.15	1.39	1.61	1.85
05	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.61	0.76	0.89	1.08	1.25	1.44
05	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.35	0.44	0.51	0.62	0.71	0.82
06	10-day	2.13	2.57	2.96	3.48	4.00	4.35	5.00	6.00	6.82	8.30	9.55	11.05
06	5-day	1.62	1.93	2.19	2.54	2.92	3.17	3.75	4.68	5.50	6.90	8.20	9.68
06	72-hr	1.45	1.70	1.92	2.22	2.56	2.78	3.30	4.15	4.98	6.06	7.25	8.55
06	48-hr	1.36	1.59	1.77	2.06	2.36	2.57	3.01	3.73	4.40	5.54	6.55	7.70
06	24-hr	1.26	1.47	1.61	1.66	2.12	2.30	2.76	3.37	3.89	4.65	5.29	6.05
06	18-hr	1.19	1.38	1.51	1.75	1.99	2.16	2.59	3.17	3.66	4.37	4.97	5.69
06	12-hr	1.10	1.28	1.40	1.62	1.84	2.00	2.40	2.93	3.38	4.05	4.60	5.26
06	6-hr	0.95	1.10	1.20	1.39	1.58	1.72	2.07	2.53	2.92	3.49	3.97	4.54
06	3-hr	0.81	0.94	1.03	1.19	1.35	1.47	1.77	2.16	2.49	2.98	3.39	3.87
06	2-hr	0.73	0.85	0.93	1.08	1.22	1.33	1.60	1.95	2.26	2.70	3.07	3.51
06	1-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.30	1.58	1.83	2.19	2.49	2.84
06	30-min	0.47	0.54	0.60	0.69	0.78	0.85	1.02	1.25	1.44	1.72	1.96	2.24
06	15-min	0.34	0.40	0.43	0.50	0.57	0.62	0.75	0.91	1.05	1.26	1.43	1.63
06	10-min	0.26	0.31	0.34	0.39	0.44	0.48	0.58	0.71	0.82	0.98	1.11	1.27
06	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.33	0.40	0.47	0.56	0.63	0.73

Table 2. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	2.53	3.05	3.52	4.14	4.76	5.17	5.99	7.29	8.46	10.28	11.91	13.74
07	5-day	1.96	2.35	2.66	3.08	3.54	3.85	4.54	5.64	6.66	8.25	9.72	11.32
07	72-hr	1.80	2.11	2.39	2.77	3.18	3.46	4.10	5.12	6.02	7.49	8.79	10.28
07	48-hr	1.65	1.93	2.15	2.50	2.87	3.12	3.68	4.56	5.35	6.62	7.77	9.08'
07	24-hr	1.52	1.77	1.93	2.24	2.54	2.76	3.27	4.00	4.65	5.66	6.52	7.47
07	18-hr	1.42	1.66	1.81	2.10	2.38	2.59	3.07	3.76	4.37	5.32	6.13	7.02
07	12-hr	1.32	1.54	1.68	1.94	2.21	2.40	2.84	3.48	4.05	4.92	5.67	6.50
07	6-hr	1.14	1.32	1.45	1.68	1.90	2.07	2.45	3.00	3.49	4.24	4.89	5.60
07	3-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.09	2.56	2.98	3.62	4.17	4.78
07	2-hr	0.88	1.02	1.12	1.30	1.47	1.60	1.90	2.32	2.70	3.28	3.78	4.33
07	1-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.54	1.88	2.19	2.66	3.06	3.51
07	30-min	0.56	0.65	0.71	0.83	0.94	1.02	1.21	1.48	1.72	2.09	2.41	2.76
07	15-min	0.41	0.48	0.52	0.61	0.69	0.75	0.88	1.08	1.26	1.53	1.76	2.02
07	10-min	0.32	0.37	0.41	0.47	0.53	0.58	0.69	0.84	0.98	1.19	1.37	1.57
07	5-min	0.18	0.21	0.23	0.27	0.30	0.33	0.39	0.48	0.56	0.68	0.78	0.90
08	10-day	2.39	2.88	3.32	3.90	4.49	4.88	5.74	6.95	7.99	9.60	11.04	12.64
08	5-day	1.90	2.27	2.57	2.98	3.42	3.72	4.50	5.54	6.43	7.71	8.88	10.18
08	72-hr	1.70	1.99	2.25	2.61	3.00	3.26	3.88	4.82	5.65	6.92	7.99	9.14
08	48-hr	1.61	1.88	2.10	2.43	2.80	3.04	3.61	4.41	5.13	6.18	7.14	8.13
08	24-hr	1.48	1.72	1.88	2.18	2.47	2.69	3.17	3.90	4.49	5.40	6.15	7.06
08	18-hr	1.39	1.62	1.77	2.05	2.33	2.53	2.98	3.67	4.22	5.08	5.78	6.64
08	12-hr	1.29	1.50	1.64	1.90	2.15	2.34	2.76	3.39	3.91	4.70	5.35	6.14
08	6-hr	1.11	1.29	1.41	1.64	1.66	2.02	2.38	2.93	3.37	4.05	4.61	5.30
08	3-hr	0.95	1.10	1.20	1.39	1.58	1.72	2.03	2.50	2.87	3.46	3.94	4.52
08	2-hr	0.86	1.00	1.09	1.26	1.44	1.56	1.84	2.26	2.60	3.13	3.57	4.09
08	1-hr	0.69	0.81	0.88	1.02	1.16	1.26	1.49	1.83	2.11	2.54	2.89	3.32
08	30-min	0.55	0.64	0.70	0.81	0.92	1.00	1.17	1.44	1.66	2.00	2.28	2.61
08	15-min	0.40	0.47	0.51	0.59	0.67	0.73	0.86	1.05	1.21	1.46	1.66	1.91
08	10-min	0.31	0.36	0.39	0.45	0.52	0.56	0.67	0.82	0.94	1.13	1.29	1.48
08	5-min	0.18	0.20	0.22	0.26	0.29	0.32	0.38	0.47	0.54	0.65	0.74	0.85
09	10-day	2.35	2.83	3.26	3.83	4.41	4.79	5.62	6.85	7.87	9.42	10.90	12.33
09	5-day	1.86	2.23	2.52	2.92	3.36	3.65	4.29	5.22	6.06	7.39	8.54	9.90
09	72-hr	1.67	1.96	2.22	2.58	2.96	3.22	3.87	4.77	5.53	6.75	7.80	8.95
09	48-hr	1.55	1.82	2.02	2.34	2.70	2.93	3.53	4.40	5.13	6.22	7.19	8.20
09	24-hr	1.36	1.58	1.73	2.00	2.27	2.47	3.03	3.81	4.42	5.39	6.20	7.12
09	18-hr	1.28	1.48	1.62	1.88	2.13	2.32	2.85	3.58	4.15	5.07	5.83	6.69
09	12-hr	1.18	1.38	1.50	1.74	1.98	2.15	2.64	3.31	3.85	4.69	5.39	6.19
09	6-hr	1.02	1.18	1.29	1.50	1.70	1.85	2.27	2.86	3.32	4.04	4.65	5.34
09	3-hr	0.87	1.01	1.11	1.28	1.45	1.58	1.94	2.44	2.83	3.45	3.97	4.56
09	2-hr	0.79	0.92	1.00	1.16	1.32	1.43	1.76	2.21	2.56	3.13	3.60	4.13
09	1-hr	0.64	0.74	0.81	0.94	1.07	1.16	1.42	1.79	2.08	2.53	2.91	3.35
09	30-min	0.50	0.58	0.64	0.74	0.84	0.91	1.12	1.41	1.64	1.99	2.29	2.63
09	15-min	0.37	0.43	0.47	0.54	0.62	0.67	0.82	1.03	1.19	1.46	1.67	1.92
09	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.64	0.80	0.93	1.13	1.30	1.50
09	5-min	0.17	0.19	0.21	0.24	0.26	0.30	0.36	0.46	0.53	0.65	0.74	0.85

Table 3. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Iowa

Sectional code (see figure 1 on page 4)

01 - Northwest *06 - East Central*
02 - North Central *07 - Southwest*
03 - Northeast *08 - South Central*
04 - West Central *09 - Southeast*
05 - Central

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.98	2.39	2.75	3.24	3.73	4.05	4.81	5.84	6.70	8.02	9.11	10.31
01	5-day	1.59	1.90	2.15	2.49	2.86	3.11	3.77	4.68	5.43	6.61	7.60	8.75
01	72-hr	1.41	1.66	1.88	2.18	2.50	2.72	3.33	4.21	4.99	6.07	7.12	8.23
01	48-hr	1.32	1.55	1.73	2.00	2.30	2.50	3.01	3.81	4.52	5.60	6.53	7.52
01	24-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.75	3.50	4.14	5.11	5.97	6.92
01	18-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.59	3.29	3.89	4.80	5.61	6.50
01	12-hr	1.06	1.24	1.35	1.56	1.78	1.93	2.39	3.05	3.60	4.45	5.19	6.02
01	6-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.06	2.62	3.11	3.83	4.48	5.19
01	3-hr	0.78	0.91	0.99	1.15	1.31	1.42	1.76	2.24	2.65	3.27	3.82	4.43
01	2-hr	0.71	0.83	0.90	1.04	1.19	1.29	1.59	2.03	2.40	2.96	3.46	4.01
01	1-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.29	1.64	1.95	2.40	2.81	3.25
01	30-min	0.45	0.52	0.57	0.66	0.75	0.82	1.02	1.30	1.53	1.89	2.21	2.56
01	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.74	0.95	1.12	1.38	1.61	1.87
01	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.73	0.87	1.07	1.25	1.45
01	6-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.42	0.50	0.61	0.72	0.83
02	10-day	1.96	2.37	2.73	3.21	3.69	4.01	5.04	6.26	7.32	8.93	10.37	11.40
02	5-day	1.75	2.10	2.37	2.75	3.16	3.44	4.13	5.05	5.80	7.00	8.03	9.28
02	72-hr	1.49	1.74	1.97	2.29	2.63	2.86	3.53	4.45	5.15	6.33	7.30	8.30
02	48-hr	1.42	1.66	1.84	2.14	2.46	2.67	3.30	4.11	4.78	5.80	6.67	7.67
02	24-hr	1.30	1.51	1.65	1.91	2.17	2.36	2.98	3.72	4.38	5.33	6.14	7.07
02	18-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.80	3.50	4.12	5.01	5.77	6.65
02	12-hr	1.13	1.31	1.43	1.66	1.89	2.05	2.59	3.24	3.81	4.64	5.34	6.15
02	6-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.24	2.79	3.29	4.00	4.61	5.30
02	3-hr	0.83	0.97	1.06	1.22	1.39	1.51	1.91	2.38	2.80	3.41	3.93	4.52
02	2-hr	0.75	0.88	0.96	1.11	1.26	1.37	1.73	2.16	2.54	3.09	3.56	4.10
02	1-hr	0.61	0.71	0.78	0.90	1.02	1.11	1.40	1.75	2.06	2.51	2.89	3.32
02	30-min	0.48	0.56	0.61	0.70	0.80	0.87	1.10	1.38	1.62	1.97	2.27	2.62
02	15-min	0.35	0.41	0.45	0.52	0.59	0.64	0.80	1.00	1.18	1.44	1.66	1.91
02	10-min	0.28	0.32	0.35	0.41	0.46	0.50	0.63	0.78	0.92	1.12	1.29	1.48
02	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.36	0.45	0.53	0.64	0.74	0.85
03	10-day	2.07	2.49	2.87	3.38	3.88	4.22	5.04	6.17	7.07	8.29	9.20	10.19
03	5-day	1.69	2.03	2.29	2.66	3.05	3.32	3.94	4.86	5.64	6.84	7.75	8.77
03	72-hr	1.49	1.74	1.97	2.29	2.63	2.86	3.44	4.33	5.14	6.19	7.00	7.84
03	48-hr	1.37	1.61	1.79	2.07	2.38	2.59	3.20	4.02	4.69	5.62	6.34	7.09
03	24-hr	1.28	1.48	1.62	1.88	2.13	2.32	2.91	3.67	4.31	5.11	5.73	6.36
03	18-hr	1.20	1.40	1.53	1.77	2.01	2.18	2.74	3.45	4.05	4.80	5.39	5.98
03	12-hr	1.11	1.29	1.41	1.64	1.86	2.02	2.53	3.19	3.75	4.45	4.99	5.53
03	6-hr	0.96	1.11	1.22	1.41	1.60	1.74	2.18	2.75	3.23	3.83	4.30	4.77
03	3-hr	0.81	0.95	1.04	1.20	1.36	1.48	1.86	2.35	2.76	3.27	3.67	4.07
03	2-hr	0.74	0.86	0.94	1.09	1.24	1.35	1.69	2.13	2.50	2.96	3.32	3.69
03	1-hr	0.60	0.70	0.76	0.88	1.00	1.09	1.37	1.72	2.03	2.40	2.69	2.99
03	30-min	0.47	0.55	0.60	0.70	0.79	0.86	1.08	1.36	1.59	1.89	2.12	2.35
03	15-min	0.35	0.40	0.44	0.51	0.58	0.63	0.79	0.99	1.16	1.38	1.55	1.72
03	10-min	0.27	0.31	0.34	0.40	0.45	0.49	0.61	0.77	0.91	1.07	1.20	1.34
03	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.35	0.44	0.52	0.61	0.69	0.76

Table 3. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	2.15	2.59	2.99	3.51	4.04	4.39	5.22	6.31	7.16	8.24	9.21	10.27
04	5-day	1.76	2.11	2.39	2.77	3.18	3.46	4.06	4.94	5.74	7.04	8.13	9.27
04	72-hr	1.52	1.79	2.02	2.34	2.70	2.93	3.51	4.37	5.13	6.28	7.26	8.46
04	48-hr	1.43	1.67	1.86	2.15	2.47	2.69	3.16	3.97	4.71	5.86	6.81	7.82
04	24-hr	1.36	1.59	1.74	2.01	2.28	2.48	2.94	3.64	4.30	5.27	6.08	7.00
04	18-hr	1.28	1.49	1.63	1.89	2.14	2.33	2.76	3.42	4.04	4.95	5.72	6.58
04	12-hr	1.19	1.38	1.51	1.75	1.99	2.16	2.56	3.17	3.74	4.58	5.29	6.09
04	6-hr	1.02	1.19	1.30	1.51	1.71	1.86	2.20	2.73	3.23	3.95	4.56	5.25
04	3-hr	0.87	1.02	1.11	1.29	1.46	1.59	1.88	2.33	2.75	3.37	3.89	4.48
04	2-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.71	2.11	2.49	3.06	3.53	4.06
04	1-hr	0.64	0.75	0.82	0.95	1.08	1.17	1.38	1.71	2.02	2.48	2.86	3.29
04	30-min	0.51	0.59	0.64	0.75	0.85	0.92	1.09	1.35	1.59	1.95	2.25	2.59
04	15-min	0.37	0.43	0.47	0.54	0.62	0.67	0.79	0.98	1.16	1.42	1.64	1.89
04	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.62	0.76	0.90	1.11	1.28	1.47
04	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.35	0.44	0.52	0.63	0.73	0.84
05	10-day	2.20	2.64	3.05	3.58	4.12	4.48	5.20	6.22	7.22	8.61	9.66	10.88
05	5-day	1.76	2.11	2.39	2.77	3.18	3.46	4.05	4.94	5.72	6.92	7.98	9.18
05	72-hr	1.51	1.77	2.00	2.32	2.67	2.90	3.47	4.41	5.16	6.22	7.06	8.12
05	48-hr	1.40	1.64	1.82	2.11	2.43	2.64	3.13	3.93	4.67	5.75	6.52	7.33
05	24-hr	1.31	1.52	1.67	1.93	2.19	2.38	2.91	3.64	4.27	5.15	5.87	6.61
05	18-hr	1.23	1.43	1.57	1.81	2.06	2.24	2.74	3.42	4.01	4.84	5.52	6.21
05	12-hr	1.14	1.32	1.45	1.68	1.90	2.07	2.53	3.17	3.71	4.48	5.11	5.75
05	6-hr	0.98	1.15	1.25	1.45	1.65	1.79	2.18	2.73	3.20	3.86	4.40	4.96
05	3-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.86	2.33	2.73	3.30	3.76	4.23
05	2-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.69	2.11	2.48	2.99	3.40	3.83
05	1-hr	0.62	0.72	0.78	0.91	1.03	1.12	1.37	1.71	2.01	2.42	2.76	3.11
05	30-min	0.48	0.56	0.62	0.71	0.81	0.88	1.08	1.35	1.58	1.91	2.17	2.45
05	15-min	0.35	0.41	0.45	0.52	0.59	0.64	0.79	0.98	1.15	1.39	1.58	1.78
05	10-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.76	0.90	1.08	1.23	1.39
05	5-min	0.16	0.19	0.20	0.23	0.27	0.29	0.35	0.44	0.51	0.62	0.70	0.79
06	10-day	2.14	2.57	2.96	3.49	4.01	4.36	5.21	6.27	7.12	8.25	9.27	10.35
06	5-day	1.84	2.20	2.48	2.88	3.31	3.60	4.12	4.89	5.61	6.70	7.75	9.00
06	72-hr	1.57	1.84	2.08	2.41	2.77	3.01	3.59	4.53	5.31	6.42	7.35	8.42
06	48-hr	1.38	1.61	1.79	2.08	2.39	2.60	3.21	4.15	5.05	6.02	6.87	7.83
06	24-hr	1.32	1.54	1.68	1.94	2.21	2.40	3.06	3.84	4.44	5.42	6.25	7.13
06	18-hr	1.24	1.45	1.58	1.83	2.08	2.26	2.88	3.61	4.17	5.09	5.88	6.70
06	12-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.66	3.34	3.86	4.72	5.44	6.20
06	6-hr	0.99	1.15	1.26	1.46	1.66	1.80	2.30	2.88	3.33	4.07	4.69	5.35
06	3-hr	0.85	0.99	1.08	1.25	1.42	1.54	1.96	2.46	2.84	3.47	4.00	4.56
06	2-hr	0.76	0.89	0.97	1.13	1.28	1.39	1.77	2.23	2.58	3.14	3.62	4.14
06	1-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.44	1.80	2.09	2.55	2.94	3.35
06	30-min	0.49	0.57	0.62	0.72	0.82	0.89	1.13	1.42	1.64	2.01	2.31	2.64
06	15-min	0.36	0.42	0.45	0.53	0.60	0.65	0.83	1.04	1.20	1.46	1.69	1.93
06	10-min	0.28	0.32	0.35	0.41	0.46	0.50	0.64	0.81	0.93	1.14	1.31	1.50
06	5-min	0.16	0.19	0.20	0.23	0.27	0.29	0.37	0.46	0.53	0.65	0.75	0.86

Table 3. Continued

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
07	10-day	2.29	2.76	3.18	3.74	4.30	4.67	5.47	6.54	7.53	9.00	10.25	11.66
07	5-day	1.81	2.17	2.45	2.84	3.27	3.55	4.26	5.30	6.20	7.59	8.71	9.86
07	72-hr	1.65	1.94	2.19	2.54	2.93	3.18	3.85	4.79	5.56	6.78	7.80	8.99
07	48-hr	1.57	1.84	2.05	2.38	2.73	2.97	3.53	4.38	5.11	6.19	7.09	8.04
07	24-hr	1.52	1.77	1.93	2.24	2.54	2.76	3.22	3.93	4.57	5.56	6.45	7.28
07	18-hr	1.42	1.66	1.81	2.10	2.38	2.59	3.03	3.69	4.30	5.23	6.06	6.84
07	12-hr	1.32	1.54	1.68	1.94	2.21	2.40	2.80	3.42	3.98	4.84	5.61	6.33
07	6-hr	1.14	1.32	1.45	1.68	1.90	2.07	2.41	2.95	3.43	4.17	4.84	5.46
07	3-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.06	2.52	2.92	3.56	4.13	4.66
07	2-hr	0.88	1.02	1.12	1.30	1.47	1.60	1.87	2.28	2.65	3.22	3.74	4.22
07	1-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.51	1.85	2.15	2.61	3.03	3.42
07	30-min	0.56	0.65	0.71	0.83	0.94	1.02	1.19	1.45	1.69	2.06	2.39	2.69
07	15-min	0.41	0.48	0.52	0.61	0.69	0.75	0.87	1.06	1.23	1.50	1.74	1.97
07	10-min	0.32	0.37	0.41	0.47	0.53	0.58	0.68	0.83	0.96	1.17	1.35	1.53
07	5-min	0.18	0.21	0.23	0.27	0.30	0.33	0.39	0.47	0.55	0.67	0.77	0.87
08	10-day	2.28	2.74	3.16	3.72	4.28	4.65	5.45	6.61	7.57	8.99	10.09	11.04
08	5-day	1.81	2.17	2.45	2.84	3.27	3.55	4.32	5.37	6.26	7.64	8.78	9.99
08	72-hr	1.60	1.88	2.13	2.46	2.83	3.08	3.67	4.68	5.64	6.90	7.96	9.24
08	48-hr	1.48	1.74	1.93	2.24	2.58	2.80	3.39	4.30	5.06	6.28	7.35	8.60
08	24-hr	1.38	1.60	1.75	2.03	2.30	2.50	3.11	3.87	4.65	5.78	6.73	7.74
08	18-hr	1.29	1.50	1.64	1.90	2.16	2.35	2.92	3.64	4.37	5.43	6.33	7.28
08	12-hr	1.19	1.39	1.52	1.76	2.00	2.17	2.71	3.37	4.05	5.03	5.86	6.73
08	6-hr	1.03	1.20	1.32	1.52	1.73	1.88	2.33	2.90	3.49	4.34	5.05	5.80
08	3-hr	0.88	1.02	1.12	1.30	1.47	1.60	1.99	2.48	2.98	3.70	4.31	4.95
08	2-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.80	2.24	2.70	3.35	3.90	4.49
08	1-hr	0.64	0.75	0.82	0.95	1.08	1.17	1.46	1.82	2.19	2.72	3.16	3.64
08	30-min	0.51	0.60	0.65	0.75	0.86	0.93	1.15	1.43	1.72	2.14	2.49	2.86
08	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.84	1.04	1.26	1.56	1.82	2.09
08	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.65	0.81	0.98	1.21	1.41	1.63
08	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.37	0.46	0.56	0.69	0.81	0.93
09	10-day	2.19	2.64	3.04	3.58	4.11	4.47	5.44	6.50	7.35	8.45	9.33	10.42
09	5-day	1.78	2.13	2.41	2.79	3.21	3.49	4.31	5.45	6.32	7.60	8.69	9.95
09	72-hr	1.55	1.82	2.06	2.38	2.74	2.98	3.79	4.87	5.74	6.95	7.88	8.98
09	48-hr	1.48	1.73	1.93	2.23	2.57	2.79	3.50	4.46	5.20	6.35	7.32	8.40
09	24-hr	1.38	1.60	1.75	2.03	2.30	2.50	3.14	4.03	4.67	5.67	6.58	7.59
09	18-hr	1.29	1.50	1.64	1.90	2.16	2.35	2.95	3.79	4.39	5.33	6.19	7.13
09	12-hr	1.19	1.39	1.52	1.76	2.00	2.17	2.73	3.51	4.06	4.93	5.72	6.60
09	6-hr	1.03	1.20	1.32	1.52	1.73	1.88	2.36	3.02	3.50	4.25	4.93	5.69
09	3-hr	0.88	1.02	1.12	1.30	1.47	1.60	2.01	2.58	2.99	3.63	4.21	4.86
09	2-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.82	2.34	2.71	3.29	3.82	4.40
09	1-hr	0.64	0.75	0.82	0.95	1.08	1.17	1.48	1.89	2.19	2.66	3.09	3.57
09	30-min	0.51	0.60	0.65	0.75	0.86	0.93	1.16	1.49	1.73	2.10	2.43	2.81
09	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.85	1.09	1.26	1.53	1.78	2.05
09	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.66	0.85	0.98	1.19	1.38	1.59
09	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.38	0.48	0.56	0.68	0.79	0.91

Table 4. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Kentucky

Sectional code (see figure 1 on page 4)

01 – Western *03 - Bluegrass*
02 - Central *04 - Eastern*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	2.57	3.09	3.56	4.19	4.82	5.24	6.27	7.74	8.94	9.99	10.60	11.12
01	5-day	2.18	2.61	2.95	3.42	3.94	4.28	5.09	6.35	7.42	8.90	9.82	10.53
01	72-hr	1.94	2.28	2.58	2.99	3.44	3.74	4.50	5.53	6.41	7.62	8.67	9.68
01	48-hr	1.80	2.11	2.35	2.72	3.13	3.40	4.09	5.10	5.90	6.92	7.84	8.74
01	24-hr	1.71	1.98	2.17	2.51	2.85	3.10	3.75	4.66	5.39	6.38	7.19	8.09
01	18-hr	1.60	1.86	2.04	2.36	2.68	2.91	3.53	4.38	5.07	6.00	6.76	7.60
01	12-hr	1.49	1.73	1.89	2.19	2.48	2.70	3.26	4.05	4.69	5.55	6.26	7.04
01	6-hr	1.28	1.48	1.62	1.88	2.13	2.32	2.81	3.49	4.04	4.78	5.39	6.07
01	3-hr	1.09	1.27	1.39	1.60	1.82	1.98	2.40	2.98	3.45	4.08	4.60	5.18
01	2-hr	0.99	1.15	1.26	1.46	1.66	1.80	2.17	2.70	3.13	3.70	4.17	4.69
01	1-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.76	2.19	2.53	3.00	3.38	3.80
01	30-min	0.63	0.74	0.80	0.93	1.06	1.15	1.39	1.72	1.99	2.36	2.66	2.99
01	15-min	0.46	0.54	0.59	0.68	0.77	0.84	1.01	1.26	1.46	1.72	1.94	2.18
01	10-min	0.36	0.42	0.45	0.53	0.60	0.65	0.79	0.98	1.13	1.34	1.51	1.70
01	5-min	0.20	0.24	0.26	0.30	0.34	0.37	0.45	0.56	0.65	0.77	0.86	0.97
02	10-day	2.52	3.03	3.50	4.11	4.73	5.14	6.03	7.45	8.68	9.86	10.57	11.05
02	5-day	2.03	2.43	2.75	3.19	3.67	3.99	4.78	6.00	7.04	8.39	9.35	10.22
02	72-hr	1.79	2.10	2.38	2.76	3.17	3.45	4.20	5.26	6.22	7.50	8.46	9.37
02	48-hr	1.67	1.96	2.18	2.53	2.91	3.16	3.88	4.82	5.65	6.82	7.75	8.75
02	24-hr	1.62	1.88	2.06	2.38	2.70	2.94	3.49	4.34	5.10	6.22	7.09	7.96
02	18-hr	1.52	1.77	1.93	2.24	2.54	2.76	3.28	4.08	4.79	5.85	6.66	7.48
02	12-hr	1.41	1.64	1.79	2.07	2.36	2.56	3.04	3.78	4.44	5.41	6.17	6.93
02	6-hr	1.21	1.41	1.54	1.78	2.02	2.20	2.62	3.26	3.82	4.66	5.32	5.97
02	3-hr	1.03	1.20	1.32	1.52	1.73	1.88	2.23	2.78	3.26	3.98	4.54	5.09
02	2-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.02	2.52	2.96	3.61	4.11	4.62
02	1-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.64	2.04	2.40	2.92	3.33	3.74
02	30-min	0.60	0.70	0.76	0.88	1.00	1.09	1.29	1.61	1.89	2.30	2.62	2.95
02	15-min	0.43	0.51	0.55	0.64	0.73	0.79	0.94	1.17	1.38	1.68	1.91	2.15
02	10-min	0.34	0.40	0.43	0.50	0.57	0.62	0.73	0.91	1.07	1.31	1.49	1.67
02	5-min	0.19	0.22	0.24	0.28	0.32	0.35	0.42	0.52	0.61	0.75	0.85	0.96
03	10-day	2.22	2.67	3.08	3.62	4.17	4.53	5.41	6.67	7.69	8.93	9.68	10.40
03	5-day	1.82	2.17	2.46	2.85	3.28	3.56	4.26	5.21	6.04	7.11	7.99	8.86
03	72-hr	1.60	1.88	2.13	2.46	2.83	3.08	3.68	4.61	5.41	6.36	7.15	7.99
03	48-hr	1.48	1.73	1.93	2.23	2.57	2.79	3.37	4.19	4.86	5.76	6.49	7.23
03	24-hr	1.41	1.64	1.79	2.07	2.36	2.56	3.05	3.76	4.36	5.15	5.78	6.44
03	18-hr	1.33	1.54	1.69	1.95	2.22	2.41	2.87	3.53	4.10	4.84	5.43	6.05
03	12-hr	1.23	1.43	1.56	1.81	2.05	2.23	2.65	3.27	3.79	4.48	5.03	5.60
03	6-hr	1.06	1.23	1.34	1.56	1.77	1.92	2.29	2.82	3.27	3.86	4.34	4.83
03	3-hr	0.90	1.05	1.15	1.33	1.51	1.64	1.95	2.41	2.79	3.30	3.70	4.12
03	2-hr	0.81	0.95	1.04	1.20	1.36	1.48	1.77	2.18	2.53	2.99	3.35	3.74
03	1-hr	0.66	0.77	0.84	0.97	1.10	1.20	1.43	1.77	2.05	2.42	2.72	3.03
03	30-min	0.52	0.61	0.66	0.77	0.87	0.95	1.13	1.39	1.61	1.91	2.14	2.38
03	15-min	0.38	0.44	0.48	0.56	0.63	0.69	0.82	1.02	1.18	1.39	1.56	1.74
03	10-min	0.30	0.35	0.38	0.44	0.50	0.54	0.64	0.79	0.92	1.08	1.21	1.35
03	5-min	0.17	0.20	0.22	0.25	0.29	0.31	0.37	0.45	0.52	0.62	0.69	0.77

Table 4. Concluded

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
04	10-day	2.31	2.78	3.21	3.78	4.34	4.72	5.53	6.48	7.27	8.31	9.06	9.79
04	5-day	1.83	2.18	2.47	2.86	3.29	3.58	4.25	5.15	5.93	6.95	7.84	8.77
04	72-hr	1.62	1.90	2.15	2.50	2.87	3.12	3.71	4.54	5.22	6.14	6.96	7.86
04	48-hr	1.54	1.80	2.00	2.32	2.67	2.90	3.42	4.13	4.73	5.60	6.38	7.23
04	24-hr	1.46	1.70	1.86	2.15	2.44	2.65	3.09	3.73	4.26	5.06	5.74	6.53
04	18-hr	1.37	1.59	1.74	2.02	2.29	2.49	2.90	3.51	4.00	4.76	5.40	6.14
04	12-hr	1.27	1.48	1.62	1.87	2.13	2.31	2.69	3.25	3.71	4.40	4.99	5.68
04	6-hr	1.09	1.27	1.39	1.61	1.83	1.99	2.32	2.80	3.20	3.80	4.30	4.90
04	3-hr	0.94	1.09	1.19	1.38	1.56	1.70	1.98	2.39	2.73	3.24	3.67	4.18
04	2-hr	0.85	0.99	1.08	1.25	1.42	1.54	1.79	2.16	2.47	2.93	3.33	3.79
04	1-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.45	1.75	2.00	2.38	2.70	3.07
04	30-min	0.54	0.63	0.69	0.79	0.90	0.98	1.14	1.38	1.58	1.87	2.12	2.42
04	15-min	0.40	0.46	0.50	0.58	0.66	0.72	0.83	1.01	1.15	1.37	1.55	1.76
04	10-min	0.31	0.36	0.39	0.45	0.52	0.56	0.65	0.78	0.89	1.06	1.21	1.37
04	5-min	0.18	0.20	0.22	0.26	0.29	0.32	0.37	0.45	0.51	0.61	0.69	0.78

Table 5. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Michigan

Sectional code (see figure 1 on page 4)

01 - West Upper	*06 - Central Lower*
02 - East Upper	*07 - East Central Lower*
03 - Northwest Lower	*08 - Southwest Lower*
04 - Northeast Lower	*09 - South Central Lower*
05 - West Central Lower	*10 - Southeast Lower*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.69	2.04	2.35	2.76	3.17	3.45	4.28	5.34	6.17	7.27	8.11	8.99
01	5-day	1.41	1.69	1.91	2.22	2.55	2.77	3.38	4.23	4.91	5.86	6.65	7.50
01	72-hr	1.24	1.46	1.65	1.91	2.20	2.39	2.96	3.69	4.29	5.11	5.79	6.49
01	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.64	3.31	3.84	4.59	5.20	5.86
01	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.39	3.00	3.48	4.17	4.73	5.32
01	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.25	2.82	3.27	3.92	4.45	5.00
01	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.08	2.61	3.03	3.63	4.12	4.63
01	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.79	2.25	2.61	3.13	3.55	3.99
01	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.53	1.92	2.23	2.67	3.03	3.40
01	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.39	1.74	2.02	2.42	2.74	3.09
01	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.12	1.41	1.64	1.96	2.22	2.50
01	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.29	1.54	1.75	1.97
01	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.65	0.81	0.94	1.13	1.28	1.44
01	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.73	0.88	0.99	1.12
01	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.29	0.36	0.42	0.50	0.57	0.64
02	10-day	1.61	1.94	2.23	2.62	3.02	3.28	3.93	4.78	5.44	6.43	7.22	7.98
02	5-day	1.25	1.50	1.70	1.97	2.26	2.46	3.00	3.71	4.25	5.11	5.81	6.55
02	72-hr	1.15	1.35	1.52	1.77	2.03	2.21	2.62	3.27	3.78	4.57	5.23	5.94
02	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.31	2.98	3.49	4.24	4.88	5.55
02	24-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.09	2.71	3.19	3.87	4.44	5.03
02	18-hr	0.86	1.00	1.09	1.26	1.44	1.56	1.96	2.55	3.00	3.64	4.17	4.73
02	12-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.82	2.36	2.78	3.37	3.86	4.38
02	6-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.57	2.03	2.39	2.90	3.33	3.77
02	3-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.34	1.73	2.04	2.48	2.84	3.22
02	2-hr	0.53	0.61	0.67	0.78	0.88	0.96	1.21	1.57	1.85	2.24	2.58	2.92
02	1-hr	0.43	0.50	0.55	0.63	0.72	0.78	0.98	1.27	1.50	1.82	2.09	2.36
02	30-min	0.34	0.39	0.43	0.49	0.56	0.61	0.77	1.00	1.18	1.43	1.64	1.86
02	15-min	0.25	0.29	0.31	0.36	0.41	0.45	0.56	0.73	0.86	1.04	1.20	1.36
02	10-min	0.19	0.22	0.24	0.28	0.32	0.35	0.44	0.57	0.67	0.81	0.93	1.06
02	5-min	0.11	0.13	0.14	0.16	0.18	0.20	0.25	0.33	0.38	0.46	0.53	0.60
03	10-day	1.63	1.96	2.26	2.66	3.06	3.33	3.99	4.92	5.65	6.66	7.50	8.35
03	5-day	1.29	1.54	1.75	2.02	2.33	2.53	3.10	3.91	4.57	5.46	6.23	7.04
03	72-hr	1.09	1.27	1.44	1.67	1.92	2.09	2.62	3.36	3.96	4.86	5.56	6.35
03	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.34	3.02	3.55	4.31	4.94	5.60
03	24-hr	0.89	1.04	1.13	1.31	1.49	1.62	2.09	2.70	3.21	3.89	4.47	5.08
03	18-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.96	2.54	3.02	3.66	4.20	4.78
03	12-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.82	2.35	2.79	3.38	3.89	4.42
03	6-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.57	2.03	2.41	2.92	3.35	3.81
03	3-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.34	1.73	2.05	2.49	2.86	3.25
03	2-hr	0.52	0.60	0.66	0.76	0.86	0.94	1.21	1.57	1.86	2.26	2.59	2.95
03	1-hr	0.42	0.49	0.53	0.62	0.70	0.76	0.98	1.27	1.51	1.83	2.10	2.39
03	30-min	0.33	0.38	0.42	0.49	0.55	0.60	0.77	1.00	1.19	1.44	1.65	1.88
03	15-min	0.24	0.28	0.31	0.36	0.40	0.44	0.56	0.73	0.87	1.05	1.21	1.37
03	10-min	0.19	0.22	0.24	0.28	0.31	0.34	0.44	0.57	0.67	0.82	0.94	1.07
03	5-min	0.10	0.12	0.13	0.15	0.17	0.19	0.25	0.32	0.39	0.47	0.54	0.61

Table 5. Continued

Rainfall inches for given recurrence interval

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
04	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.77	4.56	5.22	6.10	6.85	7.60
04	5-day	1.26	1.51	1.70	1.98	2.27	2.47	2.99	3.68	4.23	4.97	5.58	6.23
04	72-hr	1.12	1.31	1.48	1.72	1.98	2.15	2.63	3.27	3.75	4.45	5.00	5.60
04	48-hr	1.00	1.17	1.30	1.51	1.74	1.89	2.32	2.88	3.33	3.93	4.43	4.95
04	24-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.11	2.62	3.04	3.60	4.06	4.53
04	18-hr	0.89	1.03	1.13	1.30	1.48	1.61	1.98	2.46	2.86	3.38	3.82	4.26
04	12-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.84	2.28	2.64	3.13	3.53	3.94
04	6-hr	0.70	0.82	0.90	1.04	1.18	1.28	1.58	1.96	2.28	2.70	3.05	3.40
04	3-hr	0.60	0.70	0.76	0.88	1.00	1.09	1.35	1.68	1.95	2.30	2.60	2.90
04	2-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.22	1.52	1.76	2.09	2.35	2.63
04	1-hr	0.44	0.51	0.56	0.65	0.74	0.80	0.99	1.23	1.43	1.69	1.91	2.13
04	30-min	0.35	0.40	0.44	0.51	0.58	0.63	0.78	0.97	1.12	1.33	1.50	1.68
04	15-min	0.25	0.29	0.32	0.37	0.42	0.46	0.57	0.71	0.82	0.97	1.10	1.22
04	10-min	0.20	0.23	0.25	0.29	0.33	0.36	0.44	0.55	0.64	0.76	0.85	0.95
04	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.25	0.31	0.36	0.43	0.49	0.54
05	10-day	1.64	1.97	2.27	2.67	3.07	3.34	4.14	5.28	6.21	7.59	8.75	10.02
05	5-day	1.38	1.65	1.86	2.16	2.48	2.70	3.36	4.30	5.07	6.25	7.26	8.36
05	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.88	3.74	4.46	5.45	6.31	7.26
05	48-hr	1.04	1.22	1.36	1.58	1.81	1.97	2.53	3.34	4.01	4.97	5.81	6.73
05	24-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.28	3.00	3.60	4.48	5.24	6.07
05	18-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.14	2.82	3.38	4.21	4.93	5.71
05	12-hr	0.85	0.99	1.08	1.25	1.42	1.54	1.98	2.61	3.13	3.90	4.56	5.28
05	6-hr	0.73	0.85	0.93	1.08	1.22	1.33	1.71	2.25	2.70	3.36	3.93	4.55
05	3-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.46	1.92	2.30	2.87	3.35	3.88
05	2-hr	0.57	0.66	0.72	0.83	0.95	1.03	1.32	1.74	2.09	2.60	3.04	3.52
05	1-hr	0.46	0.53	0.58	0.67	0.76	0.83	1.07	1.41	1.69	2.11	2.46	2.85
05	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.84	1.11	1.33	1.66	1.94	2.25
05	15-min	0.26	0.31	0.34	0.39	0.44	0.48	0.62	0.81	0.97	1.21	1.41	1.64
05	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.48	0.63	0.76	0.94	1.10	1.27
05	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.27	0.36	0.43	0.54	0.63	0.73
06	10-day	1.76	2.12	2.44	2.87	3.30	3.59	4.31	5.36	6.21	7.46	8.51	9.54
06	5-day	1.44	1.72	1.95	2.26	2.59	2.82	3.40	4.22	4.89	6.11	7.17	8.31
06	72-hr	1.23	1.45	1.64	1.90	2.18	2.37	2.88	3.62	4.24	5.27	6.17	7.18
06	48-hr	1.09	1.28	1.42	1.65	1.90	2.06	2.51	3.17	3.71	4.59	5.35	6.20
06	24-hr	1.02	1.19	1.30	1.51	1.71	1.86	2.27	2.85	3.34	4.15	4.84	5.62
06	18-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.13	2.68	3.14	3.90	4.55	5.28
06	12-hr	0.89	1.04	1.13	1.31	1.49	1.62	1.97	2.48	2.91	3.61	4.21	4.89
06	6-hr	0.76	0.89	0.97	1.13	1.28	1.39	1.70	2.14	2.50	3.11	3.63	4.22
06	3-hr	0.65	0.76	0.83	0.96	1.09	1.19	1.45	1.82	2.14	2.66	3.10	3.60
06	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.32	1.65	1.94	2.41	2.81	3.26
06	1-hr	0.48	0.56	0.61	0.70	0.80	0.87	1.07	1.34	1.57	1.95	2.27	2.64
06	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.05	1.24	1.54	1.79	2.08
06	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.77	0.90	1.12	1.31	1.52
06	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.48	0.60	0.70	0.87	1.02	1.18
06	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.34	0.40	0.50	0.58	0.67

Table 5. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	1.57	1.89	2.18	2.56	2.94	3.20	3.88	4.75	5.39	6.21	6.83	7.48
07	5-day	1.22	1.46	1.66	1.92	2.21	2.40	2.96	3.68	4.23	4.99	5.61	6.26
07	72-hr	1.11	1.30	1.47	1.70	1.96	2.13	2.62	3.28	3.78	4.49	5.05	5.66
07	48-hr	1.02	1.20	1.33	1.54	1.78	1.93	2.37	2.97	3.41	4.03	4.52	5.04
07	24-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.14	2.65	3.05	3.56	3.97	4.40
07	18-hr	0.90	1.05	1.15	1.33	1.51	1.64	2.01	2.49	2.87	3.35	3.73	4.14
07	12-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.86	2.31	2.65	3.10	3.45	3.83
07	6-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.61	1.99	2.29	2.67	2.98	3.30
07	3-hr	0.62	0.72	0.78	0.91	1.03	1.12	1.37	1.70	1.95	2.28	2.54	2.82
07	2-hr	0.56	0.65	0.71	0.82	0.93	1.01	1.24	1.54	1.77	2.06	2.30	2.55
07	1-hr	0.45	0.52	0.57	0.66	0.75	0.82	1.01	1.25	1.43	1.67	1.87	2.07
07	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.79	0.98	1.13	1.32	1.47	1.63
07	15-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.72	0.82	0.96	1.07	1.19
07	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.45	0.56	0.64	0.75	0.83	0.92
07	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.26	0.32	0.37	0.43	0.48	0.53
08	10-day	1.81	2.18	2.51	2.95	3.39	3.69	4.33	5.23	5.96	7.39	8.63	10.03
08	5-day	1.48	1.77	2.00	2.32	2.67	2.90	3.45	4.27	4.95	6.16	7.28	8.46
08	72-hr	1.29	1.52	1.72	1.99	2.29	2.49	3.00	3.75	4.41	5.50	6.45	7.51
08	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.63	3.32	3.91	4.93	5.83	6.82
08	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.37	3.00	3.52	4.45	5.27	6.15
08	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.23	2.82	3.31	4.18	4.95	5.78
08	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.06	2.61	3.06	3.87	4.58	5.35
08	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.78	2.25	2.64	3.34	3.95	4.61
08	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.52	1.92	2.25	2.85	3.37	3.94
08	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.37	1.74	2.04	2.58	3.06	3.57
08	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.11	1.41	1.65	2.09	2.48	2.89
08	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.30	1.65	1.95	2.28
08	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.64	0.81	0.95	1.20	1.42	1.66
08	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.74	0.93	1.11	1.29
08	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.28	0.36	0.42	0.53	0.63	0.74
09	10-day	1.77	2.13	2.45	2.89	3.32	3.61	4.26	5.15	5.83	6.81	7.60	8.40
09	5-day	1.43	1.71	1.93	2.24	2.58	2.80	3.36	4.10	4.71	5.57	6.27	6.99
09	72-hr	1.27	1.49	1.68	1.95	2.24	2.44	2.93	3.59	4.16	4.95	5.59	6.28
09	48-hr	1.17	1.37	1.52	1.77	2.03	2.21	2.66	3.28	3.79	4.50	5.10	5.73
09	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.42	2.98	3.43	4.09	4.63	5.20
09	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.27	2.80	3.22	3.84	4.35	4.89
09	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.11	2.59	2.98	3.56	4.03	4.52
09	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.82	2.24	2.57	3.07	3.47	3.90
09	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.55	1.91	2.20	2.62	2.96	3.33
09	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.40	1.73	1.99	2.37	2.69	3.02
09	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.14	1.40	1.61	1.92	2.18	2.44
09	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.90	1.10	1.27	1.51	1.71	1.92
09	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.65	0.80	0.93	1.10	1.25	1.40
09	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.51	0.63	0.72	0.86	0.97	1.09
09	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.36	0.41	0.49	0.56	0.62

Table 5. Concluded

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
10	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.82	4.64	5.27	6.11	6.79	7.51
10	5-day	1.28	1.53	1.73	2.01	2.31	2.51	3.05	3.68	4.16	4.78	5.26	5.74
10	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.74	3.34	3.76	4.31	4.74	5.16
10	48-hr	1.08	1.26	1.41	1.63	1.88	2.04	2.48	3.04	3.44	3.96	4.36	4.78
10	24-hr	1.03	1.20	1.31	1.51	1.72	1.87	2.26	2.75	3.13	3.60	3.98	4.36
10	18-hr	0.97	1.13	1.23	1.43	1.62	1.76	2.12	2.59	2.94	3.38	3.74	4.10
10	12-hr	0.90	1.04	1.14	1.32	1.50	1.63	1.97	2.39	2.72	3.13	3.46	3.79
10	6-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.69	2.06	2.35	2.70	2.99	3.27
10	3-hr	0.66	0.77	0.84	0.97	1.10	1.20	1.45	1.76	2.00	2.30	2.55	2.79
10	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.31	1.59	1.82	2.09	2.31	2.53
10	1-hr	0.48	0.56	0.62	0.71	0.81	0.88	1.06	1.29	1.47	1.69	1.87	2.05
10	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.02	1.16	1.33	1.47	1.61
10	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.74	0.85	0.97	1.07	1.18
10	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.47	0.58	0.66	0.76	0.84	0.92
10	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.33	0.38	0.43	0.48	0.52

Table 6. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Minnesota

Sectional code (see figure 1 on page 4)

01 - Northwest
02 - North Central
03 - Northeast
04 - West Central
05 - Central
06 - East Central
07 - Southwest
08 - South Central
09 - Southeast

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.53	1.84	2.12	2.50	2.87	3.12	3.83	4.89	5.80	6.97	7.88	8.75
01	5-day	1.27	1.53	1.73	2.00	2.30	2.50	3.11	4.11	5.01	6.12	7.05	7.94
01	72-hr	1.11	1.30	1.47	1.70	1.96	2.13	2.70	3.61	4.43	5.55	6.41	7.27
01	48-hr	1.03	1.20	1.34	1.55	1.78	1.94	2.42	3.25	4.05	5.13	5.91	6.70
01	24-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.16	2.94	3.69	4.57	5.41	6.11
01	18-hr	0.89	1.03	1.13	1.30	1.48	1.61	2.03	2.76	3.47	4.30	5.09	5.74
01	12-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.88	2.56	3.21	3.98	4.71	5.32
01	6-hr	0.70	0.82	0.90	1.04	1.18	1.28	1.62	2.20	2.77	3.43	4.06	4.58
01	3-hr	0.60	0.70	0.76	0.88	1.00	1.09	1.38	1.88	2.36	2.92	3.46	3.91
01	2-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.25	1.71	2.14	2.65	3.14	3.54
01	1-hr	0.44	0.51	0.56	0.65	0.74	0.80	1.02	1.38	1.73	2.15	2.54	2.87
01	30-min	0.35	0.40	0.44	0.51	0.58	0.63	0.80	1.09	1.37	1.69	2.00	2.26
01	15-mín	0.25	0.29	0.32	0.37	0.42	0.46	0.58	0.79	1.00	1.23	1.46	1.65
01	10-min	0.20	0.23	0.25	0.29	0.33	0.36	0.45	0.62	0.77	0.96	1.14	1.28
01	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.26	0.35	0.44	0.55	0.65	0.73
02	10-day	1.67	2.01	2.32	2.73	3.14	3.41	4.15	5.08	5.81	6.84	7.68	8.52
02	5-day	1.35	1.61	1.82	2.11	2.43	2.64	3.27	4.14	4.84	5.86	6.71	7.57
02	72-hr	1.24	1.45	1.64	1.90	2.19	2.38	2.90	3.64	4.31	5.28	6.10	6.96
02	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.68	3.38	3.97	4.86	5.62	6.45
02	24-hr	1.07	1.24	1.36	1.57	1.78	1.94	2.41	3.06	3.58	4.39	5.10	5.88
02	18-hr	1.00	1.16	1.27	1.47	1.67	1.82	2.27	2.88	3.37	4.13	4.79	5.53
02	12-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.10	2.66	3.11	3.82	4.44	5.12
02	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.81	2.30	2.68	3.29	3.82	4.41
02	3-hr	0.68	0.79	0.87	1.00	1.14	1.24	1.54	1.96	2.29	2.81	3.26	3.76
02	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.40	1.77	2.08	2.55	2.96	3.41
02	1-hr	0.50	0.58	0.64	0.74	0.84	0.91	1.13	1.44	1.68	2.06	2.40	2.76
02	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.89	1.13	1.32	1.62	1.89	2.18
02	15-min	0.29	0.33	0.36	0.42	0.48	0.52	0.65	0.83	0.97	1.19	1.38	1.59
02	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.51	0.64	0.75	0.92	1.07	1.23
02	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.29	0.37	0.43	0.53	0.61	0.71
03	10-day	1.66	1.99	2.30	2.70	3.11	3.38	4.04	4.82	5.41	6.28	6.96	7.58
03	5-day	1.36	1.62	1.84	2.13	2.45	2.66	3.24	4.05	4.69	5.54	6.16	6.57
03	72-hr	1.19	1.39	1.57	1.82	2.10	2.28	2.83	3.57	4.16	4.96	5.53	6.09
03	48-hr	1.09	1.28	1.42	1.65	1.90	2.06	2.54	3.21	3.74	4.49	5.06	5.63
03	24-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.31	2.88	3.36	4.08	4.64	5.20
03	18-hr	0.99	1.15	1.26	1.46	1.66	1.80	2.17	2.71	3.16	3.84	4.36	4.89
03	12-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.01	2.51	2.92	3.55	4.04	4.52
03	6-hr	0.79	0.92	1.00	1.16	1.32	1.43	1.73	2.16	2.52	3.06	3.48	3.90
03	3-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.48	1.84	2.15	2.61	2.97	3.33
03	2-hr	0.61	0.71	0.78	0.90	1.02	1.11	1.34	1.67	1.95	2.37	2.69	3.02
03	1-hr	0.50	0.58	0.63	0.73	0.83	0.90	1.09	1.35	1.58	1.92	2.18	2.44
03	30-min	0.39	0.45	0.50	0.58	0.65	0.71	0.85	1.07	1.24	1.51	1.72	1.92
03	15-min	0.29	0.33	0.36	0.42	0.48	0.52	0.62	0.78	0.91	1.10	1.25	1.40
03	10-min	0.22	0.26	0.28	0.32	0.37	0.40	0.49	0.60	0.71	0.86	0.97	1.09
03	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.28	0.35	0.40	0.49	0.56	0.62

Table 6. Continued

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
04	10-day	1.70	2.04	2.35	2.77	3.18	3.46	4.18	5.21	6.08	7.25	8.17	9.07
04	5-day	1.45	1.73	1.96	2.27	2.61	2.84	3.38	4.20	4.92	6.03	7.05	8.20
04	72-hr	1.27	1.49	1.69	1.96	2.25	2.45	2.93	3.62	4.26	5.22	6.11	7.06
04	48-hr	1.18	1.38	1.53	1.78	2.04	2.22	2.65	3.28	3.83	4.64	5.38	6.23
04	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.40	2.95	3.42	4.19	4.83	5.57
04	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.26	2.77	3.21	3.94	4.54	5.24
04	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.09	2.57	2.98	3.65	4.20	4.85
04	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.80	2.21	2.57	3.14	3.62	4.18
04	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.54	1.89	2.19	2.68	3.09	3.56
04	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.39	1.71	1.98	2.43	2.80	3.23
04	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.13	1.39	1.61	1.97	2.27	2.62
04	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.89	1.09	1.27	1.55	1.79	2.06
04	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.65	0.80	0.92	1.13	1.30	1.50
04	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.50	0.62	0.72	0.88	1.01	1.17
04	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.35	0.41	0.50	0.58	0.67
05	10-day	1.76	2.12	2.44	2.87	3.30	3.59	4.19	5.43	6.24	7.34	8.25	9.23
05	5-day	1.45	1.74	1.97	2.28	2.62	2.85	3.51	4.43	5.18	6.21	7.09	8.02
05	72-hr	1.31	1.53	1.73	2.01	2.31	2.51	3.05	3.81	4.45	5.40	6.22	7.10
05	48-hr	1.22	1.43	1.59	1.84	2.12	2.30	2.78	3.48	4.05	4.88	5.59	6.37
05	24-hr	1.15	1.34	1.47	1.70	1.93	2.10	2.54	3.17	3.68	4.43	5.03	5.72
05	18-hr	1.08	1.26	1.38	1.60	1.81	1.97	2.39	2.98	3.46	4.16	4.73	5.38
05	12-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.21	2.76	3.20	3.85	4.38	4.98
05	6-hr	0.86	1.00	1.10	1.27	1.44	1.57	1.90	2.38	2.76	3.32	3.77	4.29
05	3-hr	0.74	0.86	0.94	1.09	1.23	1.34	1.63	2.03	2.36	2.84	3.22	3.66
05	2-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.47	1.84	2.13	2.57	2.92	3.32
05	1-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.19	1.49	1.73	2.08	2.36	2.69
05	30-min	0.43	0.50	0.55	0.63	0.72	0.78	0.94	1.17	1.36	1.64	1.86	2.12
05	15-min	0.31	0.36	0.40	0.46	0.52	0.57	0.69	0.86	0.99	1.20	1.36	1.54
05	10-min	0.24	0.28	0.31	0.36	0.40	0.44	0.53	0.67	0.77	0.93	1.06	1.20
05	5-min	0.14	0.16	0.17	0.20	0.23	0.25	0.30	0.38	0.44	0.53	0.60	0.69
06	10-day	1.83	2.21	2.54	2.99	3.44	3.74	4.53	5.51	6.23	7.16	7.90	8.68
06	5-day	1.55	1.85	2.09	2.42	2.79	3.03	3.66	4.50	5.15	6.11	6.86	7.69
06	72-hr	1.37	1.61	1.82	2.11	2.43	2.64	3.16	3.85	4.41	5.19	5.85	6.59
06	48-hr	1.28	1.50	1.67	1.94	2.23	2.42	2.89	3.53	4.03	4.74	5.36	6.02
06	24-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.65	3.23	3.69	4.35	4.88	5.46
06	18-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.49	3.04	3.47	4.09	4.59	5.13
06	12-hr	1.06	1.24	1.35	1.56	1.78	1.93	2.31	2.81	3.21	3.78	4.25	4.75
06	6-hr	0.91	1.06	1.16	1.34	1.53	1.66	1.99	2.42	2.77	3.26	3.66	4.10
06	3-hr	0.78	0.91	0.99	1.15	1.31	1.42	1.70	2.07	2.36	2.78	3.12	3.49
06	2-hr	0.71	0.83	0.90	1.04	1.19	1.29	1.54	1.87	2.14	2.52	2.83	3.17
06	1-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.25	1.52	1.73	2.04	2.29	2.57
06	30-min	0.45	0.52	0.57	0.66	0.75	0.82	0.98	1.20	1.37	1.61	1.81	2.02
06	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.72	0.87	1.00	1.17	1.32	1.47
06	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.56	0.68	0.77	0.91	1.02	1.15
06	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.32	0.39	0.44	0.52	0.59	0.66

Table 6. Continued

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
07	10-day	1.88	2.27	2.61	3.07	3.53	3.84	4.51	5.45	6.16	7.25	8.20	9.13
07	5-day	1.59	1.90	2.15	2.49	2.86	3.11	3.72	4.53	5.18	6.17	7.03	8.02
07	72-hr	1.44	1.68	1.90	2.21	2.54	2.76	3.24	3.96	4.57	5.50	5.93	7.13
07	48-hr	1.30	1.52	1.69	1.96	2.25	2.45	2.92	3.60	4.18	5.04	5.74	6.48
07	24-hr	1.24	1.45	1.58	1.83	2.08	2.26	2.69	3.32	3.81	4.55	5.20	5.94
07	18-hr	1.17	1.36	1.48	1.72	1.95	2.12	2.53	3.12	3.58	4.28	4.89	5.58
07	12-hr	1.08	1.26	1.38	1.60	1.81	1.97	2.34	2.89	3.31	3.96	4.52	5.17
07	6-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.02	2.49	2.86	3.41	3.90	4.45
07	3-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.72	2.12	2.44	2.91	3.33	3.80
07	2-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.56	1.93	2.21	2.64	3.02	3.45
07	1-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.26	1.56	1.79	2.14	2.44	2.79
07	30-min	0.46	0.54	0.59	0.68	0.77	0.84	1.00	1.23	1.41	1.68	1.92	2.20
07	15-min	0.34	0.39	0.43	0.49	0.56	0.61	0.73	0.90	1.03	1.23	1.40	1.60
07	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.56	0.70	0.80	0.96	1.09	1.25
07	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.32	0.40	0.46	0.55	0.62	0.71
08	10-day	1.86	2.24	2.58	3.04	3.50	3.80	4.59	5.67	6.52	7.60	8.47	9.16
08	5-day	1.55	1.85	2.09	2.42	2.79	3.03	3.71	4.66	5.43	6.38	7.72	8.43
08	72-hr	1.37	1.60	1.81	2.10	2.42	2.63	3.22	4.06	4.77	5.67	6.43	7.08
08	48-hr	1.27	1.49	1.66	1.92	2.21	2.40	2.93	3.68	4.30	5.14	5.82	6.38
08	24-hr	1.20	1.40	1.53	1.77	2.01	2.19	2.68	3.38	3.95	4.66	5.28	5.85
08	18-hr	1.13	1.32	1.44	1.67	1.90	2.06	2.52	3.18	3.71	4.38	4.96	5.50
08	12-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.33	2.94	3.44	4.05	4.59	5.09
08	6-hr	0.90	1.05	1.15	1.33	1.51	1.64	2.01	2.54	2.96	3.49	3.96	4.39
08	3-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.72	2.16	2.53	2.98	3.38	3.74
08	2-hr	0.70	0.81	0.89	1.03	1.17	1.27	1.55	1.96	2.29	2.70	3.06	3.39
08	1-hr	0.57	0.66	0.72	0.83	0.95	1.03	1.26	1.59	1.86	2.19	2.48	2.75
08	30-min	0.45	0.52	0.57	0.66	0.75	0.81	0.99	1.25	1.46	1.72	1.95	2.16
08	15-min	0.32	0.38	0.41	0.48	0.54	0.59	0.72	0.91	1.07	1.26	1.43	1.58
08	10-min	0.25	0.29	0.32	0.37	0.42	0.46	0.56	0.71	0.83	0.98	1.11	1.23
08	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.41	0.47	0.56	0.63	0.70
09	10-day	1.89	2.28	2.62	3.09	3.55	3.86	4.81	5.93	6.72	7.70	8.42	9.10
09	5-day	1.63	1.95	2.20	2.55	2.93	3.19	3.95	4.89	5.55	6.38	7.01	7.63
09	72-hr	1.42	1.67	1.88	2.18	2.51	2.73	3.48	4.35	4.97	5.74	6.30	6.83
09	48-hr	1.33	1.56	1.73	2.01	2.31	2.51	3.15	3.94	4.52	5.24	5.81	6.43
09	24-hr	1.24	1.45	1.58	1.83	2.08	2.26	2.84	3.55	4.08	4.75	5.25	5.76
09	18-hr	1.17	1.36	1.48	1.72	1.95	2.12	2.67	3.34	3.84	4.47	4.93	5.41
09	12-hr	1.08	1.26	1.38	1.60	1.81	1.97	2.47	3.09	3.55	4.13	4.57	5.01
09	6-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.13	2.66	3.06	3.56	3.94	4.32
09	3-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.82	2.27	2.61	3.04	3.36	3.69
09	2-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.65	2.06	2.37	2.75	3.04	3.34
09	1-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.33	1.67	1.92	2.23	2.47	2.71
09	30-min	0.46	0.54	0.59	0.68	0.77	0.84	1.05	1.31	1.51	1.76	1.94	2.13
09	15-min	0.34	0.39	0.43	0.49	0.56	0.61	0.77	0.96	1.10	1.28	1.42	1.56
09	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.60	0.75	0.86	1.00	1.10	1.21
09	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.34	0.43	0.49	0.57	0.63	0.69

Table 7. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Missouri

Sectional code (see figure 1 on page 4)

01 - Northwest Prairie *04 - West Ozarks*
02 - Northeast Prairie *05 - East Ozarks*
03 - West Central Plains *06 - Bootheel*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	2.18	2.62	3.02	3.55	4.08	4.44	5.60	7.01	8.01	9.27	10.20	11.25
01	5-day	1.82	2.17	2.46	2.85	3.28	3.56	4.50	5.69	6.60	7.78	8.71	9.71
01	72-hr	1.62	1.90	2.15	2.50	2.87	3.12	3.99	5.11	5.98	7.07	7.92	8.82
01	48-hr	1.48	1.73	1.93	2.23	2.57	2.79	3.59	4.63	5.43	6.43	7.17	7.99
01	24-hr	1.39	1.62	1.77	2.05	2.33	2.53	3.27	4.25	4.98	5.89	6.58	7.30
01	18-hr	1.31	1.52	1.67	1.93	2.19	2.38	3.07	3.99	4.68	5.54	6.19	6.86
01	12-hr	1.21	1.41	1.54	1.78	2.02	2.20	2.84	3.70	4.33	5.12	5.72	6.35
01	6-hr	1.04	1.22	1.33	1.54	1.75	1.90	2.45	3.19	3.74	4.42	4.93	5.48
01	3-hr	0.89	1.04	1.13	1.31	1.49	1.62	2.09	2.72	3.19	3.77	4.21	4.67
01	2-hr	0.81	0.94	1.03	1.19	1.35	1.47	1.90	2.46	2.89	3.42	3.82	4.23
01	1-hr	0.65	0.76	0.83	0.96	1.09	1.19	1.54	2.00	2.34	2.77	3.09	3.43
01	30-min	0.52	0.60	0.66	0.76	0.86	0.94	1.21	1.57	1.84	2.18	2.43	2.70
01	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.88	1.15	1.34	1.59	1.78	1.97
01	10-min	0.29	0.34	0.37	0.43	0.49	0.53	0.69	0.89	1.05	1.24	1.38	1.53
01	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.39	0.51	0.60	0.71	0.79	0.88
02	10-day	2.21	2.66	3.07	3.61	4.15	4.51	5.41	6.64	7.62	8.90	9.92	11.02
02	5-day	1.79	2.14	2.42	2.81	3.23	3.51	4.27	5.37	6.27	7.53	8.51	9.57
02	72-hr	1.63	1.91	2.16	2.50	2.88	3.13	3.82	4.81	5.66	6.81	7.74	8.76
02	48-hr	1.48	1.74	1.93	2.24	2.58	2.80	3.44	4.33	5.09	6.14	6.99	7.91
02	24-hr	1.38	1.60	1.75	2.03	2.30	2.50	3.10	3.94	4.64	5.60	6.38	7.21
02	18-hr	1.29	1.50	1.64	1.90	2.16	2.35	2.91	3.70	4.36	5.26	6.00	6.78
02	12-hr	1.19	1.39	1.52	1.76	2.00	2.17	2.70	3.43	4.04	4.87	5.55	6.27
02	6-hr	1.03	1.20	1.32	1.52	1.73	1.88	2.32	2.95	3.48	4.20	4.78	5.41
02	3-hr	0.88	1.02	1.12	1.30	1.47	1.60	1.98	2.52	2.97	3.58	4.08	4.61
02	2-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.80	2.29	2.69	3.25	3.70	4.18
02	1-hr	0.64	0.75	0.82	0.95	1.08	1.17	1.46	1.85	2.18	2.63	3.00	3.39
02	30-min	0.51	0.60	0.65	0.75	0.86	0.93	1.15	1.46	1.72	2.07	2.36	2.67
02	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.84	1.06	1.25	1.51	1.72	1.95
02	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.65	0.83	0.97	1.18	1.34	1.51
02	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.37	0.47	0.56	0.67	0.77	0.87
03	10-day	2.38	2.87	3.30	3.89	4.47	4.86	6.10	7.59	8.62	9.88	10.87	11.72
03	5-day	2.04	2.44	2.76	3.20	3.68	4.00	4.92	6.12	7.06	8.33	9.31	10.36
03	72-hr	1.79	2.10	2.38	2.76	3.17	3.45	4.25	5.33	6.20	7.39	8.32	9.30
03	48-hr	1.66	1.94	2.16	2.50	2.88	3.13	3.90	4.92	5.71	6.78	7.66	8.57
03	24-hr	1.55	1.80	1.97	2.28	2.59	2.81	3.50	4.41	5.16	6.16	6.93	7.74
03	18-hr	1.45	1.69	1.85	2.14	2.43	2.64	3.29	4.15	4.85	5.79	6.51	7.28
03	12-hr	1.34	1.56	1.71	1.98	2.24	2.44	3.05	3.84	4.49	5.36	6.03	6.73
03	6-hr	1.16	1.35	1.48	1.71	1.94	2.11	2.62	3.31	3.87	4.62	5.20	5.80
03	3-hr	0.99	1.15	1.26	1.46	1.66	1.80	2.24	2.82	3.30	3.94	4.44	4.95
03	2-hr	0.90	1.04	1.14	1.32	1.50	1.63	2.03	2.56	2.99	3.57	4.02	4.49
03	1-hr	0.73	0.84	0.92	1.07	1.21	1.32	1.64	2.07	2.43	2.90	3.26	3.64
03	30-min	0.57	0.67	0.73	0.84	0.96	1.04	1.30	1.63	1.91	2.28	2.56	2.86
03	15-min	0.42	0.49	0.53	0.62	0.70	0.76	0.95	1.19	1.39	1.66	1.87	2.09
03	10-min	0.32	0.38	0.41	0.48	0.54	0.59	0.73	0.93	1.08	1.29	1.46	1.63
03	5-min	0.19	0.22	0.24	0.28	0.31	0.34	0.42	0.53	0.62	0.74	0.83	0.93

Table 7. Concluded

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	2.63	3.17	3.65	4.30	4.94	5.37	6.59	8.05	9.13	10.49	11.52	12.61
04	5-day	2.12	2.54	2.87	3.33	3.83	4.16	5.21	6.50	7.45	8.70	9.68	10.77
04	72-hr	1.91	2.24	2.54	2.94	3.39	3.68	4.62	5.81	6.69	7.90	8.85	9.85
04	48-hr	1.75	2.05	2.28	2.64	3.04	3.30	4.14	5.25	6.07	7.17	8.05	8.97
04	24-hr	1.65	1.92	2.10	2.43	2.76	3.00	3.77	4.79	5.55	6.56	7.34	8.18
04	18-hr	1.55	1.80	1.97	2.28	2.59	2.82	3.54	4.50	5.22	6.17	6.90	7.69
04	12-hr	1.44	1.67	1.83	2.11	2.40	2.61	3.28	4.17	4.83	5.71	6.39	7.12
04	6-hr	1.24	1.44	1.57	1.82	2.07	2.25	2.83	3.59	4.16	4.92	5.51	6.14
04	3-hr	1.06	1.23	1.34	1.56	1.77	1.92	2.41	3.07	3.55	4.20	4.70	5.24
04	2-hr	0.96	1.11	1.22	1.41	1.60	1.74	2.19	2.78	3.22	3.80	4.26	4.74
04	1-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.77	2.25	2.61	3.08	3.45	3.84
04	30-min	0.61	0.71	0.78	0.90	1.02	1.11	1.39	1.77	2.05	2.43	2.72	3.03
04	15-min	0.45	0.52	0.57	0.66	0.75	0.81	1.02	1.29	1.50	1.77	1.98	2.21
04	10-min	0.35	0.40	0.44	0.51	0.58	0.63	0.79	1.01	1.17	1.38	1.54	1.72
04	5-min	0.20	0.23	0.25	0.29	0.33	0.36	0.45	0.57	0.67	0.79	0.88	0.98
05	10-day	2.30	2.77	3.20	3.76	4.32	4.70	5.96	7.36	8.29	9.48	10.34	11.31
05	5-day	1.92	2.30	2.60	3.02	3.47	3.77	4.78	5.99	6.86	8.02	8.97	9.93
05	72-hr	1.75	2.05	2.32	2.69	3.09	3.36	4.24	5.31	6.10	7.15	7.99	8.90
05	48-hr	1.61	1.88	2.09	2.42	2.79	3.03	3.82	4.78	5.50	6.47	7.24	8.06
05	24-hr	1.53	1.79	1.95	2.26	2.57	2.79	3.51	4.39	5.03	5.94	6.64	7.42
05	18-hr	1.44	1.68	1.83	2.12	2.41	2.62	3.30	4.13	4.73	5.58	6.24	6.97
05	12-hr	1.34	1.56	1.70	1.97	2.24	2.43	3.05	3.82	4.38	5.17	5.78	6.46
05	6-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.63	3.29	3.77	4.45	4.98	5.57
05	3-hr	0.98	1.15	1.25	1.45	1.65	1.79	2.25	2.81	3.22	3.80	4.25	4.75
05	2-hr	0.89	1.04	1.13	1.31	1.49	1.62	2.04	2.55	2.92	3.45	3.85	4.30
05	1-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.65	2.06	2.36	2.79	3.12	3.49
05	30-min	0.57	0.66	0.72	0.83	0.95	1.03	1.30	1.62	1.86	2.20	2.46	2.75
05	15-min	0.41	0.48	0.52	0.61	0.69	0.75	0.95	1.19	1.36	1.60	1.79	2.00
05	10-min	0.32	0.38	0.41	0.48	0.54	0.59	0.74	0.92	1.06	1.25	1.39	1.56
05	5-min	0.18	0.21	0.23	0.27	0.30	0.33	0.42	0.53	0.60	0.71	0.80	0.89
06	10-day	2.45	2.94	3.39	3.99	4.59	4.99	6.43	7.99	9.01	10.25	11.15	12.07
06	5-day	2.09	2.50	2.83	3.28	3.77	4.10	5.19	6.46	7.31	8.39	9.20	10.04
06	72-hr	1.91	2.24	2.53	2.94	3.38	3.67	4.67	5.81	6.60	7.58	8.35	9.12
06	48-hr	1.74	2.03	2.26	2.62	3.02	3.28	4.14	5.13	5.84	6.75	7.47	8.21
06	24-hr	1.64	1.91	2.09	2.42	2.75	2.99	3.74	4.65	5.29	6.16	6.83	7.51
06	18-hr	1.55	1.80	1.97	2.28	2.59	2.81	3.52	4.37	4.97	5.79	6.42	7.06
06	12-hr	1.43	1.66	1.82	2.11	2.39	2.60	3.25	4.05	4.60	5.36	5.94	6.53
06	6-hr	1.23	1.43	1.57	1.81	2.06	2.24	2.81	3.49	3.97	4.62	5.12	5.63
06	3-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.39	2.98	3.39	3.94	4.37	4.81
06	2-hr	0.95	1.11	1.21	1.40	1.59	1.73	2.17	2.70	3.07	3.57	3.96	4.36
06	1-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.76	2.19	2.49	2.90	3.21	3.53
06	30-min	0.61	0.71	0.78	0.90	1.02	1.11	1.38	1.72	1.96	2.28	2.53	2.78
06	15-min	0.45	0.52	0.57	0.66	0.75	0.81	1.01	1.26	1.43	1.66	1.84	2.03
06	10-min	0.35	0.40	0.44	0.51	0.58	0.63	0.79	0.98	1.11	1.29	1.43	1.58
06	5-min	0.20	0.23	0.25	0.29	0.33	0.36	0.45	0.56	0.63	0.74	0.82	0.90

Table 8. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Ohio

Sectional code (see figure 1 on page 4)

01 – Northwest	*06 -Central Hills*
02 - North Central	*07 - Northeast Hills*
03 – Northeast	*08 - Southwest*
04 - West Central	*09 - South Central*
05 – Central	*10 - Southeast*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.69	2.04	2.35	2.76	3.17	3.45	4.22	5.17	5.89	6.83	7.56	8.31
01	5-day	1.42	1.70	1.93	2.23	2.57	2.79	3.43	4.29	4.92	5.81	6.51	7.26
01	72-hr	1.27	1.49	1.69	1.96	2.25	2.45	3.05	3.77	4.33	5.17	5.89	6.71
01	48-hr	1.17	1.36	1.52	1.76	2.02	2.20	2.74	3.43	3.96	4.74	5.40	6.14
01	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.52	3.18	3.70	4.43	5.05	5.73
01	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.37	2.99	3.48	4.16	4.75	5.39
01	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.19	2.77	3.22	3.85	4.39	4.99
01	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.89	2.38	2.78	3.32	3.79	4.30
01	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.61	2.04	2.37	2.84	3.23	3.67
01	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.46	1.84	2.15	2.57	2.93	3.32
01	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.18	1.49	1.74	2.08	2.37	2.69
01	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.93	1.18	1.37	1.64	1.87	2.12
01	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.68	0.86	1.00	1.20	1.36	1.55
01	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.53	0.67	0.78	0.93	1.06	1.20
01	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.30	0.38	0.44	0.53	0.61	0.69
02	10-day	1.63	1.96	2.26	2.66	3.05	3.32	4.19	5.31	6.19	7.40	8.35	9.35
02	5-day	1.35	1.61	1.82	2.11	2.43	2.64	3.33	4.32	5.10	6.21	7.14	8.14
02	72-hr	1.22	1.43	1.61	1.87	2.15	2.34	2.93	3.69	4.34	5.39	6.33	7.39
02	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.67	3.37	3.94	4.86	5.70	6.68
02	24-hr	1.09	1.27	1.39	1.60	1.82	1.98	2.44	3.06	3.55	4.35	5.08	5.92
02	18-hr	1.02	1.19	1.30	1.51	1.71	1.86	2.29	2.88	3.34	4.09	4.78	5.56
02	12-hr	0.95	1.10	1.20	1.39	1.58	1.72	2.12	2.66	3.09	3.78	4.42	5.15
02	6-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.83	2.30	2.66	3.26	3.81	4.44
02	3-hr	0.70	0.81	0.89	1.03	1.17	1.27	1.56	1.96	2.27	2.78	3.25	3.79
02	2-hr	0.63	0.74	0.80	0.93	1.06	1.15	1.42	1.77	2.06	2.52	2.95	3.43
02	1-hr	0.51	0.60	0.65	0.75	0.86	0.93	1.15	1.44	1.67	2.04	2.39	2.78
02	30-min	0.40	0.47	0.51	0.59	0.67	0.73	0.90	1.13	1.31	1.61	1.88	2.19
02	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.66	0.83	0.96	1.17	1.37	1.60
02	10-min	0.23	0.27	0.29	0.34	0.39	0.42	0.51	0.64	0.75	0.91	1.07	1.24
02	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.37	0.43	0.52	0.61	0.71
03	10-day	1.70	2.05	2.36	2.78	3.19	3.47	4.29	5.34	6.17	7.30	8.19	9.14
03	5-day	1.37	1.64	1.86	2.15	2.47	2.69	3.34	4.23	4.95	5.96	6.82	7.74
03	72-hr	1.26	1.48	1.67	1.94	2.23	2.42	2.99	3.72	4.34	5.31	6.15	7.09
03	48-hr	1.18	1.38	1.53	1.78	2.04	2.22	2.75	3.42	3.99	4.87	5.66	6.55
03	24-hr	1.12	1.31	1.43	1.65	1.88	2.04	2.50	3.10	3.60	4.39	5.11	5.89
03	18-hr	1.06	1.23	1.34	1.56	1.77	1.92	2.35	2.91	3.38	4.13	4.80	5.54
03	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.17	2.70	3.13	3.82	4.45	5.12
03	6-hr	0.84	0.98	1.07	1.24	1.41	1.53	1.88	2.32	2.70	3.29	3.83	4.42
03	3-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.60	1.98	2.30	2.81	3.27	3.77
03	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.45	1.80	2.09	2.55	2.96	3.42
03	1-hr	0.53	0.61	0.67	0.78	0.88	0.96	1.17	1.46	1.69	2.06	2.40	2.77
03	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.93	1.15	1.33	1.62	1.89	2.18
03	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.68	0.84	0.97	1.19	1.38	1.59
03	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.52	0.65	0.76	0.92	1.07	1.24
03	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.30	0.37	0.43	0.53	0.61	0.71

Table 8. Continued

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
04	10-day	1.85	2.23	2.57	3.02	3.48	3.78	4.59	5.63	6.43	7.48	8.30	9.19
04	5-day	1.54	1.84	2.08	2.41	2.77	3.01	3.65	4.54	5.22	6.17	6.92	7.74
04	72-hr	1.36	1.59	1.80	2.09	2.40	2.61	3.19	3.88	4.46	5.33	6.12	6.97
04	48-hr	1.25	1.46	1.62	1.88	2.16	2.35	2.91	3.58	4.09	4.88	5.56	6.35
04	24-hr	1.18	1.38	1.50	1.74	1.98	2.15	2.69	3.34	3.80	4.46	5.06	5.70
04	18-hr	1.11	1.29	1.41	1.64	1.86	2.02	2.53	3.14	3.57	4.19	4.76	5.36
04	12-hr	1.03	1.20	1.31	1.51	1.72	1.87	2.34	2.91	3.31	3.88	4.40	4.96
04	6-hr	0.89	1.03	1.13	1.30	1.48	1.61	2.02	2.50	2.85	3.35	3.80	4.27
04	3-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.72	2.14	2.43	2.85	3.24	3.65
04	2-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.56	1.94	2.20	2.59	2.93	3.31
04	1-hr	0.56	0.65	0.71	0.82	0.93	1.01	1.26	1.57	1.79	2.10	2.38	2.68
04	30-min	0.44	0.51	0.56	0.65	0.74	0.80	1.00	1.24	1.41	1.65	1.87	2.11
04	15-min	0.32	0.37	0.41	0.47	0.53	0.58	0.73	0.90	1.03	1.20	1.37	1.54
04	10-min	0.25	0.29	0.31	0.36	0.41	0.45	0.56	0.70	0.80	0.94	1.06	1.20
04	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.40	0.46	0.54	0.61	0.68
05	10-day	1.81	2.18	2.51	2.95	3.39	3.69	4.69	5.93	6.78	7.82	8.56	9.27
05	5-day	1.49	1.78	2.01	2.34	2.69	2.92	3.67	4.65	5.39	6.37	7.11	7.89
05	72-hr	1.36	1.59	1.80	2.09	2.40	2.61	3.23	3.99	4.54	5.36	6.09	6.92
05	48-hr	1.27	1.48	1.65	1.91	2.20	2.39	2.97	3.67	4.21	5.02	5.72	6.50
05	24-hr	1.19	1.39	1.52	1.76	2.00	2.17	2.70	3.35	3.86	4.64	5.33	6.06
05	18-hr	1.12	1.31	1.43	1.65	1.88	2.04	2.54	3.15	3.63	4.36	5.01	5.70
05	12-hr	1.04	1.21	1.32	1.53	1.74	1.89	2.35	2.91	3.36	4.04	4.64	5.27
05	6-hr	0.90	1.04	1.14	1.32	1.50	1.63	2.03	2.51	2.89	3.48	4.00	4.55
05	3-hr	0.76	0.89	0.97	1.13	1.28	1.39	1.73	2.14	2.47	2.97	3.41	3.88
05	2-hr	0.69	0.81	0.88	1.02	1.16	1.26	1.57	1.94	2.24	2.69	3.09	3.51
05	1-hr	0.56	0.65	0.71	0.83	0.94	1.02	1.27	1.57	1.81	2.18	2.51	2.85
05	30-min	0.44	0.51	0.56	0.65	0.74	0.80	1.00	1.24	1.43	1.72	1.97	2.24
05	15-min	0.32	0.38	0.41	0.48	0.54	0.59	0.73	0.90	1.04	1.25	1.44	1.64
05	10-min	0.25	0.29	0.32	0.37	0.42	0.46	0.57	0.70	0.81	0.97	1.12	1.27
05	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.40	0.46	0.56	0.64	0.73
06	10-day	1.72	2.08	2.39	2.82	3.24	3.52	4.35	5.47	6.38	7.61	8.66	9.74
06	5-day	1.41	1.68	1.90	2.21	2.54	2.76	3.33	4.24	4.98	6.15	7.12	8.21
06	72-hr	1.30	1.53	1.73	2.00	2.30	2.50	2.99	3.72	4.41	5.53	6.54	7.69
06	48-hr	1.22	1.43	1.59	1.85	2.13	2.31	2.78	3.44	4.09	5.12	6.06	7.17
06	24-hr	1.16	1.35	1.48	1.71	1.94	2.11	2.51	3.11	3.68	4.57	5.41	6.39
06	18-hr	1.09	1.27	1.39	1.60	1.82	1.98	2.36	2.92	3.46	4.30	5.09	6.01
06	12-hr	1.01	1.18	1.29	1.49	1.69	1.84	2.18	2.71	3.20	3.98	4.71	5.56
06	6-hr	0.87	1.01	1.11	1.28	1.45	1.58	1.88	2.33	2.76	3.43	4.06	4.79
06	3-hr	0.74	0.86	0.94	1.09	1.24	1.35	1.61	1.99	2.36	2.92	3.46	4.09
06	2-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.46	1.80	2.13	2.65	3.14	3.71
06	1-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.18	1.46	1.73	2.15	2.54	3.00
06	30-min	0.43	0.50	0.55	0.63	0.72	0.78	0.93	1.15	1.36	1.69	2.00	2.36
06	15-min	0.31	0.36	0.40	0.46	0.52	0.57	0.68	0.84	0.99	1.23	1.46	1.73
06	10-min	0.24	0.28	0.31	0.36	0.40	0.44	0.53	0.65	0.77	0.96	1.14	1.34
06	5-min	0.14	0.16	0.17	0.20	0.23	0.25	0.30	0.37	0.44	0.55	0.65	0.77

Table 8. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	1.71	2.06	2.37	2.79	3.21	3.49	4.33	5.37	6.10	7.03	7.77	8.48
07	5-day	1.40	1.67	1.89	2.19	2.52	2.74	3.32	4.11	4.72	5.55	6.26	6.99
07	72-hr	1.28	1.51	1.70	1.98	2.27	2.47	2.98	3.64	4.15	4.94	5.63	6.39
07	48-hr	1.19	1.39	1.55	1.79	2.06	2.24	2.73	3.33	3.81	4.53	5.15	5.81
07	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.50	3.02	3.42	3.94	4.41	4.92
07	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.35	2.84	3.21	3.70	4.15	4.62
07	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.17	2.63	2.98	3.43	3.84	4.28
07	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.88	2.26	2.57	2.95	3.31	3.69
07	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.60	1.93	2.19	2.52	2.82	3.15
07	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.45	1.75	1.98	2.29	2.56	2.85
07	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.17	1.42	1.61	1.85	2.07	2.31
07	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.93	1.12	1.27	1.46	1.63	1.82
07	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.68	0.82	0.92	1.06	1.19	1.33
07	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.52	0.63	0.72	0.83	0.93	1.03
07	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.30	0.36	0.41	0.47	0.53	0.59
08	10-day	1.96	2.35	2.71	3.19	3.67	3.99	4.97	6.15	7.02	8.09	8.89	9.71
08	5-day	1.59	1.90	2.15	2.49	2.86	3.11	3.92	4.94	5.66	6.58	7.32	8.05
08	72-hr	1.45	1.70	1.92	2.22	2.56	2.78	3.43	4.22	4.83	5.70	6.47	7.29
08	48-hr	1.35	1.58	1.76	2.04	2.35	2.55	3.15	3.87	4.44	5.26	5.98	6.77
08	24-hr	1.28	1.49	1.63	1.89	2.14	2.33	2.86	3.49	3.99	4.70	5.32	6.04
08	18-hr	1.20	1.40	1.53	1.77	2.01	2.19	2.69	3.28	3.75	4.42	5.00	5.68
08	12-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.49	3.04	3.47	4.09	4.63	5.25
08	6-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.14	2.62	2.99	3.52	3.99	4.53
08	3-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.83	2.23	2.55	3.01	3.40	3.87
08	2-hr	0.74	0.86	0.94	1.09	1.24	1.35	1.66	2.02	2.31	2.73	3.09	3.50
08	1-hr	0.61	0.70	0.77	0.89	1.01	1.10	1.34	1.64	1.88	2.21	2.50	2.84
08	30-min	0.47	0.55	0.60	0.70	0.79	0.86	1.06	1.29	1.48	1.74	1.97	2.23
08	15-min	0.35	0.40	0.44	0.51	0.58	0.63	0.77	0.94	1.08	1.27	1.44	1.63
08	10-min	0.27	0.31	0.34	0.40	0.45	0.49	0.60	0.73	0.84	0.99	1.12	1.27
08	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.34	0.42	0.48	0.56	0.64	0.72
09	10-day	1.91	2.30	2.65	3.12	3.59	3.90	4.91	6.09	6.92	7.92	8.62	9.35
09	5-day	1.61	1.92	2.17	2.52	2.90	3.15	3.92	4.92	5.66	6.65	7.43	8.24
09	72-hr	1.46	1.71	1.94	2.25	2.59	2.81	3.42	4.20	4.82	5.78	6.65	7.58
09	48-hr	1.35	1.58	1.76	2.04	2.35	2.55	3.10	3.79	4.39	5.31	6.14	7.08
09	24-hr	1.26	1.47	1.60	1.85	2.11	2.29	2.79	3.42	4.01	4.87	5.66	6.50
09	18-hr	1.18	1.38	1.50	1.74	1.98	2.15	2.62	3.21	3.77	4.58	5.32	6.11
09	12-hr	1.09	1.27	1.39	1.61	1.83	1.99	2.43	2.98	3.49	4.24	4.92	5.66
09	6-hr	0.95	1.10	1.20	1.39	1.58	1.72	2.09	2.57	3.01	3.65	4.24	4.88
09	3-hr	0.81	0.94	1.03	1.19	1.35	1.47	1.79	2.19	2.57	3.12	3.62	4.16
09	2-hr	0.73	0.85	0.93	1.08	1.22	1.33	1.62	1.98	2.33	2.82	3.28	3.77
09	1-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.31	1.61	1.88	2.29	2.66	3.06
09	30-min	0.47	0.54	0.60	0.69	0.78	0.85	1.03	1.27	1.48	1.80	2.09	2.40
09	15-min	0.34	0.40	0.43	0.50	0.57	0.62	0.75	0.92	1.08	1.31	1.53	1.76
09	10-min	0.26	0.31	0.34	0.39	0.44	0.48	0.59	0.72	0.84	1.02	1.19	1.37
09	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.41	0.48	0.58	0.68	0.78

Table 8. Concluded

		Rainfall (inches) for given recurrence interval											
Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
10	10-day	1.70	2.04	2.35	2.77	3.18	3.46	4.41	5.58	6.38	7.38	8.09	8.80
10	5-day	1.43	1.71	1.93	2.24	2.58	2.80	3.52	4.44	5.07	5.86	6.42	6.98
10	72-hr	1.28	1.51	1.70	1.98	2.27	2.47	3.07	3.78	4.32	5.08	5.69	6.33
10	48-hr	1.18	1.38	1.54	1.78	2.05	2.23	2.77	3.42	3.94	4.67	5.25	5.88
10	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.54	3.17	3.64	4.34	4.91	5.51
10	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.39	2.98	3.42	4.08	4.62	5.18
10	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.21	2.76	3.17	3.78	4.27	4.79
10	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.90	2.38	2.73	3.26	3.68	4.13
10	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.63	2.03	2.33	2.78	3.14	3.53
10	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.47	1.84	2.11	2.52	2.85	3.20
10	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.19	1.49	1.71	2.04	2.31	2.59
10	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.94	1.17	1.35	1.61	1.82	2.04
10	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.69	0.86	0.98	1.17	1.33	1.49
10	10-mín	0.24	0.28	0.30	0.35	0.40	0.43	0.53	0.67	0.76	0.91	1.03	1.16
10	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.30	0.38	0.44	0.52	0.59	0.66

Table 9. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Wisconsin

Sectional code (see figure 1 on page 4)

01 – Northwest *06 - East Central*
02 - North Central *07 - Southwest*
03 – Northeast *08 - South Central*
04 - West Central *09 - Southeast*
05 – Central

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.90	2.29	2.64	3.10	3.57	3.88	4.78	5.83	6.58	7.63	8.47	9.37
01	5-day	1.55	1.85	2.09	2.42	2.79	3.03	3.75	4.66	5.35	6.27	7.05	7.90
01	72-hr	1.39	1.63	1.85	2.14	2.47	2.68	3.31	4.12	4.78	5.67	6.39	7.16
01	48-hr	1.30	1.53	1.70	1.97	2.26	2.46	3.05	3.82	4.41	5.23	5.88	6.56
01	24-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.77	3.50	4.04	4.79	5.36	5.98
01	18-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.60	3.29	3.80	4.50	5.04	5.62
01	12-hr	1.06	1.24	1.35	1.56	1.78	1.93	2.41	3.05	3.51	4.17	4.66	5.20
01	6-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.08	2.62	3.03	3.59	4.02	4.49
01	3-hr	0.78	0.91	0.99	1.15	1.31	1.42	1.77	2.24	2.59	3.07	3.43	3.83
01	2-hr	0.71	0.83	0.90	1.04	1.19	1.29	1.61	2.03	2.34	2.78	3.11	3.47
01	1-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.30	1.64	1.90	2.25	2.52	2.81
01	30-min	0.45	0.52	0.57	0.66	0.75	0.82	1.02	1.30	1.49	1.77	1.98	2.21
01	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.75	0.95	1.09	1.29	1.45	1.61
01	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.73	0.85	1.01	1.13	1.26
01	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.42	0.48	0.57	0.64	0.72
02	10-day	1.98	2.39	2.75	3.24	3.73	4.05	4.79	5.68	6.44	7.55	8.49	9.52
02	5-day	1.59	1.90	2.15	2.50	2.87	3.12	3.77	4.63	5.33	6.36	7.27	8.28
02	72-hr	1.40	1.65	1.86	2.16	2.48	2.70	3.30	4.08	4.72	5.69	6.50	7.41
02	48-hr	1.29	1.51	1.68	1.94	2.24	2.43	2.99	3.73	4.31	5.16	5.89	6.67
02	24-hr	1.22	1.41	1.55	1.79	2.03	2.21	2.74	3.39	3.90	4.66	5.29	6.01
02	18-hr	1.14	1.33	1.46	1.68	1.91	2.08	2.58	3.19	3.67	4.38	4.97	5.65
02	12-hr	1.06	1.23	1.34	1.56	1.77	1.92	2.38	2.95	3.39	4.05	4.60	5.23
02	6-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.06	2.54	2.93	3.49	3.97	4.51
02	3-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.75	2.17	2.50	2.98	3.39	3.85
02	2-hr	0.70	0.82	0.90	1.04	1.18	1.28	1.59	1.97	2.26	2.70	3.07	3.49
02	1-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.29	1.59	1.83	2.19	2.49	2.82
02	30-min	0.45	0.52	0.57	0.66	0.75	0.82	1.01	1.25	1.44	1.72	1.96	2.22
02	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.74	0.92	1.05	1.26	1.43	1.62
02	10-min	0.25	0.29	0.32	0.37	0.42	0.46	0.58	0.71	0.82	0.98	1.11	1.26
02	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.41	0.47	0.56	0.63	0.72
03	10-day	1.78	2.15	2.48	2.91	3.35	3.64	4.45	5.38	6.06	7.01	7.84	8.74
03	5-day	1.38	1.65	1.87	2.17	2.49	2.71	3.33	4.08	4.68	5.64	6.47	7.45
03	72-hr	1.21	1.42	1.60	1.86	2.13	2.32	2.87	3.59	4.18	5.07	5.84	6.74
03	48-hr	1.12	1.31	1.46	1.70	1.95	2.12	2.61	3.28	3.82	4.66	5.38	6.22
03	24-hr	1.04	1.22	1.33	1.54	1.75	1.90	2.34	2.94	3.46	4.24	4.94	5.77
03	18-hr	0.98	1.15	1.25	1.45	1.65	1.79	2.20	2.76	3.25	3.99	4.64	5.42
03	12-hr	0.91	1.06	1.15	1.34	1.52	1.65	2.04	2.56	3.01	3.69	4.30	5.02
03	6-hr	0.78	0.91	0.99	1.15	1.31	1.42	1.75	2.20	2.60	3.18	3.70	4.33
03	3-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.50	1.88	2.21	2.71	3.16	3.69
03	2-hr	0.61	0.70	0.77	0.89	1.01	1.10	1.36	1.71	2.01	2.46	2.87	3.35
03	1-hr	0.49	0.57	0.62	0.72	0.82	0.89	1.10	1.38	1.63	1.99	2.32	2.71
03	30-min	0.38	0.45	0.49	0.57	0.64	0.70	0.87	1.09	1.28	1.57	1.83	2.13
03	15-min	0.28	0.33	0.36	0.41	0.47	0.51	0.63	0.79	0.93	1.14	1.33	1.56
03	10-min	0.22	0.26	0.28	0.32	0.37	0.40	0.49	0.62	0.73	0.89	1.04	1.21
03	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.28	0.35	0.42	0.51	0.59	0.69

Table 9. Continued

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
04	10-day	1.83	2.21	2.54	2.99	3.44	3.74	4.78	5.94	6.76	7.95	8.96	9.92
04	5-day	1.57	1.87	2.12	2.46	2.82	3.07	3.88	4.88	5.69	6.85	7.80	8.85
04	72-hr	1.40	1.64	1.86	2.15	2.47	2.69	3.43	4.36	5.17	6.24	7.07	8.06
04	48-hr	1.29	1.51	1.68	1.95	2.24	2.44	3.12	3.98	4.66	5.60	6.43	7.33
04	24-hr	1.23	1.43	1.56	1.81	2.05	2.23	2.92	3.72	4.40	5.28	6.02	6.88
04	18-hr	1.15	1.34	1.47	1.70	1.93	2.10	2.74	3.50	4.14	4.96	5.66	6.47
04	12-hr	1.07	1.24	1.36	1.57	1.78	1.94	2.54	3.24	3.83	4.59	5.24	5.99
04	6-hr	0.92	1.07	1.17	1.35	1.54	1.67	2.19	2.79	3.30	3.96	4.51	5.16
04	3-hr	0.79	0.92	1.00	1.16	1.32	1.43	1.87	2.38	2.82	3.38	3.85	4.40
04	2-hr	0.71	0.83	0.90	1.04	1.19	1.29	1.69	2.16	2.55	3.06	3.49	3.99
04	1-hr	0.58	0.67	0.73	0.85	0.97	1.05	1.37	1.75	2.07	2.48	2.83	3.23
04	30-min	0.46	0.53	0.58	0.67	0.76	0.83	1.08	1.38	1.63	1.95	2.23	2.55
04	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.79	1.00	1.19	1.43	1.63	1.86
04	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.61	0.78	0.92	1.11	1.26	1.44
04	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.35	0.45	0.53	0.63	0.72	0.83
05	10-day	1.90	2.29	2.64	3.10	3.57	3.88	4.77	5.81	6.53	7.59	8.50	9.52
05	5-day	1.54	1.84	2.08	2.41	2.77	3.01	3.69	4.49	5.14	6.09	6.94	7.87
05	72-hr	1.35	1.59	1.79	2.08	2.39	2.60	3.18	3.89	4.49	5.36	6.09	6.90
05	48-hr	1.25	1.46	1.63	1.89	2.17	2.36	2.90	3.58	4.11	4.87	5.48	6.17
05	24-hr	1.18	1.38	1.50	1.74	1.98	2.15	2.65	3.25	3.71	4.38	4.93	5.52
05	18-hr	1.11	1.29	1.41	1.64	1.86	2.02	2.49	3.06	3.49	4.12	4.63	5.19
05	12-hr	1.03	1.20	1.31	1.51	1.72	1.87	2.31	2.83	3.23	3.81	4.29	4.80
05	6-hr	0.89	1.03	1.13	1.30	1.48	1.61	1.99	2.44	2.78	3.29	3.70	4.14
05	3-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.70	2.08	2.37	2.80	3.16	3.53
05	2-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.54	1.88	2.15	2.54	2.86	3.20
05	1-hr	0.56	0.65	0.71	0.82	0.93	1.01	1.25	1.53	1.74	2.06	2.32	2.59
05	30-min	0.44	0.51	0.56	0.65	0.74	0.80	0.98	1.20	1.37	1.62	1.82	2.04
05	15-min	0.32	0.37	0.41	0.47	0.53	0.58	0.72	0.88	1.00	1.18	1.33	1.49
05	10-min	0.25	0.29	0.31	0.36	0.41	0.45	0.56	0.68	0.78	0.92	1.04	1.16
05	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.39	0.45	0.53	0.59	0.66
06	10-day	1.70	2.05	2.36	2.78	3.19	3.47	4.28	5.29	6.11	7.36	8.51	9.85
06	5-day	1.34	1.60	1.81	2.10	2.42	2.63	3.22	4.01	4.74	5.91	6.98	8.28
06	72-hr	1.21	1.42	1.61	1.66	2.14	2.33	2.83	3.55	4.20	5.25	6.23	7.42
06	48-hr	1.13	1.32	1.47	1.70	1.96	2.13	2.61	3.26	3.87	4.86	5.77	6.88
06	24-hr	1.08	1.25	1.37	1.59	1.80	1.96	2.40	3.00	3.56	4.46	5.32	6.35
06	18-hr	1.01	1.18	1.29	1.49	1.69	1.84	2.26	2.82	3.35	4.19	5.00	5.97
06	12-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.09	2.61	3.10	3.88	4.63	5.52
06	6-hr	0.81	0.94	1.03	1.19	1.35	1.47	1.80	2.25	2.67	3.35	3.99	4.76
06	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.54	1.92	2.28	2.85	3.40	4.06
06	2-hr	0.63	0.73	0.80	0.92	1.05	1.14	1.39	1.74	2.06	2.59	3.09	3.68
06	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.13	1.41	1.67	2.10	2.50	2.98
06	30-min	0.40	0.47	0.51	0.59	0.67	0.73	0.89	1.11	1.32	1.65	1.97	2.35
06	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.65	0.81	0.96	1.20	1.44	1.71
06	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.75	0.94	1.12	1.33
06	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.36	0.43	0.54	0.64	0.76

Table 9. Concluded

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	1.85	2.23	2.57	3.02	3.48	3.78	4.88	6.19	7.16	8.45	9.49	10.60
07	5-day	1.56	1.87	2.11	2.45	2.82	3.06	3.92	5.04	5.91	7.22	8.29	9.52
07	72-hr	1.40	1.65	1.86	2.16	2.48	2.70	3.42	4.43	5.23	6.43	7.49	8.68
07	48-hr	1.31	1.53	1.70	1.98	2.27	2.47	3.12	4.05	4.82	5.91	6.88	7.95
07	24-hr	1.24	1.44	1.57	1.82	2.07	2.25	2.82	3.60	4.31	5.29	6.17	7.15
07	18-hr	1.17	1.36	1.48	1.72	1.95	2.12	2.65	3.38	4.05	4.97	5.80	6.72
07	12-hr	1.08	1.25	1.37	1.59	1.80	1.96	2.45	3.13	3.75	4.60	5.37	6.22
07	6-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.12	2.70	3.23	3.97	4.63	5.36
07	3-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.80	2.30	2.76	3.39	3.95	4.58
07	2-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.64	2.09	2.50	3.07	3.58	4.15
07	1-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.33	1.69	2.03	2.49	2.90	3.36
07	30-min	0.46	0.53	0.58	0.67	0.76	0.83	1.04	1.33	1.59	1.96	2.28	2.65
07	15-min	0.34	0.39	0.43	0.49	0.56	0.61	0.76	0.97	1.16	1.43	1.67	1.93
07	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.59	0.76	0.91	1.11	1.30	1.50
07	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.34	0.43	0.52	0.63	0.74	0.86
08	10-day	1.82	2.19	2.52	2.97	3.41	3.71	4.72	5.93	6.86	8.21	9.33	10.60
08	5-day	1.52	1.82	2.06	2.39	2.75	2.99	3.78	4.86	5.73	7.03	8.14	9.36
08	72-hr	1.40	1.65	1.86	2.16	2.48	2.70	3.38	4.34	5.16	6.34	7.34	8.47
08	48-hr	1.30	1.53	1.70	1.97	2.26	2.46	3.07	3.96	4.68	5.79	6.75	7.82
08	24-hr	1.24	1.44	1.57	1.82	2.07	2.25	2.78	3.53	4.20	5.18	6.06	7.06
08	18-hr	1.17	1.36	1.48	1.72	1.95	2.12	2.61	3.32	3.95	4.87	5.70	6.64
08	12-hr	1.08	1.25	1.37	1.59	1.80	1.96	2.42	3.07	3.65	4.51	5.27	6.14
08	6-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.09	2.65	3.15	3.88	4.55	5.30
08	3-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.78	2.26	2.69	3.32	3.88	4.52
08	2-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.61	2.05	2.44	3.00	3.51	4.09
08	1-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.31	1.66	1.97	2.43	2.85	3.32
08	30-min	0.46	0.53	0.58	0.67	0.76	0.83	1.03	1.31	1.55	1.92	2.24	2.61
08	15-min	0.34	0.39	0.43	0.49	0.56	0.61	0.75	0.95	1.13	1.40	1.64	1.91
08	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.74	0.88	1.09	1.27	1.48
08	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.42	0.50	0.62	0.73	0.85
09	10-day	1.81	2.18	2.52	2.96	3.40	3.70	4.55	5.65	6.58	7.89	9.09	10.49
09	5-day	1.50	1.79	2.03	2.35	2.70	2.94	3.66	4.66	5.50	6.72	7.85	9.14
09	72-hr	1.36	1.60	1.81	2.10	2.41	2.62	3.25	4.14	4.85	5.90	6.84	7.80
09	48-hr	1.27	1.49	1.66	1.92	2.21	2.40	2.98	3.78	4.43	5.36	6.22	7.14
09	24-hr	1.20	1.40	1.53	1.77	2.01	2.18	2.70	3.33	3.86	4.66	5.38	6.24
09	18-hr	1.13	1.31	1.43	1.66	1.89	2.05	2.54	3.13	3.63	4.38	5.06	5.87
09	12-hr	1.04	1.22	1.33	1.54	1.75	1.90	2.35	2.90	3.36	4.05	4.68	5.43
09	6-hr	0.90	1.04	1.14	1.32	1.50	1.63	2.03	2.50	2.89	3.49	4.03	4.68
09	3-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.73	2.13	2.47	2.98	3.44	3.99
09	2-hr	0.69	0.81	0.88	1.02	1.16	1.26	1.57	1.93	2.24	2.70	3.12	3.62
09	1-hr	0.56	0.65	0.71	0.83	0.94	1.02	1.27	1.57	1.81	2.19	2.53	2.93
09	30-min	0.45	0.52	0.57	0.66	0.75	0.81	1.00	1.23	1.43	1.72	1.99	2.31
09	15-min	0.32	0.38	0.41	0.48	0.54	0.59	0.73	0.90	1.04	1.26	1.45	1.68
09	10-min	0.25	0.29	0.32	0.37	0.42	0.46	0.57	0.70	0.81	0.98	1.13	1.31
09	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.40	0.46	0.56	0.65	0.75

Computing Flood Discharges
For Small Ungaged Watersheds

Peak Discharge Calculations:

Watercourse	Clear Creek		
Drainage Area	18.23	sq. mile	
Cont Drainage Area	16.80	sq. mile	
Basin Number	12		
Basin Name	Clinton		
Quad	P23SW		
Section	14		Insert information in
Town/Range	T03NR03E		green cells.
Latitude	42.222222		Place your cursor over
Longitude	-84.111111		the red triangles for
County	Macomb		additional tips.
Township	Ray		
Location	First Street		
Job Number	29990999		
By	Smith		
Date	Jun-04-2010		

Frequency	*50%*	*20%*	*10%*	*4%*	*2%*	*1%*	*0.50%*	*0.20%*
Discharge (cfs)	192	317	415	553	665	786	914	1100
Volume (Acre-ft)	389	644	842	1122	1350	1595	1854	2232
Ponding								
% throughout/mid	***2.1***	2.1	2.1	2.1	2.1	2.1	2.1	2.1
% upper reaches	***0***	0	0	0	0	0	0	0
% design point	***0***	0	0	0	0	0	0	0
Ponding Adjustment	0.77	0.78	0.80	0.82	0.84	0.86	0.88	0.90
Adjusted Flow (cfs)	148	247	332	453	560	679	800	985

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Michigan Department of Natural Resources and Environment
Land and Water Management Division
June 22, 2010
www.michigan.gov/hydrology

This report supersedes and replaces all previous versions that describe this method, including *Computing Flood Discharges For Small Ungaged Watersheds* (Sorrell and Hamilton, September 1991, July 2000, October 2001; *Computing Flood Discharges For Small Ungaged Watersheds* (Sorrell, July 2003 and June 2008), as well as *SCS UD-21 Method* (Sorrell, 1980 and 1985).

Revisions Summary

January 2010: Clarifies that the Appendix B hydrologic soil groups are not current and provides reference for current soils data. Clarifies maximum length for sheet flow and use of ponding adjustment at design point. Presents ordinates of Michigan unit hydrograph for use in WinTR-55. Changes unit hydrograph peak designation from Q_{up} as q_p' to match SCS designation. Contact: Linda Burke, 517-241-3720.

August 2008: Clarifies the minimum T_c applicable to the Michigan Unit hydrograph and designate the unit hydrograph peak as Q_{up} instead of Q_p. Contact: Dave Fongers, 517-373-0210.

June 2008: Revises three curve numbers that were less than 30 up to 30 (on Table 6-1) to reflect revised Natural Resources Conservation Service guidance, http://directives.sc.egov.usda.gov/media/pdf/H_210_630_9.pdf. Contact: Dave Fongers, 517-373-0210.

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Computing Flood Discharges
For Small Ungaged Watersheds

1. Introduction

Concern for potential flooding is a critical factor in the safe design of water-related projects. The magnitudes of floods are described by flood discharge, flood elevation, and flood volume. This report will detail a procedure that can be used to estimate both the discharge and volume of a flood given a design rainfall and a physical description of the watershed.

There are a variety of methods for estimating design floods. They can be grouped into three general categories.

1. Statistical analysis of gage data
   This method is used for streams which have a number of years of recorded flood data. It involves fitting a probability distribution to the data (usually the log-Pearson Type III) and using the parameters of the distribution to estimate large floods. Since this method utilizes actual flood data, it is generally regarded as the best estimator of design floods and should be used whenever possible.

2. Regression analysis
   This method involves correlating watershed characteristics to streamflow using data from a number of gaged streams. The predicting equation derived from this type of analysis usually expresses flood discharge as a function of multiple watershed characteristics. These equations almost always include drainage area as the most significant factor and may also include channel slope, precipitation intensity, and other characteristics related to land uses, soil types, and geologic formations in the watershed. This method can be used for ungaged stream locations.

3. Unit hydrograph techniques
   This method involves determining the peak rate of runoff, q_p', expressed in cubic feet per second (cfs) per inch of runoff from a given drainage area. This factor is primarily a function of the time it takes for runoff to travel through the basin to the design point. Once this rate of runoff is determined, it can be multiplied by the amount of runoff to produce a discharge. The versatility of this method is that it can account for changes in watershed travel time, and subsequently q_p', that are caused by alterations in the hydraulic capacity of the stream, such as channel maintenance operations, flood control structures, etc. The volume of runoff from a given amount of rainfall can also be adjusted to reflect changing land use within a watershed. This method is suitable for ungaged watersheds.

4. Drainage Area Ratio method
   Flows can be estimated if the flows are known at an upstream or downstream location using a drainage area ratio equation. Contact DNRE Hydrologic Studies program staff for more information.

This report presents a method for computing flood discharges using unit hydrograph (UH) techniques. The procedure is similar to that developed by the U.S. Department of Agriculture Soil Conservation Service (SCS), now known as the Natural Resource Conservation Service (NRCS). The “SCS Method” is described in the NRCS National Engineering Handbook (NEH), Part 630: Hydrology (2004).

The advantage of this method is that it is straightforward to apply and the physical parameters are easily determined. The primary disadvantage is that the method presented here is only valid for use with a 24-hour rainfall. For other rainfall durations, one should follow the full procedure in the NRCS reference. This method should also be limited to watersheds with a drainage area of approximately 20 square miles or less. One of the reasons for this limit is that UH theory assumes uniform rainfall and runoff from the entire drainage basin. This assumption is less reliable if the drainage area becomes too large. If a large watershed is being analyzed, it should be divided into subbasins and the flows from the individual sub-areas routed to the design location.

The SCS Method is also less accurate in cases where a large fraction of precipitation infiltrates into the ground, or for small rainfall values. In both cases, runoff is a small fraction of precipitation. Therefore, the SCS Method is not recommended to estimate low flows or small, more frequent flood flows. (See Hawkins, et. al., 1985, for a precise measure of “small”.)

The physical description of the watershed includes drainage area, soil types, land uses, and time of concentration. These are discussed in subsequent sections of this report.

A comprehensive application of the SCS Method is presented in Appendix A.

2. The Unit Hydrograph

The unit hydrograph (UH) theory was first proposed by Sherman (1932). It is defined as a surface runoff hydrograph (SRH) resulting from one inch of excess rainfall generated uniformly over the drainage area at a constant rate for an effective unit time duration. Sherman originally used the word “unit” to denote a unit of time, but since then it has often been interpreted as a unit depth of excess rainfall. Sherman classified streamflow into surface runoff and groundwater runoff or baseflow. The UH is defined for use only with surface runoff. When analyzing a recorded flood hydrograph, the baseflow contribution should be subtracted from the total flow before deriving the UH. Likewise, when using a UH to compute a design flow, a baseflow should be added to obtain the total design discharge.

The following basic assumptions are inherent to the UH:

1. The excess rainfall has a constant intensity within the unit duration.

2. The excess rainfall is uniformly distributed throughout the whole drainage area.

3. The base time of the SRH (the duration of surface runoff) resulting from an excess rainfall of a given duration is constant.

4. The ordinates of all SRH of a common base time are directly proportional to the total amount of surface runoff represented by each hydrograph.

5. For a given watershed, the hydrograph resulting from a given excess rainfall reflects the unchanging characteristics of the watershed.

Assumption 3 implies that all 24-hour rainfalls will produce a SRH where the time to peak and base time of the SRH remain constant. Assumption 4 implies that if the ordinates of the UH represent one inch of runoff, then a hydrograph representing two inches of runoff is obtained by simply multiplying each ordinate of the UH by two. If all unit hydrographs conform to a constant shape, that is, a constant amount of volume under the rising limb of the UH, then both the time and discharge ordinates can be normalized to produce a dimensionless UH. The SCS examined many hydrographs nationwide and computed a standard dimensionless UH which has 37.5 percent of the volume under the rising limb. This volume has been known to vary, according to the SCS, in the range of 23 to 45 percent.

Over the years, use of the SCS dimensionless hydrograph consistently overestimates discharges when compared to recorded gage flows for Michigan streams. To partially compensate for this, the SCS Type I rainfall distribution has been used in place of the recommended, but more intense, Type II distribution. A review of hourly rainfall data shows, however, that the Type II distribution is the appropriate one to use. Therefore, a study has been done to evaluate whether the shape of the standard SCS dimensionless UH is applicable to Michigan streams.

This study involved 24 gaged streams with drainage areas less than 50 square miles. Seventy-four different flood events were analyzed. The results from this study demonstrate that the recorded floods are best reproduced if the SCS UH is revised to have 28.5 percent of the volume under the rising limb. This value is within the SCS-acknowledged range for this parameter.

3. Design Rainfall

Atlases are available from various governmental agencies which provide design rainfall amounts for durations from 30 minutes to 24 hours and recurrence intervals from 1 to 100 years. Normal practice in Michigan has been to use 24 hours as the design rainfall duration.

Formerly, rainfall amounts were taken almost exclusively from Hershfield (1961), commonly known as the U.S. Weather Bureau's Technical Paper 40 (TP-40).

However, rainfall amounts well in excess of the frequency predicted by TP-40 have been occurring in Michigan and throughout the country for a number of years. Part of the reason may be that TP-40 utilized a shorter data set ending in 1958. Sorrell and Hamilton (1991) analyzed 24-hour rainfall data through 1986 for Michigan gages in order to update the TP-40 information. Huff and Angel (1992) also analyzed rainfall data for the Midwest, including Michigan, for durations from 5 minutes to 10 days. The 24-hour results from these two studies are similar.

Since the Huff and Angel study cover more durations and frequencies, we recommend its use to obtain design rainfall for the method presented in this report. This study was published as the "Rainfall Frequency Atlas of the Midwest" by the Midwestern Climate Center and the Illinois State Water Survey, and is commonly known as "Bulletin 71".

The Bulletin 71 study divided the state into ten climatic zones that correspond to the weather forecast divisions used by the National Weather Service at that time. These 10 climatic zones are depicted in Figure 3.1. The rainfall frequency data for each climatic zone is presented in Table 3.1. To use this map and table, locate the design point in Figure 3.1 and use the corresponding climatic zone number to obtain the rainfall amounts from the corresponding Section in Table 3.1. If the watershed straddles two or more climatic zones, use the rainfall for the zone that contains the largest percentage of the total drainage area.

The design rainfall data are point estimates and must be adjusted if the drainage area is greater than ten square miles. The adjustment ratio, listed in Table 3.2, accounts for uncertainty in the areal distribution. These adjustment ratios are taken from Figure 21.2 in Chapter 21 of the NRCS National Engineering Handbook. Values for intermediate drainage areas may be interpolated from the table.

4. Soil Type

Soil properties influence the process of generating runoff from rainfall and must be considered in methods of runoff estimation. When runoff from an individual storm is the major concern, the properties can be represented by a hydrologic parameter which reflects the minimum rate of infiltration obtained for a bare soil after prolonged wetting. The influences of both the surface and the horizons of the soil are therefore included.

Four hydrologic soil groups are used. The soils are classified on the basis of water intake at the end of long-duration storms occurring after prior wetting and an opportunity for swelling and without the protective effects of vegetation. In the definitions to follow, the infiltration rate is the rate at which water enters the soil at the surface, which is controlled by surface conditions. The transmission rate is the rate at which the water moves downward through the soil and is controlled by the horizons. The hydrologic soil groups, as defined by NRCS soil scientists, are:

A. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

B. Soils having moderate infiltration rates when thoroughly wetted and consisting of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes the downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Figure 3.1 - Climatic Zones for Michigan

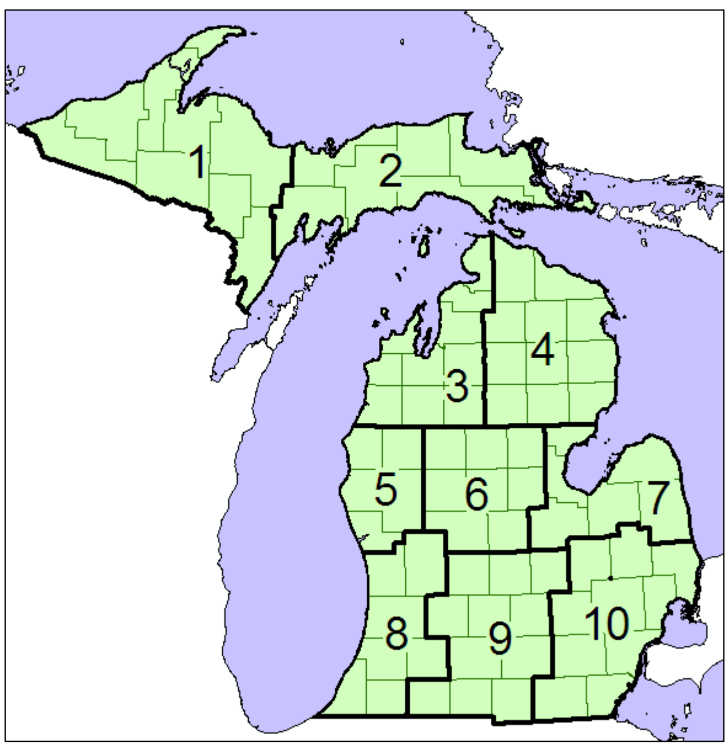

Table 3.1 - Rainfall depths corresponding to the climatic zones in Figure 3.1

Zone	Annual probability storm depth, 24-hour duration (rainfall in inches)					
	50%	20%	10%	4%	2%	1%
1	2.39	3.00	3.48	4.17	4.73	5.32
2	2.09	2.71	3.19	3.87	4.44	5.03
3	2.09	2.70	3.21	3.89	4.47	5.08
4	2.11	2.62	3.04	3.60	4.06	4.53
5	2.28	3.00	3.60	4.48	5.24	6.07
6	2.27	2.85	3.34	4.15	4.84	5.62
7	2.14	2.65	3.05	3.56	3.97	4.40
8	2.37	3.00	3.52	4.45	5.27	6.15
9	2.42	2.98	3.43	4.09	4.63	5.20
10	2.26	2.75	3.13	3.60	3.98	4.36

Table 3.2 - Ratios for areal adjustment of point rainfall

Area (mi^2)	Ratio
10	1.000
15	0.978
20	0.969
25	0.964
30	0.960
35	0.957
40	0.953

Appendix B tabulates the hydrologic soil group for many soil series as of March 1990, and is presented as an example only. See below for information on obtaining current soils data

As shown in Appendix B, in some cases, several possible hydrologic soil groupings may be listed for a soil series. When this occurs, the first hydrologic group shown is the native or natural group under which the soil series is usually classified when its water intake characteristics have not been significantly changed by artificial drainage, land use, or other factors. The second group shown is the probable maximum improvement that can be made through artificial drainage and the maintenance or improvement of soil structure. For example, the Adrian soil series is classified as D/A. This means that the natural hydrologic soil group is D. If a field inspection shows that drains and tiles have been constructed to improve the drainage or a county drain has been installed nearby, then the hydrologic soil group may be lowered to A. In general, those soils having several possible classifications are those with relatively high water tables so that artificial drainage measurably improves their ability to absorb rainfall and thus reduce runoff.

County soil surveys have been performed by the NRCS and were originally published in book form. Surveys published since 1970 show the soil type delineations superimposed on an aerial photograph. This format allows for determining land use at the same time the soil determinations are made.

A soil's hydrologic classification may occasionally change based upon updated experimental data defining its infiltration and transmission characteristics.

The soils listed in Appendix B were last reviewed and updated in March 1990. To obtain current soils data, visit the NRCS Soil Data Mart at http://soildatamart.nrcs.usda.gov/ (this URL is current as of the date of this report).

Soils data can be downloaded at no cost as GIS shapefiles at this site, or the Web Soil Survey interactive map can be used to generate a soils map and report for any identified project site. The GIS data file must still be downloaded to access the attribute data (file name ending in .dbf) to obtain the hydrologic group for the soils complex. This file can be opened using the Excel spreadsheet program.

5. Land Use

The SCS Method evaluates the effects of the surface conditions of a watershed by means of land use and treatment classes. Land use is a means to estimate the effects of watershed cover on infiltration and runoff, and it includes most kinds of vegetation, litter, and mulch; fallow (bare) soil, as well as nonagricultural uses such as water surfaces (lakes, swamps, etc.) and impervious surfaces, such as roads, roofs, etc. Land treatment applies mainly to agricultural land uses and includes mechanical practices such as contouring and terracing, and management practices like grazing control and crop rotation. The classes consist of land use and treatment combinations likely to be found in watersheds. The following is a brief description of various land uses.

Pasture or range is grassed land that is continuously used for grazing animals. The hydrologic condition is characterized by the degree of grazing and plant cover. Poor condition is heavily grazed with plant cover on less than half of the area. Fair condition has a moderate amount of grazing with plant cover on ½ to ¾ of the area. Good condition refers to light grazing with plant cover on more than ¾ of the area.

Meadow is a field on which grass is continuously grown, protected from grazing, and generally mowed for hay.

Woods or forest are characterized by their vegetative condition and density of the tree canopy. Poor condition refers to those woods which are either heavily grazed, regularly burned, or have had the undergrowth cleared for recreational uses. Litter, small trees, and brush are absent in this condition. Woods in fair condition may still be grazed but have not been burned. In a good condition, the woods are protected from grazing, and litter, small trees, and shrubs cover the soil.

Fallow is the agricultural land use and treatment with the highest runoff potential. The land is kept as bare as possible to conserve moisture for use by a succeeding crop, the concept being that soil moisture lost to runoff is offset by the gain due to reduced transpiration.

Row crop is any field crop (corn, soybeans, and sugar beets) planted in rows far enough apart that most of the soil surface has no vegetative cover through the growing season.

Small grain (wheat, oats, and barley) is planted in rows close enough that the soil surface is vegetated except during planting and shortly thereafter.

Close-seeded legumes or rotation meadow (alfalfa, sweet clover) are either planted in close rows or broadcast. This cover may be allowed to remain for more than a year so that the soil is vegetated year-round.

The four preceding agricultural land uses are also characterized by the farming practice employed. Straight row fields are those farmed in straight rows either up and down the hill or across the slope. Where land slopes are less than about two percent, farming across the slope in straight rows is equivalent to contouring. Contoured fields are those farmed as nearly as possible to conform to the natural land contours. The hydrologic effect of contouring is due to the surface storage provided by the furrows, because the storage prolongs the time during which infiltration can take place. Terracing refers to systems containing open-end level or graded terraces, grassed waterway outlets, and contour furrows between the terraces. The hydrologic effects are due to the replacement of a low-infiltration land use by grassed waterways and to the increased opportunity for infiltration in the furrows and terraces.

The four agricultural land uses are further characterized by the crop rotation. Hydrologically, rotations range from “poor” to “good” in proportion to the amount of dense vegetation in the rotation. Poor rotations are generally one-crop land uses, such as continuous corn or wheat or combinations of row crops, small grains, and fallow soil. Good rotations generally contain alfalfa or other close-seeded legume or grass to increase infiltration.

6. Runoff Curve Number

6.1 Method

In 1954, the SCS developed a unique procedure for estimating surface runoff from rainfall. This procedure, the Runoff Curve Number (RCN) technique, has proven to be a very useful tool for evaluating effects of changes in land use and treatment on surface runoff. It is the procedure most frequently used within the NRCS and by hydrologists nationwide to estimate surface runoff from ungaged watersheds.

The combination of a hydrologic soil group and a land use and treatment class is a hydrologic soil-cover complex. Each combination is assigned a RCN, which is an index to its runoff potential on soil that is not frozen. A list of these values is shown in Table 6.1. (See TR-55 documentation, Tables 2-2a through 2-2d, for additional curve numbers.)

Table 6.1 – Runoff curve numbers for hydrologic soil-cover complexes (AMC-II conditions)

Land use	Treatment or practice	Hydrologic condition	Hydrologic soil group			
			A	B	C	D
Fallow soil	Straight row		77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured and terraced	Poor	66	74	80	82
		Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
		Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
		Fair	30	59	75	83
		Good	30	35	70	79
Meadow			30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	30	55	70	77
Residential	⅛ acre		77	85	90	92
	¼ acre		61	75	83	87
	1/3 acre		57	72	81	86
	½ acre		54	70	80	85
	1 acre		51	68	79	84
Open spaces (parks, golf courses, cemeteries, etc.)	Good condition: Grass cover > 75% of area		39	61	74	80
	Fair condition: Grass cover 50-75% of area		49	69	79	84
Commercial or business area (85% impervious)			89	92	94	95
Industrial district (72% impervious)			81	88	91	93
Farmsteads			59	74	82	86
Paved areas (roads, drive-ways, parking lots, roofs)			98	98	98	98
Water surfaces (lakes, ponds, reservoirs, etc.)			100	100	100	100
Swamp	At least 1/3 is open water		85	85	85	85
	Vegetated		78	78	78	78

RCN values are published for wet, dry, and normal soil moisture conditions. These conditions were referred to as Antecedent Moisture Condition (AMC) I (dry), II (normal), and III (wet). The AMC is related to the amount of rainfall in the five days previous to the design storm.

Note: In the late 1990s and early 2000s it was recognized that the range of RCNs for a soil/ land use condition did not correlate well to the antecedent moisture as defined above. It was determined instead that the RCN for conditions I and III represent the outer confidence limits for RCN values, and the RCN for condition II represents the mean value within the range of accepted values. The term AMC was changed to Antecedent Runoff Condition (ARC) to clarify the change in philosophy.

However, studies in Michigan have shown a strong correlation between antecedent moisture and peak runoff. For this reason, it is recommended to continue to use the antecedent moisture conditions previously recommended by the SCS for studies in Michigan.

AMC-I has the lowest runoff potential and represents dry watershed soils. AMC-III has the highest runoff potential as it represents soils that are practically saturated from antecedent rainfall or snowmelt. The AMC can be estimated from the 5-day antecedent rainfall using Table 6.2. In this table, the “growing” season in Michigan is assumed to be June through September. The limits for “dormant” season apply the remainder of the year, except when the soils are frozen or there is snow cover on the ground.

Table 6.2 – Seasonal Rainfall Limits for AMC

Antecedent Moisture Condition (AMC)	Total 5-day antecedent rainfall (inches)	
	Dormant season	Growing season
I	< 0.5	< 1.4
II	0.5 - 1.1	1.4 - 2.1
III	> 1.1	> 2.1

Although the runoff curve numbers in Table 6.1 are for AMC-II conditions, an analysis of an actual storm event may require an equivalent RCN for AMC-I or AMC-III. They may be computed by the following equations:

$$RCN(I) = \frac{4.2 * RCN(II)}{10 - 0.058 * RCN(II)} \qquad \text{(Eq. 6.1)}$$

and

$$RCN(III) = \frac{23 * RCN(II)}{10 + 0.13 * RCN(II)} \qquad \text{(Eq. 6.2)}$$

When estimating the peak discharge for an annual percent chance storm, such as the 1% annual chance storm, it is standard practice to assume AMC-II conditions. Other AMC conditions may be assumed when estimating the peak flow for an actual event, based on the observed rainfall before the event. When evaluating pre-development and post-development peak discharge rates, it is important to assume a consistent AMC for both existing and proposed conditions.

A typical watershed is comprised of many different combinations of soil types and land uses. In using the method presented here, the runoff characteristic of the watershed is represented using a weighted average or composite RCN for the entire watershed. The most practical way to determine this is to tabulate each of the four hydrologic soil groups as a percentage of the total drainage area. Land uses should then be tabulated as a percentage within each specific hydrologic soil group, along with the appropriate RCN. Multiplying the RCN by the two percentages and summing the partial RCNs over all the different soil-cover complexes yields the average watershed RCN.

An example runoff curve number calculation follows.

6.2 Runoff Curve Number Sample Calculation:

The following table was prepared for a sample watershed. The first and second columns are a summary of soil complex by hydrologic group, presented as a percentage of the drainage area. The land use for each hydrologic group is summarized next, presented as a percentage of the total area for that hydrologic group. These values are obtained by planimetry of county soils and land use maps, or from a Geographic Information System (GIS). See below for documentation on using GIS to calculate runoff curve numbers.

The runoff curve number for each land use / hydrologic soil group combination is obtained from Table 6.1 and added to the table in the column titled "RCN".

The "Partial RCN" column is the product of the percentage of the drainage area times the percent of the soil hydrologic group, times the runoff curve number. When all the partial RCNs are summed, the result is a composite runoff curve number (also called a "weighted RCN") for the watershed.

Table 6.3 – Sample RCN Calculation Table

Hydrologic Soil Group	Percent of Total Drainage Area	Land Use	Percent of Soil Group	RCN	Partial RCN
A	30	Meadow	100	30	9.0
B	50	Woods (good cover)	25	55	6.9
		Fallow soil	75	86	32.3
C	10	Pasture (fair condition)	80	79	6.3
		Woods (poor cover)	20	77	1.5
D	10	Meadow	100	78	7.8
		Composite Runoff Curve Number:		**Sum**	**63.8**

In this instance, an average RCN of 64 would be used for this watershed. Tabulating in this manner makes it easier to estimate how a change in land use will alter runoff. Here the bulk of the Partial RCN (and therefore the runoff volume) is contributed by the fallow soil. If all of this land is developed into ¼-acre residential lots (RCN 75), the composite RCN for the watershed would decrease to 60.

On the other hand, if all of the fallow land is developed into an industrial area (RCN 88), the composite RCN would increase to 65, thereby increasing surface runoff volume.

This method of computing a composite RCN works very well if all of the individual RCNs are at least 45 or above, where the correlation between RCN and SRO is virtually linear. This method also works well if all of the individual RCNs are less than 45. But there may be an occasion where the watershed has a significant amount of very low RCNs and a large amount of very high ones. Since the RCN/SRO relationship becomes less linear for the very low RCNs, proportioning the RCN to compute a composite value as described above will produce an RCN which underestimates the correct amount of runoff.

In this instance, a more accurate runoff estimate can be made by computing the incremental surface runoff (see Section 7) for each land use and summing these to obtain the total runoff. Equations 6.1 and 6.2 may then be solved to yield the composite RCN, if desired. This method of weighting the runoff requires more work than simply proportioning the RCNs. It should only be needed if more than 20 percent of the watershed has RCNs less than 45 with most of the remaining RCNs at the higher end of the scale.

This procedure can also be performed with a Geographic Information System (GIS) using land use and soils shape files. Information describing calculation of curve numbers with Geographic Information Systems (GIS) is at www.mi.gov/deqhydrology, GIS category, "Calculating Runoff Curve Numbers with GIS".

7. Surface Runoff

The total precipitation (P) in a storm can be divided into three paths that the water will follow in the hydrologic cycle. There is some initial amount of rainfall for which no runoff will occur. This quantity is the initial abstraction (I_a) and consists of interception, evaporation, and the soil-water storage that must be satisfied before surface runoff will begin. After this initial abstraction is met, the soil has a continuing abstraction capacity (F), depending on the type of soil. A rainfall rate greater than this continuing abstraction is surface runoff (SRO). These quantities can be described by the equation:

$$P = SRO + I_a + F \qquad \text{(Eq. 7.1)}$$

All parameters are as described above, in total inches for the entire storm event.

While F is a continuing abstraction, there is a potential maximum retention S characteristic to each RCN. The hypothesis of the SCS Method is that the ratio of F to S is equal to the ratio of the actual runoff SRO to the potential maximum runoff, P - I_a. This is expressed as:

$$\frac{F}{S} = \frac{SRO}{P - I_a} \qquad \text{(Eq. 7.2)}$$

Combining (7.1) and (7.2) to solve for SRO:

$$SRO = \frac{(P - I_a)^2}{P - I_a + S} \qquad \text{(Eq. 7.3)}$$

An empirical relation was developed by studying many small experimental watersheds:

$$I_a = 0.2 * S \qquad \text{(Eq. 7.4)}$$

Substituting this into (7.3) produces:

$$SRO = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad \text{(Eq. 7.5)}$$

where:

$$S = \frac{1000}{RCN} - 10 \qquad \text{(Eq. 7.6)}$$

where S is in inches. Therefore, for a given 24-hour rainfall depth and watershed RCN, equations (7.5) and (7.6) can be solved to compute the surface runoff volume in inches over the watershed.

8. Time of Concentration

Time of concentration (T_c) is the time it takes for runoff to travel from the hydraulically most distant point in the watershed to the design point. In hydrograph analysis, T_c is the time from the end of rainfall excess to the inflection point on the falling limb of the hydrograph. This point signifies the end of surface runoff and the beginning of baseflow recession. The time of concentration may vary between different storms, especially if the rainfall is non-uniform in either areal coverage or intensity. However, in practice, a watershed's T_c is considered to be constant.

Measuring from a recorded hydrograph provides the most accurate estimate of T_c. For ungaged watersheds, T_c is calculated by estimating the travel time from the most hydraulically distant point in the watershed. Since travel time (T) equals length (L) divided by velocity (V), it is necessary to estimate the velocity through the various components of the stream network.

There are many methods used to estimate the velocity. The method presented in this report expresses velocity in the form:

$$V = K * S^{0.5} \qquad \text{(Eq. 8.1)}$$

where K is a coefficient depending on the type of flow, S is the slope of the flow path in percent, and V is the velocity in feet per second.

Three flow types are used based on their designation on U.S. Geological Survey topographic maps.

Small tributary: Permanent or intermittent streams which appear as a solid or dashed blue line on the topo maps. This also applies to a swamp that has a defined stream channel. Man-made channels and swales as shown on engineering drawings should be considered small tributaries.

Waterway: A travel path as shown by the curves in the elevation contours on a USGS topographic map (such as a valley, swale, or shallow drainage course), but does not have a blue streamline denoting a defined channel. This also applies to a swamp that does not have a defined channel flowing through it.

Sheet Flow: This is any overland flow path which does not conform to the waterway definition. Studies have shown that after approximately 300 feet, sheet flow forms shallow concentrated rivulets that are better defined as "waterway" flow. For this reason, Sheet Flow reach lengths should be terminated at a maximum length of 300 feet. The remaining downstream portion of the reach should be modeled using the "Waterway" velocity equation.

An illustration of each of these flow types is included in the example in Appendix A. The coefficients for each of these in Equation 8.1 are shown in Table 7-1.

Table 7.1 – Velocity Coefficients for Flow Type

Flow type	K
Small tributary	2.1
Waterway	1.2
Sheet flow	0.48

These coefficients were derived by Richardson (1969) as a means of estimating velocities when detailed stream hydraulic data are unavailable.

Once the velocity is determined, the travel time for each flow path can be computed as:

$$Tc = \sum T_{\mathrm{i}} = \sum \frac{L_i}{V_i * 3600} \qquad \text{(Eq. 8.2)}$$

where T_c is time of concentration; T_i is travel time in hours; L_i is the length in feet; and V_i is velocity in feet per second for each individual flow path segment *i*.

In most watersheds, all three flow types will be present. Starting at the basin divide, the runoff may proceed from sheet flow to waterway to small tributary, then waterway again, then small tributary, etc. The T_i for each segment should be computed and then summed to give the total T_c.

It is important that the length used to compute each T_i has a uniform slope. As an example, assume a 5,000-foot length of small tributary has a change in elevation of 10.4 feet. This slope of 0.208% produces a single $T_1 = T_c$ of 1.45 hours. However, if it is known that the upper 1,000 feet of this stream falls 10 feet, and the lower 4,000 feet only falls 0.4 feet, this would produce $T_1 + T_2$ for a total T_c of 5.42 hours. Therefore, it is best to sum T_i over the smallest possible contour interval; which is usually the contour interval given for the topographic map. This interval can be increased if a visual examination of the topographic map shows a uniform spacing between successive elevation contours.

It may be necessary to evaluate several travel paths to determine which one is most hydraulically distant from the design point (has the longest travel time as described above). The longest travel time may not occur along the main channel, if a side tributary has a flatter slope.

The discharge calculation method in this report is not applicable for watersheds with a T_c less than one hour. Another SCS method, such as WinTR-55, is recommended in this case. The Michigan-specific unit hydrograph should be used with WinTR-55 to be compatible with the method presented here. The ordinates of the Michigan-specific unit hydrograph are [0.0, 0.5, 1.0, 0.8, 0.6, 0.4, 0.2, and 0.0]. Contact DNRE Hydrologic Studies Program staff for additional assistance if needed.

9. Unit Hydrograph Peak

The unit hydrograph peak (q_p') is a function of travel time through the stream system or T_c. An expression relating q_p' to T_c was developed in the following manner.

Discharges were computed for a hypothetical watershed having a drainage area of one square mile, a runoff curve number of 75, and a 24-hour design rainfall of 5 inches. The discharges were computed using the SCS TR-20 computer program and the SCS “Type II” rainfall distribution. However, in lieu of using the standard dimensionless unit hydrograph in TR-20, these simulations used the Michigan-specific unit hydrograph determined from the gage analysis discussed in Section 2 of this report.

The T_c for this hypothetical basin was varied from 1 hour to 40 hours. The peak discharge for each different T_c was divided by the volume of surface runoff to obtain q_p' which has the units of cfs per inch of runoff per square mile of drainage area. The data set of q_p' versus T_c was analyzed using a log-linear regression to obtain:

$$q_p' = 238.6 \cdot T_c^{-0.82} \qquad \text{(Eq. 9.1)}$$

This equation is only valid for T_c equal to or greater than one hour.

Q, the peak discharge in cubic feet per second (cfs), is estimated as follows:

$$Q = q_p' \cdot SRO \cdot DA \cdot POND \qquad \text{(Eq. 9.2)}$$

Where q_p' is the unit hydrograph peak in cfs per inch of runoff per square mile of drainage area; SRO is surface runoff volume in inches; DA is contributing drainage area in square miles; and POND is the ponding adjustment factor, unitless, described in the following section.

10. Adjustments for Surface Ponding

Peak flows determined in this method assume that the topography is such that surface flow into ditches, drains, and streams is approximately uniform. In areas where ponding or swampy areas occur in the watershed, a considerable amount of surface runoff may be retained in temporary storage. The peak rate of runoff should be reduced to reflect this condition.

Table 10.1 provides adjustment factors to determine this reduction based on the ratio of ponding or swampy area (as shown by the USGS map symbol for “marsh”) to the total drainage area for a range of flood frequencies. The three sections of this table provide different adjustment factors depending on where the ponding occurs in the watershed. These values were determined by the NRCS (1975) from experimental watersheds of less than 2,000 acres. These factors may still be used for larger basins until newer data become available. For percentages beyond the range in the tables, the data may be extrapolated on semi-log paper with the reduction factor on the log scale.

In some cases, it is appropriate to apply the ponding adjustment more than once. For example, assume a watershed has ponding equal to two percent of the drainage area scattered throughout and a lake that is one percent of the drainage area located in the lower portion of the basin near the design point. If the 100-year frequency flood is being determined, the peak flow should be multiplied by 0.87 for the scattered ponding and further reduced by 0.89 for the lake. This produces a total reduction factor of 0.77.

It is important to note that the ponding adjustment factor is not intended to replace a reservoir routing procedure when such is called for. The ponding adjustment factor should not include a water body immediately upstream of a design point, such as a lake outlet or dam spillway. In this case, only the peak inflow to the water body can be estimated using the method presented here. A reservoir routing model, such as HEC-HMS, must be used to estimate the peak outflow from the water body.

Table 10.1 - Adjustment factors for ponding

Percentage of ponded and swampy area	**Annual Storm Probability**					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Ponding occurs in central parts of the watershed or is spread throughout						
0.2	0.94	0.95	0.96	0.97	0.98	0.99
0.5	0.88	0.89	0.90	0.91	0.92	0.94
1.0	0.83	0.84	0.86	0.87	0.88	0.90
2.0	0.78	0.79	0.81	0.83	0.85	0.87
2.5	0.73	0.74	0.76	0.78	0.81	0.84
3.3	0.69	0.70	0.71	0.74	0.77	0.81
5.0	0.65	0.66	0.68	0.72	0.75	0.78
6.7	0.62	0.63	0.65	0.69	0.72	0.75
10	0.58	0.59	0.61	0.65	0.68	0.71
20	0.53	0.54	0.56	0.60	0.63	0.68
Ponding occurs only in upper reaches of watershed						
0.2	0.96	0.97	0.98	0.98	0.99	0.99
0.5	0.93	0.94	0.94	0.95	0.96	0.97
1.0	0.90	0.91	0.92	0.93	0.94	0.95
2.0	0.87	0.88	0.88	0.90	0.91	0.93
2.5	0.85	0.85	0.86	0.88	0.89	0.91
3.3	0.82	0.83	0.84	0.86	0.88	0.89
5.0	0.80	0.81	0.82	0.84	0.86	0.88
6.7	0.78	0.79	0.80	0.82	0.84	0.86
10	0.77	0.77	0.78	0.80	0.82	0.84
20	0.74	0.75	0.76	0.78	0.80	0.82
Ponding occurs only in lower reaches of watershed						
0.2	0.92	0.94	0.95	0.96	0.97	0.98
0.5	0.86	0.87	0.88	0.90	0.92	0.93
1.0	0.80	0.81	0.83	0.85	0.87	0.89
2.0	0.74	0.75	0.76	0.79	0.82	0.86
2.5	0.69	0.70	0.72	0.75	0.78	0.82
3.3	0.64	0.65	0.67	0.71	0.75	0.78
5.0	0.59	0.61	0.63	0.67	0.71	0.75
6.7	0.57	0.58	0.60	0.64	0.67	0.71
10	0.53	0.54	0.56	0.60	0.63	0.68
20	0.48	0.49	0.51	0.55	0.59	0.64

11. Summary of Method

This section summarizes the steps needed to compute discharges using the procedures in this report.

1. Delineate the watershed boundaries on a topographic map and measure the total drainage area. If there are deep depressions within this boundary or other areas that do not contribute to runoff, measure these and subtract them from the total drainage area. The area remaining is termed the 'contributing drainage area' and is the portion of the watershed which will be used in subsequent calculations.

   Note: Some judgment needs to be used when defining noncontributing areas. If a topo map with a five-foot contour interval shows two nested depression contours, we know that portions of the entire depression are at least five feet deep. The volume of the depression can be calculated and compared to the volume of runoff which drains into it. If it can contain all of the runoff, the entire area draining into the depression may be deleted as 'noncontributing area'. However, if the topo map only shows a single depression contour, it could be anywhere from a few inches deep to just under five feet deep. In this case, there is no definitive way to tell how much runoff this depression can store. In this instance, it may be necessary to conduct a field inspection of the watershed to ascertain the storage potential of the depression area.

2. Overlay the boundaries of the contributing drainage area on soil and land use maps and tabulate the hydrologic soil-cover/land use complexes in the watershed. Assign curve numbers using Table 6.1 and calculate the composite RCN as outlined in Section 6.

3. Starting at the design point and working upstream, tabulate incremental travel times using the procedure in section 8. When reaching a junction of two or more streams, follow the one which will result in the longest T_c. After reaching the most upstream point (as defined by a blue line on topo maps), determine any additional contribution to T_c due to overland and sheet flow paths. Add all of the incremental travel times to determine the watershed T_c. Compute q_p' using equation 9.1.

4. Select a design frequency and determine the 24-hour rainfall from Table 3.1. If the contributing drainage area is greater than 10 square miles, adjust the rainfall using Table 3.2.

5. Using the weighted RCN computed in step 2, calculate the surface runoff for the selected design event using equations 7.5 and 7.6.

6. Estimate surface ponding as a percent of the contributing drainage area and determine the ponding adjustment factor from Table 10.1.

7. Compute the peak discharge using Equation 9.2.

12. References

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Appendix A - Sample Application

The bridge at the Brocker Road crossing of the example watershed needs to be replaced. The watershed that contributes runoff to this point, which is depicted in Figure A.1, has a drainage area of 2.43 square miles and is undergoing urbanization. All of the areas which are currently either pasture or meadow will be developed into ¼-acre residential subdivisions. What effect will this have on the design flood produced by the 100-year, 24-hour rainfall?

Figure A.1 is an enlargement of a USGS topographic map. The contour interval for this map is 10 feet. In this figure, a thick black line is used to denote the watershed boundary. The blue lines inside the boundary show the small tributaries in the basin. The irregularly shaped blue areas show the locations of lakes and ponds, while the lighter green patches show the wooded portions of the watershed. The following table shows the different soil groups and associated land uses as they currently exist in the watershed.

Table A.1 – RCN Calculation

Hydrologic Soil Group	Percent of Total Drainage Area	Land Use	Percent of Soil Group	RCN	Partial RCN
A	7	Meadow	25	30	0.5
		Pasture (fair)	15	49	0.5
		Row crop (cont./good)	60	65	2.7
B	84	Small grain (cont./good)	60	73	36.8
		Pasture (fair condition)	25	69	14.5
		Woods (poor cover)	10	66	5.5
		Meadow	5	58	2.4
D	9	Meadow	35	78	2.5
		Woods (good cover)	5	77	0.3
		Lakes and ponds	15	100	1.4
		Swamps (vegetated)	35	78	2.5
		Swamps (open water)	10	85	0.8
				Sum	70.4

Deleting the contribution from meadows and pastures and replacing them with the RCNs for the residential lots changes the composite RCN to 73.4. Common practice is to round off the computed RCN, so this watershed would have curve numbers of 70 and 73 to represent existing and proposed development conditions, respectively.

The time of concentration is computed along the travel path beginning at the headwaters in Section 36 and proceeding in a northeastward direction. The travel path begins with a short section of sheet flow to the area shown as swamp (waterway flow), then continues to the upstream end of the tributary. The small tributary portions were generally divided into lengths which correspond with the contour interval of the topo map. The following table shows the computations:

Table A.2 – Time of Concentration Calculation

Type of flow	Length (ft)	Δ Elevation (ft)	Slope (%)	Velocity (fps)	Incremental T_c (hr)
Small trib.	1640	12	0.73	1.80	0.25
" "	1380	10	0.73	1.79	0.21
" "	1970	10	0.51	1.50	0.37
" "	1520	10	0.66	1.70	0.25
" "	6870	8	0.12	0.72	2.66
Waterway	1840	2	0.11	0.40	1.29
Sheet	150	22	14.67	1.84	0.02
				Sum	**5.05**

Summing the incremental travel times produces a total T_c of 5.05 hours. Substituting this into equation (9.1) produces a peak discharge of 63.24 cfs per square mile per inch of runoff. The table shows that the slope of the small tributary is not uniform over its entire length. If the slope is calculated as a 50-foot drop over the 13,400-foot length, the resulting total T_c is 4.21 hours. This produces a q_p' of 65.79 cfs/square mile-in. Thus, the design discharge would have been 13 percent higher because of an error in calculating T_c. This illustrates the importance of using the most refined data available; in this case, the distance between successive 10-foot contours.

The 100-year, 24-hour rainfall obtained from Table 3.1 is 4.36 inches. Using this value and the previously computed RCNs, the runoff can be determined using equations (7.5) and (7.6). For existing conditions (RCN=70), the runoff is 1.57 inches. The runoff for proposed development conditions (RCN=73) is 1.79 inches.

The design discharge is obtained by simply multiplying the computed q_p' by the drainage area and the computed runoff. These results are:

Existing: Q = 63.24 cfs/square mile-in * 2.43 square mile * 1.57 in
= 241 cfs

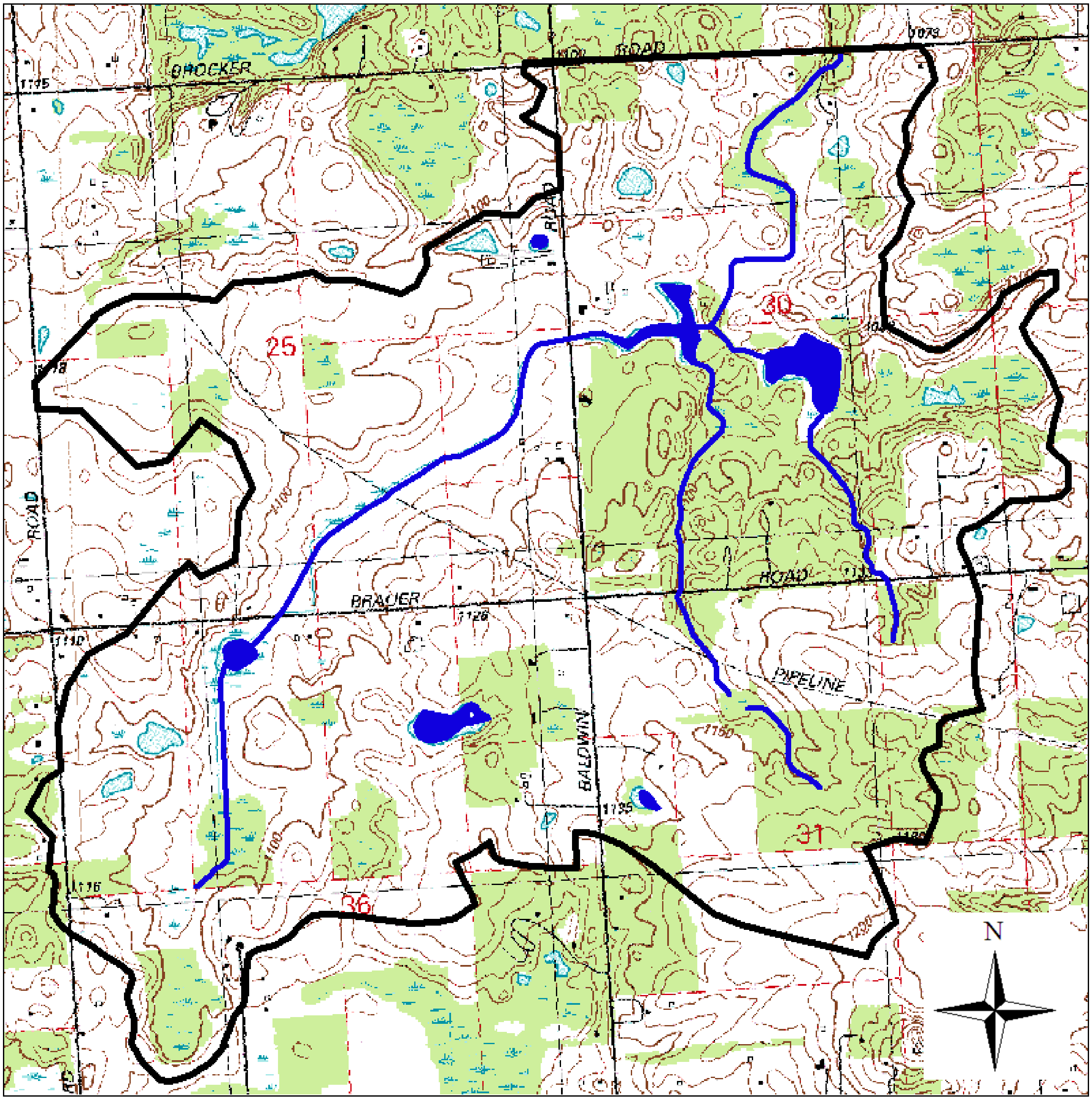
Proposed: Q = 275 cfs

These numbers need to be adjusted for ponding. The land use table shows that 5.4 percent of the watershed is either open water or swamps. These areas are spread uniformly throughout the basin. An adjustment factor of 0.77 can be interpolated from Table (10.1). The final design discharges are:

Existing: Q = 241 * 0.77
= 186 cfs

Proposed: Q = 212 cfs

Figure A.1 – Example watershed



Appendix B – Hydrologic Soil Groups for Michigan Soils

These soils data were last reviewed and updated in March 1990. To obtain current soils data by county, visit the NRCS Soil Data Mart at http://soildatamart.nrcs.usda.gov/ (this URL is current as of the date of this report).

NOTE: When two soil groups are listed (such as D/B), this indicates the hydrologic group for the soil under undrained/drained conditions.

Soil Series	Hydrologic Group	Soil Series	Hydrologic Group	Soil Series	Hydrologic Group
Abbaya	B	Abscota	A	Adrian	D/A
Alcona	B	Algansee	B	Allendale	B
Allouez	B	Alpena	A	Alstad	C
Amasa	B	Angelica	D/B	Arkona	B
Arkport	B	Arnheim	D	Ashkum	D/B
Assinins	B	Au Gres	B	Aubarque	D/C
Aubbeenaubbee	B	Aurelius	D/B	Avoca	B
Bach	D/B	Badaxe	B	Banat	B
Barry	D/B	Battlefield	D/A	Beavertail	D
Beechwood	C	Belding	B	Belleville	D/B
Benona	A	Bergland	D	Berville	D/B
Biscuit	D/B	Bixby	B	Bixler	C
Blount	C	Blue Lake	A	Bohemian	B
Bonduel	C	Bono	D	Boots	D/A
Borski	B	Bowers	C	Bowstring	D/A
Boyer	B	Brady	B	Branch	B
Brassar	C	Breckenridge	D/B	Brems	A
Brevort	D/B	Brimley	B	Bronson	B
Brookston	D/B	Bruce	D/B	Burleigh	D/A
Burt	D	Cassopolis	B	Cadmus	B
Capac	C	Carbondale	D/A	Carlisle	D/A
Cathro	D/A	Celina	C	Ceresco	B
Champion	B	Channahon	D	Channing	B
Charity	D	Charlevoix	B	Chatham	B
Cheboygan	B	Chelsea	A	Chesaning	B
Chestonia	D	Chippeny	D	Cohoctah	D/B
Coloma	A	Colonville	C	Colwood	D/B
Conover	C	Coral	C	Corunna	D/B
Coupee	B	Covert	A	Crosier	C
Croswell	A	Cunard	B	Cushing	B
Dawson	D/A	Deer Park	A	Deerton	A
Deford	D/A	Del Rey	C	Detour	B

Appendix B – Hydrologic Soil Groups for Michigan Soils, contd.

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NOTE: When two soil groups are listed (such as D/B) this indicates the hydrologic group for the soil under undrained/drained conditions.

Soil Series	Hydrologic Group	Soil Series	Hydrologic Group	Soil Series	Hydrologic Group
Dighton	B	Dixboro	B	Dora	D/B
Dowagiac	B	Dresden	B	Dryburg	B
Dryden	B	Duel	A	Dungridge	B
East Lake	A	Eastport	A	Edmore	D
Edwards	D/B	Eel	B	Eleva	B
Elmdale	B	Elston	B	Elvers	D/B
Emmet	B	Ensign	D	Ensley	D/B
Epoufette	D/B	Epworth	A	Ermatinger	D/B
Esau	A	Escanaba	A	Essexville	D/A
Evart	D	Fabius	B	Fairport	C
Fence	B	Fibre	D/B	Filion	D
Finch	C	Fox	B	Frankenmuth	C
Freda	D	Frenchette	B	Froberg	D
Fulton	D	Gaastra	C	Gagetown	B
Gay	D/B	Genesee	B	Gilchrist	A
Gilford	D/B	Gladwin	A	Glawe	D/B
Glendora	D/A	Glynwood	C	Gogebic	B
Gogomain	D/B	Goodman	B	Gorham	D/B
Grace	B	Granby	D/A	Grattan	A
Graveraet	B	Graycalm	A	Grayling	A
Greenwood	D/A	Grindstone	C	Grousehaven	D
Guardlake	A	Guelph	B	Gutport	D
Hagensville	C	Halfaday	A	Hatmaker	C
Henrietta	D/B	Hessel	D/B	Hettinger	D/C
Hillsdale	B	Hodenpyl	B	Houghton	D/A
Hoytville	D/C	Huntington	B	Ingalls	B
Ingersoll	B	Ionia	B	Iosco	B
Isabella	B	Ishpeming	A	Ithaca	C
Jacobsville	D	Jeddo	D/C	Jesso	C
Johnswood	B	Kakkawlin	C	Kalamazoo	B
Kalkaska	A	Kallio	C	Karlin	A
Kawbawgam	C	Kendallville	B	Kent	D
Keowns	D/B	Kerston	D/A	Keweenaw	A
Kibbie	B	Kidder	B	Kilmanagh	C

Appendix B – Hydrologic Soil Groups for Michigan Soils, contd.

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NOTE: When two soil groups are listed (such as D/B) this indicates the hydrologic group for the soil under undrained/drained conditions.

Soil Series	Hydrologic Group	Soil Series	Hydrologic Group	Soil Series	Hydrologic Group
Kingsville	D/A	Kinross	D/A	Kiva	A
Klacking	A	Kokomo	D/B	Koontz	D
Krakow	B	Lacota	D/B	Lamson	D/B
Landes	B	Lapeer	B	Latty	D
Leelanau	A	Lenawee	D/B	Leoni	B
Liminga	A	Linwood	D/A	Locke	B
Lode	B	London	C	Longrie	B
Loxley	D/A	Lupton	D/A	Mackinac	B
Macomb	B	Mancelona	A	Manistee	A
Manitowish	B	Markey	D/A	Marlette	B
Martinsville	B	Martisco	D/B	Matherton	B
Maumee	D/A	McBride	B	Mecosta	A
Melita	A	Menagha	A	Menominee	A
Mervin	D/A	Metamora	B	Metea	B
Miami	B	Michigamme	C	Millsdale	D/B
Milton	C	Minoa	C	Minocqua	D/B
Minong	D	Misery	C	Mitiwanga	C
Moltke	B	Monico	C	Monitor	C
Montcalm	A	Moquah	B	Morley	C
Morocco	B	Mudsock	D/B	Munising	B
Munuscong	D/B	Mussey	D/B	Nadeau	B
Nahma	D/B	Napoleon	D/A	Nappanee	D
Nester	C	Net	C	Newaygo	B
Newton	D/A	Nottawa	B	Nunica	C
Oakville	A	Ockley	B	Oconto	B
Ocqueoc	A	Ogemaw	D/C	Okee	B
Oldman	C	Olentangy	D/A	Omega	A
Omena	B	Onaway	B	Onota	B
Ontonagon	D	Ormas	B	Oshtemo	B
Otisco	A	Ottokee	A	Owosso	B
Paavola	B	Padus	B	Palms	D/A
Parkhill	D/B	Paulding	D	Pelkie	A
Pella	D/B	Pemene	B	Pence	B
Pendleton	C	Pequaming	A	Perrin	B

Appendix B – Hydrologic Soil Groups for Michigan Soils, contd.

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NOTE: When two soil groups are listed (such as D/B) this indicates the hydrologic group for the soil under undrained/drained conditions.

Soil Series	Hydrologic Group	Soil Series	Hydrologic Group	Soil Series	Hydrologic Group
Perrinton	C	Pert	D	Peshekee	D
Petticoat	B	Pewamo	D/C	Pickford	D
Pinconning	D/B	Pinnebog	D/A	Pipestone	B
Plainfield	A	Pleine	D	Ponozzo	C
Posen	B	Poseyville	C	Potagannissing	D
Poy	D	Proctor	B	Randolph	C
Rapson	B	Remus	B	Rensselaer	D/B
Richter	B	Riddles	B	Rifle	D/A
Riggsville	C	Rimer	C	Riverdale	A
Rockbottom	B	Rockcut	B	Rodman	A
Ronan	D	Rondeau	D/A	Roscommon	D/A
Roselms	D	Rousseau	A	Rubicon	A
Rudyard	D	Ruse	D	Saganing	D/A
Sanilac	B	Saranac	D/C	Sarona	B
Satago	D	Saugatuck	C	Saylesville	C
Sayner	A	Scalley	B	Schoolcraft	B
Sebewa	D/B	Selfridge	B	Selkirk	C
Seward	B	Shebeon	C	Shelldrake	A
Shelter	B	Shiawassee	C	Shinrock	C
Shoals	C	Sickles	D/B	Sims	D
Sisson	B	Skanee	C	Sleeth	C
Sloan	D/B	Solona	C	Soo	D/C
Sparta	A	Spinks	A	Springlake	A
St. Clair	D	St. Ignace	D	Stambaugh	B
Steuben	B	Sturgeon	B	Sugar	B
Summerville	D	Sundell	B	Sunfield	B
Superior	D	Tacoosh	D/B	Tallula	B
Tamarack	B	Tappan	D/B	Tawas	D/A
Teasdale	B	Tedrow	B	Tekenink	B
Thetford	A	Thomas	D/B	Tobico	D/A
Toledo	D	Tonkey	D/B	Toogood	A
Trenary	B	Trimountain	B	Tula	C
Tuscola	B	Tustin	B	Twining	C
Tyre	D/A	Ubly	B	Velvet	C

Appendix B – Hydrologic Soil Groups for Michigan Soils, contd.

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NOTE: When two soil groups are listed (such as D/B) this indicates the hydrologic group for the soil under undrained/drained conditions.

Soil Series	Hydrologic Group	Soil Series	Hydrologic Group	Soil Series	Hydrologic Group
Vestaburg	D/A	Vilas	A	Volinia	B
Wainola	B	Waiska	B	Wakefield	B
Wallace	B	Wallkill	D/C	Warners	D/C
Wasepi	B	Washtenaw	D/C	Watton	C
Waucedah	D	Wauseon	D/B	Wautoma	D/B
Wega	B	Westbury	C	Whalan	B
Wheatley	D/A	Whitaker	C	Whitehall	B
Willette	D/A	Winneshiek	B	Winterfield	D/A
Wisner	D/B	Witbeck	D/B	Wixom	B
Wolcott	D/B	Woodbeck	B	Yalmer	B
Ypsi	C	Zeba	B	Ziegenfuss	D
Zilwaukee	D	Zimmerman	A		

Construction and redevelopment projects on EMU are regulated under the National Pollutant Discharge Elimination System (NPDES) permit #MIG610000, May 2008 for storm water discharges, as issued by the Michigan Department of Environmental Quality (MDEQ). The following information is required from the project, and must be submitted to the EMU Certified Stormwater Operator/Facilities Maintenance and Operations Director, Physical Plant.

A) Complete Project Information:

Project Name:
Project Number:
Total Area of Earth Disturbance for the project (to the nearest 0.1 acres): 1 acre = 43,560 sq. ft.
Design Supervisor:
Design Supervisor Phone:
Project Start Date:
Project Completion Date:

B) Complete Questions 1 & 2 –

1. Is this project part of a larger common plan of development which will disturb 1 acre or more (for the entire planned development)?
   YES NO

2. Is the Total Disturbed Acreage of Project 1 acre or greater (to the nearest 0.1 acre):
   YES NO

C) Evaluate –

If both answers to 1 and 2 are NO, stop and fax this page to EMU Facilities Maintenance / Operations.

If you answered YES to either 1 OR 2, the project must prepare a Post-Construction Storm Water Plan for the site. First, fax this page to the EMU Facilities Maintenance / Operations office. Then, refer to the Post-Construction Storm Water Plan Checklist to aid you in identifying and completing the required elements for the post-construction storm water plan.

D) FAX Completed Worksheet (Page 1) to:
EMU Facilities Maintenance / Operations (734) 487-8680

Post-Construction Storm Water Plan – Checklist

Provide the post-construction storm water management plan, all calculations, and BMP details, including TSS designed removal rates and the O&M plan to EMU Certified Stormwater Operator at the Physical Plant for review and comment.

Minimum Treatment Volume Standard Requirements:

A. What is the volume (cubic feet) required for storage of one (1) inch of runoff from the entire site?

B. What is the calculated site runoff from the *90 percent annual non-exceedance storm* for the region? For EMU, use 0.9 inches of rain. Alternatively, use the storm/rainfall information found in the MDEQ memo *90 percent annual non-exceedance storms* found on the EMU Physical Plant website under Stormwater tab.

C. Explain how the site-specific design addresses the treatment methods required to achieve:

a. 80 percent removal of total suspended solids (TSS) as compared with uncontrolled runoff,

OR

b. Discharge concentrations of TSS not to exceed 80 milligrams per liter (mg/l)

Channel Protection Criteria:

Items D and E (below) require the utilization of the *Rainfall Frequency Atlas of the Midwest* (for rain amount) AND the calculation methodology provided by the MDEQ's guidance document *Computing Flood Discharges for Small Ungaged Watersheds*.

D. What is the volume and peak flow rate for the existing conditions at the site, for the 2-year, 24-hour event?

E. What is the volume and peak flow rate for the proposed conditions at the site, for the 2-year, 24-hour event?

Operation & Maintenance Plan

F. Provide a plan for all structural and vegetative BMPs installed to meet the storm water requirements of NPDES permit #MIG610000, (as above), including a plan for maintaining maximum design performance through long-term operation and maintenance. Include inspection frequencies needed, estimated maintenance frequency, criteria for maintenance (e.g. 12” sediment or 25% of storage capacity, etc.), and the manufacturers recommendations/manual.

Preferred Design Elements for Storm Water Protection*:

- Preserve /restore undisturbed natural areas
- Preserve riparian buffers, floodplains, & shorelines
- Preserve steep slopes
- Preserve porous and erodible soils
- Preserve existing topography
- Restore prairie/meadow areas
- Site reforestation
- Soil amendments/soil rejuvenation
- Avoid sensitive areas
- Reduce clearing and grading limits
- Conservation development
- Reduce roadway lengths and widths
- Shorter or shared driveways
- Shared parking
- Reduce building footprints
- Reduce parking lot footprints
- Reduce setbacks and frontages
- Use fewer or alternative cul-de-sacs
- Use natural drainage ways
- Infill and redevelopment within targeted development zones
- Cover loading areas
- Covered fueling areas
- Covered vehicle storage areas
- Storm drain disconnection
- Downspout disconnection
- Covered dumpsters
- Covered material storage areas
- Secondary containment structures

*Source – Center for Watershed Protection, *Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program,* EPA Publication No:833-R-08-001

Rules of the Washtenaw County Water Resources Commissioner

Procedures and Design Criteria for Storm Water Management Systems

Pursuant to Section 105(c) of Act 591 of the Public Acts of Michigan of 1996, as Amended and the Michigan Drain Code Public Act of 1956, as Amended

May 15, 2000

Part 3:

APPENDICES

INTRODUCTION

This edition of the Rules of the Washtenaw County Drain Commissioner continues a storm water management philosophy that considers stream channel protection and stormwater quality management in addition to flood control. These revisions are based upon the most current body of knowledge concerning stormwater management from across the state and country, modified as appropriate for application in Washtenaw County.

The following discussion outlines basic ideas and principals of stormwater management, and provides a conceptual foundation for the design standards contained in this document.

IMPACTS OF DEVELOPMENT ON WATER QUANTITY

The hydrology of a watershed changes immediately in response to site clearing and development of the natural landscape. A site's existing storm water storage capacity is quickly lost as vegetation is removed, natural depressions are graded and both topsoil and wetlands are eliminated. As the soil is compacted and resurfaced with impervious materials, rainfall can no longer penetrate into the ground and so runs off of the land. These modifications, along with the installation of "efficient" drainage facilities, such as catch basins and pipes, greatly alter natural drainage patterns. Hydrological changes will eventually cause changes in stream morphology.

Changes in Watershed Hydrology

- Volume of runoff increases. This raises the magnitude and frequency of severe flood events.
- Frequency of bankfull floods increases. These floods fill the stream channel to the top of its banks, but do not spill over into the floodplain. Increased bankfull flooding subjects the stream channel to continual disturbance and scour.
- Flow velocities increase. This is due to the combined effect of greater discharge, rapid time of concentration, and smoother hydraulic surfaces.
- Stream flow fluctuations increase dramatically. As runoff is concentrated into sharper, faster and higher peaks, equally abrupt returns to pre-storm level discharges will follow. Increased flow fluctuations disrupt habitats and reduce the diversity of aquatic species regardless of water quality.
- Infiltration into the underlying water table is reduced. This in turn lowers the level of surface waterbodies that are dependent on groundwater to maintain base flows during dry periods.

Changes in Stream Morphology

- Channel widening and downcutting are the primary consequences of increased runoff and flow fluctuations.
- Streambank erosion is accelerated, as channels are severely disturbed by undercutting, tree-falls and bank slumping.
- Sediment loads increase sharply due to streambank erosion and construction site runoff. These sediments settle out and form shifting bars that often accelerate the erosion process by deflecting runoff into sensitive bank areas.

- Increased sedimentation and channel widening modify aquatic habitats. Pools and riffles are eliminated as the gradient of the stream adjusts to accommodate frequent floods. Sediment deposition destroys insect and benthic organism habitat as well as fish spawning areas.

IMPACTS OF DEVELOPMENT ON WATER QUALITY

As development occurs, changes in land use contribute new or additional pollutants to storm-water runoff. In addition, the accompanying impervious surfaces provide efficient delivery of these pollutants into receiving waterways. Leaves, litter, animal droppings, exposed soil from construction sites, fertilizer and pesticides are all washed off of the land. Vehicles and deteriorating urban surfaces deposit trace metals, oil, and grease onto streets and parking lots. These and other toxic substances are carried by storm water and conveyed through creeks, ditches and storm drains into our rivers and lakes. The major categories of pollutants and their specific impacts are included within Appendix B.

In short, the ecology of urban streams may be completely re-shaped by the extreme shifts in hydrology, morphology and water quality that can accompany the development process. The stresses that these changes place on the aquatic community, although gradual and often not immediately visible, are profound: Michigan Department of Environmental Quality (MDEQ) has identified streams in the urban and urbanizing portions of the County as requiring special initiatives to restore degraded habitats, and to improve water quality.

To mitigate stream impacts, it is necessary to reevaluate the way that stormwater and land development are managed. The following discussion provides a framework for this reevaluation, which must encompass the entire development process from land use planning and zoning to site design and construction.

FRAMEWORK FOR THE DESIGN OF STORM WATER MANAGEMENT SYSTEMS

Note: The Rules of the Washtenaw County Drain Commissioner govern only the design of storm water management systems within certain new development projects; the following discussion applies to all aspects of managing land and storm water.

Thoughtful site planning can substantially reduce environmental impacts associated with development. Towards this end, communities, regulatory agencies, and designers must begin to evaluate the impact of each individual development project over the long term, and on a watershed scale. Such an approach requires consideration of Best Management Practices (BMPs) that function together as a system to ensure that the volume, rate, timing and pollutant load of runoff remains similar to that which occurred under natural conditions. This can be achieved through a coordinated network of structural and nonstructural methods, designed to provide both source and site control. In such a system, each BMP by itself may not provide major benefits, but becomes very effective when combined with others.

Source Controls

Source controls reduce the volume of runoff generated on-site, and eliminate initial opportunities for pollutants to enter the drainage system. By working to prevent problems, source controls are the best option for controlling storm water, and include the following key practices:

- Preservation of existing natural features that perform storm water management functions, such as depressions, wetlands, and woodland and vegetative buffers along streambanks.

- The minimization of impervious surface area through site planning that makes efficient use of paved, developed areas and maximizes open space. Encouraging flexible street and parking standards, and the use of permeable ground cover materials can also reduce impervious surfaces.
- Direction of storm water discharges to open grassed areas such as swales and lawns rather than allowing stormwater to run off from impervious areas directly into the storm water conveyance system.
- Careful design and installation of erosion control mechanisms and rigorous maintenance throughout the construction period. Effective erosion control measures include minimizing the area and length of time that a site is cleared and graded, and the immediate vegetative stabilization of disturbed areas.

Site Controls

Site controls are the subject of this document. After the implementation of source controls, site controls are then required to convey, pre-treat, and treat (e.g., detain, retain or infiltrate) the storm water runoff generated by development. The range of engineering and design techniques available to achieve these objectives is to some degree dictated by site configuration, soil type, and the receiving waterway. For example, flat or extremely steep topography may preclude the use of grassed swales, which are otherwise preferable to curb and gutter systems. Likewise, sites upstream of cold-water fisheries may not be suitable for permanent wet ponds that discharge heated surface waters. But while each site will be unique, some universal guidelines for controlling storm water quality and quantity can be stated.

Preferred Hierarchy of Structural Site Controls

1) In general, the most effective storm water quality controls are infiltration practices, which reduce both the runoff peak and volume. But to date, structural infiltration devices such as basins and, to a lesser degree, trenches have suffered extremely high failure rates due to clogging. Therefore, an aggressive maintenance program and extensive upstream pre-treatment measures, such as oil/grit separators, sedimentation basins and grass filter strips, must be incorporated into any storm water management system that employs these devices. In addition, these practices are only feasible for smaller drainage areas with suitable soils and no potential for groundwater contamination.

2) The next most effective storm water site controls reduce the runoff peak, and involve storage facilities such as retention and detention ponds. In the selection of an appropriate storm water pond design, wet ponds and extended detention ponds are generally preferable to dry detention ponds, since they hold storm water much longer, allowing more particulate matter to settle out. In addition, the aquatic plants and algae within wet ponds take up soluble pollutants (nutrients) from the water column. These nutrients are then transformed into plant materials that settle to the pond floor, decay, and are consumed by bacteria. Since this biological process is dependent upon the presence of water, it does not occur in dry ponds.

3) Where site conditions make the use of a wet pond infeasible, dry ponds should be designed to provide extended detention of storm water, again to promote as much settling of particulate matter as possible. A notable exception to this preference exists within areas where thermal impacts are a concern. Since they hold storm water longer, wet and extended detention ponds tend to increase the exposure of runoff to solar warming before releasing it. Where thermal impacts are of primary concern, a balance must be struck

between the goals of pollutant removal and the reduction of thermal impacts. Source controls and infiltration of storm water, where feasible, are preferable approaches.

4) Once all possible methods of reducing and treating storm water on-site have been implemented, excess runoff must be discharged into conveyance systems and carried off-site. Discharges must be at rates, velocities and volumes that will not cause adverse downstream impacts to land or waterways. For this purpose, vegetated swales with check dams are generally preferred to curb and gutter systems and enclosed storm drains.

5) Regardless of the design, any storm water system will lose effectiveness without regular maintenance. Depending on the specific BMP, maintenance must be performed at regular intervals. This may include inspection, sediment removal, maintenance of vegetation and structures, replacement of filters, et cetera. Maintenance plans should be developed concurrent with the system designs. The design must include adequate maintenance access.

Pond Design

1) Storm water must be pre-treated prior to entering a retention or detention pond, by passing first through a sediment forebay. Sediment forebays function to reduce incoming water velocities, and to trap and localize incoming sediments, making their removal easier during maintenance. Sediment forebays also extend the flow path of storm water, increasing its residence time. Infiltration systems require more extensive pre-treatment, including grassed channels, grassed filter strips, filter fabric and/or other methods.

2) Whereas detention basin design for flood control is concerned with relatively infrequent, severe runoff events, such as the 25-, 50- or 100-year storm, design for water quality benefit is concerned with controlling the more frequent storm events (e.g. 1.5-year storm or less). The negative impacts of erosive "bankfull" floods are effectively avoided by capturing and detaining the 1.5-year storm.

3) Also of primary importance to water quality is the capture and treatment of the "first flush", a term used to describe the initial washing action that stormwater has on impervious surfaces. Pollutants that have accumulated on these surfaces are flushed clean by the early stages of runoff, which then carries a shock loading of these pollutants into receiving waterways. The majority of all pollutants that are washed off the land can be removed from storm water before it leaves the site by capturing and treating the first 1/2-inch of runoff.

4) Treatment of the "bankfull" flood and "first flush" may be accomplished via the design of "dual detention basins". These basins control storm water discharge rates for both extreme events to prevent flooding and more frequent runoff events to mitigate water quality impacts and channel erosion.

THE ROLE OF THE WASHTENAW COUNTY DRAIN COMMISSIONER

The preferred hierarchy discussed above and summarized in Table 1 provides a comprehensive framework for evaluating the place and function of individual BMPs within a storm water management system. While the most important BMPs are source controls that preserve and protect the natural environment, the Washtenaw County Drain Commissioner cannot mandate these. We must look to the staff and officials of local governments, as well as to developers and their design engineers and planners, to implement source reduction approaches described earlier.

The Office of the Drain Commissioner exercises authority over the design and construction of structural facilities that convey and treat storm water runoff that will be generated from a site as a result of its design. The Drain Commissioner's Rules will govern the design of such management facilities with the following objectives:

- Incorporate design standards that control both water quantity and quality
- Encourage innovative storm water management practices that meet the criteria contained within these rules
- Ensure future maintenance of facilities by planning for it as a part of system design
- Make the safety of facilities a priority
- Strengthen the protection of natural features
- Encourage more effective soil erosion and sedimentation control measures

Table 1. Hierarchy of Preferred Best Management Practices

Non-Structural (Source) Controls

1) Preservation of the natural environment
2) Minimization of impervious surfaces
3) Use of vegetated swales and natural storage

Structural (Site) Controls

1) Infiltration of runoff on-site (trenches, etc.)
2) Storm water retention ponds
3) Storm water detention structures
4) Conveyance off-site
5) Proper maintenance

PART 1:

PROCEDURES FOR SUBMISSION &REVIEW OF PLATS & CONSTRUCTION PLANS

PART 1

PROCEDURES FOR PLAN SUBMISSION AND REVIEW

I. PURPOSE AND INTRODUCTION

A. All plats recorded with the Register of Deeds must conform to Act 288 of the Public Acts of 1967, as amended. Under this Act, the Drain Commissioner is responsible for ensuring that the drainage or storm water management system of a subdivision is adequate for the development, and for protecting downstream landowners and resources. The procedures, standards and recommendations set forth in these rules are designed for these purposes.

B. In accordance with the provisions of Act 288, the Drain Commissioner has the authority, through the subdivision review process, to require that county drains and natural water courses, both inside and outside a plat, be improved to the standards established by the Drain Commissioner when necessary for the proper drainage of a proposed subdivision.

C. Under these rules, the Drain Commissioner will ensure that all storm water facilities necessary for a proposed subdivision have an appropriate governmental unit responsible in perpetuity for performing maintenance or for overseeing the performance of maintenance by a private entity, such as a property owner's association. As specified in Act 288, the County Drain Commissioner may acquire jurisdiction over the drainage systems within subdivisions as deemed necessary for adequate operation and maintenance. The appropriate forms may be obtained from the Drain Commissioner's Office.

D. The general standards set forth herein will also be applied by the Washtenaw County Drain Commissioner in the review of the following:

1. Site Condominium plans prepared under Act 59, P.A. 1978, as amended, where local government ordinances require.

2. Mobile home plans prepared under Act 96, P.A. 1987.

3. Applications for permits to discharge to a county drain under P.A. 40 of 1956, as amended.

4. Review of storm water system plans in other classes of developments or re-developments, when requested by local governments.

E. These rules provide minimum standards to be complied with by proprietors, and in no way limit the authority of the local municipality in which the development is situated to adopt and enforce higher standards as a condition of approval of the final plat or site plan. If the local municipality has adopted more stringent standards, the Drain Commissioner's Office will review plans in accordance with those standards.

II. PRELIMINARY PLAN SUBMITTAL AND APPROVAL

A. SUBMITTAL REQUIREMENTS

These requirements have been developed in the context of preliminary plat submittal under the Michigan Land Division Act. However, they shall also be followed as closely as possible for all other categories of development, including site condominiums and site plans.

1. A preliminary plan showing the layout of the area intended to be subdivided or developed will be submitted to the Drain Commissioner's Office by the proprietor. This plan will be prepared under the direction of, and sealed by, a registered professional engineer or a registered land surveyor. The preliminary plan shall be drawn to a standard engineering scale on sheets not exceeding 24" x 36".

2. Three copies of the preliminary plan, prepared in accordance with the rules set forth in this section, will be submitted together with a letter of transmittal requesting that the preliminary plan be reviewed and, if found satisfactory, approved. The names of the proprietor and engineering or surveying firm, with mailing addresses, fax and telephone numbers for each, will be included with the transmittal.

3. Payment of applicable review fees is required before any review will commence. See Fee Schedule, Appendix O.

4. The proprietor will describe the mechanism to be established for long-term maintenance of the subdivision's storm water management system, and the government agency responsible for maintenance oversight if maintenance is to be performed by a private entity. Where jurisdiction exists, the Drain Commissioner may require that a County drainage district be established for future maintenance.

   Where maintenance is to be performed by a private entity. Where jurisdiction exists, the Drain Commissioner will require formal documentation from the local government of its intent to assume responsibility for oversight of maintenance and for ensuring that maintenance is performed if the private entity fails to do so.

5. Should the proprietor plan to subdivide or develop a given area but wishes to begin with only a portion of the total area, the original preliminary plan will include the proposed general layout for the entire area. The first phase of the subdivision will be clearly superimposed upon the overall plan in order to illustrate clearly the method of development that the proprietor intends to follow. Each subsequent plat or phase will follow the same procedure until the entire area controlled by the proprietor is subdivided.

6. Final acceptance by the Drain Commissioner of only one portion or phase of the subdivision does not ensure final acceptance of any subsequent phases or the overall general plat for the entire area; nor does it mandate that the overall general plat or plan be followed as originally proposed, if deviations or modifications acceptable to the Drain Commissioner are proposed.

7. Preliminary plan approval shall remain in effect for one year. Extensions must be requested in writing.

B. GENERAL INFORMATION REQUIREMENTS

All preliminary plans will include the following information:

1. The location of the proposed development by means of a small location map.
2. The township, city or village in which the parcel is situated.
3. The section and part of section in which the parcel is situated.
4. The number of acres to be developed.
5. Contours, at 2-foot intervals or less, with U.S.G.S. datum.
6. The proposed drainage system for the development.
7. The proposed street, alley and lot layouts and approximate dimensions.
8. The location and description of all on-site and adjacent off-site features that may be relevant in determining the overall requirements for the subdivision. These features may include, but are not limited to the following:
   - Adjoining roads, subdivisions, and other developments
   - Schools, parks, and cemeteries
   - Drains, sewers, water mains, septic fields and wells
   - High tension power lines, underground transmission lines, gas mains, pipelines or other utilities
   - Railroads
   - Existing and proposed easements
   - Natural and artificial watercourses, wetlands and wetland boundaries, floodplains, lakes, bays and lagoons
   - Designated natural areas
   - Soils description in accordance with the USDA NRCS standard soils criteria
   - Any proposed environmental mitigation features
9. Soil borings may be required at various locations including the sites of proposed retention/detention facilities, and as needed in areas where high ground water tables exist.

B. DRAINAGE INFORMATION REQUIREMENTS

1. Calculations used in designing all components of storm water management systems must be submitted to the Drain Commissioner along with plans.
2. All preliminary plans will include the following required storm water management information:

a. The overall storm water management system for the proposed development, indicating how storm water management will be provided and where the drainage will outlet.

b. The location of any on-site and/or off-site storm water management facilities and appropriate easements that will be dedicated to the entity responsible for future maintenance. Easement information will be consistent with PART 2, Section XI of these Rules.

c. A description of the off-site outlet and evidence of its adequacy. See Engineer's Certificate of Outlet, Appendix Q.

d. If no adequate watercourse exists to effectively handle a concentrated flow of water from the proposed development, discharge will be reduced to sheet flow prior to exiting the site. Additional volume controls will be required in such cases, as will acquisition of rights-of-way from downstream property owners receiving the storm water flow.

e. A map, at the U.S.G.S. scale, showing the drainage boundary of the proposed development and its relationship with existing drainage patterns.

f. Any drainage originating outside of the development limits that flows onto or across the development. Drainage from off-site shall not be passed through on-site storm water storage facilities unless alternatives are proposed for the off-site flow that will achieve the water quality objectives of these standards, such as separate basins for water quality treatment and storage of the 100-year storm volume.

g. Any natural water courses and/or County Drains passing through the proposed development, along with the following:

(1) Area of upstream watershed and current zoning.

(2) Preliminary calculations of runoff from the upstream area for both the 100-year and 1.5-year 24-hour design storms, for fully developed conditions according to the current land use plan for the area.

h. Any natural watercourses or County Drains that abut the development.

3. The increased volume of water discharged due to development of the site must not create adverse impacts to downstream property owners and water courses These adverse impacts may include, but are not limited to flooding, excessive soil saturation, crop damage, erosion, and/or degradation in water quality or habitat.

4. Proposed drainage for the development will conform to any established County drainage districts.

5. The proposed drainage plan will, in every way feasible, respect and conform to the natural drainage patterns within the site and the watershed in which it is located.

6. In general, the Drain Commissioner will not accept responsibility for roadside ditches serving public roads. The Washtenaw County Road Commission maintains these, if they are within the right-of-way of a public road.

7. Proposed drainage should complement any local storm water management plans that may exist and/or comply with any ordinance in effect in the municipality/ies where the proposed development is located.

D. SUBDIVISION PRELIMINARY PLAT APPROVAL

1. The Drain Commissioner will approve or reject a preliminary plat within 30 days of its submittal. If the proposed preliminary plat is not approved as originally submitted, the Commissioner will notify the proprietor in writing, setting forth the reasons for withholding approval, and will state the changes necessary to obtain approval. If the proposed preliminary plat as submitted meets all requirements, one approved copy of the preliminary plat will be returned to the proprietor. Approval of the preliminary plat is required before the Drain Commissioner will proceed with review of final construction plans.

2. Payment of all fees is prerequisite to approval.

III. CONSTRUCTION PLAN SUBMITTAL AND APPROVAL

A. SUBMITTAL REQUIREMENTS

1. For all projects to be reviewed by the Drain Commissioner, the proprietor will submit construction plans with a letter of transmittal requesting review and a permit application, if required.

2. For platted subdivisions, review of construction plans by the Drain Commissioner will not proceed until preliminary plat approval has been granted. The Land Division Act gives no time limit in which final construction plans must be reviewed. The Drain Commissioner's office will attempt to review these plans in the shortest possible time.

3. For all other developments, if a preliminary plan was not reviewed and approved by the Drain Commissioner, all aspects of PART 1, Section II, must also be adhered to during the construction plan review.

4. If development is proposed in an area where special drainage problems exist or are anticipated at the site, on adjacent properties or downstream, more stringent design requirements than are contained within PART 2 of these Rules may be required.

5. Payment of applicable review fees is required before any review will commence. See Fee Schedule, Appendix O.

B. CONSTRUCTION PLAN REQUIREMENTS

The Drain Commissioner will review construction plans to assure that adequate storm drainage will be provided and that the proposed storm water management system provides adequately for water quantity and quality management to ensure protection of property owners, lands, and watercourses both within the proposed development and downstream.

1. The names of the proprietor and engineering firm, with mailing addresses, fax and telephone numbers for each, shall be included with the transmittal. Plans will be prepared under the direction of, and sealed by, a registered professional engineer and will be in accordance with PART 2 of these Rules.

2. Two complete sets of construction plans are required, drawn to a scale no smaller than 1" = 50', and on sheets no larger than 24" x 36". The plans shall be drawn to standard engineering scales. The construction plan submittal shall include all required information listed in PART 1, Section II, Articles B and C, as well the following, where applicable:

    a. The property description, the total acreage, and a project location map. If the project is to be completed in phases, the number of acres in each phase shall also be included.

    b. The proposed project layout with all dimensions, including the proposed drainage system for the project.

    c. Topographic maps, at two-foot contour intervals or less on U.S.G.S. datum, showing existing and proposed grades, as well as off-site topography over at least 150' of the adjoining property. Maps will also show all existing watercourses, lakes and wetlands, and the extent of all off-site drainage areas contributing flow to the development.

    d. Calculations, design data and criteria used for sizing all drainage structures, channels and retention basins, including weighted runoff coefficient calculations.

    e. Plans and details of proposed retention/detention facilities. Soil borings may be required at the sites of these facilities.

    f. Plans, profiles and details of all roads and storm sewers. The storm sewer details will include type and class and size of pipe, length of run, percent of slope, invert elevations, rim elevations, and profile of the hydraulic gradient, as specified in PART 2 of these Rules.

    g. Storm sewer calculations indicating the number of acres, calculated to the nearest tenth of an acre, contributing to each specific inlet/outlet, the calculated hydraulic gradient elevation, maximum flow in cfs and the flow velocities for enclosed systems.

    h. A drainage area map, overlaid onto a copy of the site grading plan, which clearly shows the areas tributary to each inlet and/or storage basin.

    i. Plans, profiles and details of all open drains, drainage swales and drainage structures.

    j. Plans and details of the proposed soil erosion and sedimentation control measures, both temporary during construction and permanent.

    k. All construction specifications for the storm water management facilities.

    l. Locations of all drain fields as approved by the Washtenaw County Environmental Services Division and of all expansion areas. Drain fields shall not be located within drainage easements.

m. A single sheet showing all proposed storm drainage facilities with drainage easements shall be submitted. This sheet shall be overlaid on the overall road and utility plan and drawn to a scale no smaller than 1"=100'.

C. CONSTRUCTION PLAN APPROVAL

1. When plans have been completed with computer aided design technology, copies of the electronic files of the final plan set shall be provided for those items that specifically relate to the storm drainage facilities and information required in these Rules. These items include, but are not limited to, storm sewers, swales, ponds, grading plans, etc., as well as all available information such as complete site layout, sanitary sewer and water main plans, and topographic surveys.

2. A storm water facility maintenance plan, schedule, and budget shall be submitted. This will be used in estimating the costs that will be associated with system maintenance. See PART 2, Section XIII.

3. A cost estimate of the entire stormwater management system shall be submitted. This estimate shall include, but is not limited to, grading, soil erosion control, stabilization, basin construction, and pipe construction. All fees associated with construction inspection, contingencies and letters of credit will be based on this estimate.

4. Construction inspection fees equal to 5% of the cost estimate but not less than $2500.00 shall be submitted prior to construction plan approval.

5. For site condominiums, all items outlined in PART 1, Section IV, Articles B through F, Article I and Article J regarding final approval must be completed prior to the approval of construction plans. Complete master deed documents, including by-laws and exhibit B Drawings must be submitted for the Drain Commissioner's review and approval prior to recording.

6. The Drain Commissioner shall be invited to all pre-construction meetings with other agencies, utility companies and contractors. Prior to the approval of the final construction plans, the proprietor will make arrangements acceptable to the Drain Commissioner for inspection during construction, including submittal of inspection reports, and for final verification of the construction by a Michigan registered professional engineer. These arrangements will include an inspection schedule that defines the specific junctures during construction when on-site inspection and written verification by a professional engineer will occur. See Appendix G, Engineer's Certificate of Construction.

7. A soil erosion permit under "The Michigan Soil Erosion and Sedimentation Control Act", P.A. 451, Part 91 Public Acts of 1994 as amended, will be obtained from the appropriate agency prior to any construction.

8. Approval of construction plans by the Drain Commissioner's office is valid for one calendar year. If an extension beyond this period is needed, the proprietor will submit a written request to the Drain Commissioner for an extension. The Drain Commissioner may grant a one year extension of the approval. This extension may require updated or additional information if needed, and/or

design modifications to meet the currently prevailing Rules of the Washtenaw County Drain Commissioner.

9. Payment of all fees is prerequisite to approval.

IV. FINAL SUBDIVISION PLAT SUBMISSION AND APPROVAL

Final subdivision plat review will be completed by the Drain Commissioner's office within 10 days of submission by the proprietor. If the plat is not acceptable, written notice of rejection and the reasons there for will be given to the proprietor. If the Drain Commissioner approves the plat, s/he will affix his/her signature to it and the plat will be executed. As a condition of final plat approval, the Drain Commissioner will require the following:

A. The municipal governing body in which the proposed development is located must approve the preliminary plat. Evidence of this approval will be submitted to the Drain Commissioner's office with the final plat.

B. Before approval of the final plat, it must be demonstrated that all necessary Wetland, Floodplain, Inland Lakes and Streams, Erosion Control or other needed state, federal or local permits are in place.

C. A satisfactory agreement that assures long-term maintenance of all drainage improvements will be in place before submission of the final plat. Documentation of maintenance agreement will be supplied to the Drain Commissioner.

D. Complete subdivision agreements (including deed restrictions) must be submitted for the Drain Commissioner's review and approval prior to recording. These agreements must include the appropriate easement language for the development. See Appendix L, Typical Easement Language.

E. Reproducible mylar drawings of the as-built storm water management system will be submitted to the Drain Commissioner along with the final plat, or upon completion of system construction. The mylars are to be of quality material and 3 mils in thickness.

F. The proprietor will post a contingency deposit in an amount of not less than 10% of the approved construction cost estimate of the storm water facilities. This contingency deposit will be held for one year after the date of completion of construction and final inspection of the storm water facilities by the Drain Commissioner, or until construction and soil stabilization is complete on all lots in the development, whichever time period is longer.

1. This deposit may be in the form of cash, a letter of credit, or an escrow account. A letter of credit or escrow account established as a contingency deposit shall not have an expiration date and will contain the following clause regarding the expiration of the letter or the account:

"This letter of credit (or escrow account) shall expire upon receipt of a written statement by the Washtenaw County Drain Commissioner that the storm water management system in the above-mentioned development has received final approval by the Washtenaw County Drain Commissioner."

2. Depending on the nature of the deposit, it will be returned to the proprietor or allowed to expire provided that all storm water facilities are clean, unobstructed and in good working order and that the Drain Commissioner has received all required documents, certificates, and as-builts drawings. It is the proprietor's responsibility to request final inspection.

G. An Engineer's Certificate of Construction will be submitted by either a contracted registered professional engineer, or the registered professional engineer of the local governing body if it provides construction inspection. See Appendix G, Engineer's Certificate of Construction, for the appropriate language. Where certification is by a registered professional engineer other than that employed by the local governing body, the Washtenaw County Drain Commissioner will approve the registered professional engineer.

H. The following procedure shall prevail when storm water management facilities are constructed prior to submission of the Final Plat.

1. If the proprietor desires to construct the storm water management facilities necessary in the proposed subdivision before submission of the final plat, construction plans as required in Part 1, Section III will be submitted to, and approved by the Drain Commissioner's office before any work commences.

2. Construction inspection deposits equal to 5% of the cost estimate but not less than $2500.00 shall be submitted prior to construction plan approval. The proprietor will be responsible for inspection costs incurred by the Drain Commissioner.

3. If the drainage work involves crossing, tapping into, or other work within an existing County Drain or its easement, a permit application will be filed with, and approved by the Office of the Drain Commissioner prior to construction. This permit application will be accompanied by any necessary release of rights-of-way in recordable form, executed by all owners of interest. Prior to construction, copies of any required state or local permits shall be submitted to the Drain Commissioner.

I. The following procedure shall prevail when storm water management facilities are constructed after submission of the Final Plat.

1. If the proprietor desires to have the plat recorded before completing the drainage improvements, he or she will enter into an agreement with the Drain Commissioner and post a cash deposit, letter of credit, or escrow account in an amount sufficient to complete construction of the storm water management facilities, as determined by the proprietor's engineer and approved by the Drain Commissioner.

2. A letter of credit or escrow account established as completion assurance will contain the following clause regarding the expiration of the letter or the account:

"It is a condition of this letter of credit (or escrow account) that it shall be automatically renewed for additional periods of one (1) year from the present or each future expiration date, unless at least 60 days prior to such date, the Washtenaw County Drain Commissioner is notified in writing via certified mail, that the credit (or account) will not be renewed for such an additional period."

3. Under this agreement, the time of completion of construction of storm water management facilities will not extend for a period greater than one year from the original date of the agreement. If after this period the improvements are not completed, the Drain Commissioner may exercise the right, under the terms of the escrow account or letter of credit, to use proceeds of the proprietor's deposit to fulfill the proprietor's obligation under such agreement, at such time and in such manner as the Drain Commissioner may determine.

4. The financial assurance mechanism shall remain in place until construction and soil stabilization over 80% of the development is complete. Thereafter, the Drain commissioner may refund portions of the original deposit as the work progresses. However, the amount of deposit retained by the Commissioner will at no time be reduced to less than the cost for completion of the remaining work.

J. Payment of all fees is prerequisite to approval.

K. A final plat, when submitted to the Drain Commissioner for signature, will include the Drain Commissioner's Certificate. The form of this certificate is as follows:

County Drain Commissioner's Certificate

Approved on _________________, as complying with Section 192 of Act 288, P.A. of 1967, and the applicable rules and regulations published by my office in the County of Washtenaw.

____
Janis A. Bobrin
Drain Commissioner

V. DRAINS UNDER THE JURISDICTION OF THE DRAIN COMMISSIONER

A. Drainage districts will not be altered when designing development drainage, except as provided under Sections 425 and 433 of Act 40, Public Act 1956 as amended.

B. Existing county drain easements will be indicated on plans and final plats and will be designated as "_____________" (County) Drain. County drain easements prior to 1956 were not required by statute to be recorded immediately; therefore, it may be necessary to check the permanent records of the Drain Commissioner's Office to see if a drain easement is in existence on the subject property.

C. Proposed modifications to county drains will require a permit application to the Office of the Drain Commissioner. State and local permits may also be necessary.

D. A permit will be obtained from the Drain Commissioner prior to any work that affects a county drain, including tapping into or crossing. The permit must be obtained prior to construction plan approval.

1. Detailed construction plans along with the appropriate review fees shall be submitted for review with the permit application. These shall be prepared in accordance with PART 1 Section III.

2. Payment of all fees is prerequisite to permit approval.

3. Upon receipt of an approved permit, the permitee must contact the Drain Commissioner 48 hours prior to the start of construction.

4. All work shall be completed in accordance with the plans and specifications approved by the Drain Commissioner.

5. A cash deposit in an amount satisfactory to the Drain Commissioner shall be deposited to insure satisfactory completion of the project in accordance with the approved plans. The permitee shall contact the Drain Commissioner to perform an inspection of the permitted activity.

6. The Drain Commissioner shall be notified in writing within 10 days of completion of an approved project.

7. Authority granted by a permit from the Drain Commissioner does not convey, provide or otherwise imply approval of any other governing act, ordinance, or regulation, nor does it waive the permitee's obligation to acquire any federal, state, county or local approval or authorization necessary to conduct the activity.

VI. APPEAL PROCEDURES

A. If the proprietor wishes to appeal a decision made by the Drain Commissioner, a written appeal may be filed 14 calendar days of that decision. If an appeal is filed with the Drain Commissioner's Office, an informal hearing will be scheduled within 20 calendar days from the date of the filing.

B. The informal hearing will allow the proprietor an opportunity to submit additional information or re-emphasize previously submitted data. The Drain Commissioner will then review the information and make a final decision, within 20 days of the informal hearing, and forward this final decision to the proprietor by first class mail.

PART 2:

DESIGNE CRITERIA FOR STORM WATER MANAGEMENT SYSTEMS

PART 2

DESIGN CRITERIA FOR STORM WATER MANAGEMENT SYSTEMS

This section sets forth specific design and construction standards that will be used by the Drain Commissioner in review of proposed storm water management systems in accordance with the objectives of managing both the quantity and quality of storm water runoff. A Glossary of Terms used throughout this section is provided in Appendix A.

It is difficult or impossible to develop one set of uniform standards that is capable of accommodating all variables and unique site circumstances. In particular, it is recognized that these standards may be difficult to realize on small sites. Waivers or variances from specific provisions of these standards may be requested, and alternatives consistent with the overall intent of storm water quantity and quality management may be proposed, subject to the approval of the Drain Commissioner.

Whereas basin design for flood control is concerned with capturing and detaining relatively infrequent, severe runoff events, such as the 10-, 25-, or 100-year storm, designs for water quality control require that the more frequent storm events (e.g. 1.5-year storm or less) must be addressed as well. The need for managing smaller storms is directly related to urbanization within Washtenaw County and the accompanying increase in impervious area, which affects surface water quality in two important ways.

First, eroded soil and other pollutants that accumulate on impervious surfaces, such as metals, fertilizers, pesticides, oils and grease, are flushed off by the early stages of runoff, which then carries a shock loading of these pollutants into receiving waterways. By capturing and treating the first 0.5-inch of runoff, pollutants that are washed off of the land can be removed from storm water before it flows offsite.

Second, as recent studies by the MDNR have shown, development within the County has caused stream flow fluctuations to rise dramatically. As impervious surface area increases and opportunities for infiltration are reduced, the frequency and duration of bankfull flow conditions, typically represented by the 1.5-year storm event, have intensified. As a result, streams adjust their capacities to convey the increased flows, leading to channel and bank erosion and the destruction of aquatic habitat.

To manage both water quantity and quality, basins must be designed to capture and treat three different storm events:

1. The 100 year storm event
2. The bankfull flood; the 1.5-year/24 hour storm event
3. The first flush volume; the runoff from the first 0.5 inch of rain from the entire contributing watershed

Controlling both extremely large events, to prevent flooding, and more frequent events, to mitigate water quality impacts and channel erosion, can be achieved through the proper design of detention/retention basins. Among alternatives, wet ponds and constructed pond/wetland marsh systems are the most effective for achieving control of both storm water volume and quality. Extended detention ponds providing two-stage pond designs that contain an upper, dry stage and a lower stage with a permanent pool are also acceptable, though their ability to remove critical pollutants such as total phosphorus is limited. Dry ponds providing extended storage will be accepted only when the site's physical characteristics or other local circumstances make the use of a wet pond infeasible, or when thermal impacts are a primary concern.

The phosphorus removal capability of wet ponds, wet extended detention ponds, multiple ponds, pond/wetland marsh systems and infiltration systems is superior to other BMPs. This is of particular importance in a geographical area designated as the "Middle Huron River." This area, extending from Sylvan Township at the County's western boundary, through Ypsilanti Township on the east, is under a Total Maximum Daily Load (TMDL) limit by the Michigan Department of Environmental Quality (MDEQ). This limit requires the reduction of current phosphorus loadings to the Huron River by 50%. See Appendix C, Special Areas of Concern.

Extensive literature is available on specific design concepts and alternatives, and selected references are available within this document's appendix. Diagrams for a number of these concepts are contained within Appendix D. Several other structural Best Management Practices (BMPs) not referenced within the following text are also illustrated.

Individuals seeking to develop land within Washtenaw County are encouraged to contact local governments regarding their local storm water BMP requirements. Standards in addition to those contained in these rules may be in effect in specific communities or creeksheds.

I. STORM WATER DISCHARGE

A. In no event will the maximum design rate or volume of discharge exceed the maximum capacity of the downstream land, channel, pipe or watercourse to accommodate the flow. It is the proprietor's obligation to meet this standard. Should a storm water system, as built, fail to comply, it is the proprietor's responsibility to design and construct, or to have constructed at his/her expense, any necessary additional and/or alternative storm water management facilities. Such additional facilities will be subject to the Drain Commissioner's review and approval.

B. A description of the off-site outlet and evidence of its adequacy is required. See Appendix Q, Engineer's Certificate of Outlet.

C. If no adequate watercourse exists to effectively receive a concentrated flow of water from the proposed development, discharge will be reduced to sheet flow prior to exiting the site. Further, if the proposed storm water management system cannot achieve pre-development conditions, with respect to both volume and rate of storm water runoff, it is the responsibility of the developer to secure necessary easement(s) from downstream property owner(s). See Appendix T.

D. Discharge should outlet within the drainage basin where flows originate, and generally may not be diverted to another basin.

II. DETERMINATION OF SURFACE RUNOFF

A. The rational method of calculating storm water runoff is generally acceptable for highly impervious sites less than 120 acres in size. However, it may not be considered an adequate design tool for sizing large drainage systems. All composite runoff coefficients shall be based on the values shown in the table below. The slopes listed for the semi-pervious surfaces are the proposed finished slope of the tributary area.

Table 1. Minimum Acceptable Runoff Coefficients for use in Rational Method

Type of Surface	**Runoff Coefficient**		
Water Surfaces	1.00		
Roofs	0.95		
Asphalt or concrete pavements	0.95		
Gravel, brick, or macadam surfaces	0.85		
Semi-pervious; lawns, parks, playgrounds	Slope <4%	Slope 4%-8%	Slope >8%
Hydrologic Soil Group A	0.15	0.20	0.25
Hydrologic Soil Group B	0.25	0.30	0.35
Hydrologic Soil Group C	0.30	0.35	0.40
Hydrologic Soil Group D	0.45	0.50	0.55

B. More precise methodologies for predicting runoff such as runoff hydrographs are widely available, and may be required by the Drain Commissioner for sizing the drainage systems on large sites and/or smaller sites that are deemed potentially problematic. Acceptable alternative methods include:

1. U.S. Army Corps of Engineers HEC-HMS, HEC-1
2. Natural Resources Conservation Service UD-21, TR-20 and TR-55
3. U.S. EPA's SWMM
4. Continuous simulation (HSPF)

C. Unless a continuous simulation approach to drainage system hydrology is used, all design rainfall events will be based on the SCS Type II distribution.

D. Computations of runoff hydrographs that do not rely on a continuous accounting of antecedent moisture conditions will assume a conservative wet antecedent moisture condition.

E. For sites with upstream watersheds equal to or greater than 2 square miles, approval of the MDEQ is required, pursuant to Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. The MDEQ will compute the runoff rates at no charge. The MDEQ requires applicants to use the UD-21 method by SCS in lieu of the rational method. This method was developed for small watersheds by SCS, and can be used for watersheds up to 10 square miles. Computer programs such as HEC-HMS, HEC-1 and HEC-RAS, DEQ permit applications, and other relevant information, can be downloaded from the MDEQ web site. See Appendices I and J for more information.

RETENTION AND DETENTION SYSTEMS

A. General Requirements

All runoff generated by proposed impervious surfaces must be conveyed into a storm water storage facility for water quality treatment and detention/retention prior to being discharged from the site. The following criteria will apply to the design of all storm water retention and detention facilities.

1. Wet ponds and storm water marsh systems will be preferred to dry ponds. Dry ponds providing extended storage will be accepted only when the development site's physical characteristics or other local circumstances make the use of a wet pond infeasible.

2. Public safety will be a paramount consideration in storm water system and pond design. See PART 2, Section XII. Providing a safe design for storm water storage is the proprietor's responsibility. Pond designs will incorporate gradual side slopes, vegetative and barrier plantings, and safety shelves. Where further safety measures are required, the proprietor is expected to include them within the proposed development plans.

3. For safety purposes and to minimize erosion, basin side slopes will not be steeper than one-foot vertical to five feet horizontal (5:1). Steeper slopes may be allowed if perimeter fencing at least 5 feet in height is provided. In general, the side slopes shall not be flatter than one-foot vertical to 20 feet horizontal (20:1).

4. Detention and retention facilities shall be located on common-owned property in multi-ownership developments such as subdivisions and site condominiums, and not on private lots or condominium units.

5. Adequate maintenance access from a public or private right-of-way to the basin will be provided. The access will be on a slope of 5:1 or less, stabilized to withstand the passage of heavy equipment, and will provide direct access to the forebay, control structure, and the outlet.

6. When discharge is within a watershed where thermal impacts are a primary concern, deep wet ponds with bottom draw or dry ponds may be preferred. In addition for extended dry detention ponds, first flush and bankfull requirements, may be reduced to 12 hours. See Appendix C, Special Areas of Concern. Shade plantings on the west and south sides of facilities are encouraged. Infiltration of storm water should be considered where site conditions allow.

7. Storage Volumes and Release Rates: On-site management of storm drainage will be designed for control of flooding, downstream erosion and water quality. Submission of flow calculations, cross sections and other pertinent data will be required.

   a. The volume of storage provided for flood control will be equal to or in excess of that required for a 100-year frequency storm as outlined in Appendix H.

      The allowable release rate from the flood control storage volume will normally be between 0.1 and 0.15 cfs per acre of the property being drained, or as determined by the Drain Commissioner. If discharge does not outlet to a clearly defined downstream channel, it is the developer's responsibility to secure necessary easement(s) from downstream property owner(s).

b. The volume and storage provided for controlling the bankfull flood will be equal to or in excess of the runoff from a 1.5-year, 24-hour storm, which can be determined by:

<u>8170 x acreage x the relative imperviousness factor C</u>

The release rate from the bankfull storage volume will be such that this volume will be stored not less than 24 nor more than 48 hours.

c. The first flush volume of runoff will be captured and detained for at least 24 hours or within a permanent pool. This volume is determined by the runoff from 0.5 inches of rain per acre of the land tributary to the basin. This volume can be determined by:

<u>1815 x acreage x the relative imperviousness factor C</u>

8. Sediment forebays will be provided at the inlet of all storm water management facilities, to provide energy dissipation and to trap and localize incoming sediments.

   a. The forebay will be a separate basin, which can be formed by gabions, a compacted earthen berm, or other suitable structure.

   b. The capacity of the forebay will be equivalent to 5% of the 100-year storm volume based on the area tributary to the inlet.

   c. Exit velocities from the forebay shall not be erosive during the 1.5-year design storm.

   d. Direct maintenance access to the forebay for heavy equipment will be provided.

   e. A permanent vertical depth marker will be installed in the forebay to measure sediment deposition over time. Storm water system maintenance plans will require that sediment be removed when sediment reaches a depth of equal to 50% of the depth of the forebay or 12 inches, whichever is less. See PART 2, Section XIII regarding maintenance plans.

   f. An adequate area for temporary staging of spoils, prior to ultimate disposal, will be provided. This area will be protected such that no runoff will be directed back into the storm water management system or onto private property. For subdivisions and site condominiums, an easement dedicated to the Drain Commissioner or other governmental agency with long-term maintenance responsibility must be provided over the staging area.

9. Basin Inlet/Outlet Design

   a. Velocity dissipation measures will be incorporated into basin designs to minimize erosion at inlets and outlets, and to minimize the resuspension of pollutants.

b. To the extent feasible, the distance between inlets and outlets will be maximized. The length and depth of the flow path across basins and marsh systems can be maximized by:

   (1) Increasing the length to width ratio of the entire design

   (2) Increasing the dry weather flow path within the system to attain maximum sinuosity

   If possible, inlets and outlets should be offset at opposite longitudinal ends of the basin.

c. Ponds with a dry pilot channel shall have a french drain located 2 to 3 feet below the riprap to prevent excessive warming of storm water during periods of low flow.

d. The use of dual outlets, risers, V-notched weirs or other designs that assure an appropriate detention time for all storm events is required.

e. The outlet will be well protected from clogging. A reverse slope submerged orifice or a hooded, broad crested weir are recommended options. If a reverse-slope pipe is used, an adjustable valve may be necessary to regulate flows.

f. Where a pipe outlet or orifice plate is to be used to control discharge, it will have a minimum diameter of 4 inches. If this minimum orifice size permits release rates greater than those specified in these rules, an alternative outlet design that incorporates self-cleaning flow restrictors will be required. Examples include perforated risers and "V" notch orifice plates that provide the required release rate. Calculations verifying this rate will be submitted to the Drain Commissioner for approval.

g. Any backwater effects on the outlet structure caused by the downstream drainage system will be evaluated when designing the outlet.

h. Riser Design

   (1) Inlet and outlet barrels and risers will be constructed of reinforced concrete or corrugated metal. Plastic is not acceptable as a riser material. The minimum diameter for riser pipes shall be 24". Riser pipes greater than 4 feet in height shall be 48" in diameter.

   (2) Riser pipes shall be set into a cast-in-place concrete base or properly grouted to a pre-cast concrete base. All riser pipes constructed of material other than concrete must be set into a cast-in-place base.

   (3) All orifice configurations shall consist of the minimum number of holes with the largest diameter that meet the detention requirements.

   (4) A gravel filtration jacket consisting of 3" washed stone and 1" washed stone shall be placed around all riser pipes. The orifice configuration shall be wrapped with hard wire of an appropriate opening size to prevent any stone from passing through the orifice. The 3" stone shall be placed immediately adjacent to the riser pipe

with the 1" stone covering the larger stone. The gravel jacket shall extend sufficiently above all orifice patterns.

(5) Orifices used to maintain a permanent pool level should withdraw water at least one foot below the surface of the water.

(6) Hoods or trash racks shall be installed on the riser to prevent clogging. Grate openings shall be a maximum of three inches on center.

(7) The riser shall be placed near or within the embankment, to provide for ready maintenance access.

(8) Where feasible, a drain for completely de-watering wet ponds should be installed for maintenance purposes.

(9) All outlets will be designed to be easily accessible for heavy equipment required for maintenance purposes.

10. Protection of Receiving Waters

    a. Flared end sections are required.

    b. In the case of environmentally sensitive riparian zones, a step pool arrangement shall be used to convey the discharge to the stream.

    c. The channel immediately below the pond outlet shall be modified to prevent erosion and conform to the natural dimensions in the shortest possible distance.

    d. A stilling basin or other measure shall be incorporated to prevent erosive velocities of outflow.

11. Storm water management systems incorporating pumps shall not be permitted in developments with multiple owners, such as subdivisions and site condominiums. Variance requests, submitted in accordance with PART 1, Section VI of these standards, will be considered on a case-by-case basis. However, variances from this rule will be considered only as a measure of last resort, subsequent to demonstration that no alternative system designs are feasible. Special requirements, such as the establishment of an operations/maintenance/replacement account by the Developer, will be imposed to help defray special assessments that would be levied upon future property owners for maintenance of the system.

12. In-line detention basins are strongly discouraged in all circumstances, and are prohibited on watercourses greater than 2 square miles upstream or on a County drain. In-line basins are also prohibited if the waterway to be impounded traverses any area outside of the proposed development.

13. The placement of retention/detention basins within a 100-year floodplain is prohibited. Any appeal to this prohibition must be accompanied with adequate information that verifies that the facility will meet the requirements of these rules during flood events.

14. Anti-seep collars should be installed on any piping passing through the sides or bottom of the basin to prevent leakage through the embankment.

15. A minimum of one foot of freeboard will be required above the 100-year storm water elevation on all detention/retention facilities.

16. All basins will have provisions for a defined emergency spillway, routed such that it will flow unobstructed to the main outflow channel.

    a. The emergency spillway elevation will be set at the elevation of the maximum pond design volume.

    b. The spillway will be sized to pass the maximum design flow tributary to the pond.

17. Vegetative Plantings Associated with Retention/Detention Facilities

    a. Basins and marsh designs will be accompanied by a landscaping plan that incorporates plant species native to the local region and indicates how aquatic and terrestrial areas will be vegetated, stabilized and maintained. See Appendix R for a list of native species.

    b. Whenever possible, native wetland plants should be encouraged in the pond design, either along the aquatic bench, fringe wetlands, safety shelf and side slopes or within the shall areas of the pools.

    c. A permanent buffer strip of natural vegetation extending at least 25 feet in width beyond the freeboard elevation will be maintained or restored around the perimeter of all storm water storage facilities. No lawn care chemicals shall be applied to the buffer area. This requirement will be cited in the subdivision restrictions or master deed documents.

    d. Viability of plantings will be monitored for two years after establishment by the proprietor, and reinforcement and replacement plantings provided as needed.

18. Requirements for storm water quantity control may be waived for developments in the downstream-most locations of a watershed, although quality management will still be necessary. Determinations will be made on an individual site basis.

19. Additional water quality measures will be installed at sites where land uses are identified as pollutant hotspots. See Appendix E.

20. For sites where chemicals may be stored and used, such as certain commercial and industrial developments, a spill response plan will be developed that clearly defines the emergency steps to be taken in the event of an accidental release of harmful substances that may migrate to the storm water system. As a result of this plan, design elements such as shut-off valves or gates may be needed.

B. Permanent Retention Ponds

1. Retention basins with no outlet will be capable of storing two consecutive 100-year storms, which can be determined by:

   <u>33,000 x acreage x the relative imperviousness factor C</u>

2. An overflow assessment will be required. The assessment will include descriptions of the surrounding areas that would be impacted in the event of an overflow.

3. The proprietor must submit a soil boring log, taken within the basin bottom area to a depth of 25 feet below existing ground or 20 feet below proposed basin bottom elevation. Information regarding the seasonal groundwater elevations must also be provided.

4. The volume required may be modified based upon the percolation rate of the soil, groundwater elevation and supporting data prepared by a registered professional engineer or certified professional geologist.

C. Wet Detention Basins

1. Storage volume on a gravity outflow wet basin is defined as, "the volume of detention provided above the invert of the outflow device." Any volume provided below the invert of the outflow device will not be considered as detention.

   At a minimum, the volume of the permanent pool should be at least 2.5 times the first flush volume:

   <u>4540 x runoff coefficient x site drainage area</u>

2. Wet detention pond configuration will be as follows:

   a. Surface area to volume ratio should be maximized to the extent feasible.

   b. In general, depths of the permanent pool shall be varied and average between 3 and 6 feet.

   c. A minimum length to width ratio of 3:1 shall be used unless structural measures are used to extend the flow path.

   d. Ponds shall be wedge-shaped, narrower at the inlet and wider at the outlet. Irregular shorelines are preferred.

   e. A marsh fringe shall be established near the inlet and forebay and around at least 50% of the pond's perimeter.

   f. A shelf, a minimum of 4 feet wide at a depth of one foot, will surround the interior of the perimeter to provide suitable conditions for the establishment of aquatic vegetation, and to reduce the potential safety hazard to the public.

   g. To avoid drawdown, a reliable supply of baseflow and/or groundwater will be required.

D. Extended Detention Basins

A two-stage design is required; with separate outlet controls to detain both the 1.5-year and larger rain events.

1. The lower stage shall contain a shallow, permanent pool designed to store and treat the first flush volume, or the runoff from 0.5 inch of rain over the entire site.

   a. This pool shall be managed as a shallow marsh or wetland, and average 6-12 inches in depth.

   b. At a minimum, the volume of runoff detained in the entire lower stage shall be equivalent to the runoff volume produced by a1.5-year storm.

2. The upper stage shall be sized for the 100 year, 24 hour storm, as provided in PART 2 Section II, A.2.i.1 of these rules, and shall be graded to remain dry except during large storms.

   a. A low flow channel, stabilized against erosion, will be provided through the dry portion of the basin. This channel should have a minimum grade of 0.5%, and the remainder of the basin should drain toward this channel at a grade of at least 1%.

   b. The low flow channel should end at the lip of the lower stage, where riprap or gabion baffles will be placed, to prevent scour and resuspension.

E. Storm Water Wetland Systems

Storm water wetlands are defined as constructed systems explicitly designed to mitigate the storm water quality and quantity impacts associated with development. They do so by temporarily storing storm water runoff in shallow pools that create growing conditions suitable for emergent and riparian wetland plants. The runoff storage, complex microtopography and emergent plants in the storm water facilities that couple ponds and constructed wetlands together form an ideal system for the removal of urban pollutants. Because of their water quality benefits, the use of storm water wetlands is encouraged.

1. As a general rule, storm water wetlands may not be located within delineated natural wetland areas, nor within created wetlands that are used to mitigate the loss of natural wetlands.

2. The design of an effective and diverse storm water wetland requires a sophisticated understanding of hydrology and wetland plant ecology. Therefore, a qualified professional with specific wetland expertise must oversee wetland construction, re-construction or modification.

3. Storm water wetland systems must be designed to perform in conformance with all standards for storage volume and discharge rate established in these rules.

4. The proprietor will provide for the monitoring of wetland plantings and replacement as needed for a two-year period after construction.

STORM WATER CONVEYANCE

A All structures will be constructed in accordance with governing specifications including Michigan Department of Transportation, Washtenaw County Road Commission, and the City or Township. In the event of no other governing specifications, the latest edition of the Michigan Department of Transportation standards will be observed.

B. Storm water conveyance systems incorporating pumps shall not be permitted in developments with multiple owners, such as subdivisions and site condominiums.

C. Natural Streams and Channels

5. Natural streams are to be preserved. Natural swales and channels should be preserved, whenever possible.

6. If channel modification must occur, the physical characteristics of the modified channel will duplicate the existing channel in length, cross-section, slope, sinuosity, and carrying capacity.

7. Streams and channels will be expected to withstand all events up to the 100-year storm without increased erosion. Armoring banks with riprap and other manufactured materials will be accepted only where erosion cannot be prevented in any other way, such as by the use of vegetation.

D. Vegetated Swales/Open Ditches

Open swale/ditch drainage systems are preferred to enclosed storm sewers where applicable governmental standards and site conditions permit.

Swales will be required to:

a. Follow natural, pre-development drainage paths insofar as possible.

b. Be well vegetated, wide and shallow.

8. Open ditch flow velocities will be neither siltative nor erosive. The minimum acceptable velocity will be 2.0 ft./sec., and the maximum acceptable velocity will be 6.0 ft./sec.

9. Open ditch slopes will depend on existing soils and vegetation. However the minimum acceptable slope is 1.5 %, unless other techniques such as infiltration devices are implemented. Maintenance for such devices must be detailed in the overall maintenance plan.

10. Side slopes of ditches shall be no steeper than 3:1. Soil conditions, vegetative cover and maintenance ability will be the governing factors for determining side slope requirements.

11. Slopes and bottoms of open ditches and swales will be stabilized to prevent erosion.

12. Swale length shall be a minimum of 200 feet whenever possible, to increase the contact time of storm water. The maximum length will be based on soil type, slope and catchment area.

13. A minimum clearance of 5 feet is required between open swale/ditch inverts and underground utilities unless special provisions are employed. Special

provisions, for example, could be the encasement of utility lines in concrete when crossing under the channel. In no case will less than 2 feet of clearance be allowed.

14. Permanent metal or plastic markers will be placed on each side of the drain to show the location of underground utilities.

15. All bridges will be designed to provide a 2-foot minimum flood stage freeboard to the underside of the bridge. Footings will be at least one foot below the invert grade of the channel. Depending on soils, additional footing depth may be required.

16. A series of check dams or drop structures across swales shall be provided to enhance water quality performance and reduce velocities.

17. Designers should consider integrating additional redundant pollutant removal enhancement features such as stilling basins and stone infiltration trenches.

E. Enclosed Drainage Structures

18. Enclosed storm drain systems will be sized to accommodate the 10-year storm, with the hydraulic gradient kept below the top of the pipe.

19. Restricted conveyance systems designed to create backflow into storm water storage facilities are not permitted.

20. Drainage structures will be located as follows:

    a. To assure complete positive drainage of all areas of the subdivision.

    b. At all low points of streets and rear yards.

    c. Such that there is no flow across a street intersection.

    d. For smaller enclosed pipes, 12 to 24 inches in diameter, manholes will not be spaced more than 400 feet apart. Longer runs may be allowed for larger sized pipe but in all cases maintenance access must be deemed adequate by the Drain Commissioner.

21. The catch basin or inlet covers shall be designed to accept the 10-year design storm. No ponding of water should occur during this storm event.

22. Discharge from enclosures will be as follows:

    a. All outlets will be designed so that velocities will be appropriate to, and will not damage, receiving waterways.

    b. Outlet protection using riprap or other approved materials will be provided as necessary to prevent erosion.

    c. The soils above and around the outlet will be compacted and stabilized to prevent piping around the structure. Riprap extending 3 feet above the ordinary high water mark is required for all outlets.

    d. When the outlet empties into a detention/retention facility, channel or other watercourse, it will be designed such that there is no free overfall from the end of the apron to the receiving waterway.

23. Pipe will conform to the following criteria:

a. The minimum pipe acceptable pipe diameter is 12 inches.

b. In order to avoid accumulation of sediment in the drain, pipe will be designed to have minimum velocity flowing full of 3 ft/sec., with the exception of sediment chambers.

c. The maximum allowable velocity flowing full will be 10 ft/sec.

d. Pipe joints will be such as to prevent excessive infiltration or exfiltration.

e. All materials will be of such quality as to guarantee a maintenance-free expectancy of at least 50 years and will meet all appropriate A.S.T.M. standards.

f. The minimum depth of pipe shall be 42 inches from grade to the springline of the pipe.

24. In areas where local ordinance requires sump pump leads to be connected into an enclosed system, these taps shall be made directly into storm sewer structures or into cleanouts approved by the Drain Commissioner's Office.

25. Sump pump lines and connections shall not fall under the long term operation and maintenance of the Drain Commissioner's Office and will not become part of an established county drain. Maintenance of such lines will be the responsibility of the property owners, and should be so specified in subdivision rules or condominium master deed agreements.

F. Channel/Pipe Design

1. Manning's formula will be used to size the open channel or pipe. See Table 2 below for roughness coefficients.

$$Q = \frac{1.486}{n} AR^{2/3}S^{1/2}$$

2. A minimum "n" of 0.035 will be used for the roughness coefficient for open channels, unless special treatment is given to the bottom and side slopes, such as sodding, riprap or paving.

3. If Manning's equation is not used, the Drain Commissioner shall approve the alternative method used.

Table 2. Manning Roughness Coefficients for Various Surfaces

Boundary Material	n value	Boundary Material	n value
HDPE pipe, smooth lined	0.011	Brick	0.016
Concrete pipe	0.013	Riveted steel	0.018
Vitrified clay pipe	0.014	Rubble	0.025
Cast iron pipe	0.015	Gravel	0.029
HDPE pipe, unlined	0.018	Riprap	0.033
Finished concrete	0.012	Natural channels in good condition	0.025
Planed wood	0.012	Natural channels with stones & weeds	0.035
Unplaned wood	0.013	Natural channels in poor condition	0.060
Unfinished concrete	0.014	Natural channels with heavy brush	0.100

G. Culvert Design

1. Under Michigan State Law, Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, crossroad culverts draining two square miles or more must be reviewed and approved by the Michigan Department of Environmental Quality.

2. Crossroad culverts draining less than 2 square miles of upstream watershed will be sized by the proprietor's engineer and approved by the Washtenaw County Road Commission and Washtenaw County Drain Commissioner's Office.

3. At a minimum, culverts will be designed to convey the peak 10-year storm flow with the velocity not exceeding 8 fps. The 100-year storm must pass the embankment with no adverse increase in water elevation occurring off of the development property or flooding of structures within the development. A minimum of one foot of freeboard is required.

4. Acceptable methods of determining the flowrate required to pass through the culvert are listed below. The proprietor's engineer may use any of the methods listed or another if approved by the Drain Commissioner's Office:

   a. Rational Method

   b. USDA Soil Conservation Service Method

   c. The Michigan Department of Natural Resources Method

   d. Continuous flow modeling

5. The discharge velocity from culverts should consider the effect of high velocities, eddies, or other turbulence on the natural channel, downstream property and roadway embankment. The culvert exit velocity should not cause downstream channel erosion or scour.

6. Sizing of culvert crossings will consider entrance and exit losses as well as tailwater conditions on the culvert. Once the design flow is determined, the required size of the culvert will be determined by one of the following methods:

   a. The "Mannings" formula

   b. The inlet headwater control/outlet tailwater control nomographs

   c. Other methods approved by the Drain Commissioner

7. Wing walls, headwalls and all other culvert extremities will be designed to assure the stability of the surrounding soil. It is recommended that Michigan Department of Transportation standard designs be observed unless special exemption is given.

ADDITIONAL STORM WATER MANAGEMENT BMPs: INFILTRATION FACILITIES AND SAND FILTERS

A variety of best management practices, other than those detailed within these rules, provide effective water quality and quantity control. The following section provides design standards for only two of many approaches acceptable to the Drain Commissioner, presuming site suitability and adequate maintenance provisions. *A reference bibliography is provided at the end of this document (Appendix N).*

A. INFILTRATION FACILITIES

Infiltration devices are designed to capture and treat storm water runoff from smaller rain events, which are managed for water quality purposes. They function to reduce runoff at its source, since the diverted "first flush" is not discharged to surface water but is stored until it is gradually removed by infiltration and evaporation. Through these mechanisms, infiltration can remove pollutants, provide groundwater recharge and help reduce the volume of runoff leaving a site. Infiltration devices are generally incorporated as one component of an overall storm water system that utilizes other management approaches as well.

While the concept of infiltration best conforms to the storm water management goals of water quantity and quality control stated within these rules, in practice, infiltration approaches to storm water management somewhat have limited application. Although many infiltration devices are very effective for removing fine sediment particles and the pollutants associated with them, coarse sediments and oil will clog infiltration systems, and must be removed prior to entering them. Clogging of infiltration devices is a primary reason for failure, causing many to fail during the first few years of operation. The use of erosion control measures, sedimentation basins and grass filter strips to pre-treat runoff is essential, as is a very aggressive maintenance program. In addition, studies have shown that many infiltration facilities fail or do not work as designed due to poor initial site selection. Therefore, soil suitability and the contributing drainage area must be carefully assessed. The potential for groundwater contamination must also be seriously considered prior to implementation.

Infiltration approaches to storm water management are particularly effective for small catchment areas of less than 10 acres in size, and in areas where thermal impact is a primary concern.

1. Site Criteria for Infiltration Facilities

    a. Infiltration facilities will be permitted only on sites with undrained hydrologic soil group classifications of A or B. Where infiltration facilities are proposed, a sufficient number of soil borings will be provided in each location to evaluate the site suitability. See Appendix K for the appropriate classifications.

    b. The maximum tributary area to an individual infiltration facility shall be limited to 5 acres.

    c. Infiltration facilities are not feasible where the slope of the site is greater than 6%, unless proper energy dissipation devices are installed.

    d. Infiltration facilities are also not recommended where the slope of the watershed contributing directly to the device is greater than 5%.

    e. Trenches and underground components will be readily accessible for maintenance purposes.

    f. Infiltration facilities will not be located within 100 feet of a water supply well or a building foundation.

    g. Infiltration facilities will not be built downslope of new construction until the entire development area has been permanently stabilized.

2. Design Criteria for Infiltration Facilities

    a. Minimum design volume will be based on infiltration of 0.5-inch runoff over the entire drainage basin.

    b. All facilities will be designed to hold water for a minimum of 6 hours and a maximum of 72 hours.

    c. The bottom of the device will be a minimum of 4 feet above seasonally high groundwater and bedrock.

    d. To remain operative in freezing weather, the bottom of the device will be placed 12 inches below the frost line.

    e. An observation well, consisting of a perforated vertical pipe within the trench, will be installed in every trench to monitor performance.

    f. The bottom of the infiltration trench will be scarified to a depth of 4”-6”, to reduce the possibility of initial soil compaction caused by excavation with heavy equipment.

    g. The slope of the trench bottom should be close to zero to evenly distribute exfiltration.

    h. Uniform, washed stone a minimum of 1 inch in diameter will be used within the device.

    i. Where an overflow pipe is provided for flows in excess of design, the pipe will be placed near the surface of the trench and outlet to an acceptable point of discharge.

    j. A legally enforceable and binding maintenance agreement will be included for infiltration systems. All systems will require annual inspection and maintenance.

3. Storm water Pre-treatment

   a. Each infiltration facility shall have redundant pre-treatment methods to protect the long-term integrity of the infiltration rate.

   b. A sediment settling basin or other storm water management practice will be provided to remove coarse sediment from storm water flows before they reach infiltration trenches.

   c. For surface trenches, a minimum 25-foot wide grass buffer is required as a filter.

   d. Underground trenches will receive water directed through an oil/grit separator or other form of pre-treatment that will remove both coarse solids and oils.

B. Sand Filters

A sand filter is a storm water treatment devise, whereby the first flush of runoff is diverted into an off-line, self-contained bed of sand. The runoff is then strained through the sand, collected in underground pipes and returned back to the stream or channel. Enhanced sand filters utilize layers of peat, limestone, and/or topsoil, and may also have a grass cover crop. In general, sand filters have a limited ability to reduce peak discharges and are usually designed solely to improve water quality.

Because a sand filter is a self-contained, artificially constructed soil system, it has few constraining factors and can be applied to most development sites, including those too small to be effectively served by ponds (i.e. small infill developments.) Sand filters are also useful in areas with concerns about groundwater contamination and poor soil infiltration rates, and as end-of-pipe retrofits. The upper limit on sand filters appears to be about 50 acres; however, a contributing watershed between 0.5 and 10 acres is recommended.

While the technology is still developing, a number of standard sand filter designs are available and may be acceptable to the Drain Commissioner.

General standards for the design of sand filter systems are as follows:

1. All designs shall incorporate the following three basic components:

   a. A pre-treatment wet pool or sedimentation basin;

   b. An on-line diversion weir for isolating the storm water to be treated

   c. An off-line sand filter bed area.

2. The system should be designed to capture and treat the first 0.5-inch of runoff from the impervious portion of the contributing watershed.

3. Pre-treatment of storm water will be required before discharge into the sand filter. The following pre-treatment mechanisms are acceptable, depending on site-specific considerations:

   a. Wet pools

   b. Sedimentation basins

   c. Oil-grit separators

d. Grass filter strips

4. Sufficient sediment storage volume will be provided within pre-treatment devices, so that clean-out intervals are reduced to once every 2 to 3 years.

5. Design storm flows will be conveyed to the sand filter bed basin at a non-erosive velocity. Generally, this velocity will be less than one foot per second.

6. An over-sized perforated hood/trash guard will be incorporated into weir designs to minimize clogging of the baseflow pipe.

7. Excess runoff volumes will be returned to the receiving conveyance channel via a riprapped baseflow/overflow channel.

8. Design of Sand Filter Beds

   a. Several formulas for sizing sand filter beds are available, and may be acceptable to the Drain Commissioner.

   b. The maximum surface ponding time for the design runoff volume will be limited to 24 hours.

   c. An impermeable liner may be required to eliminate potential groundwater infiltration/exfiltration problems.

9. Because of the potential for system failure due to bed clogging, sand filter system use is restricted to stabilized drainage areas.

10. Regular inspection and timely periodic removal of sediment and trash will be required. Grass cover crops, when provided, will be mowed whenever they exceed 10 cm. height (approx. once per week) and all grass cuttings removed.

11. The filter bed area will be clearly marked, and an appropriate drainage easement provided.

III. NATURAL WETLANDS

This section governs natural wetlands (as distinct from storm water wetland systems that are constructed expressly for storm water management purposes), when a natural wetland is incorporated in an overall storm water management scheme.

A. Wetlands will be protected from damaging modification and adverse changes in runoff quality and quantity associated with land developments. Before approval of the final plan, all necessary wetland permits from the MDEQ and local governments will be in place.

B. Direct discharge of untreated storm water to a natural wetland is prohibited. All runoff from the development will be pre-treated to remove sediment and other pollutants prior to discharge to a wetland. Such treatment facilities will be constructed before property grading begins.

C. Site drainage patterns will not be altered in any way that will modify existing water levels in protected wetlands without proof that all applicable permits from the MDEQ and/or local government agencies have been obtained.

D. A qualified professional with specific wetland expertise will oversee wetland construction, re-construction, or modification.

E. Whenever possible, a permanent buffer strip, vegetated with native plant species, will be maintained or restored around the periphery of wetlands. See Appendix R.

F. Wetlands will be protected during construction by appropriate soil erosion and sediment control measures.

IV. LOT GRADING

Approval of final lot grading is the responsibility of the local municipality. The Drain Commissioner's office is not responsible for inspection of, or enforcing corrections to, final lot grading. It is the Drain Commissioner's responsibility to ensure that the overall plan is consistent with sound storm water management and drainage practices. The subdivision storm water management plan will provide for the following:

A. The grading of lots will be such that surface runoff is away from homes and toward swales, ditches or drainage structures. Provision for drainage through properly graded storm water conveyance systems will be made for all areas within the proposed subdivision.

B. Where finished grades indicate a substantial amount of drainage across adjoining lots, a drainage swale of sufficient width, depth and slope will be provided on the lot line to intercept this drainage. To ensure that property owners do not alter or fill drainage swales, easements will be required over areas deemed necessary by the Drain Commissioner, as stipulated in PART 2, Section XI.

V. SOIL EROSION, SEDIMENTATION AND POLLUTION CONTROL

Discharge of sediment or other polluting materials to a waterway that is under jurisdiction of the Drain Commissioner, either within or outside of the subdivision, will be considered pollution to a county drain, and hence a violation of section 280.423 of the Michigan Drain Code. Under the Michigan Drain Code, pollution of a county drain is a criminal misdemeanor, punishable by fine of $25,000 or imprisonment.

A. SOIL EROSION/SEDIMENTATION CONTROL

All erosion control measures will be regularly inspected and maintained.

1. During Construction

   a. The development plan shall fit the topography and soil so as to create the least erosion potential.

   b. An approved soil erosion permit from the local enforcing agent, as well as a National Pollution Discharge Elimination System (NPDES) permit where applicable, will be required.

   c. Sediment shall not be permitted to leave the site. Recommended procedures to achieve this goal are as follows:

(1) Wherever feasible, natural vegetation should be retained and protected.

(2) The smallest practical area of raw land should be exposed at any one time (i.e. only areas under active construction).

(3) The entire site should be planted with temporary vegetation immediately after mass grading operations.

(4) Temporary vegetation and/or mulching should be used to protect critical areas exposed during development.

(5) Sediment basins where needed should be installed and maintained by the proprietor.

(6) The permanent, final vegetation and structures should be installed as soon as practicable in the development.

d. Areas within open drain easements that have been cleaned, reshaped or disturbed in any manner will be stabilized with seed and mulch or sod as quickly as possible.

e. All storm sewer facilities that are or will be functioning during construction will be protected, filtered, or otherwise treated to prevent sediment from entering the system. Construction activities will be complete before the construction of any storm water management facilities susceptible to clogging such as infiltration devices.

2. Permanent Erosion Control Measures

a. Before entering any natural watercourse, protected wetland, county drain or other body of water, best management practices will be utilized to remove pollutants, including sediment, from storm water runoff. Pollutant removal methods will include capture and treatment of the first flush and bankfull storm events, as previously described in these standards. In addition, receiving waters shall be protected as previously described.

b. Permanent erosion protection will be placed at bends, drain inlets and outlets, and other locations as needed in all open ditches. Headwalls, grouted riprap, soil bioengineering methods, or other stabilization measures will be provided where necessary to prevent erosion.

c. Outlets to ditches will be placed at the average low water elevation of the watercourse. Outlet velocities will be non-erosive.

d. Ditches with steep grades or unstable soils will be protected by sod, vegetative erosion control, geotextile fabric, riprap or other means to prevent scour.

e. All detention/retention basins will be permanently stabilized to prevent erosion.

B. OTHER POLLUTION CONTROL

1. Discharge of runoff that may contain oil, grease, toxic chemicals, or other polluting materials is prohibited. Measures will be employed to reduce and trap pollutants and meet any prevailing federal, state, or local water quality requirements.

2. In commercial and industrial developments where large amounts of oil and grease may accumulate, appropriate methods for separating pollutants will be required. When used, oil and grit separator will be installed off-line or in locations where flow velocities have been determined to be lower than scouring velocity in a 10-year storm. Where such facilities are proposed, a maintenance program, including an identified method and site for waste disposal, is required.

3. For sites where chemicals may be stored and used (e.g. certain commercial and industrial developments) a spill response plan must be developed that clearly defines the emergency steps to be taken in the event of an accidental release of harmful substances to the storm water system.

4. Structures designed to remove trash and other debris from storm water will be installed as required on storm water management facilities prior to their outlet.

5. Additional water quality protection measures may be required depending on the nature and location of the development and the receiving waters.

VI. BUFFER STRIPS

A. Buffer strips are defined as zones where construction, paving, and lawn care chemical applications are prohibited.

B. Buffer strips shall be established adjacent to all surface waters through deed restrictions or provisions of condominium master deed documents.

C. Plantings capable of filtering storm water shall be preserved or established.

D. The minimum width shall be 25 feet measured from the top of bank.

VII. FLOODPLAINS

A. It is the responsibility of the developer to demonstrate that any activity proposed within a 100-year floodplain will not diminish flood storage capacity.

B. In certain instances an analysis to determine the 100-year floodplain may be required. Where available, the community flood insurance study shall be used.

C. Compensatory storage will be required for all lost floodplain storage.

VIII. EASEMENTS

A. Wording relative to easement information will be as specifically required by the Drain Commissioner's Office. If a county drain is to be established under the Michigan Drain Code, related easement language will be depicted on final mylar plats and condominium exhibit B drawings as follows:

" ____ foot wide private easement to Washtenaw County Drain Commissioner and the __________ Homeowner's (or Condominium) Association for drainage."

B. The typical easement language as specified in Appendix L will be included in the subdivision deed restrictions or condominium master deed.

C. The location and purpose of drainage easements should be clearly described in subdivision deed restrictions or condominium master deeds.

Language will be included within the subdivision deed restriction or condominium master deed that clearly notifies property owners of the presence storm water management facilities and accompanying easements, as well as restrictions on use or modification of these areas.

D. If a utility is to be located within the right-of-way of any county drain or drainage easement, it will be located such that it will not increase the expense of maintaining the drainage facility.

E. Retention/detention basins or other storm water management facilities will have sufficient easements for maintenance purposes. Easements will be sized and located to accommodate access and operation of equipment, spoils deposition, and other activities identified in the development's storm water system maintenance plan.

F. Easement widths will be determined by the Drain Commissioner and be situated in such a way as to allow maximum maintenance access, for example, offsetting them from the centerline. In general, easement widths will conform to the following:

1. Open channels and watercourses: A minimum of 50 feet total width. Additional width may be required in some cases, including but not limited to: watercourses with floodplains delineated by FEMA; sandy soils, steep slopes, at access points from road crossings.

2. Open swales (cross lot drainage): minimum of 30 feet total width.

3. Enclosed storm drains: A minimum of 20 feet will be required, situated in such a way as to allow maximum maintenance access. Additional width will be required in some cases. These may include but are not limited to, pipe depths exceeding 4 feet from the top of pipe, sandy soils and steep slopes.

G. Drain fields (septic areas) shall not be located within drainage easements.

IX. SAFETY CONSIDERATIONS

A. Drainage system components, especially all ponds, will be designed to protect the safety of all persons coming in contact with the system. The following criteria will apply:

1. The side slopes of all detention basins should not exceed 5H:1V, and will be as gradual as practicable to prevent accidental falls into the basin and for stability and ease of maintenance.

   a. If steeper slopes are proposed, continuous fencing at least 5 feet in height with gates at least 12 feet wide for access by emergency and or maintenance vehicles shall be provided.

   b. An area at least 12 feet in width around the basin shall be provided inside of the fencing for maintenance equipment.

   c. Fencing materials shall meet with the approval of the Drain Commissioner.

2. Side slopes of open channels will not be steeper than 3:1.

3. Velocities throughout the surface drainage system will be controlled to safe levels taking into consideration rates and depths of flow.

4. All wet detention basins will have a level safety ledge at least 4 feet in width and one foot below the normal water depth, and other design and landscaping features as may be needed to provide for protection of the public.

X. STORM WATER MANAGEMENT SYSTEM MAINTENANCE PLANS

A. Maintenance plans will be submitted with all construction plans and included in the subdivision agreement or master deed documents of all subdivisions and site condominiums. These plans shall include the following information:

1. An annual maintenance budget itemized in detail by task. The financing mechanism shall also be described.

2. A copy of the final approved drainage plan for the development that delineates the facilities and all easements, maintenance access, and buffer areas.

3. A listing of appropriate tasks defined for each component of the system described, and a schedule for their implementation. The following areas will be covered:

   a. Maintenance of facilities such as pipes, channels, outflow control structures, infiltration devices and other structures.

   b. Debris removal from catch basins, channels and basins.

   c. Dredging operations for both channels and basins to remove sediment accumulation. Storm water system maintenance plans shall require that sediment be removed when sediment reaches a depth of equal to 50% of the depth of the forebay or 12 inches, whichever is less.

4. The party responsible for performing each of the various maintenance activities described, which will be recorded with final approved plans and plats.

5. A detailed description of the procedure for both preventative and corrective maintenance activities. The preventative maintenance component will include:

   a. Periodic inspections, adjustments and replacements.

   b. Record-keeping of operations and expenditures.

6. Provision for the routine and non-routine inspection of all components within the system described:

   a. Wet weather inspections of structural elements and inspection for sediment accumulation in detention basins, shall be conducted annually, with as-built plans in hand. These should be carried out by a professional engineer reporting to the responsible agency or owner.

   b. Housekeeping inspections, such as checking for trash removal, should take place at least twice per year.

   c. Emergency inspections on an as-needed basis, upon identification of problems, should be conducted by a professional engineer.

7. A description of ongoing landscape maintenance needs. Landscaping shall consist of low maintenance and/or native plant species. The proprietor will monitor the viability of plantings for at least two years after establishment and plantings will be replaced as needed. Subsequent monitoring shall be conducted by the landowner or development association. The Drain Commissioner is not responsible for landscape maintenance.

8. Provision for the maintenance of vegetative buffers by landowner, development associations, conservation groups or public agencies. Buffers must be inspected annually for evidence of erosion or concentrated flows through or around the buffer.

B. All Infiltration systems must be aggressively maintained and protected from clogging by sediment.

   1. In the event of clogging by accumulated sediments, partial or total reconstruction of infiltration facilities may be required.

   2. Porous pavement shall be vacuum swept and jet hosed at least four times per year to remove any grit or sediment trapped in the pores of the open-graded asphalt.

   3. Evidence of a regular service contract for performing this activity will be required.

C. Property deed restrictions or condominium master deed documents will specify the timeframe for action to address needed maintenance of storm water management facilities. These restrictions or documents will also specify that, should the private entity fail to act within this timeframe, the responsible governmental entity may perform the needed maintenance and assess the costs against the property owners within the subdivision or condominium association:

1. Routine maintenance of storm water management facilities will be completed per the schedule submitted with the construction plans or within 30 days of receipt of written notification by the responsible governmental entity that action is required, unless other acceptable arrangements are made with the supervising governmental entity.

2. Emergency maintenance will be completed within 36 hours of written notification unless threat to public health, safety and welfare requires immediate action.

D. The proprietor may fulfill the obligation to ensure that a governmental entity will be responsible for drainage system maintenance by establishing a county drainage district, or any other similar mechanism approved by the Drain Commissioner, to provide for the permanent maintenance of storm water management facilities and necessary funding.

E. If a County Drain is not established, the proprietor will submit evidence of a legally binding agreement with another governmental agency responsible for maintenance oversight.

F. A legally binding maintenance agreement will be executed before final project approval is granted. The agreement shall be included in the property deed restrictions or condominium master deed documents so that it is binding on all subsequent property owners.

G. A sample maintenance plan and annual budget is illustrated in Appendix P.

PART 3:

APPENDICES

APPENDIX A
Glossary of Terms

Antecedent Moisture Content (AMC)

The quantity of moisture present in the soil at the beginning of a rainfall event. The Soil Conservation Service has three classifications, AMC I, II, and III.

A.S.T.M.

American Society for Testing Materials.

Backwater

The increased depth of water upstream of a restriction or obstruction, such as a dam, bridge or culvert.

Bankfull Flood

A condition where flow completely fills the stream channel to the top of the bank. In undisturbed watersheds, this occurs on average every 1.5 to 2 years and controls the shape and form of natural channels.

Barrel

The concrete or corrugated metal pipe that passes runoff from the riser through the embankment, and finally discharges to the pond's outfall.

Base Flow

The portion of stream flow that is not due to runoff from precipitation, usually supported by water seepage from natural storage areas such as ground water bodies, lakes or wetlands.

Best Management Practice (BMP)

A practice or combination of practices that prevent or reduce storm water runoff and/or associated pollutants.

Borings

Cylindrical samples of a soil profile used to determine infiltration capacity.

Buffer Strip

A zone where plantings capable of filtering storm water are established or preserved, and where construction, paving and chemical applications are prohibited.

Catch Basin

A collection structure below ground designed to collect and convey water into the storm sewer system. It is designed so that sediment falls to the bottom of the catch basin and not directly into the pipe.

Check Dam

1) An earthen, aggregate or log structure, used in grass swales to reduce velocity, promote sediment deposition, and enhance infiltration.
2) A log or gabion structure placed perpendicular to a stream to enhance aquatic habitat.

County Drain

An open or enclosed storm water conveyance system that is under the legal jurisdiction of the Drain Commissioner's Office for construction, operation and maintenance.

Culvert

A closed conduit used for the passage of surface water under a road, or other embankment.

Design Storm

A rainfall event of specified size and return frequency, (e.g., a storm that occurs only once every 1.5 years). Typically used to calculate the runoff volume and peak discharge rate to or from a BMP.

Detention

The temporary storage of storm runoff, to control peak discharge rates and provide gravity settling of pollutants.

Detention Basin

A constructed basin that temporarily stores water before discharging into a surface water body. Basins can be classified into four groups:

1) Dry Detention Basin

A basin that remains dry except for short periods following large rainstorms or snow melt events. This type of basin is not effective at removing pollutants.

2) Extended Dry Detention Basin

A dry detention basin that has been designed to increase the length of time that storm water will be detained, typically between 24-40 hours. This type of basin is not effective at removing nutrients such as phosphorus and nitrogen, unless a shallow marsh is incorporated into the lower stage of the design.

3) Wet Detention Basin

A basin that contains a permanent pool of water that will effectively removes nutrients in addition to other pollutants.

4) Extended Wet Detention Basin

A wet detention basin that has been designed to increase the length of time that storm water will be detained, typically between 24-40 hours.

Detention Time

The amount of time that a volume of water will remain in a detention basin.

Discharge

The rate of flow or volume of water passing a point in a given time. Usually expressed as cubic feet per second.

Drainage area

The area of a watershed usually expressed in square miles or acres.

Drawdown

The gradual reduction in water level in a pond BMP due to the combined effect of infiltration and evaporation.

Easement

A legal right, granted by a property owner to another entity, allowing that entity to make limited use of the property involved for a specific purpose. The Drain Commissioner secures temporary and permanent easements adjacent to county drains for the purpose of construction and maintenance access. Easements are recorded on the title to the land and transfer with the sale of land. Also known as a right-of-way.

Extended Detention

A storm water design feature that provides for the holding and gradual release of storm water over a longer period of time than that provided by conventional detention basins, typically 24-40 hours. Extended detention allows pollutants to settle out before storm water is discharged from the basin.

Extended Detention Control Device

A horizontal pipe or series of pipes or vertical riser pipe designed to gradually release storm water from a pond over a 24-40 hour interval.

Fill

Added earth that is designed to change the contour of the land.

Filter Fabric

Textile of relatively small mesh or pore size. The two major classifications are as follows:

Permeable. This allows water to pass through while holding sediments back.

Impermeable. This type prevents both runoff and sediment from passing through.

First Flush

The delivery of a highly concentrated pollutant loading during the early stages of a storm, due to the washing effect of runoff on pollutants that have accumulated on the land.

Floodplain

For a given flood event, that area of land adjoining a continuous watercourse that has been covered temporarily by water.

Flow Path

The distance that a parcel of water travels through a storm water detention pond or wetland. It is defined as the distance between the inlet and outlet, divided by the average width.

Flow Splitter

An engineered, hydraulic structure designed to divert a portion of stream flow to a BMP located out of the channel, or to direct storm water to a parallel pipe system, or to bypass a portion of baseflow around a pond.

Forebay

A small, separate storage area near the inlet to a detention basin, used to trap and settle incoming sediments before they can be delivered to the basin.

Freeboard

The space from the top of an embankment to the highest water elevation expected for the largest design storm to be stored or conveyed. The space is required as a safety margin in a pond, basin or channel.

French Drain

A subgrade drain consisting of a trench filled with aggregate to permit movement through the trench and into the soil. The trench may also contain perforated pipe to enhance the efficiency of the system.

Gabion

A rectangular box of heavy gage wire mesh that holds large cobbles and boulders. Used in streams and ponds to change flow patterns, stabilize banks, or prevent erosion.

Ground Water

Naturally existing water beneath the earth's surface between saturated soil particles and rock that supplies wells and springs.

Ground Water Table

The upper surface or top of the saturated portion of the soil or bedrock layer, indicates the uppermost extent of groundwater.

Hydraulic Radius

The area of a stream of conduit divided by its wetted perimeter

Hydrograph

A graph showing the variation in stage or discharge in a stream or channel, over time, at a specific point along a stream.

Infiltration

The absorption of water into the ground, expressed in terms of inches/hour.

Infiltration Capacity

The maximum rate at which the soil can absorb falling rain or melting snow. Usually expressed in inches/hour, or centimeters/second.

In-line Detention

Detention provided within the flow-carrying network.

Invert

The elevation of the bottom interior surface of a conduit at any given cross section.

Level-Spreader

A device used to spread out storm water runoff uniformly over the ground surface as sheet flow i.e., not through channels. The purpose of level spreaders is to prevent concentrated, erosive flows from occurring, and to enhance infiltration.

Manhole

A structure that allows access into the sewer system.

Manning's Roughness Coefficient ("n")

A coefficient used in Manning's Equation to describe the resistance to flow due to the surface roughness of a culvert or stream channel.

Mean Storm

Over a long period of years, the average rainfall event, usually expressed in inches.

Multiple Pond System

A collective term for a cluster of pond designs that incorporate redundant runoff treatment techniques within a single pond or series of ponds. These pond designs employ a combination of two or more of the following: extended detention, permanent pool, shallow marsh or infiltration.

Natural Wetland

Land characterized by the natural presence of water sufficient to support wetland vegetation.

Non-point Source Pollution

Storm water conveyed pollution that is not identifiable to one particular source, and is occurring at locations scattered throughout the drainage basin. Typical sources include erosion, agricultural activities, and runoff from urban lands.

Off-line BMP

A water quality facility designed to treat storm water that has been diverted outside of the natural watercourse or storm sewer system.

Off-site Detention

Detention provided at a regional detention facility as opposed to storage on-site.

One Hundred Year Flood (100-year flood)

The flood that has a 1 percent chance of occurring in any given year.

Ordinary High Water Mark

The line between upland and bottomland which persists through successive changes in water level, below which the presence of water is so common or recurrent that the character of the soil and vegetation is markedly different from the upland.

Orifice

An opening in a wall or plate.

Peak Discharge

The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Petition (Under P.A. 40 of 1956)

A legal request to the Drain Commissioner to perform maintenance or construction, or to establish a drainage district. Either the township or individual(s) can petition to have work performed or a district established.

Pilot Channel

A riprap or vegetated low flow channel that routes runoff through a BMP to prevent erosion of the BMP surface.

Plat, Platting Process

A legal procedure, and the document that depicts it, whereby a larger piece of property is divided into smaller sections, and is accompanied by a full description of the original property, the dimension of each lot to be subdivided, and all relevant deed restrictions and easements.

Plunge Pool

A small permanent pool located at either the inlet to, or outfall from a BMP. The primary purpose of the pool is to dissipate the velocity of storm water runoff, but it can also provide some pre-treatment.

Pocket Wetlands

A storm water wetland design adapted for small drainage areas with no reliable source of baseflow. The surface area of pocket wetlands is usually less than a tenth of an acre. The pocket wetland is usually intended to provide some pollutant removal for very small development sites.

Pretreatment

Technique to capture or trap coarse sediments within runoff, before they enter a BMP to preserve storage volumes or prevent clogging. Examples include swales, forebays and micropools.

Proprietor

Any person, firm, association, partnership, corporation or any combination thereof.

Protected Wetland

Any wetland protected by state law or local government regulation.

Rational Formula

A simple technique for estimating peak discharge rates for very small developments, based on the rainfall intensity, watershed time of concentration, and a runoff coefficient.

Release Rate

The rate of discharge in volume per unit time from a detention facility.

Retention

The holding of runoff in a basin without release except by means of evaporation, infiltration, or emergency bypass.

Retention Basin

A storm water management facility designed to capture runoff that does not discharge directly to a surface water body. The water is "discharged" by infiltration or evaporation. Also know as a Wet Pond.

Return Interval

A statistical term for the average time of expected interval that an event of some kind will equal or exceed given conditions (e.g., a storm water flow that occurs every 2 years).

Reverse Slope Pipe

A technique for regulating extended detention times that is resistant to clogging. A reverse slope pipe is a pipe that extends downwards from the riser into the permanent pool and sets the water surface elevation of the pool. The lower end of the pipe is located up to 1 foot below the water surface.

Riparian Lands

Land directly adjacent to a surface water body.

Riprap

A combination of large stones, cobbles and boulders used to line channels, stabilize banks, reduce runoff velocities, or filter out sediment.

Riser

A vertical pipe extending from the bottom of a basin that is used to control the discharge rate from the basin for a specified design storm.

Routing

The derivation of an outflow hydrograph for a given reach of stream or detention pond from known inflow characteristics. The procedure uses storage and discharge relationships and/or wave velocity.

Runoff

The excess portion of precipitation that does not infiltrate into the ground, but "runs off" and reaches a stream, water body or storm sewer.

Runoff Coefficient

The ratio of the amount of water that is NOT absorbed by the surface to the total amount of water that falls during rainstorm.

Sediment

Soil material that is transported from its site of origin by water. May be in the form of bed load, suspended or dissolved.

Sheetflow

Runoff which flows over the ground surface as a thin, even layer, not concentrated in a channel.

Short Circuiting

The passage of runoff through a BMP in less than the theoretical or design detention time.

Soil Group, Hydrologic

A classification of soils by the Soil Conservation Service into four runoff potential groups. The groups range from “A Soils” which are very permeable and produce little runoff, to “D Soils” which are relatively impermeable and produce much more runoff.

Spillway

A depression in the embankment of a pond or basin, used to pass peak discharges in excess of the design storm.

Storm water Wetland

A conventional storm water wetland is a shallow pool that creates growing conditions suitable for the growth of marsh plants. Storm water wetlands are designed to maximize pollutant removal through wetland uptake, retention and settling. These constructed systems are not located within delineated natural wetlands.

Stream

By MDNR definition: "a river, creek, or surface waterway that may or may not be defined by Act 40, P.A. of 1956; has definite banks, a bed, and visible evidence of continued flow or continued occurrence of water, including the connecting water of the Great Lakes." Even if water flow is intermittent, it is classified as a stream.

Swale

A natural depression or wide shallow ditch used to temporarily convey, store, or filter runoff.

Tailwater

The depth of water at the downstream end of a culvert or crossing.

Time of Concentration

The time it takes for surface runoff to travel from the hydraulically farthest portion of the watershed to the design point.

Timing

The relationship in time of how runoff from sub-watersheds combines within a watershed.

Underdrain

Perforated pipe installed to collect and remove excess runoff.

Watershed

The complete area or region of land draining into a common outlet such as a river or body of water.

Weir

A structure that extends across the width of a channel, and is used to impound, measure, or in some way alter the flow of water through the channel.

Wetland Mitigation

A regulatory term that refers to the process of constructing new wetland acreage to compensate for the loss of natural wetlands during the development process. Mitigation seeks to replace structural and functional qualities of the natural wetland type that has been destroyed. Storm water wetlands typically do not count for credit as mitigation, because their construction does not replicate all the ecosystem functions of a natural wetland.

Wetted Perimeter

The wetted surface of a stream or culvert cross section that causes resistance to flow. The water to surface interface is a distance, typically expressed in feet.

APPENDIX B

Major Categories of Non-point Source Pollutants and Associated Impacts

Sediments

Source: Construction sites, agricultural lands and other disturbed and/or non-vegetated lands, including eroding stream banks.

Impacts: Once deposited, sediment can decrease the storage capacity of a water body, as well as smother organisms that dwell on the bottom and destroy their habitat. Suspended sediment can lower the transmission of light through water, and interfere with animal respiration and digestion. Contaminated sediments act as a reservoir for particulate forms of pollutants, such as organic matter, phosphorus, or metals that can be released later.

Nutrients (e.g. Phosphorous and Nitrogen)

Source: Septic systems, fertilizers, animal waste, detergents and plant debris.

Impacts: Slow moving waters become choked with nutrient induced algae and weeds that take up dissolved oxygen in the water needed by fish and other aquatic life. This reduction in dissolved oxygen can also cause pollutants trapped within sediments to be released back into the water column.

Temperature Enhancement

Source: Impervious surfaces collect heat and warm storm water as it passes over them and into receiving waterways. The creation of storage ponds and impoundments, and the removal of trees and other vegetation that shade streambanks increases the surface area of water exposed to solar heating.

Impacts: Temperature enhancement severely interferes with cold-water organisms such as trout and stoneflies, and may cause their extinction in intensively developed areas.

Toxic Compounds

Source: Pesticides, Road de-icing materials, motor vehicles, industrial activities, atmospheric deposition, and illicit dumping and sewage connections.

Impacts: Toxic substances can degrade the appearance of water surfaces, lower dissolved oxygen, stress sensitive flora and fauna and enter into the aquatic food chain.

Bacteria

Source: Animal waste (including pets and birds), failing septic systems and illicit sewer connections.

Impacts: Increased bacteria levels can pose health risks and close or restrict the use of recreational areas.

Litter and Debris (Organic and non-organic)

Source: Urban and suburban landscapes contribute grass clippings and leaves. Non-organic debris is generated by careless disposal practices, e.g. street litter.

Impacts: Litter, leaves and trash wash through the storm drain system, clogging pond outlets and creating large debris jams within streams and floodplains. In addition, organic materials require oxygen to decompose and so lower the level of dissolved oxygen available to aquatic life.

APPENDIX C

Special Areas of Concern

The Middle Huron River Phosphorus Total Maximum Daily Load (TMDL)

Excessive phosphorus in the waters of the Huron River is responsible for excess weed growth and algal blooms that have interfered with recreational uses of the River's impoundments and are undermining aesthetic values as well. In 1996, the Huron River Watershed Council working on behalf and in partnership with 21 communities in the watershed – most within Washtenaw County, and MDEQ agreed upon a strategy to meet significant goals of reduction of phosphorus loadings to the Huron River. Much of the reductions, necessary to meet DEQ imposed Total Maximum Daily Load (or TMDL) requirements must be achieved through improving the quality of storm water runoff.

Many BMPs, such as wet extended detention ponds and pond wetland systems, have demonstrated superior phosphorus reduction ability. These should be used in the Middle Huron watershed as the BMPs of choice wherever feasible. Map 1 displays the Middle Huron River Phosphorus Reduction Project Area. Table 1 displays the phosphorus removal capabilities of various BMPs based on the most current literature. All BMPs are shown in the diagrams contained in Appendix D. Selected references for Storm Water Best Management Practices (Appendix N) provide information regarding BMP's that achieve superior phosphorus removal.

The Paint and Johnson Creeks - Thermally Sensitive Streams

The Paint Creek and the Johnson Creek are cold-water streams that support aquatic life sensitive to increases in water temperature. Their watersheds are displayed on Map 2. Until 1995, both creeks were stocked each spring by the Michigan Department of Natural Resources with over 7000 brown trout. Angler license fees and federal excise taxes that are paid on fishing tackle pay for the stocking. At this time, the MDNR has discontinued the trout stocking of the Paint Creek. It is hoped that this stocking will be resumed.

The Paint Creek and the Johnson Creek are also inhabited by naturally occurring, thermally sensitive fish populations. In addition to the fish that had been stocked in the past, the Paint Creek has its own brown trout population, and it also supports a small population of steelhead that occasionally run up the stream from Lake Erie. The Johnson Creek is home to native populations of red side dace (a threatened species), black side dace, and mottled sculpin. All of these species are negatively impacted by increases in water temperature.

Some of the most effective storm water site controls involve storage facilities such as retention and detention ponds. When thermal impact is not a major concern, wet ponds are generally preferable to dry ponds, and ponds that detain storm water for an extended period of time are required where wet ponds are not feasible. However, wet and extended detention ponds tend to increase the exposure of runoff to solar warming before releasing it. Therefore, where thermal impacts are a concern, such as in the Paint and Johnson Creek watersheds, extended detention requirements may be reduced. Shade plantings on the west and south sides of facilities to provide additional protection against solar warming are also strongly encouraged. Retention facilities provide another option. Infiltration approaches to storm water management are encouraged where soils and site conditions allow.

Map 1

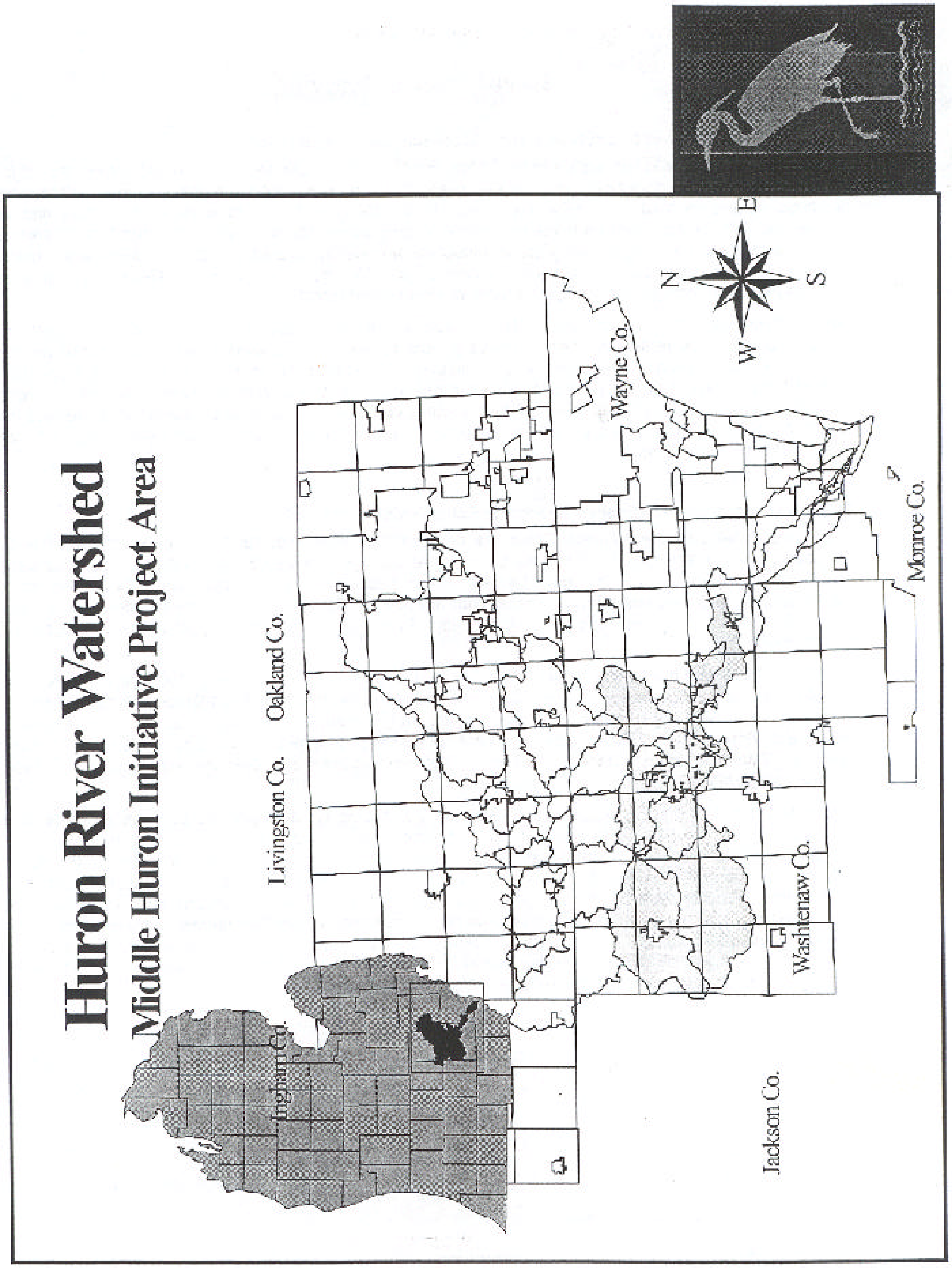

Huron River Watershed
Middle Huron Initiative Project Area
N
E
S
W
Livingston Co.
Oakland Co.
Wayne Co.
Monroe Co.
Washtenaw Co.
Jackson Co.
Ingham Co.

Table 95.3: Comparison of Median Pollutant Removal Efficiencies Among Selected BMP Groups: Conventional Pollutants

BMP Groups	N	Median Removal Rate For Stormwater Pollutants (%) TSS	TP	Sol P	Total N	Nitrate	Carbon
Detention Pond	2	7	10	2	5	3	(-1)
Dry ED Pond	6	61	19	(-9)	31	9	25
Wet Pond	30	77	47	51	30	24	45
Wet ED Pond	6	60	58	58	35	42	27
PONDS [a]	36	67	48	52	31	24	41
Shallow Marsh	14	84	38	37	24	78	21
ED Wetland	5	63	24	32	36	29	ND
Pond/Wetland	11	72	54	39	13	15	4
WETLANDS	35	78	51	39	21	67	28
Surface Sand Filters	6	83	60	-37	32	(-9)	67
FILTERS [b]	11	87	51	-31	44	(-13)	66
CHANNELS	9	0	(-14)	(-15)	0	2	18
SWALES [c]	9	81	29	34	ND	38	67

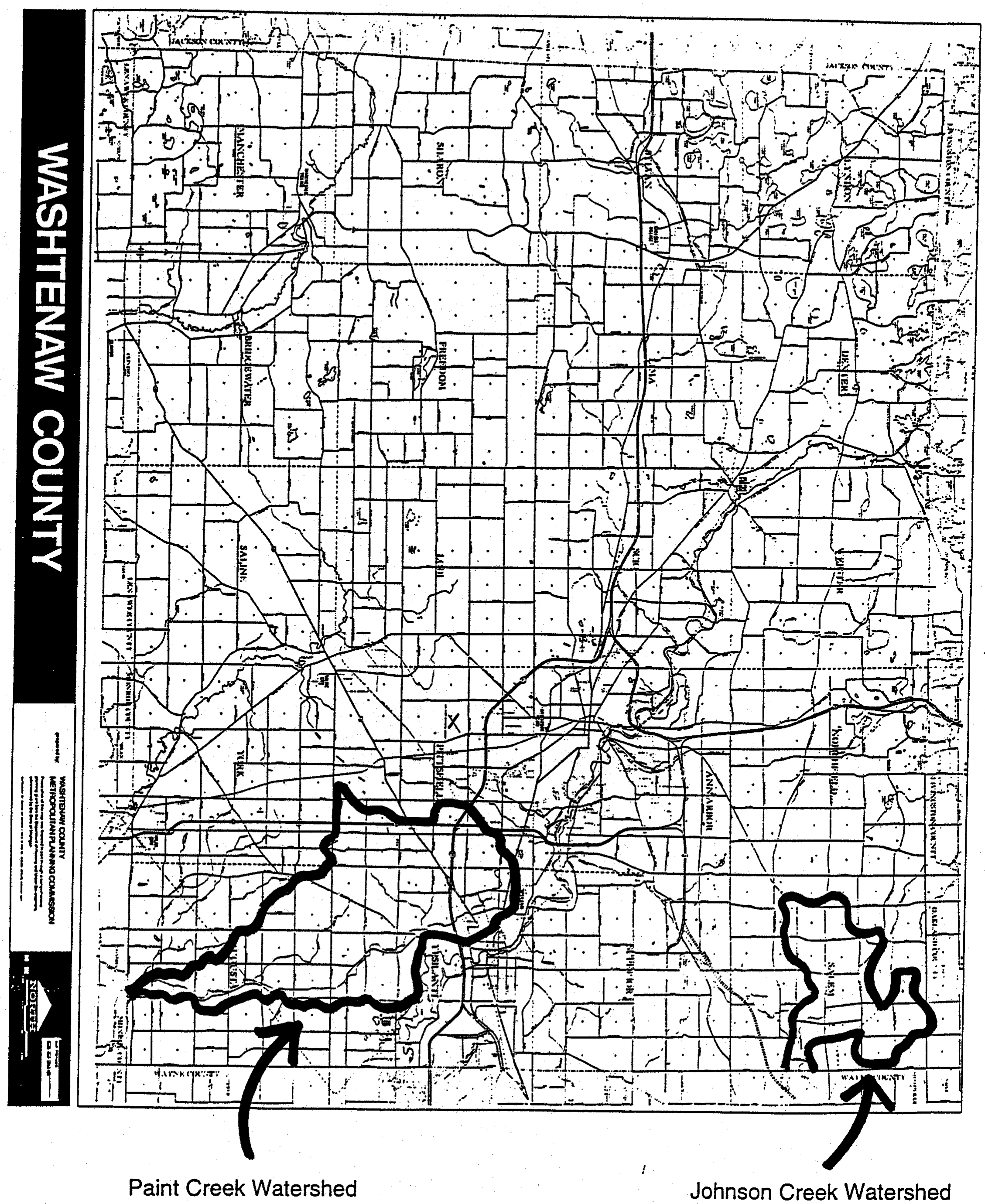
N = Number of performance monitoring studies. The actual number for a given parameter is likely to be slightly less.
Sol P = Soluble phosphorus, as measured as ortho-P, soluble reactive phosphorus or biologically available phosphorus.
Total N = Total Nitrogen. Carbon= Measure of organic carbon (BOD, COD or TOC).
[a] Excludes conventional and dry ED ponds.
[b] Excludes vertical sand filters and vegetated filter strips.
[c] Includes biofilters, wet swales and dry swales.

Table 95.4: Median Stormwater Pollutant Removal Reported for Selected BMP Groups – Fecal Coliform Bacteria, Hydrocarbons and Selected Trace Metals

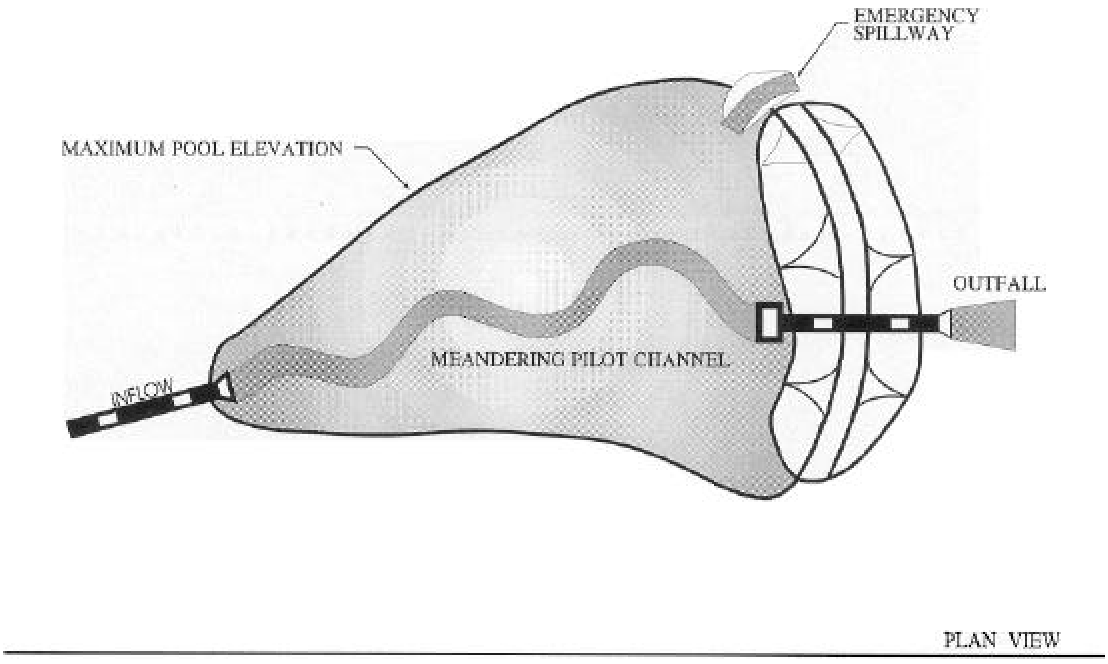
BMP Groups	Median Stormwater Pollutant Removal [d] Bacteria [e]	HC [f]	Cd	Copper	Lead	Zinc
Detention and Dry ED Ponds	ND	ND	54%	26%	43%	26%
PONDS [a]	65%	83%	24	57	73	51
WETLANDS	77	90	69	39	63	54
FILTERS [b]	55	81	—	34	71	80
CHANNELS	0	ND	55	14	30	29
SWALES [c]	(-50)	62	42	51	67	71

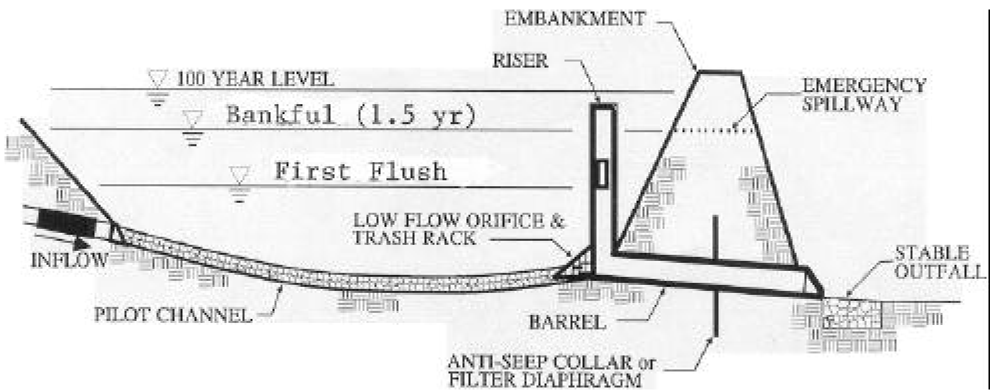
[a] Excludes dry ED and conventional detention ponds.
[b] Excludes vertical sand filters and vegetated filter strips.
[c] Includes biofilters, wet swales and dry swale.
[d] N is less than 5 for some BMP groups for bacteria, TPH and Cd, and medians should be considered provisional.
[e] Bacteria values represent mean removal rates.
[f] HC = hydrocarbons measured as total petroleum hydrocarbons or oil/grease.

Areas Sensitive to Thermal Impact: Paint Creek and Johnson Creek Watersheds



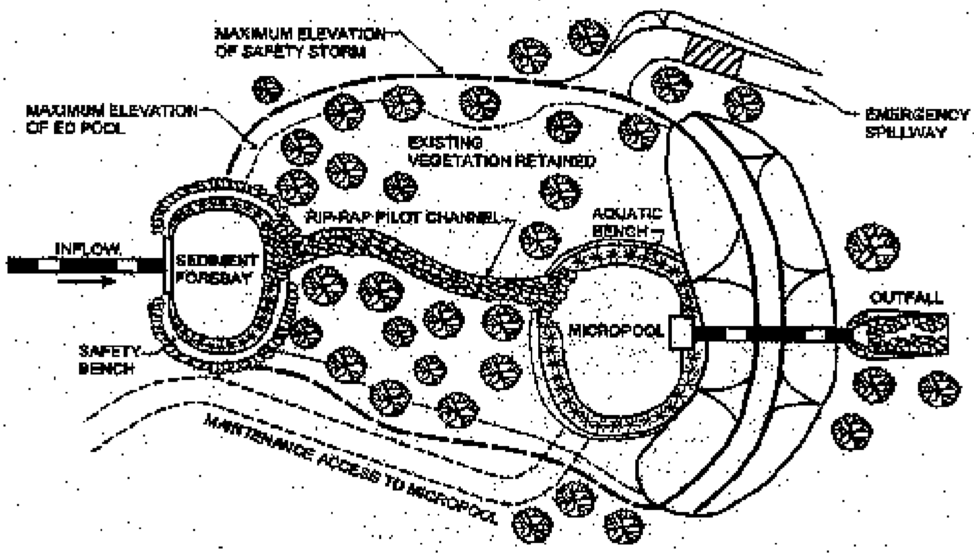
Example of Conventional Storm Water Detention Pond



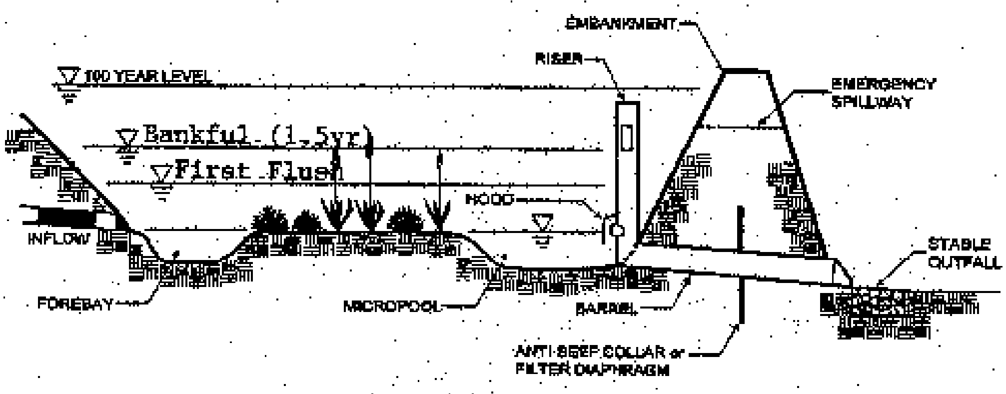


Source: Adapted from State of Maryland Storm Water Design Manual, Dec. 1999

Example of "Micropool" Extended Detention Pond



PLAN VIEW

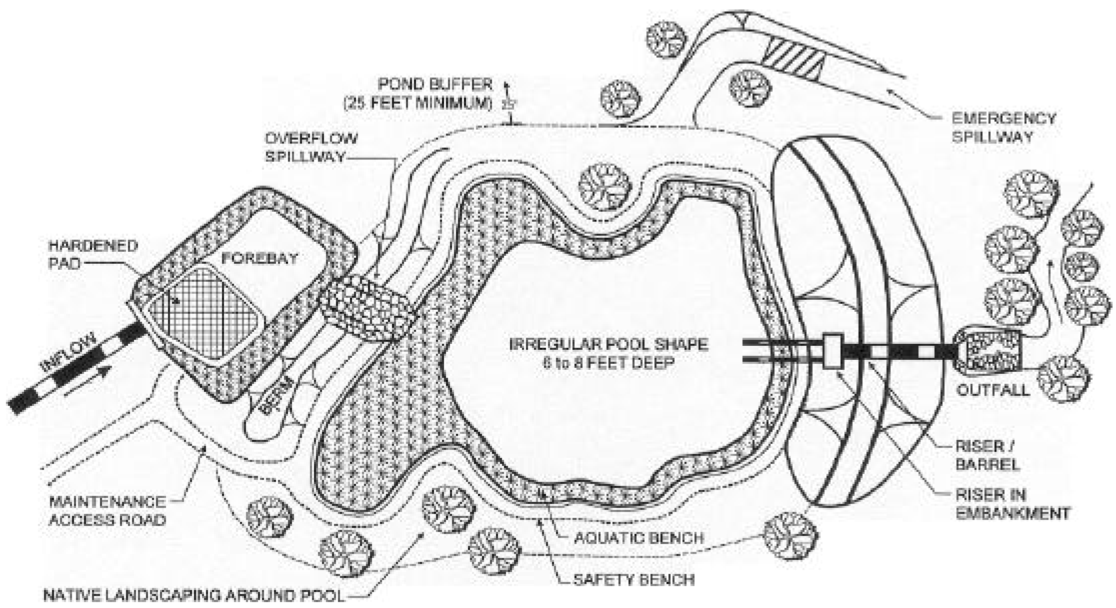


PROFILE

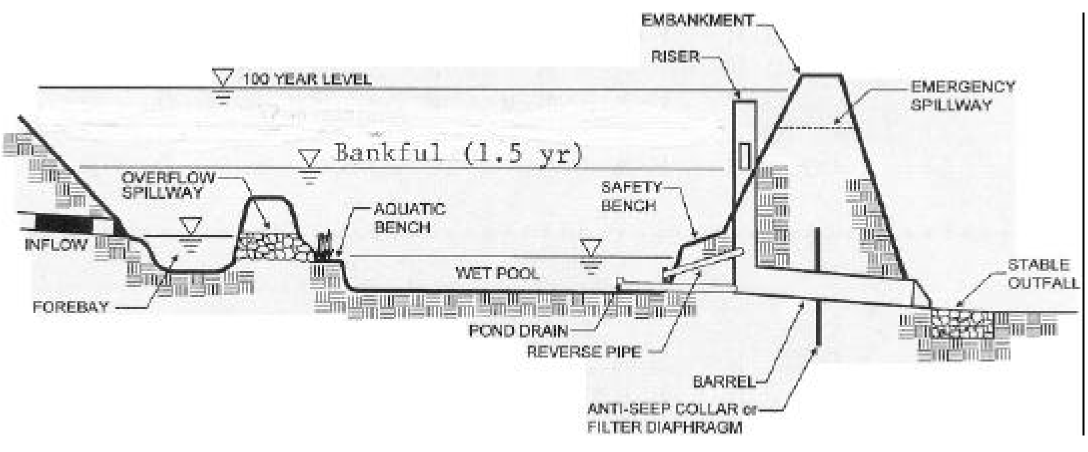
Source: Adapted from State of Maryland Storm Water Design Manual, Dec. 1999.

A micropool is provided in an extended detention pond to prevent resuspension of previously settled sediments and prevent clogging of the low flow orifice.

Example of Wet Pond



PLAN VIEW

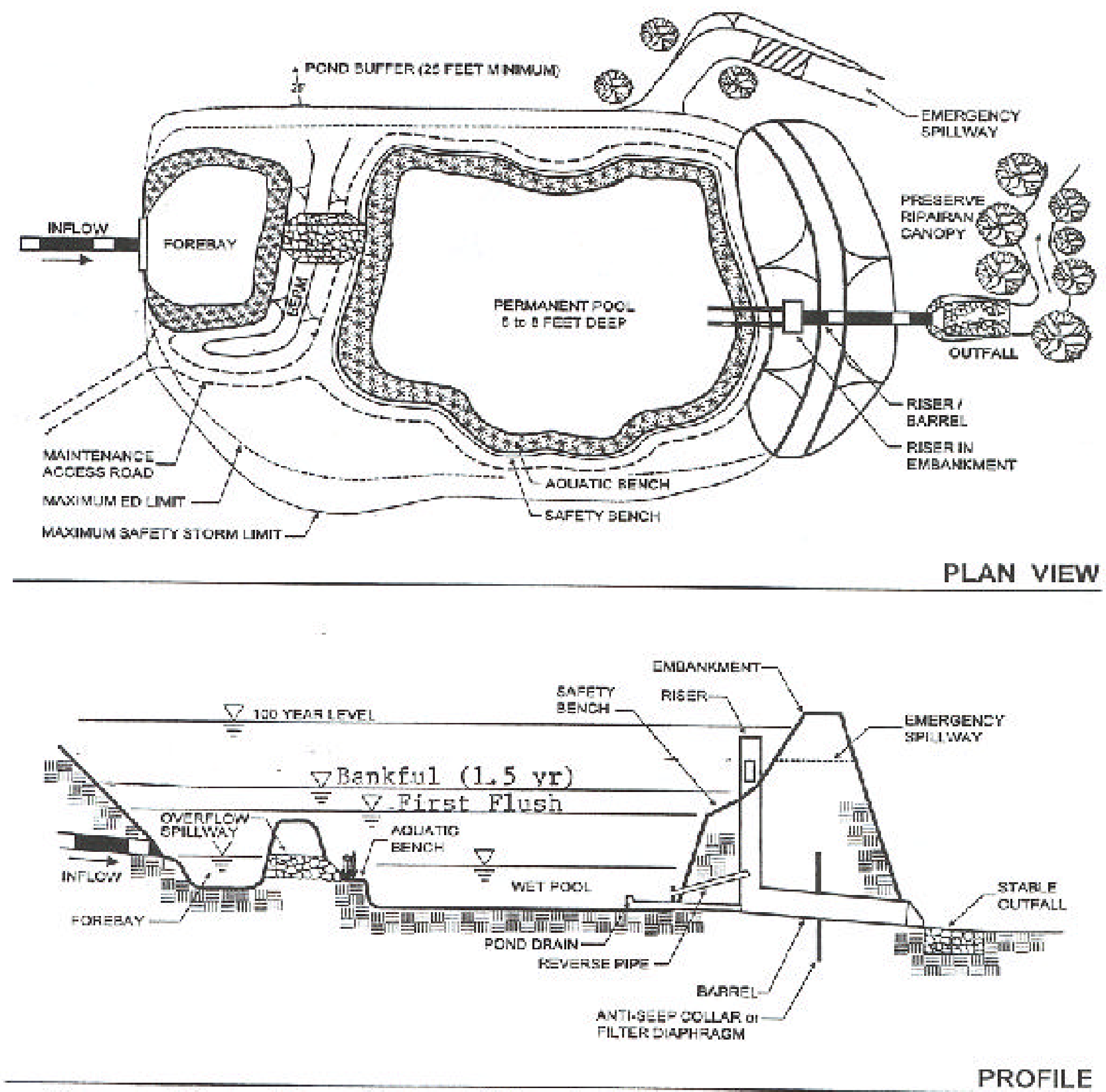


PROFILE

Source: Adapted from State of Maryland Storm Water Design Manual, Dec. 1999,

A wet pond provides all water quality volume storage in a permanent pool.

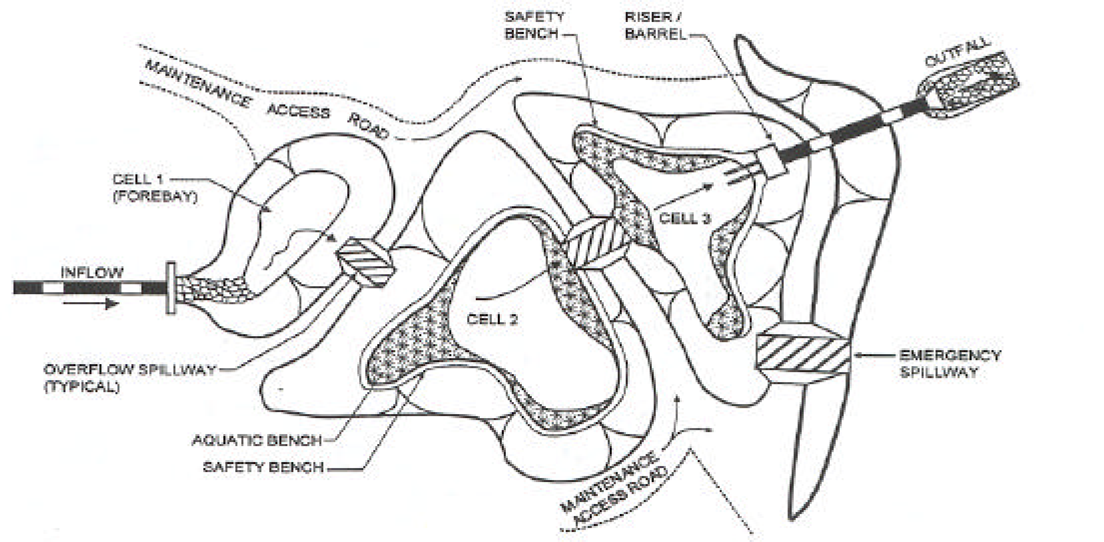
	Example of Wet Extended Detention Pond	



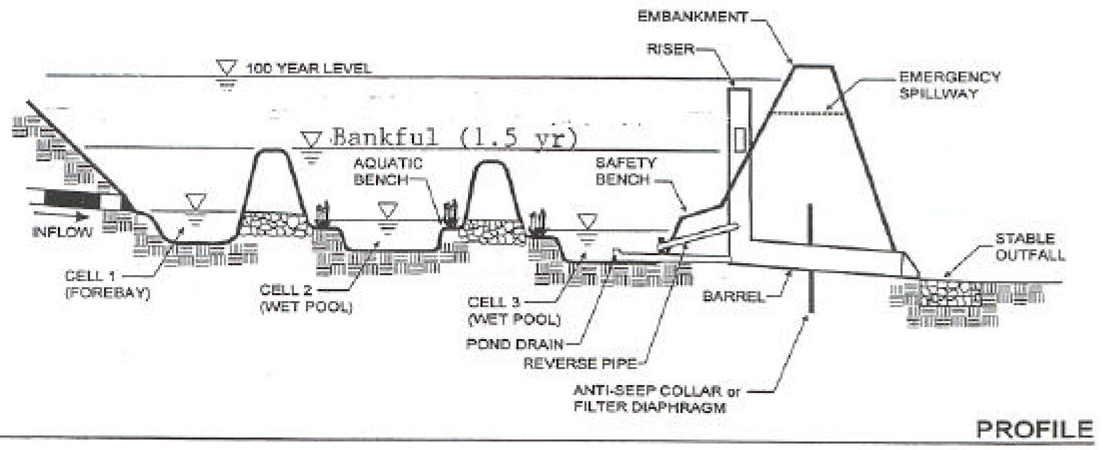
Source: Adapted from State of Maryland Storm Water Design Manual, Dec. 1999.

The wet ED pond provides water quality storage through a combination of permanent pool and extended detention storage.

Example of Multiple Pond System



PLAN VIEW

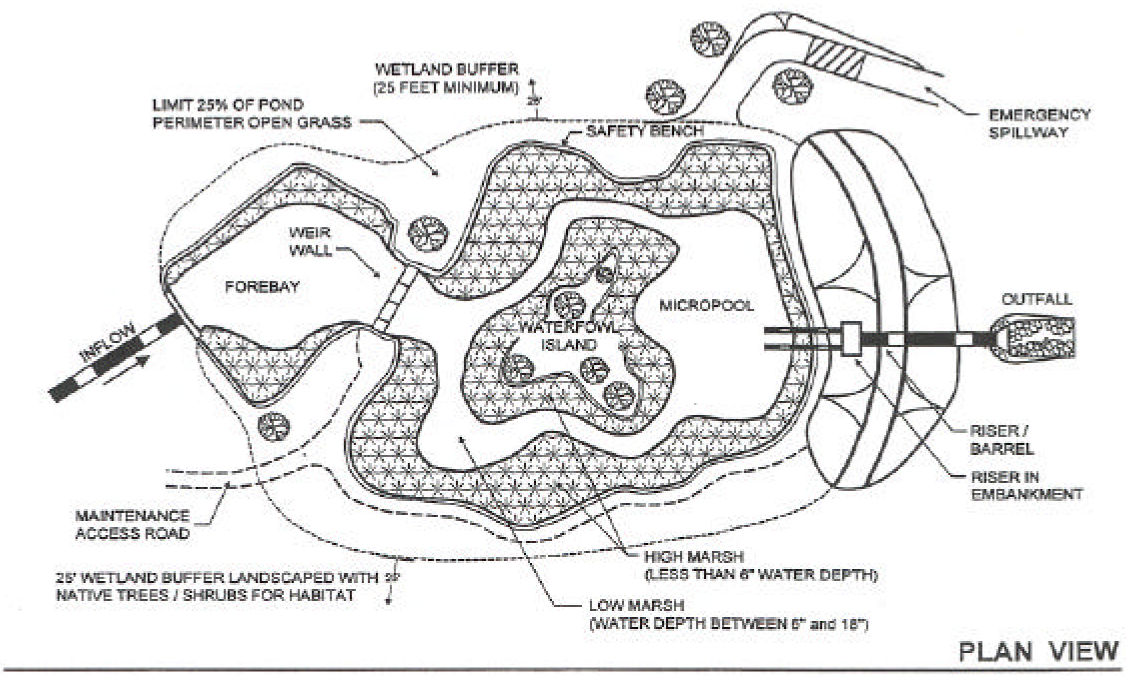


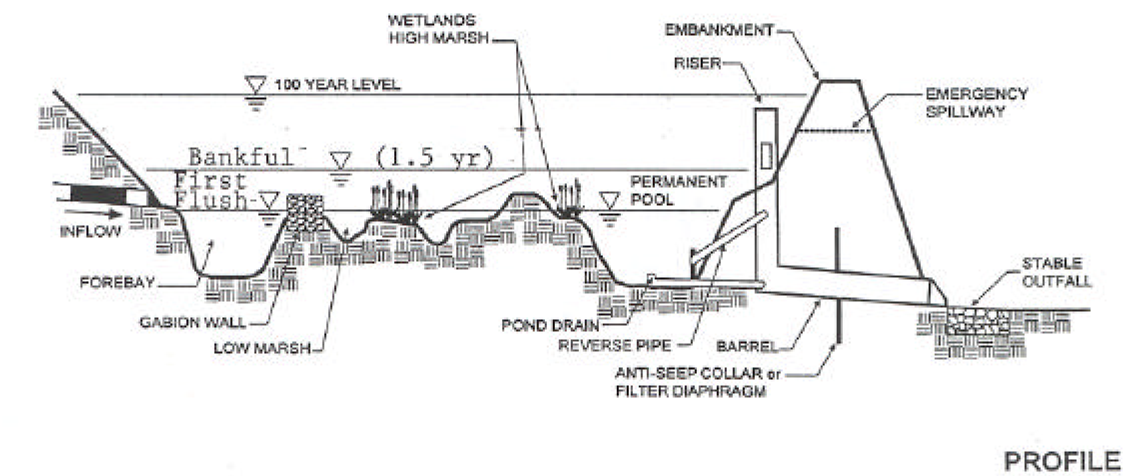
PROFILE

Multiple pond systems provide WQ_v storage in two or more cells that create longer pollutant removal pathways.

Source: Adapted from State of Maryland Storm Water Design Manual, Dec. 1999.

Example of Shallow Wetland

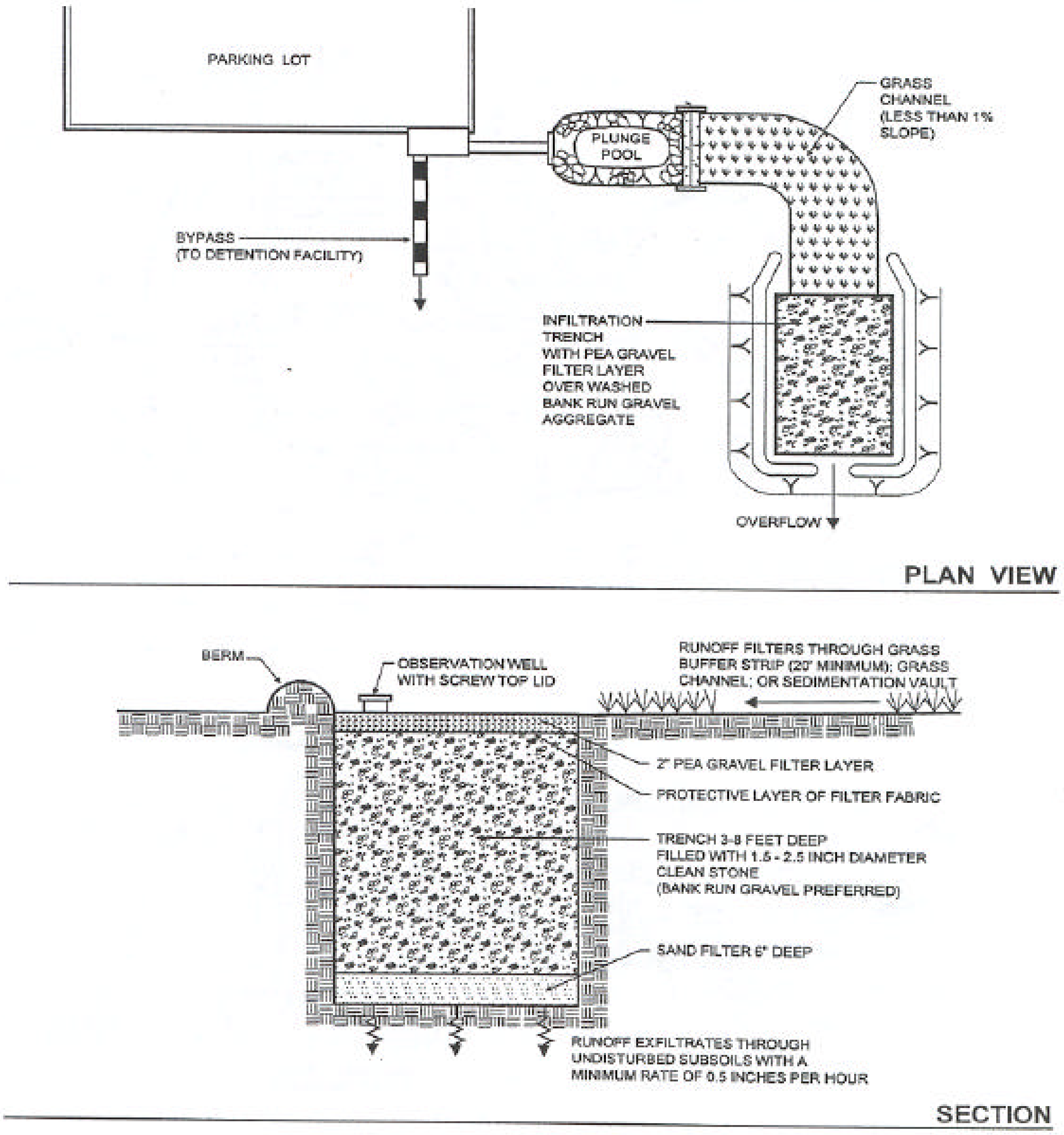




Shallow wetlands provide WQ_v in a shallow pool that has a large surface area.

Source: Adapted from State of Maryland Storm Water Design Manual, Dec. 1999.

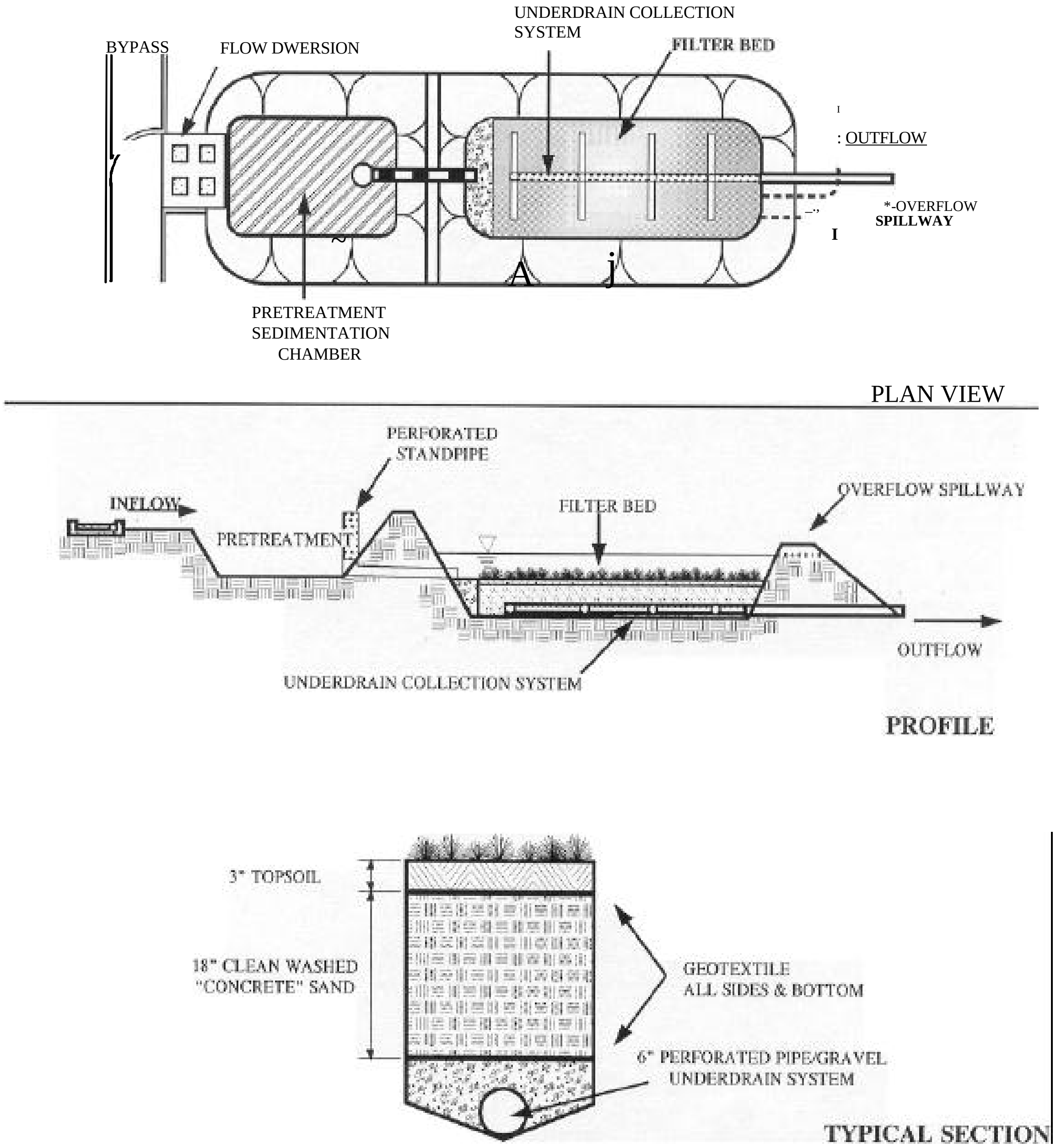
Example of Infiltration Trench



The infiltration trench provides groundwater recharge volume and water quality volume (WQ_v) in one location.

Source: Adapted from State of Maryland Storm Water Design Manual, Dec. 1999.

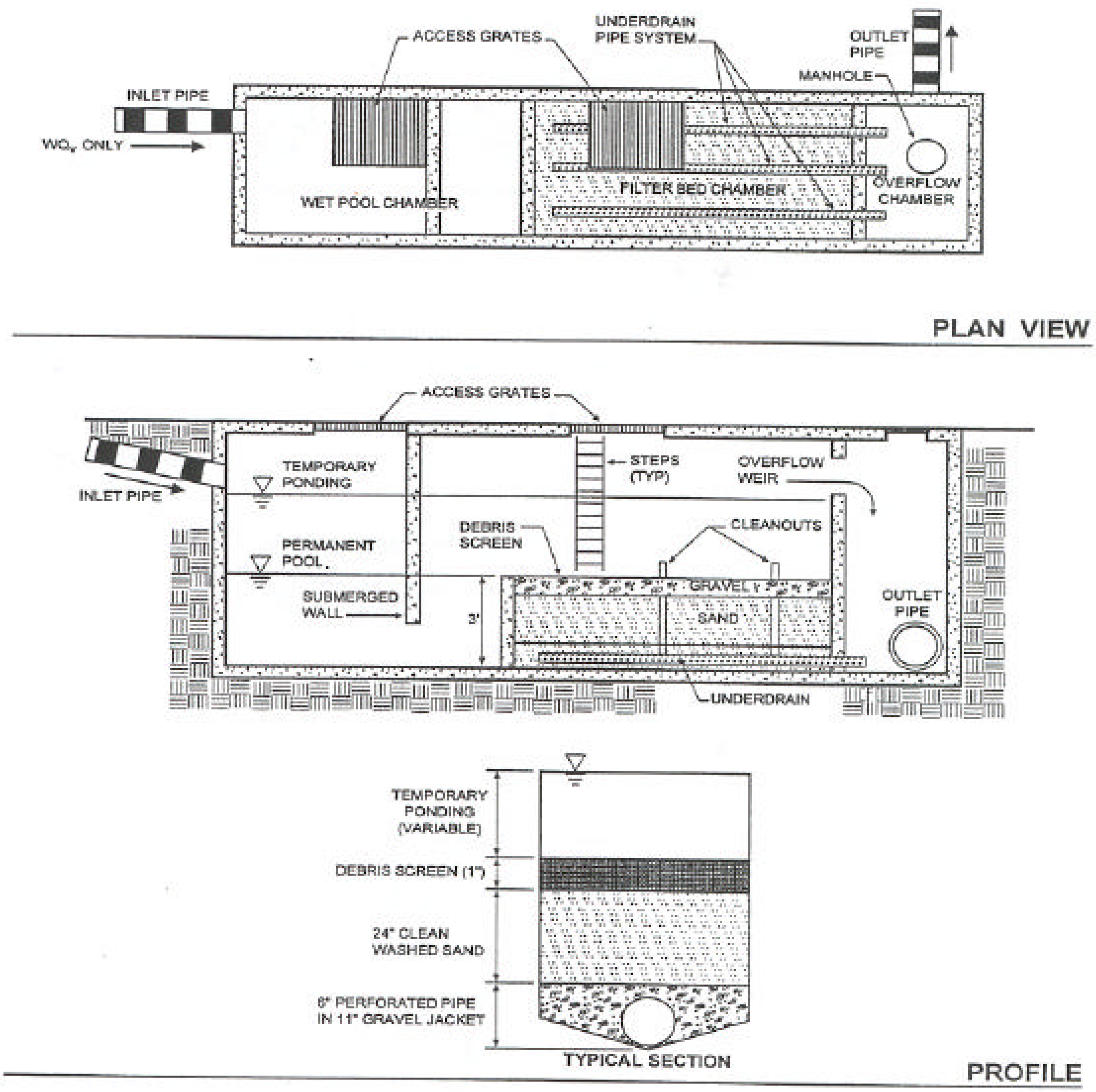
Example of Surface Sand Filter



Surface sand filters can serve the largest drainage area of all the filtering systems.

Source: Adapted from State of Maryland Storm Water Design Manual, Dec. 1999.

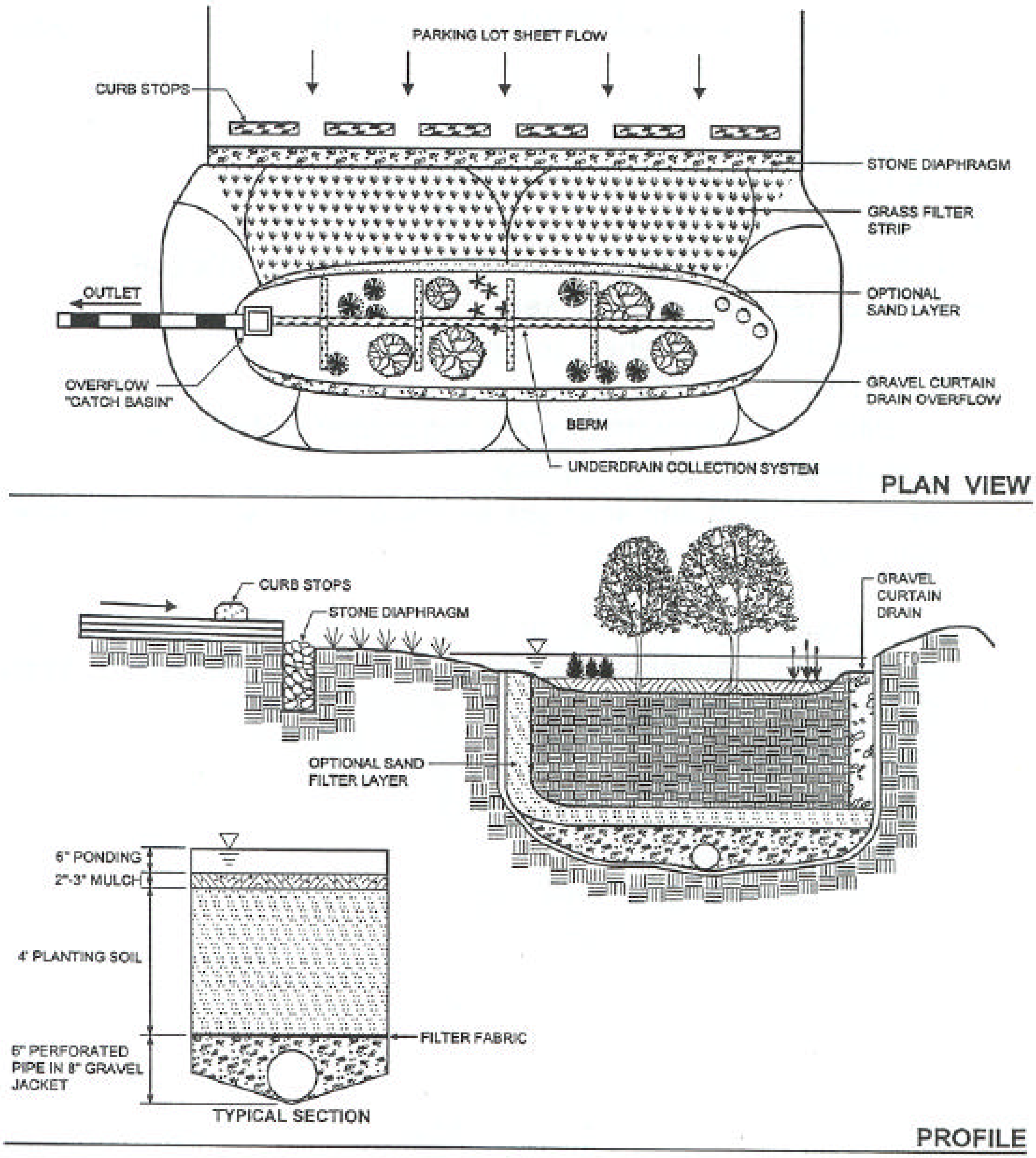
Example of Underground Sand Filter



The underground sand filter is an option for providing WQ$_v$ where space is limited.

Source: Adapted from State of Maryland Storm Water Design Manual, Dec. 1999.

Example of Bioretention



Bioretention combines open space with stormwater treatment.

Water-tolerant plantings are essential.

Source: Adapted from State of Maryland Storm Water Desgin Manual, Dec. 1999.

APPENDIX E

Storm Water Pollutant Hotspots

The following land uses and activities are deemed *storm water hotspots:*

- Vehicle salvage yards and recycling facilities #
- Vehicle service and maintenance facilities
- Vehicle and equipment cleaning facilities #
- Fleet storage areas (bus, truck, etc.) #
- Industrial sites (for SIC codes outlined in Appendix D-6)
- Marinas (service and maintenance) #
- Outdoor liquid container storage
- Public works storage areas
- Facilities that generate or store hazardous materials #
- Commercial container nursery
- Other land uses and activities as designated by an appropriate review authority

# Indicates that the land use or activity is required to prepare a storm water pollution prevention plan under the EPA NPDES Storm Water Program (see Appendix D-6).

APPENDIX F

CONSTRUCTION, OPERATION AND MAINTENANCE OF CLUSTER WASTEWATER TREATMENT SYSTEMS, COMMUNITY DRAIN FIELDS AND OTHER SANITARY TREATMENT FACILITIES UNDER THE MICHIGAN DRAIN CODE

Sections 280.433 of the Michigan Drain Code authorizes the establishment of County drainage districts for the purpose of construction, operation and maintenance of sanitary wastewater treatment facilities. Special assessment districts can be set up through procedures similar to those utilized for storm water management (drainage) districts under the Code. The facilities may be constructed privately with jurisdiction subsequently assumed by the County Drain Commissioner for operation, maintenance and replacement, or may be constructed by the Drain Commissioner. Once a drainage district is established and operating, all future costs and responsibilities rest with the special assessment district.

To date, the Washtenaw County Drain Commissioner has not been involved with the operation of sanitary treatment facilities. Because, however, inquiry has been made regarding policies relative to such systems, the following preliminary guidance has been drafted to describe the terms and conditions under which establishment of drainage districts to manage operations of sanitary facilities may be considered. (It is assumed that facilities will be constructed by the private developer, and jurisdiction subsequently assumed by the Drain Commissioner.)

- In order to be considered by the Washtenaw County Drain Commissioner, the system must be proposed to alleviate an existing health problem, or to allow clustering of development so as to preserve natural features and open space in a proposed new development. A minimum of 50% preserved open space will be required.

- The proposed density of the development to be served must be consistent with both the County's and the local government's master plans.

- Formal written request from the local government in which the district would be located is a prerequisite to consideration of establishment of a county drainage district for cluster systems, community drain fields or other waste treatment facilities. Private developers' proposals will not be considered unless accompanied by request of the affected community(ies).

- Approval must be obtained for system design and installation by the Office of the County Drain Commissioner, County Environment and Infrastructure Services Division, as well as MDEQ where required.

- The private developer of the system will pay all administrative, technical review and inspection costs. The developer must fund the cost of review of plans, and supervision of installation, by an independent professional engineer under contract to the Office of the Washtenaw County Drain Commissioner.

- The system must be warranted, at the developer's expense, through 2 freeze-thaw periods.

- A maintenance program and a contract for ongoing maintenance with a private or public entity acceptable to the Office of Drain Commissioner must be in place. Costs should be borne by the Condominium or Subdivision Association of the area served, though the Drain Commissioner will have necessary work performed and levy special assessments to cover the cost incurred should the homeowners' association fail to fulfill this obligation. A schedule for reporting to the Drain Commissioner, as well as a timeframe for response by the homeowners' group upon notification of needed maintenance must be specified in the Rules or Agreement governing its operation.

- A clear definition must be set forth in the Subdivision Agreement or Condominium Master Deed as to those facilities that remain the responsibility of individual property owners for operation, maintenance and replacement, verses those that fall under jurisdiction of the County Drainage District. All property owners will bear equally in paying costs of any service, repair or replacement of the County portions of the system.

- Provision must be made for annual inspection of system by the Washtenaw County Environment and Infrastructure Services Division, or its designee, at property owners' expense.

- An escrow fund sufficient to cover replacement of the system shall be established in the name of the Drainage District at the time the County assumes responsibility.

Other terms and conditions may be developed to serve site specific needs on a case-by-case basis.

APPENDIX G

Engineer's Certificate of Construction

Date: _________________

Development Name:____

Township of:______________________   Section:________

Washtenaw County, Michigan

I hereby certify that the construction of the drainage facilities of the subdivision known as _______________________________________ is complete and that:

1) I have supervised inspection of the construction.

2) All improvements to date have been installed in accordance with construction plans approved by the Washtenaw County Drain Commissioner.

3) Reports of construction material tests have been filed with the Washtenaw County Drain Commissioner.

Signed: ___________________________

Registered Professional Engineer

NOTE: The engineer's certificate must be stamped with the engineer's seal. The certificate submitted must be the original.

APPENDIX H

Detention Basin Design Utilizing the Rational Method of Runoff Determination

The following procedure utilizing the Rational Method of Design has been adopted from the Erosion Control Manual of Oakland County, Michigan. This method has been revised to include the particular requirements of the Washtenaw County Drain Commissioner.

A. Determine the acreage tributary to the detention basin and the composite runoff coefficient. The runoff coefficient must be based on the area and surface types tributary to the basin.

Example Extended Detention Pond Volume Calculations and Outlet Design

The following is an example for one method of extended detention pond design that meets the minimum standards of the Washtenaw County Drain Commissioner. More complex systems are preferred and shall be provided where feasible. The example is based on a 7.3 acre site with a runoff coefficient of 0.75. The release rate specified in the example is based on a pond which outlets to an existing watercourse that is adequate to effectively handle a concentrated flow of water from the proposed development.

C= 0.75
A= 7.3 Ac.

The allowable release rate is 0.15 cfs/ac:

$$Q_a = \left(0.15\tfrac{cfs}{ac}\right)(A)$$
$$Q_a = \left(0.15\tfrac{cfs}{ac}\right)(7.3ac)$$
$$Q_a = 1.10cfs$$

<u>100-Year Flood Volume Required</u>

$$Q_o = \frac{Q_a}{AC}$$
$$Q_o = \frac{1.10cfs}{(7.3ac)(0.75)}$$
$$Q_o = 0.20\tfrac{cfs}{ac-imp}$$

$$T = -25 + \sqrt{\frac{10312.5}{Q_o}}$$
$$T = -25 + \sqrt{\frac{10312.5}{0.2\tfrac{cfs}{ac-imp}}}$$
$$T = 202.1\min$$

$$V_s = \frac{16500T}{T+25} - 40Q_oT$$

$$V_s = \frac{(16500)(202.1\min)}{202.1\min + 25} - (40)\left(0.2\tfrac{cfs}{ac-imp}\right)(202.1\min)$$

$$V_s = 13066.8\tfrac{cf}{ac-imp}$$

$$V_t = V_s AC$$

$$V_t = \left(13066.8\tfrac{cf}{ac-imp}\right)(7.3ac)(0.75)$$

$$V_t = 71541cf$$

Bankfull Flood Volume

The bankfull storm is defined as the 24 hour, 1.5-year storm event:

$$V_{bf} = (2.25'')\left(\tfrac{1'}{12''}\right)\left(\tfrac{43560\ ft^2}{1ac}\right)AC$$

$$V_{bf} = \left[(2.25'')\left(\tfrac{1'}{12''}\right)\left(\tfrac{43560\ ft^2}{1ac}\right)\right](7.3ac)(0.75) = (8170)(7.3)(0.75)$$

$$V_{bf} = 44731cf$$

First Flush Volume

The first flush storm is defined as the first 0.5" of rain over the entire watershed:

$$V_{ff} = (0.5'')\left(\tfrac{1'}{12''}\right)\left(\tfrac{43560\ ft^2}{1ac}\right)AC$$

$$V_{ff} = \left[(0.5'')\left(\tfrac{1'}{12''}\right)\left(\tfrac{43560\ ft^2}{1ac}\right)\right](7.3ac)(0.75) = (1815)(7.3)(0.75)$$

$$V_{ff} = 9937cf$$

Storage Provided

Elevation	Area (sf)	Depth (ft)	Volume (cf)	Total Volume (cf)
94.0	28,960	1	26,640	80,080
93.0	24,320	1	22,240	53,440
92.0	20,160	1	18,000	31,200
91.0	15,840	1	13,200	13,200
90.0	10,560	1	0	0

Storage Elevations

First flush:

$$\frac{91.0-90.0}{13200-0} = \frac{x_{ff}-90.0}{9937-0}$$

$$x_{ff} = 90.75(approx.90.8)$$

Bankfull:

$$\frac{93.0-92.0}{53440-31200} = \frac{x_{bf}-92.0}{44731-31200}$$

$$x_{bf} = 92.61(approx.92.6)$$

100 year:

$$\frac{94.0-93.0}{80080-53440} = \frac{x_{100}-93.0}{71541-53440}$$

$$x_{100} = 93.68(approx.93.7)$$

Outlet Control Structure

First flush of runoff:

The *average* allowable release rate for runoff resulting from 0.5” of rain over watershed area in 24 hours:

$$Q_{ff} = \frac{V}{T_{24}}$$

$$Q_{ff} = \frac{9937cf}{(24hr)\left(\frac{3600\sec}{1hr}\right)}$$

$$Q_{ff} = 0.115cfs$$

Place openings in standpipe at bottom of basin (90.0):

To determine the appropriate size orifice to release the first flush volume, an average head value can be used in the orifice equation. If the basin is designed to be trapezoidal in shape, 2/3 of the total head is an acceptable approximation for the average head.

$$h_{ave} = \tfrac{2}{3}\left(elev._{ff} - elev._{bot}\right)$$

$$h_{ave} = \tfrac{2}{3}(90.8 - 90.0)$$

$$h_{ave} = 0.53\,ft$$

$$A = \frac{Q_{ff}}{0.62\sqrt{2gh_{ave}}}$$

$$A = \frac{0.115cfs}{0.62\sqrt{2\left(32.2\,\frac{ft}{\sec^2}\right)(0.53\,ft)}}$$

$$A = 0.032sf$$

The number and size of orifices to meet the area requirements is variable. In general larger holes are preferable, although multiple outlets should be used if possible. For this example, we will choose a 1.25” diameter orifice (which has an area of 0.0085 sf).

$$\# = \frac{0.032sf}{0.0085sf}$$

$$\# = 3.76$$

Therefore, use 3 – 1.25” diameter holes @ elev. 90.0

The detention time for 3 – 1.25” diameter holes is:

$$Q_{ff}^{new} = A_{ff}^{new}(0.62)\sqrt{2gh_{ave}}$$

$$Q_{ff}^{new} = (3)(0.0085sf)(0.62)\sqrt{2\left(32.2\,\frac{ft}{\sec^2}\right)(0.53\,ft)}$$

$$Q_{ff}^{new} = 0.092cfs$$

$$T_{ff}^{new} = \frac{V_{ff}}{Q_{ff}^{new}}$$

$$T_{ff}^{new} = \frac{9937cf}{(0.092cfs)\left(\frac{3600\sec}{1hr}\right)}$$

$$T_{ff}^{new} = 30.0hr$$

<u>Bankfull flood:</u>

The bankfull flood must be detained 36-48 hours; check the discharge through the first flush orifice to see if additional holes are necessary:

$$h_{ave} = \tfrac{2}{3}\left(elev._{bf} - elev._{bot}\right)$$

$$h_{ave} = \tfrac{2}{3}(92.6 - 90.0)$$

$$h_{ave} = 1.73$$

$$Q = 0.62A_{ff}\sqrt{2gh_{ave}}$$

$$Q = (0.62)(3)(0.0085sf)\sqrt{(2)\left(32.2\tfrac{ft}{\sec^2}\right)(1.73ft)}$$

$$Q = 0.17cfs$$

$$T = \frac{V_{bf}}{Q}$$

$$T = \frac{44731cf}{(0.17cfs)\left(\frac{3600\sec}{1hr}\right)}$$

$$T = 73.1hr$$

Because the holding time exceeds 48 hours, additional orifices in the standpipe are required. The release rate may be considered occurring in two phases; the release rate when both the ff and bf orifices are contributing, and the release rate when the water elevation is below the bf orifice (ff elevation). The time for the ff volume to release was calculated above, so the remaining volume (bf volume – ff volume) must be released so the total detention time does not exceed 36 – 48 hours.
A target detention time of 44 hours was chosen for this example.

$$V_{rem} = V_{bf} - V_{ff}$$

$$V_{rem} = 44731cf - 9937cf$$

$$V_{rem} = 34794cf$$

$$T_{rem} = T_{tot} - T_{ff}^{new}$$

$$T_{rem} = 44hr - 30.0hr$$
$$T_{rem} = 14.0hr$$

Volume through 3 – 1.25” diameter holes in 14.0 hours:

$$h_{ave}^{ff} = \tfrac{2}{3}\left(elev._{bf} - elev._{ff}\right) + \left(elev._{ff} - elev._{bot}\right)$$
$$h_{ave}^{ff} = \tfrac{2}{3}\left(92.6 - 90.8\right) + \left(90.8 - 90.0\right)$$
$$h_{ave}^{ff} = 2\,ft$$

Q_1will be defined as the discharge through the ff orifices when both the ff and bf holes are contributing.

$$Q_1 = 0.62 A_{ff}\sqrt{2gh_{ave}^{ff}}$$
$$Q_1 = (0.62)(3)(0.0085sf)\sqrt{2\left(32.2\tfrac{ft}{\sec^2}\right)(2\,ft)}$$
$$Q_1 = 0.18cfs$$
$$V_1 = T_{rem}Q_1$$
$$V_1 = (14.0hr)(0.18cfs)\left(\tfrac{3600\sec}{1hr}\right)$$
$$V_1 = 9072cf$$

The leftover volume will be released by the bankfull orifice. V_2 will be defined as the amount of water to be discharged by the bf orifices in 14.0 hours.

$$V_2 = V_{rem} - V_1$$
$$V_2 = 34794cf - 9072cf$$
$$V_2 = 25722cf$$
$$Q_2 = \frac{V_2}{T_{rem}}$$
$$Q_2 = \frac{25722cf}{(14.0hr)\left(\tfrac{3600\sec}{1hr}\right)}$$
$$Q_2 = 0.51cfs$$
$$h_{ave}^{bf} = \tfrac{2}{3}\left(elev._{bf} - elev._{ff}\right)$$
$$h_{ave}^{bf} = \tfrac{2}{3}\left(92.6\,ft - 90.8\,ft\right)$$
$$h_{ave}^{bf} = 1.2\,ft$$
$$A_2 = \frac{Q_2}{0.62\sqrt{2gh_{ave}^{bf}}}$$
$$A_2 = \frac{0.51cfs}{0.62\sqrt{2\left(32.2\tfrac{ft}{\sec^2}\right)(1.2\,ft)}}$$
$$A_2 = 0.094sf$$

A 2" diameter orifice has an area of 0.022 sf

$$\# = \frac{0.094sf}{0.022sf}$$
$$\# = 4.27$$

Therefore, use 4 – 2" diameter holes @ elev. 90.8

<u>100-year flood:</u>

Q_a = 1.10 cfs

Q_a is a *peak* or maximum flow. Calculate the maximum flow passing through first flush and bankfull orifices, using the total head, and subtract from Q_a to determine the orifice size to release the 100-year storm volume:

$$Q_{ff} + Q_{bf} = 0.62A_{ff}\sqrt{2gh_{tot}} + 0.62A_{bf}\sqrt{2gh_{tot}^{bf}}$$
$$Q_{ff} + Q_{bf} = (0.62)(3)(0.0085sf)\sqrt{2\left(32.2\tfrac{ft}{\sec^2}\right)(93.7-90.0)} + (0.62)(4)(0.022sf)\sqrt{2\left(32.2\tfrac{ft}{\sec^2}\right)(93.7-90.8)}$$
$$Q_{ff} + Q_{bf} = 0.99cfs$$
$$Q_{100} = Q_a - (Q_{ff} - Q_{bf})$$
$$Q_{100} = 1.10cfs - 0.99cfs$$
$$Q_{100} = 0.11cfs$$
$$A_{100} = \frac{Q_{100}}{0.62\sqrt{2gh_{100}}}$$
$$A_{100} = \frac{0.11cfs}{0.62\sqrt{2\left(32.2\tfrac{ft}{\sec^2}\right)(93.7-92.6)}}$$
$$A_{100} = 0.021sf$$

A 1" diameter orifice has an area of 0.0055 sf

$$\# = \frac{0.021sf}{0.0055sf}$$
$$\# = 3.82$$

Therefore, use 3 - 1" diameter holes @ elev. 92.6

APPENDIX I

Hydrograph Methods

There are a variety of hydrologic analysis packages available to calculate the runoff from a watershed. These are classified into single event (i.e. HEC-1) or continuous simulation models (i.e. HSPF). Several programs are listed below.

HEC-HMS Hydrologic Modeling System

The U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) developed HEC-HMS. The HEC-HMS program supercedes HEC-1 and provides a similar variety of options for simulating precipitation-runoff processes.

HEC-1, The Flood Hydrograph Package

The HEC-1 model is designed to simulate the surface runoff response of a drainage basin to a precipitation input. The model represents the basin as an interconnected system of hydrologic and hydraulic components. Each component models an aspect of the precipitation-runoff process within a portion of the basin. A component may represent a surface runoff entity, a stream channel, or a reservoir. The result of the model is the computation of streamflow hydrographs at desired locations.

HSPF, The Hydrological Simulation Program – FORTRAN

HSPF is a comprehensive package developed by the U.S. EPA for simulating water quantity and quality for a wide range of organic and inorganic pollutants from agricultural watersheds. The model uses continuous simulations of water balance and pollutant generation, transformation, and transport. Time series of the runoff flow rate, sediment yield, and user-specified pollutant concentrations can be generated at any point in the watershed.

TR20, Technical Release No. 20

The Technical Release No. 20, "Computer Program for Project Formulation - Hydrology", TR-20 was originally developed by the USDA, Soil Conservation Service (SCS) and has been modified by the Natural Resources Conservation Service (NRCS) and other groups. TR-20 uses the procedures described in the NRCS National Engineering Handbook, Section 4, Hydrology (NEH-4), except for the newly revised reach routing procedure (Att-Kin method) which has superseded the Convex method.

TR55, Technical Release No. 55

The Technical Release No. 55, "Urban Hydrology for Small Watersheds", TR-55 presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for detention structures. These procedures are applicable in small watersheds, especially urbanizing watersheds. First issued in January 1975, TR-55 incorporates current NRCS procedures described in the NRCS national Engineering Handbook, Section 4, Hydrology (NEH-4).

Storm Water Management Model (SWMM)

Developed by the EPA, SWMM is a comprehensive watershed-scale model used to represent urban storm water runoff and combined sewer overflow phenomena. SWMM simulates the runoff of a drainage basin for any prescribed rainfall pattern. A total watershed is segmented into a number of smaller basins that can be readily described by its hydraulic or geometric properties. The SWMM model simulates both water quantity and quality aspects that are associated with urban runoff and combined sewer systems.

APPENDIX J

Rainfall Precipitation Data

Precipitation Frequency Data: **Washtenaw County, Michigan**

The following table indicates the expected design precipitation for a particular duration and return period. The data was obtained from the *U.S. Weather Bureau Technical Paper No. 40, Rainfall Frequency Atlas of the United States, 1961*. The 24-hour data for return periods greater than one year was obtained from *Computing Flood Discharges for Small Ungaged Watersheds, Sorrell and Hamilton, Michigan Department of Natural Resources, 1991*.

	Return Period						
Duration	*1 yr.*	*2 yr.*	*5 yr.*	*10 yr.*	*25 yr.*	*50 yr.*	*100 yr.*
30 min.	0.8	1.0	1.2	1.4	1.6	1.8	1.9
1 hour	1.0	1.2	1.5	1.7	2.0	2.3	2.5
2 hours	1.2	1.4	1.8	2.1	2.3	2.7	2.9
3 hours	1.3	1.6	1.9	2.3	2.6	2.8	3.2
6 hours	1.6	1.8	2.3	2.7	3.0	3.2	3.7
12 hours	1.7	2.2	2.7	3.1	3.5	3.8	4.3
24 hours	2.1	2.5	3.0	3.4	4.0	4.4	4.9

U.S. Soil Conservation Service Type II Storms

The data in the following table was obtained from the *"Engineering Field Manual for Conservation Practices", U.S. Dept. of Agriculture, Soil Conservation Service.*

Storm Frequency	**24 Hour Rainfall (inches)**
1 yr.	2.2"
2 yr.	2.4"
5 yr.	3.1"
10 yr.	3.6"
25 yr.	4.1"
50 yr.	4.5"
100 yr.	4.8"

APPENDIX K

Hydrologic Soil Groups for Washtenaw County

Soil properties influence the process of generation of runoff from rainfall and must be considered in methods of runoff estimation. The soils are classified on the basis of water intake at the end of the long-duration storms occurring after prior wetting and after an opportunity for swelling, and without the protective effects of vegetation. The hydrologic soil groups, as defined by the NRCS are:

A. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission and low runoff potential.

B. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay-pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission and high runoff potential.

Soil Series	**Group**	**Soil Series**	**Group**	**Soil Series**	**Group**
Adrian	D/A	Kendallville	B	Pewamo	D/C
Blount	C	Kibbie	B	Riddles	B
Boyer	B	Kidder	B	Sebewa	D/B
Boyer-Kidder	B	Lamson-Colwood	D/B	Seward	B
Brookston	D/B	Macomb	B	Sisson	B
Cohoctah	D/B	Matherton	B	Sloan	D/B
Conover	C	Metamora	B	Spinks	A
Conover-Brookston	D/B	Miami	B	Spinks-Oshtemo	B
Dixboro-Kibbie	B	Morley	C	St. Clair	D
Edwards	D/B	Nappanee	D	Tedrow	B
Fox	B	Oakville	A	Thetford	A
Gilford	D/B	Oshtemo	B	Wasepi	B
Granby	D/A	Owosso	B	Wauseon	D/B
Houghton	D/A	Palms	D/A	Ypsi	C
Hoytville	D/C	Pella	D/B		

The first group is the native or undrained classification when the water intake has not been changed by artificial drainage. The second group is the classification after artificial drainage improvements. For use in the determination of developed runoff only the undrained classification will be accepted.

APPENDIX L

Required Easement and District Language for Chapter 18 Drainage Districts

Language Required for Platted Subdivisions

The following language shall be included in a section of the subdivision deed restrictions that describes the drainage district.

...subject to a perpetual and permanent easement in favor of the Washtenaw County Drain Commissioner, the __________________________ Drainage District, (collectively referred to as "grantee), and grantee's successors, assigns and transferees, in, over, under and through the property described on the plat (liber, page) hereto, which easement may not be amended or revoked except with the written approval of grantee, and which contains the following terms and conditions and grants the following rights:

1) The easement shall be for the purposes of developing, establishing, constructing, repairing, maintaining, deepening, cleaning, widening and performing any associated construction activities and grading in connection with any type of drainage facilities or storm drains, in any size, form, shape or capacity;

2) The grantee shall have the right to sell, assign, transfer or convey this easement to any other governmental unit for the purposes identified in subsection (1), above;

3) No owner in the subdivision shall build or convey to others any permanent structures on the said easement;

4) No owner in the subdivision shall build or place on the area covered by the easement any type of structure, fixture or object, or engage in any activity or take any action, or convey any property interest or right, that would in any way either actually or threaten to impair, obstruct, or adversely affect the rights of grantee under the said easement;

5) The grantee and its agents, contractors and designated representative shall have right of entry on, and to gain access to, the easement property;

6) All owners in the subdivision release grantee and its successors, assigns or transferees from any and all claims to damages in any way arising from or incident to the construction and maintenance of a drain or sewer or otherwise rising from or incident to the exercise by grantee of its rights under the said easement, and all owners covenant not to sue grantee for any such damages.

The rights granted to the Washtenaw County Drain Commissioner, the _________________ _______________ Drainage District, and their successors and assigns, under Section _____ of these restrictions may not, however, be amended without the express written consent of the grantee hereunder. Any purported amendment or modification of the rights granted there under shall be void and without legal effect unless agreed to in writing by the grantee, its successors or assigns.

Language Required for Site Condominiums

The following language shall be included in a section of the Master Deed that describes the drainage district.

...subject to a perpetual and permanent easement in favor of the Washtenaw County Drain Commissioner, the ________________________ Drainage District, (collectively referred to as "grantee"), and grantee's successors, assigns and transferees, in, over, under and through he property described on Exhibit B hereto, which easement may not be amended or revoked except with the written approval of grantee, and which contains the following terms and conditions and grants the following rights:

1) The easement shall be for the purposes of developing, establishing, constructing, repairing, maintaining, deepening, cleaning, widening and performing any associated construction activities and grading in connection with, any type of drainage facilities or storm drains, in any size, form, shape or capacity;

2) The grantee shall have the right to sell, assign, transfer or convey this easement to any other governmental unit for the purposes identified in subsection (1), above;

3) No owner in the condominium shall build or convey to others any permission to build any permanent structures on the said easement;

4) No owner in the condominium shall build or place on the area covered by the easement any type of structure, fixture or object, or engage in any activity or take any action, or convey any property interest or right, that would in any way either actually or threaten to impair, obstruct, or adversely affect the rights of grantee under the said easement;

5) The grantee and its agents, contractors and designated representative shall have right of entry on, and to gain access to, the easement property

6) All owners in the condominium release grantee and its successors, assigns or transferees from any and all claims to damages in any way arising from or incident to the construction and maintenance of a drain or sewer or otherwise rising from or incident to the exercise by grantee of its rights under the said easement, and all owners covenant not to sue grantee for any such damages.

The rights granted to the Washtenaw County Drain Commissioner, the ________________ Drainage District, and their successors and assigns, under Section _____ of these restrictions may not, however, be amended without the express written consent of the grantee hereunder. Any purported amendment or modification of the rights granted there under shall be void and without legal effect unless agreed to in writing by the grantee, its successors or assigns.

APPENDIX M

This document is generated by the Drain Commissioner's Office. The following is for reference only and should not be generated for filing purposes.

(Sample Agreement Form Attached)

This agreement must be recorded with the Washtenaw County Register of Deeds. Therefore, it must abide by the following recording requirements:

1. Use full names. For example, do not write "John and Mary Doe". Write "John Doe and Mary Doe".
2. Signatures must be original and names must be typed, stamped or printed beneath all written signatures in black ink. MCLA 565.201(a)(e)
3. No discrepancy in the names shall exist between the printed names of such person, as appears either in the body of the instrument, the signature, the acknowledgment or jurat. MCLA 565.201(b)
4. Instruments conveying or mortgaging any interest in real estate shall state the marital status of any male grantors. MCLA 565.221
5. The addresses of all parties must appear on any instrument by which title to any interest therein is conveyed, assigned, encumbered or other wise disposed of. MCLA 565.201 (a)(f)
6. The name and address of the person who drafted the document must appear on documents executed in Michigan. MCLA 565.201(a), 565.203
7. Documents purporting to convey or encumber real estate executed in Michigan must have two (2) witnesses and an acknowledgment by a notary public. MCLA 565.8
8. A certified copy of the death certificate or proof of death must be recorded when the instrument of conveyance states "survivor" in the grantor's section. MCLA 565.48
9. The first page must have a 2 1/2" top margin. All other sides and pages must have a 1/2" minimum margin. The type size shall be no smaller than 10 point. MCLA 5858

Please note that revisions were made to this form on page 4, item 6 on August 30, 1999.

APPENDIX M

AGREEMENT TO ESTABLISH THE____________________________
DRAINAGE DISTRICT

THIS AGREEMENT, made and entered into this ______ day of ____________, 20___, by and between JANIS A. BOBRIN, Washtenaw County Drain Commissioner, (COMMISSIONER) acting for and on behalf of the _________________ _______________ DRAINAGE DISTRICT (P.O. Box 8645, Ann Arbor, MI 48107), of the County of Washtenaw, State of Michigan, a public body corporate, hereinafter referred to as the DISTRICT, and ________________________________, (address:____), hereinafter referred to as the DEVELOPER.

WITNESSETH:

WHEREAS, Section 433 of Act Number 40 of the Public Acts of 1956, Michigan, as amended, The Drain Code, authorizes the Drain Commissioner to enter into an agreement with a landowner and developer, if any, to establish an existing private drain which was constructed by the landowner or developer to service an area on his, her or its own land as a County or Intercounty Drain; and

WHEREAS, JANIS A. BOBRIN, Washtenaw County Drain Commissioner, acting on behalf of the _____________________________ DRAINAGE DISTRICT, will have under her jurisdiction the ________________________________ DRAIN (DRAIN); and

WHEREAS, the DRAIN COMMISSIONER, through and by the DISTRICT, is in charge of operation and maintenance of the ____________________ DRAIN to service lands in the ____________________ DRAINAGE DISTRICT; and

WHEREAS, the ____________________ DRAIN will be a County drain located in the ____________ of _______________; and

WHEREAS, the DEVELOPER has provided storm drainage for the lands comprised within the ______________________ DRAINAGE DISTRICT, which are described in Exhibit A as attached and made a part hereof.

WHEREAS, the DEVELOPER further understands that as the freeholder and owner of the lands included in this Agreement in the ______________ of __________ ____________ in which said _________________________ DRAIN and the lands to be drained thereby are located, that these above described lands known as the "____________________________________" will be subject to assessments for the cost of construction, operation, inspection and maintenance of the DRAIN; and

WHEREAS, these lands being drained, thereby, and to be assessed, therefore, are in the __________________________ DRAINAGE DISTRICT; and

WHEREAS, the DEVELOPER, pursuant to Section 433 of the Drain Code, as amended, desires to establish his or her private drain as a County Drain; and

WHEREAS, the DEVELOPER, has agreed to assume the total cost of said improvement; and

WHEREAS, a certificate has been obtained from a registered professional engineer retained by the DEVELOPER to the effect that the existing drain is the only reasonably available outlet for the drain and that there is sufficient capacity in the existing outlet for the proposed drain to serve as an adequate outlet, without detriment to or diminution of the drainage service which the outlet presently provides.

NOW, THEREFORE, in consideration of the premises and covenants of each, the parties hereto agree to as follows:

1. The DISTRICT agrees to establish the _____________________________ DRAIN as a County Drain upon the execution of this Agreement by the DISTRICT and the DEVELOPER.

2. The storm water drainage facilities of the ____________________________ DRAIN shall be constructed under the supervision, direction and control of the DISTRICT according to plans, specifications and project designs approved by the DISTRICT and on file in the Office of the Washtenaw County Drain Commissioner.

3. The DEVELOPER agrees hereto to assume the cost of the project set forth in the above-mentioned plans, specifications and project designs. Said cost shall include:

a. Administrative Fees for the establishment of the ____________________ DRAIN, computed as follows:

Number of Lots	Fee
1 - 50	$1,500.00
51 - 100	$2,000.00
100 - 150	$2,500.00
151- 200	$3,000.00
200 - 250	$3,500.00
251 - 300	$4,000.00
301+	$5,000.00

b. Actual expenses incurred by the DISTRICT for inspection of the construction of the DRAIN.

c. A 10% construction contingency item computed as a percent of the construction cost as determined by the DISTRICT provided, should any balance remain in the contingency fund, such balance shall be refunded to the DEVELOPER upon the following terms and conditions:

(1) A period of one (1) year shall expire after final acceptance of the project by the DISTRICT at which time the DEVELOPER shall request that he DISTRICT make a final inspection.

(2) The DISTRICT shall proceed with final inspection of the project, and following such inspection, the DISTRICT shall make the necessary correction of any defects on the project payable out of contingency funds. At such time as the corrections have been completed by the DISTRICT, the DEVELOPER shall file with the DISTRICT a sworn statement that all claims for amounts due for labor, materials and equipment furnished for this work have been paid in full, or he or she shall so file in lieu thereof, a sworn statement showing in detail the nature and amount of all unpaid claims for said labor, materials and equipment. The Contractor shall also submit a Contractor's Declaration and Affidavit. The remaining contingency balance may then be refunded to the DEVELOPER.

d. The establishment of a permanent maintenance fund in an amount of 5% of the construction cost but not to exceed $2500.00.

The DEVELOPER'S cost to the DISTRICT to establish the DRAIN, incidental of actual construction expenses, is hereby determined as follows:

(1) Administrative fees	$ _______________
(2) Estimated Inspection 10% of project cost; unused monies to be returned to the DEVELOPER. DEVELOPER may secure services of a certified professional engineer for inspection; in such cases, inspection procedures and schedule must be approved by the Office of the Washtenaw County Drain Commissioner.	$ _______________
(3) Contingency 10%	$ _______________
(4) Permanent Maintenance Fund	$ _______________
Total Cost:	$ _______________

4. The DEVELOPER shall forthwith deposit said Balance Due with the DISTRICT, to be used only for the purposes herein set forth and agreed upon.

5. The DEVELOPER shall provide the Washtenaw County Drain Commissioner and/or the DISTRICT with a Letter of Credit, Escrow account, or cash in the sum of 100% of the construction cost of the DRAIN, to remain in effect until final acceptance of the project by the DISTRICT.

6. It is agreed that the DEVELOPER shall convey to the DISTRICT the final plat or condominium documents, description of the drainage district and such easement and Rights-of-Way as may be necessary to accomplish the purposes herein set forth, and legal description of route and course of drain, and do so without charge therefore.

7. The DEVELOPER further agrees to provide, without charge, one (1) set of reproducible mylar "Record Drawings" of the drain as built, which shall include design calculations showing flow rates, imperviousness factors, drainage district and sub-districts and any other data needed by the DISTRICT for proper drain operation.

8. The DEVELOPER further agrees to provide to the DISTRICT, without charge, one (1) copy of the Master Deed Agreement, as recorded with the Washtenaw County Clerk/Registrar of Deeds for (condominium developments).

9. The foregoing payment of the cost of the project is agreed and understood as being for the sole benefit of the ____________________ DISTRICT at large or part thereof, and that such payment shall not relieve the subject property from any future assessments levied pursuant to the Michigan

Drain Code of 1956, as amended, for construction, improvements and/or maintenance of the DRAIN arising by virtue of proper and legal petitions and hearings and procedures thereon.

10. It is agreed that the Drain Commissioner's maintenance of these drainage facilities shall be consistent with the Drain Commissioner's normal standards and requirements. This maintenance does not include such items as lawn cutting, litter pick-up, etc.

11. This Agreement shall become effective upon its execution by the DEVELOPER and by the DISTRICT and shall be binding upon the successors and assigns of each party.

IN WITNESS WHEREOF the parties hereto have caused this agreement to be executed by their duly authorized officers as of the day and year first above written.

_________________________ DRAINAGE DISTRICT, County of Washtenaw, State of Michigan, acting as Its governing body, the Washtenaw County Drain Commissioner

____

By: Janis A. Bobrin
Washtenaw County Drain Commissioner

By:_________________________________
(Print Here)

Its: _________________________________

Drafted by: Deborah L. Neaton
Office of the Drain Commissioner
P.O. Box 8645
Ann Arbor MI 48107-8645

When recorded, please return to:
Office of the Drain Commissioner
P.O. Box 8645
Ann Arbor MI 48107-8645

ACKNOWLEDGMENT

STATE OF MICHIGAN)
)
COUNTY OF)

On this _______ day of __________________ 20__ before me, a Notary Public in and for said County, appeared JANIS A. BOBRIN, Washtenaw County Drain Commissioner, to me personally known to be the person described in and who executed the foregoing instrument and acknowledged the same to be her free act and deed.

____
Linda D. Oslin, Notary Public
Washtenaw County, Michigan
My Commission Expires December 20, 2005.

ACKNOWLEDGMENT

STATE OF MICHIGAN)
)
COUNTY OF)

On this ______ day of ___________________ 20___ before me, a Notary Public in and for said County, appeared _______________________________, to me personally known, who being duly sworn did say that s/he is the _______________ of _________________________, and that said instrument was signed in behalf of said ________________________ by authority of its Board of Directors and the said Board acknowledged said instrument to be the free act and deed of said ________________.

____
____________________, Notary Public
County, Michigan
My Commission Expires ________________.

ACKNOWLEDGMENT

STATE OF MICHIGAN)
)
COUNTY OF)

On this ______ day of __________________ 20__ before me, a Notary Public in and for said County, appeared ______________________________, to me personally known to be the person described in and who executed the foregoing instrument and acknowledged the same to be _____ free act and deed.

____
_____________________, Notary Public
County, Michigan
My Commission Expires _________________.

DRAINAGE DISTRICT APPLICANT INFORMATION SHEET

The following are the sole owners of the following lands:

Tax Code Number	Parcel Number

Located in Section __________ of __________________________Township, County of Washtenaw, State of Michigan, which encompasses the lands in the proposed _____________________________________ DRAINAGE DISTRICT. Following are the names and addresses of all persons who are required to sign the final plat or master deed agreement as proprietors:

APPENDIX N
Selected References for Storm Water Best Management Practices

WEBSITES:

Center for Watershed Protection: www.cwp.org (various publications are available through CWP)

City of Fort Worth, Texas Storm Drain Monitoring Program:
www.CI.fort-worth.tx.us/dem/stormcontacts.htm
This site includes links to storm water management programs across the country.

EPA Web site: Go to: http://search.epa.gov/ Enter: storm, water, best, management, practices then click on “search”.

Maryland Storm Water Design Manual:
www.mde.state.md.us/environment/wma/stormwatermanual/toc.html

PUBLICATIONS:

Guidance Specifying Management Measures for Sources of Non-Point Pollution in Coastal Waters, EPA, 1993

Guidebook of Best Management Practices for Michigan Watersheds - MDEQ Water Quality Division

Site Planning for Urban Stream Protection, Center for Watershed Protection, December 1995

APPENDIX O

Review and Inspection Fees

All review and inspection fees are charged at an hourly rate. Prior to any review or inspection being scheduled, an initial fee submittal or any outstanding fees must be paid. The required initial submittal for residential developments is based on the acreage of the development and is outlined in the table below. For all other developments and permit applications, a minimum submittal equal to two hours of review time is required. Any additional time spent after depletion of the initial submittal will be billed at the hourly rate. Review time will be billed for all work necessary to complete the review process including but not limited to, plan review, archived file review, meetings, site inspections, phone and conference calls, etc.

An inspection fee deposit of 5% of the cost estimate shall be submitted prior to construction plan approval. Any unused inspection fees will be returned upon completion of the required inspections. See Part 1, Section III, Construction Plan Approval.

Current hourly rates

Review rate = $90.00/hour

Inspection rate = $ $90.00 / hour + vehicle charges (engineers);
= $56.50 / hour + vehicle charges (field staff)

Development Size	< 5 acres	5-20 acres	20-50 acres	50-100 acres	> 100 acres
Initial Submittal Fee:	$400	$500	$625	$750	$750 + $4/acre

APPENDIX P

Maintenance Plan and Budget

Sample Maintenance Plan and Budget

"XYZ" Leasing Company

Storm Water Management System Maintenance Plan

1. Responsibility For Maintenance
    a. During construction, it is the developer's responsibility to perform the maintenance.
    b. Following construction, it will be the responsibility of "XYZ" Company to perform the maintenance.
    c. The Master Deed will specify that routine maintenance of the storm water facilities must be completed within ___ days of receipt of written notification that action is required, unless other acceptable arrangements are made with the (Township of _________), (Washtenaw County Drain Commissioner) or successors. Emergency maintenance (i.e. when there is endangerment to public health, safety or welfare) shall be performed immediately upon receipt of written notice. Should "XYZ" Company fail to act within these time frames, the (Township) (County) or successors may perform the needed maintenance and assess the costs against "XYZ" Company.

2. Source Of Financing

    "XYZ" Company is required to pay for all maintenance activities on a continuing basis.

3. Maintenance Tasks And Schedule

a. See the charts on the next two pages: The first describes maintenance tasks during construction to be performed by the developer, the second describes maintenance tasks by "XYZ" Company.
b. Immediately following construction, the developer will have the storm water management system inspected by an engineer to verify grades of the detention and filtration areas and make recommendations for any necessary sediment removal.

MAINTENANCE TASKS AND SCHEDULE DURING CONSTRUCTION
Components

Tasks	Storm Sewer System	Catch Basin Sumps	Catch Basin Inlet Casings	Channels	Outflow control Structures	Rip-Rap	Filtration Basins	Storm Detention Areas	Wetlands	Emergency Overflow	Emergency Overflow	Schedule
Inspect for sediment accumulation				X	X		X	X				Weekly
Removal of sediment accumulation				X	X		X	X				As needed* & prior to turnover
Inspect for floatables and debris				X	X		X	X				Quarterly
Cleaning of floatables and debris				X	X		X	X				Quarterly & at turnover
Inspection for erosion				X	X		X	X				Weekly
Re-establish permanent vegetation on eroded slopes				X			X	X				As needed & prior to turnover
Replacement of Stone					X							As needed*
Mowing				X			X	X				0 to 2 times per year
Inspect Structural elements during wet weather and compare to as-built plans (by professional engineer reporting to the developer)				X	X		X	X				Annually and at turnover
Make adjustments or replacements as determined by pre-turnover inspection				X	X		X	X				As needed

PERMANENT MAINTENANCE TASKS AND SCHEDULE

Components

Tasks	Catch Basin Inlet Casings	Ditches & Swales	Outflow control Structures	Rip-Rap	Filtration Basins	Storm Detention Areas	Wetlands	Emergency Overflow	**Schedule**
Inspect for sediment accumulation		X	X		X	X			Annually
Removal of sediment accumulation		X	X		X	X			Every 2 years as needed
Inspect for floatables and debris	X	X	X		X	X			Annually
Cleaning of floatables and debris	X	X	X		X	X			Annually
Inspection for erosion		X	X		X	X			Annually
Re-establish permanent vegetation on eroded slopes		X			X	X			As needed
Replacement of Stone			X						Every 3-5 years as needed
Clean Streets									Semi-Annually
Mowing		X			X	X			0-2 times per year
Inspect Storm water system components during wet weather and compare to as-built plans (by professional engineer reporting to XYZ Co.)	X	X	X	X	X	X	X	X	Annually
Make adjustments or replacements as determined by annual wet weather inspection	X	X	X	X	X	X	X	X	As needed
Keep records of all inspections and maintenance activities and report to XYZ Company									Annually
Keep records of all costs for inspections, maintenance and repairs. Report to XYZ.									Annually

I. Maintenance Plan Budget

Annual inspection for sediment accumulation	$100.00
Removal of sediment accumulation every 2 years as needed	$500.00
Inspect for floatables and debris annually and after major storms	$100.00
Removal of floatables and debris annually and after major storms	$150.00
Inspect system for erosion annually and after major storms	$100.00
Re-establish permanent vegetation on eroded slopes as needed	$350.00
Replacement of stone	$100.00
Mowing 0-2 times per year	$400.00
Inspect structural elements during wet weather and compare to as-built plans every 2 years	$150.00
Make structural adjustments or replacements as determined by inspection as needed	$400.00
Have professional engineer carry out emergency inspections upon identification of severe problems	$200.00
A. Total Annual Budget	**$2,550.00**

Note: Maintenance Plans and budgets vary widely due to the size and unique characteristics of each storm water management system proposed. Appendix P is intended for use as a starting point in the development of an appropriate maintenance plan specific to the size and components of each system.

APPENDIX Q

ENGINEER'S CERTIFICATE OF OUTLET

Date ____

Development Name____

City, Village, or Township of ___________________________ Sec. ________

Washtenaw County, Michigan

I hereby certify that the existing drain is the only reasonable available storm water outlet for the proposed storm water management system and that the existing drain has sufficient capacity to serve as an adequate outlet fo the proposed system, with out detriment to or diminution of the drainage service that the existing outlet presently provides.

Signed: _______________________________

Registered Professional Engineer

NOTE: The engineer's certificate must be stamped with the engineer's seal.

The certificate submitted must be the original.

APPENDIX R

Native Plants of Michigan

COMMON NAME	SCIENTIFIC NAME	SITE/SOIL	SUN AVAILABILITY	OTHER NOTES
American Elderberry	*Sambucus canadensis*	Mesic woodlands; savanna grasses are often part of this community.		Native shrub
American Hazelnut	*Corylus americana*	Oak savanna site.		Native shrub
Basswood	*Tilia americana*	Mesic woodlands; savanna grasses are often part of this community.		Native tree
Big Bluestem Grass	*Andropogon gerardii*	All textures of soils except organic; all drainage conditions.	Full sun grass	Woodland Community
Black Oak	*Quercus velutina*	Oak savanna site.		Native tree
Bloodroot	*Sanguinaria canadensis*		Best for shaded areas	Native perennial; suitable for use as groundcover.
Bottle Brush Grass	*Hystrix patula*		Full sun/part shade area	Native grass
Bur Oak	*Quercus macrocarpa*	Oak savanna site or mesic woodlands where savanna grasses are often part of the community		Native tree
Butterfly Milkweed	*Asclepias tuberosa*		Full sun/part shade area	Native perennial
Canadian Wild Rye	*Elymus canadensis*	All textures of soils except organic; all drainage conditions.	Full sun/part shade area	Native grass
Dark-green Bullrush	*Scirpus atrovirens*	Organic soils; somewhat poorly drained or poorly-drained soils without artificial drainage		Best suited for marshy soils which provide wet conditions.
Dutchman's Breeches	*Dicentra cucullaria*		Best for shaded areas	Native perennial
Grey Dogwood	*Cornus racemosa*	Mesic woodlands where savanna grasses are often part of the community		
Hackberry	*Celtis occidentalis*	Floodplain forest area		Native tree
Indian Grass	*Sorghastrum nutans*	Sand, loamy sand, sandy loam, loam, silt loam, and clay loam textures; well and moderately well drained soils.	Full sun grass	Native grass

Native Plants Continued

COMMON NAME	SCIENTIFIC NAME	SITE/SOIL	SUN AVAILABILITY	OTHER NOTES

Junegrass	*Koeleria macrantha*	oak savanna community		Native grass
Little Bluestem Grass	*Andropogon scoparius*	oak savanna community	Full sun grass	Native grass
May Apple	*Podophyllum peltatum*		Best for shaded areas	Native perennial
New Jersey Tea	*Ceanothus americanus*	Oak savanna community		Native shrub
Pennsylvania Sedge	*Carex pennsylvanica*	Sand, loamy sand, sandy loam, loam, silt loam, and clay loam textures; well and moderately well drained soils.		Native sedge; suitable for use as groundcover
Prairie Cord Grass	*Spartina pectinata*	Wet conditions are favorable; usually found in wet prairie	Full sun grass	Native grass
Purple Love Grass	*Eragrostis spectabillis*	Oak savanna community		Native grass
Red Oak	*Quercus rubra*	Mesic woodlands where savanna grasses are abundant		Native tree
Rough Blazing Star	*Liatris aspera*	Oak savanna community		Native perennial
Shagbark hickory	*Carya ovata*	Mesic woodlands where savanna grasses are often found; oak savanna.		Native tree
Silver Maple	*Acer saccharinum*	Floodplain forest		Native tree
Swamp White Oak	*Quercus bicolor*	Mesic woodlands where savanna grasses are abundant		
Switchgrass	*Panicum virgatum*	Sand, loamy sand, sandy loam, loam silt loam and clay loam textures; well and moderately well-drained soils	Full sun grass	Native grass
Trillium	*Trillium grandiflorum*		Best for shaded areas	Native perennial; suitable for use as groundcover
White Oak	*Quercus alba*	Oak savanna; Mesic woodlands where savanna grasses are often abundant		Native tree
Wild Geranium	*Geranium maculatum*		Best for shaded areas	Native perennial
Wild Ginger	*Asarum canadense*		Best for shaded areas	Native perennial

Native Wetland Plants of Michigan

COMMON NAME	SCIENTIFIC NAME	SITE/SOIL	SUN AVAILABILITY	OTHER NOTES
Beggar-Ticks	*Bidens frondosa*	Moist, open ground, stream banks and roadsides		Provides food and cover for ducks.
Button Bush	*Cephalanthus occidentalis*	Low wet ground, swamps, bogs, and lake edges.		Good source of nectar
Common Boneset	*Eupatorium perfoliatum*	Soil provides generally wet conditions often marshy area.		Native perennial
False Solomon's Seal	*Smilacina racemosa*	Woods and shaded edges; moist soi	Partial to full shade	Decorative
Golden Alexanders	*Zizia aurea*	Wooded bottomland, stream banks, moist meadows, and floodplains.		
Marsh Marigold	*Caltha palustris*	Calcareous wet soil communities; fens.		Native perennial
Nannyberry	*Viburnum lentago*	Woods, swamps, roadsides.		
Northern Arrow-Wood Viburnum	*Viburnum recognitum*	Swamps, boggy woods, swampy pastures and stream banks		
Obedient Plant or False Dragonhead	*Physostegia virginiana*		Full sun/part shade forb	Native perennial
Red-Osier Dogwood	*Cornus stolonifera*	Swamps, moist fields and thickets		
Silky Dogwood	*Cornus amomum*	Moist woods, meadows, old fields, and swamps.		Fruit are an excellent source of food for wildlife
Smooth Aster	*Aster laevis*		Full sun/part shade forb	Native perennial
Solomon's Seal	*Polygonatum pubescens*	Wooded slopes and stream banks		Decorative plant
Southern Arrow-Wood Viburnum	*Viburnum dentatum*	Swamps, wet woods, and open wetlands.		
Spiderwort	*Tradescantia ohiensis*		Full sun/part shade forb	Native perennial
Spotted Joe Pye Weed	*Eupatorium maculatum*	Generally marshy, wet conditions		Native perennial
Sugar Maple	*Acer saccharum*	Mesic woodlands where savanna grasses are abundant		Native tree
Swamp Milkweed	*Asclepias incarnata*	Marshy, wet conditions		Native perennial
Turtlehead	*Chelone glabra*	Calcareous wet soil communities; fens.		Native perennial

Wetland Plants Continued

COMMON NAME	SCIENTIFIC NAME	SITE/SOIL	SUN AVAILABILITY	OTHER NOTES
Tussock Sedge	*Carex stricta*	Sand, loamy sand, sandy loam, loam, silt loam and clay loam textures;		Native sedge; generally found in wet conditions.

		well and moderately well-drained soils		
Virginia Wild Rye	*Elymus virginicus*	All textures of soils except organic; all drainage conditions	Full sun/part shade grass	Native grass
Wild Bergamot/ Bee-balm	*Monarda fistulosa/ didyma*		Full sun/part shade forb	Native perennial
Winterberry	*Ilex verticillata*	Swamps, bogs, moist woods, and wet shores.		

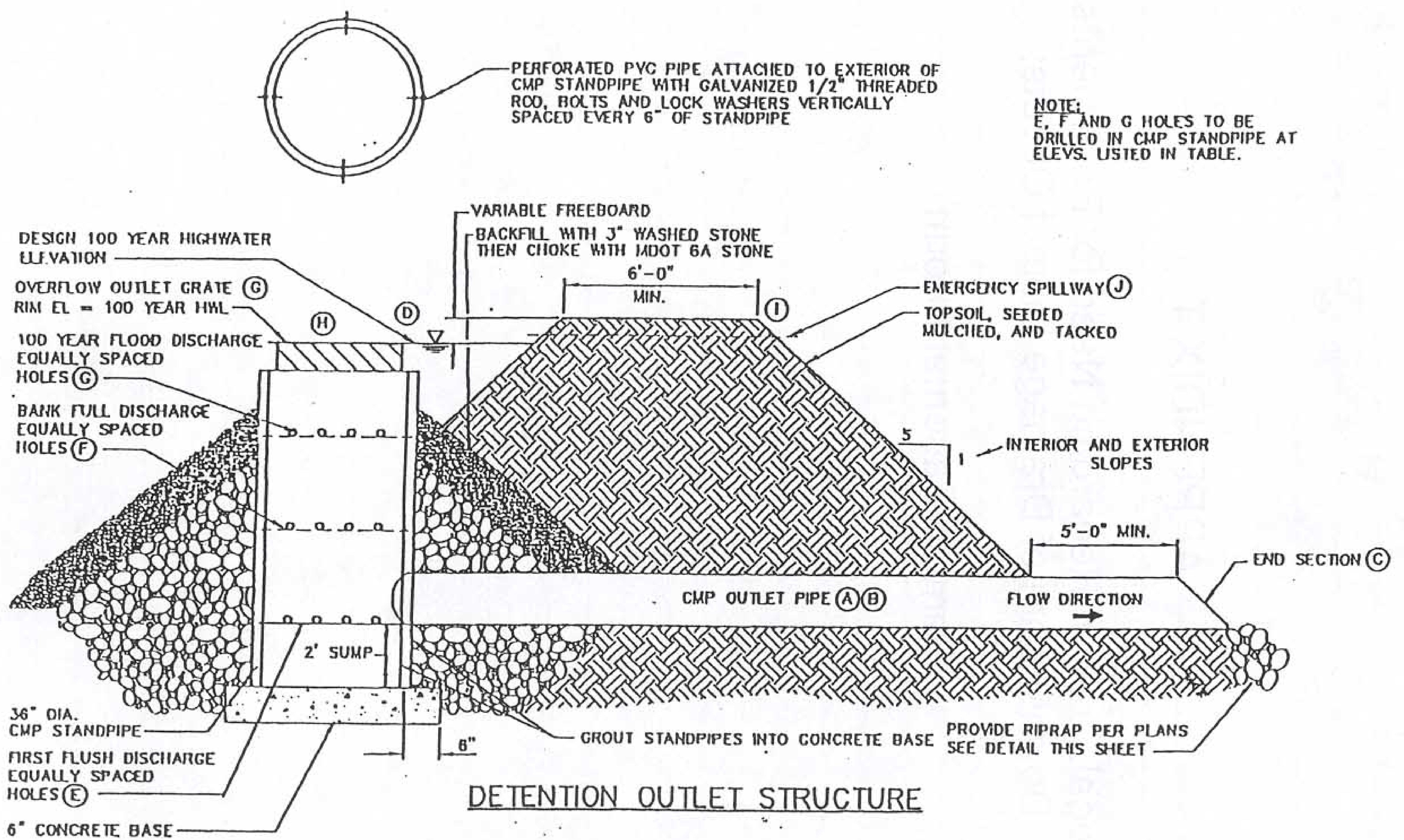
The following publications may be helpful regarding wetlands plantings and are available from the Washtenaw County MSU Extension (734) 971-0079:

1. "Water Front Buffer Zones", MSU Cooperative Extension Service.

2. "Working with Wet Areas in the Landscape", Harold Davidson, Department of Horticulture, MSU.

3. "Shoreline Plants and Landscaping", A series of water quality fact sheets for residential areas, University of Wisconsin Extension in cooperation with the Wisconsin Department of Natural Resources.

E.C. 1/19/00



DETENTION OUTLET STRUCTURE

DETENTION OUTLET SCHEDULE										
OUTLET PIPE LENGTH (A)	OUTLET PIPE SLOPE (B)	END SECTION INVERT (C)	100-YEAR HWL (D)	FIRST FLUSH DISCHARGE INV/ORIFICE SIZE (E)	BANK FULL DISCHARGE INV/ORIFICE SIZE (F)	100 YEAR FLOOD DISCHARGE INV/ORIFICE SIZE (G)	TOP OF STAND PIPE ELEVATION (H)	POND CREST ELEVATION (I)	EMERGENCY SPILLWAY ELEVATION (J)

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OF COUNSEL:
ALLISON K. THOMAS

May 27, 1999

Via Fax 734-994-2459 & US Mail

Ms. Janis A. Bobrin
Washtenaw County Drain Commissioner
Courthouse Annex Bldg.
P.O. Box 8645
Ann Arbor, MI 48107-8645

Dear Ms. Bobrin:

You have asked our opinion as to what a Drainage District should require under a 433 Agreement to protect the Drainage District from liability due to sheet flow from a development's drainage district.

As a general rule an upland owner has the right to natural drainage flow over and across the adjacent lower properties. Any instance where the natural surface flow of water is increased or concentrated, and a neighboring property receives more surface water resulting from the change, the increase in flow constitutes a trespass. If there is an increase in water on neighboring lands, the Drainage District could be liable for damages under the cause of action of trespass nuisance. Therefore, to protect the Drainage District from future liability, flooding easements should be required for adjacent properties of a development when the development's drainage "sheet flows" onto neighboring properties.

In circumstances involving the outlet of the development's drainage system into a watercourse, a different set of standards apply. When water flows into a watercourse with defined banks and bottom, riparian rights apply. This means that the development has the right to utilize the watercourse as long as the use is reasonable and does not unduly burden the other riparian owners. Depending on the circumstances, the Drain Commissioner’s office may require easements downstream if there is a probability of flooding. Again, requiring downstream easements protects the Drainage District from future liability should flooding occur. These easements should be granted to the Drainage District, and may or may not considered part of the route and course of the drain.

Ms. Janis A.Bobrin
May 27, 1999
Page 2

Please note that Section 433 of the Drain Code envisions the requirement of securing an adequate outlet. Subsection (7) of Section 433 states that a registered engineer must certify that the outlet for the existing drain is the only reasonable available outlet for the drain and that there is sufficient capacity in the existing outlet for the proposed drain to serve as an adequate outlet without detriment or diminution of the drainage service which the outlet presently provides.

Should you have any questions relative to these issues, please do not hesitate to contact Geoff Seidlein or myself.

Sincerely,

HUBBARD, FOX, THOMAS,
WHITE & BENGTSON, P.C.

Stacy L. Hissong

SLH/kmo

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EASEMENT AGREEMENT

THIS AGREEMENT, made and entered into this day of , 2000 for and in consideration of $ and prospective benefits to be derived by reason of the construction, operating and maintaining of a certain Drain under the supervision of the Washtenaw County Drain Commissioner and the County of Washtenaw and the State of Michigan, as hereinafter described, INSERT NAME, MARITAL STATUS AND ADDRESS OF LANDOWNER (the "Landowners") do hereby convey and release to Janis A. Bobrin, Washtenaw County Drain Commissioner on behalf of the INSERT NAME OF DRAINAGE DISTRICT, (the "Drainage District") of Courthouse Annex Building, P.O. Box 8645, Ann Arbor, Michigan 48107-8645, an Easement for the INSERT NAME OF DRAIN Drain situated in the Township of INSERT TOWNSHIP, County and State aforesaid. Landowners do hereby convey and release to Drainage District a Drainage Easement with an elevation of approximately feet above mean sea level, USGS datum, for drainage purposes and flood control.

WHEREAS, Landowners are the owner of lands in the aforesaid County described as:

INSERT LEGAL DESCRIPTIONS OF ENTIRE PROPERTY HERE

WHEREAS, the Drainage District wishes to obtain an easement from Landowners in the event that there is an increase in the velocity or quantity of water flowing onto Landowners' property as a result of the construction of the Drain.

NOW THEREFORE, the parties hereto agree as follows:

1. Landowners hereby grant, convey and release unto Drainage District an Easement over and upon their lands for the purpose of allowing for increases in velocity or quantity of water flow onto Landowners' property.

Said Easement is described separately as follows:

Insert LEGAL DESCRIPTION OF EASEMMNT

~ Landowners, their heirs, executors, administrators, successors and assigns reserve its rights and privileges to the area encompassed by the Easement as may be used and enjoyed to include the planting and harvesting of agricultural crops so long as the use(s) do not interfere with or abridge the rights granted to and easement hereby acquired by the Drainage District;

~ Landowners, their heirs, executors, administrators, successors and assigns hold Drainage District harmless to all claims to damages in any way arising from or incident to the drainage and any increased flow onto premises by reason of the drain and maintenance or improvement thereof during the time of maintenance and improvement of said drain, or at any time in the future, such release for damages releases the Drainage District, its successors and assigns from any damages whatsoever arising out of the flooding of said lands within the easement right of way to any depth at any time in the future by reason of the construction of such drainage improvements and the flooding caused by such construction or their use during the time of construction or at any time in the future;

~ This Easement may be terminated in whole or in part by written agreement of all of the parties;

~ This conveyance shall be deemed sufficient to vest in Drainage District an Easement in said lands for the uses and purposes of any increased flow onto Landowners' property.

In witness whereof, the parties hereto have executed this Agreement the day and year first above written.

WITNESSES: LANDOWNERS:

~

______________________ ______________________
(TYPE NAME OF LANDOWNER)

______________________ ______________________
(TYPE NAME OF LANDOWNER)

WITNESSES:

INSERT NAME OF DRAIN
DRAINAGE DISTRICT

~

______________________ ______________________
Janis A. Bobrin
Washtenaw County Drain Commissioner

STATE OF NUCIEGAN N ~

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)ss.

COUNTY OF

The foregoing instrument was acknowledged before me _,~ day of
2000, by

Notary
County, Michigan
My commission expires:

STATE OF MICHIGAN
)ss.
COUNTY OF

The foregoing instrument was acknowledged before me _, day of
2000, by
~

, Notary
County, Michigan
My commission expires:

STATE OF MICHIGAN
)ss.
COUNTY OF

The foregoing instrument was acknowledged before me this day of
1999, by Janis A- Bobrin, Washtenaw County Drain Commissioner on behalf of the ______________
DRAINAGE DISTRICT

, Notary
County, Michigan
My commission expires:

When Recorded Return To:
Janis A. Bobrin
Washtenaw County Drain Commissioner
Courthouse Annex Building
P.O. Box 8645
Ann Arbor, Michigan 48107-86455
(734) 994-2525
1

Drafted By:
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